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FLIGHTS INTO THE PAST

Aerial photography, photo interpretation and mapping for archaeology

Chris Musson, Rog Palmer and Stefano Campana

With contributions by:

Marcello Cosci; Michael Doneus & Wolfgang Neubauer; Colin Shell; Anthony R. Beck, Graham Philip, Daniel N. M. Donoghue & Nikolaos Galiatsatos; Maurizio Forte; Damian Grady

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Hard copies of the Italian publication are still available from a number of sources.
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Neither the 2005 volume nor the present one could have been produced without the generosity of the original photographers in allowing their images to be used without charge. Thanks are due above all Dr Otto Braasch, for nearly three decades now recognised as among the finest archaeological air photographers in Europe.

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DEDICATION

For
Riccardo Francovich,
Piero Spagna
and Otto Braasch

The excitement of the Siena school in 2001 owed its source to three very special men, each linking the past to the future through aerial photography. Firstly, the late Professor Riccardo Francovich, long-time champion of exploratory air survey in Italy and instigator of the Siena school. Secondly, Dr Piero Spagna, co-ordinator of work on the new Italian law on aerial photography that came into effect at the turn of the millennium. Finally, Dr Otto Braasch, pilot and air photographer extraordinary, who for more than a decade has flown around Europe, opening the eyes of fellow archaeologists to the very different perspectives that the aerial viewpoint can bring.

PREFACE

The first Aerial Archaeology Research School at Siena in May 2001 held a special excitement for its participants. The restrictive law that had inhibited **exploratory aerial survey** in Italy since 1939 had recently been repealed. At last the tutors from across Europe and their young colleagues from across Italy could take to the air, legally, to explore and record the **landscape** below. Drawing on the experience of generations of airborne archaeologists elsewhere they felt that they were about open a window that had been closed abruptly over sixty years before.

In the decades since 1939 the study of air photo evidence in Italy had indeed reached high levels of sophistication through the work of specialists in universities and institutions such as the Istituto Geografiche Militare (IGM) at Florence and Aerofototeca Nazionale (at ICCD) in Rome. In 2003 the range and application of these skills had been splendidly displayed in the spectacular exhibition and accompanying book *Lo Sguardo di Icaro* (*Guaitoli 2003*).

A characteristic of Italian aerial studies, however, had been its almost total reliance on vertical photography, mostly taken for non-archaeological purposes. Over more than half a century the resulting archives had become an invaluable and continuing resource for the interpretation and documentation of Italy's past, from early times to the radical landscape **transformation**s of recent decades.

Virtually absent from the Italian experience, however, had been exploratory aerial survey by archaeologists themselves, using light aircraft and oblique aerial photography. This technique has allowed archaeologists in other parts of Europe to seek out and photograph, in favoured locations and at the right times of the year, the half-hidden **trace**s that can often be seen only from the air. Freed of the 1939 law, Italian archaeologists could now join in the everyday use of this revealing and cost-effective technique.

In Part I of this book, **Flights into the Past**, Chris Musson discusses the basic concepts, methods and uses of exploratory aerial survey. This technique has enlightened our view of the past, helped us to communicate with the general public and made a growing contribution to the conservation and protection of archaeological **site**s and **landscape**s in the face of threats from agriculture and industrial or urban development.

The airborne archaeologist's dialogue with the landscape below is in some senses enshrined in the prints and digital images so carefully captured and catalogued. But an archive of photographs is of little value if the resulting information has not been interpreted, mapped and recorded in ways that make it readily available to those who might want or need to use it.

Hence Part II, **Mapping the Past**, by Rog Palmer. For a long time there had been problems in creating adequately accurate maps from **oblique aerial photographs**. But from the mid 1990s onwards purpose-made computer programs have made this a progressively more easy and effective process, using simple scanners and non-specialist desktop computers. In the new millennium we can genuinely view **aerial information**, whether from pre-existing photographs or from newly undertaken aerial exploration, as a major source of archaeological data and understanding, at its most effective when applied in symbiosis with field survey, excavation, documentary studies and other forms of **remote sensing**.

In Part III, **Aerial Survey at Work**, Chris Musson and Stefano Campana (in 2004) used Italian examples to illustrate the uses and techniques of exploratory aerial survey and oblique air photography, treating the pictures as just a foretaste of things to come. The authors genuinely hoped, and still hope now (in 2012) that this book will soon be replaced by something broader in scope, both as regards the techniques described and the geopgraphical coverage, with examples of the ways in which aerial and related techniques have helped archaeologists across Europe to explore, map and explain the ancient sites and landscapes of their own countries. In time, no doubt, **aerial archaeology** and remote sensing will bring to the whole of Europe entirely new perspectives on the past, enriching but never replacing the longer-established methods of archaeological exploration and interpretation.

In Part IV, **Flights into the Future**, Stefano Campana describes the approach being taken, in 2004, by the University of Siena to tackle the particular problems of landscape archaeology in Tuscany. Other contributors then look at various achievements and prospects in the application of then-fledgling remote sensing techniques. These are in a sense 'snapshots in time', recording what the authors were doing and thinking in the years up to 2004. They will hopefully provide a perspective on the advances that have been made since.

The book ends with updated technical appendixes on digital photography, European projects between 1996 and 2015, photo-credits and lists of publications that will act as source material for all who want to know more about **aerial archaeology** in promoting research, conservation and public understanding of heritage sites and landscapes across Europe. There is also an indexed glossary of terms used throughout the book.

Robert Bewley (August 2004 and September 2013)

Dr Bewley opening the first Italian training school at Siena in May 2001

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This book could not have been produced without the unstinting help of a host of friends, colleagues and financial supporters, too many to name individually here. A special debt of gratitude is owed, however, to Otto Braasch and the other pilots at the Siena and Foggia training schools of 2001 and 2003 – Klaus Leidorf, Mick Webb and (from the Aero Club di Foggia) Luigi Fruggiero, Massimiliano di Peco and Luigi Catalano. Pietro Baci and pilots from the Aero Club di Firenze have assisted the continuing programme of aerial survey over Tuscany, mounted by the Department of Medieval Archaeology at the University of Siena and the Laboratory of Landscape Archaeology and Remote Sensing (LAP&T) at Grosseto.

The aerial archaeology training schools at Siena in 2001 and Foggia in 2003 were promoted by the Aerial Archaeology Research Group (AARG) and its dedicated team of tutors and pilot-instructors, including (in addition to those already mentioned) Cinzia Bacilieri, Bob Bewley, Michael Doneus, Martin Gojda, Damian Grady, Darja Grosman, Pete Horne, Francesca Radliffe, Cathy Stoertz and Helen Winton. Funding for the schools, and for preparatory visits to various parts of Italy, was provided by the British Academy, the Association for Cultural Exchange and AARG itself. Generous help also came from the Banca Monte dei Paschi di Siena through the University of Siena, and in Puglia from a number of local and regional sources through Professor Giuliano Volpe of the University of Foggia. The Siena School and specialist workshop were part of a project in the European Community's Culture 2000 programme, sponsored by English Heritage, the Universities of Siena and Vienna and the Brandenburg Museum.

The authors owe personal thanks for advice and support over the years to a wide range of professional colleagues, especially Professor Paul Athur, the late Philip Barker, Mauro Campana, Giuseppe Ceraudo, Toby Driver, Cristina Felici, the late Riccardo Francovich, Roberto Goffredo, Wlodek Rączkowski, Valentino

Romano, Piero Spagna and Rowan Whimster. Illustrations for the book have been provided by the tutors and students of the Siena and Foggia schools, the University of Cambridge, English Heritage, the Royal Commission on the Ancient and Historical Monuments of Wales, the Clwyd-Powys Archaeological Trust, the Universities of Siena and Grosseto and others. Photographs from aerial tours of Italy in the 1980s by Dr Otto Braasch and the late Dr Derrick Riley add a historical element to the book's visual content. Publication scans were produced by the authors and various specialists, those for Part III being made in Wales by Advance Colour Techniques (ACT), through funding provided by AARG.

Mapping work of the kind described in Part II drew its first inspiration in Britain from the initiatives of John Hampton and the then Air Photographs Unit of the Royal Commission on the Historical Monuments of England. More recently photo rectification and mapping from oblique air photographs have been facilitated through the computer skills of Dr Irwin Scollar, formerly of the University of Bonn, whose AirPhoto mapping program is featured in this book, and of John Haigh, formerly of the University of Bradford, whose AERIAL program is used by a number of official and academic organisations in Britain.

For the hard-copy version of the book in 2005 the arduous task of translating the English text into Italian was undertaken with great skill and perseverance by Cinzia Bacilieri and Stefano Campana. The book itself was seen through the press with scrupulous attention to detail and quality by the original publishers, All'Insegna del Giglio, of Florence.

Any errors or omissions in the text of course remain the responsibility of the authors, who hope they will be fewer in number than the times their friends and families forgave them when book production took precedence over more important personal or social obligations.

PART I

FLIGHTS INTO THE PAST

Chris Musson

11. Aerial archaeology: different histories
12. Aerial survey: merits and limitations
13. Planning a programme of aerial survey
14. The tools of the trade
15. Aerial survey in practice

1. AERIAL ARCHAEOLOGY: DIFFERENT HISTORIES

Introductory Note

The 2005 text is published here with only minor alterations and additions, including some extra bibliographical references. The background, however, remains largely that of Italy and the United Kingdom. A section on the practice of aerial archaeology across Europe has been added at the end of Chapter 1 and a Supplentary Bibliography lists key publications for those countries of Europe for which it has proved possible to assemble the relevant information. For the most part the advice offered in Chapters 2-5 has relevance for the whole of Europe, subject to national and regional differences in geology, land-use, climate and administrative organisation etc. (CM, September 2013)

Why write this book?

In January 1991, at one of the University of Siena's annual 'summer schools', a pair of British archaeologists watched in amazement as two of their fellow-tutors, Italians, tried through the latest computer techniques of the time to extract information from a vertical air photograph provided by the Italian national air photo archive, Aerofototeca. Over the better part of two hours many words passed, many enhancements were tried, many algorithms discussed. But to British eyes very little was achieved. The reason? The photograph was hopeless from the outset, a bare-soil image acquired on a dull day, showing a marginally lighter patch of soil where a Roman villa was already known to exist. Without this foreknowledge there was nothing in the photograph that was even vaguely interpretable as archaeology. The visitors had only one piece of advice to offer – throw the picture away and take new aerial photographs at a time when there was a real chance of recording archaeological information – for instance as a **soilmark** in the right conditions of dampness, as a **shadow mark** in low winter sunlight, or as colour variations in a ripening arable crop.

The advice was politely if quietly received. So too was the subsequent talk on **aerial archaeology** in Britain (*Musson–Whimster 1992*). So quiet, indeed, was the reception that one of the visitors eventually lost patience and asked how many of the audience had actually flown in a light aircraft with archaeological intent. Only one hand was raised. But at least the discussion became more lively, though no less depressing from the British point of view. The kind of exploratory survey that had brought such benefits to Britain just would not work in Italy (they were told), the soils and geology were wrong, half the country was covered in trees, it wasn't really necessary, it would serve no useful purpose for the Soprintendenza (the national heritage agency), it might even make matters worse by revealing even more possible but unverifiable **site**s that could be neither understood nor protected. And anyway, in Italy, a long-standing law from the run-up to the Second World War had made it virtually impossible for archaeologists or other private citizens to take their own aerial photographs.

This last point was a fair one, though the others prevarications were not. The 1939 law (*Piccarreta–Ceraudo 2000*, pp. 198-203) made it so difficult to obtain a permit, to conduct the flight, to take and process the photographs, and to arrange for their subsequent use and publication that the effort seemed to all but a handful of Italian archaeologists out of proportion to the benefits that might be gained. The British visitors returned home, dispirited that a country so rich in its heritage was still denied the benefits of **exploratory aerial survey**. There the matter rested throughout the1990s, while British and other members of the Aerial Archaeology Research Group (AARG) turned their attention to the newly accessible states of central and eastern Europe, where the fall of communism had (in some places at least) swept away the military and bureaucratic controls that had made aerial survey impossible there for sixty years or more.

Fortunately, there remained in Italy at least one believer in the benefits that free-ranging aerial survey could bring to the exploration, interpretation and conservation of Italy's past. So, in 1999, the late Riccardo Francovich, Professor of Medieval Archaeology at the University of Siena, again invited British **aerial archaeologist**s to speak at one of the university's now-famous 'summer schools' (*Driver–Musson 2001*). This time the reaction from the audience was far more positive, though the same draconian edict was still in place. But by now there were moves to liberalise the law. A key figure here was Piero Spagna, Secretary General of the Office of Cartography for the Region of Tuscany and leader of a consortium of officials advising the government on the wording of a new law to free the skies for aerial photography. With this possibility in mind, Professor Francovich floated the idea of an aerial archaeology research and training school at Siena, perhaps in the following year. The new law came into force in the final days of 2000 and the training school took place, with great success, in June 2001.

Under the new law there was no longer any legal or bureaucratic reason why Italian archaeologists could not carry out their own aerial research and air photography. The problem, of course, was that aerial archaeology had taken a quite different direction in Italy compared with Britain and other parts of Europe. In Britain, which had enjoyed decades of virtual freedom of the skies, the post-war focus had been on free-ranging exploratory survey, using **oblique aerial photographs** taken by archaeologists themselves, or by aviators who had turned their skills to archaeology. The previous decade or so had also seen a significant effort (in England at least, less so in Scotland and Wales) to map all of the archaeological information that could be extracted both from these oblique photographs and from the vast number of vertical photographs taken over the preceding sixty years for military purposes, for national **mapping** or for **landscape** survey.

In Italy, hampered by the 1939 law, the focus had instead been on the extraction of information from pre-existing archives of vertical photographs, at least as rich in Italy as in Britain and otherc parts of Europe. There had in practice been at least a little exploratory work (and some 'unofficial' photography of individual **site**s or areas) but the main thrust had been the analysis of essentially non-archaeological vertical photographs for research into communication routes or land division, or for the creation of metrically accurate maps of specific sites or study areas, often for management purposes. It was this kind of study, under titles such as '*topografia antica*', '*aerotopografia archeologica*' and '*fotogrammetria finalizzata*', that formed the subject of three relatively recent manuals on the subject (*Piccarreta 1987*; *Alvisi 1989*; *Piccarreta–Ceraudo 2000*; *Ceraudo 2003*). The problem, for Italy, after sixty years of virtual prohibition, was a lack of basic skills and experience to undertake the 'flights into the past' which had now become both possible and necessary. Nor was there an Italian-language guide to the use of simple desktop computers for the rapid **mapping** of archaeological information from oblique as well as vertical aerial photographs.

Hence the original version of this book, published in Italian in 2005. The aim – at that time, and also now in this English-language internet publication – was not to write an exhaustive manual but simply to set out the key ideas and techniques that have underpinned the practice of aerial archaeology in Britain and other parts of Europe in past decades. The bulk of the photographs used in the book were drawn from Italy and some of the text was tailored to fit the Italian situation. But most of the lessons drawn remain broadly valid several years later and little would have been gained by trying to make the illustrations (or text) in the internet version more representative of Europe as a whole. The general layout of the book also remains unchanged.

Thus Part I deals with the principles and practice of **exploratory aerial survey** and oblique air photography. Part II describes the interpretation and mapping of information from both oblique and vertical aerial photographs. Part III presents results from free-ranging aerial survey over central and southern Italy, mainly in the first three summers of the new century. Part IV describes approaches to the use of aerial and satellite evidence, and of geophysics, in Italy and elsewhere, that were in 2004 beginning to provide their own kinds of access to archaeological and environmental information. Finally, there are technical Appendixes, in particular bringing matters up to date regarding digital photography and the handling of digital data. The closing Bibliography has a supplement which provides a wider range of European sources than were covered in the original publication.

Fig 1. 1 The Roman city of Silchester, England

First seen as cropmarks, from ground level, in the seventeenth century

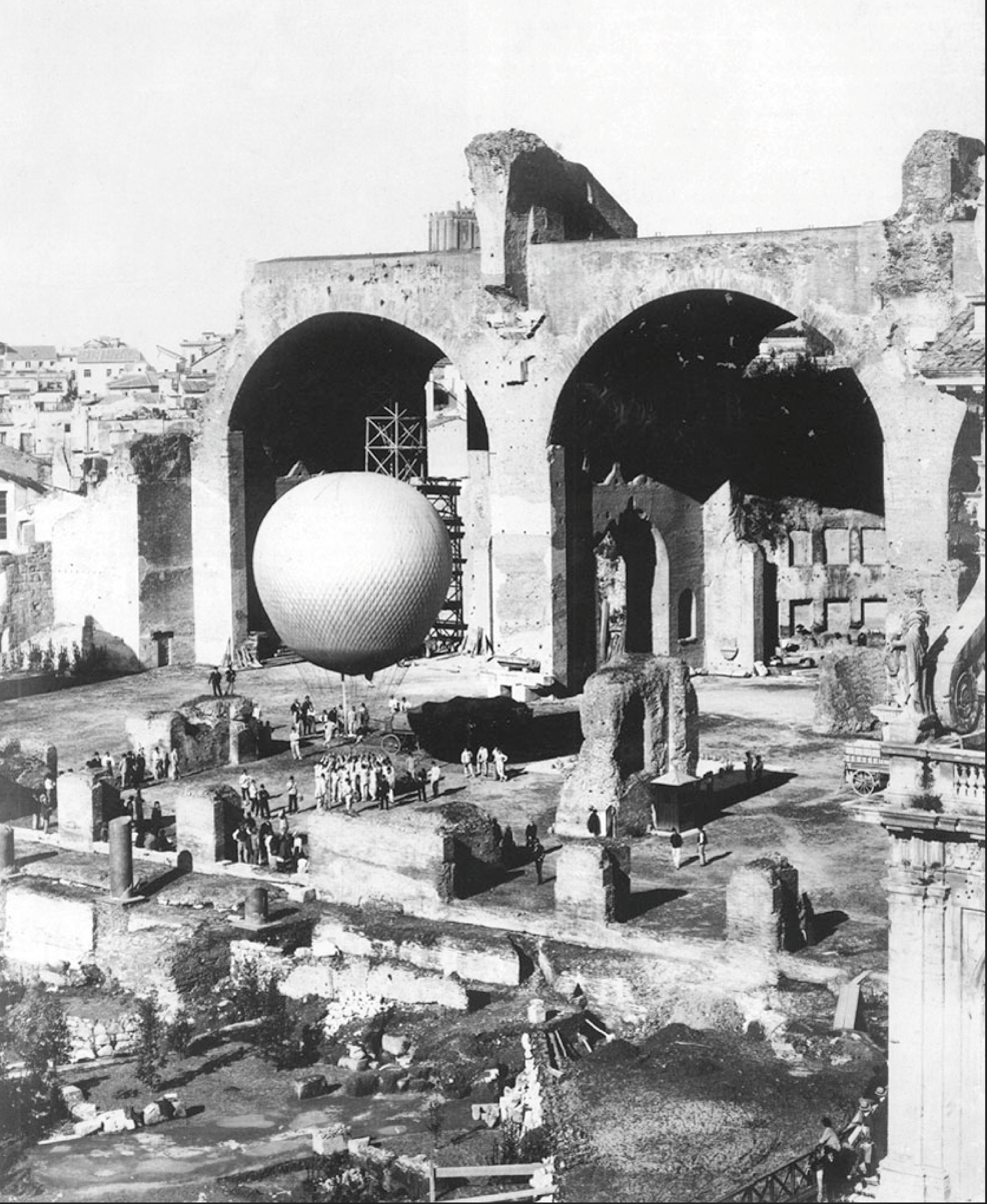

Fig 1. 2 **Early balloon flights in England and Italy**

Above. The young Italian diplomat, Vincenzo Lunardi, takes off in a hot air balloon from the grounds of the Honourable Artillery Company, near London, on 15 September 1784. Lunardi took with him his cat. When the cat got cold, Lunardi landed the balloon, gave his pet to a friend, and continued his flight.
Left. A century or so later, in 1899 and early 1900, a tethered air balloon was used to record the Giacomo Boni's archaeological excavations in the Foro Romano.

From first beginnings to the Great War

For a fuller account of the history and development of archaeological air photography in the United Kindom see Barber 2011*. For Italy see contributions by M. M. Boemi in* Guaitoli 2003*, pp. 17-42; also* Tozzi 2004 *and* Ceraudo 2004*,* 2005 *and* 2010*, in the last case in an issue of "Archeologia Aerea" which contains many other contributions on the history and current practice of aetrial archaeology in Italy.*

Italy and Italians have played prominent parts in the history of aerial archaeology. At the beginning of her own short history of the aerial archaeology Alvisi *(1989*, p. 13) tells how the eighteenth-century political philosopher C. L. de Montesquieu, on his travels through Italy, always sought out a bell tower or other high point for his first view of a town, then returned to the same place at the end of his stay to fix the layout in his mind (*de Montesquieu 1971*, p. 172). Alvisi remarks, too, on man's longstanding urge to see – and represent – the world from above, from the makers of a Mesopotamian clay tablet of over three thousand years ago to Italian painters of the Middle Ages who represented both town and country from the air. British topographers of the seventeenth and eighteenth centuries, perhaps learning something from their Italian counterparts, used aerial perspectives rather than plans to illustrate the towns of their own day.

We can go several centuries back, too, for one of aerial archaeology's basic tenets, that **feature**s buried beneath the ground can, at the right time of year and in the right climatic conditions, become visible as changes in the colour and growth of the crop above the otherwise vanished remains. Such **cropmarks** were noted in the seventeenth and eighteenth centuries by British writers who saw the streets of Roman towns marked out by lines of yellowing and stunted crop in the ripening grain (Fig 1.1). In Italy, as *sentieri del diavolo* ('tracks of the devil' or 'devil's footsteps') much the same happened in the eighteenth century when the street plan of the Greco-Roman city of Metaponto was traced through differing growth in the grain crop. The marks could still be seen periodically a hundred years later, when their significance was confirmed by excavation (*Alvisi 1989*, pp. 26, 39).

Coming forward in time, an entertaining story is told about the British archaeologist Leonard Woolley, excavating in the early years of the twentieth century at Wadi Halfa, in the Sudan (*Woolley 1937*, p. 30, quoted by *Deuel 1971*, pp. 35-36). After weeks of painstaking but not entirely successful work he and the expedition leader had made their way one evening to a hillside overlooking their concession. Suddenly, from the momentary strike of the setting sun across the ground below, they saw clear circles that had entirely escaped them before. Woolley rushed down the hill but as he approached the marks they seemed to disappear before his eyes. His companion, however, from the vantage point above, was able to direct Woolley to each circle in turn. Beneath each, in time, was found a tomb, undetectable from close up but revealed from a distance by the slightly different reflection of the sunlight on the scattered stone above the otherwise vanished tombs. It is a commonplace of aerial archaeology that **pattern**s which are quite clear from above may be virtually invisible at ground level (Fig 1.6).

Balloons, and to a lesser extent kites, played a significant part in the history of aerial archaeology. The first manned balloon ascent was made near Paris in November 1783, the first in Italy barely three months later near Milan and the first in England in September 1784, when the balloonist was Vincenzo Lunardi, a dashing young Italian from Lucca then on service with the Neapolitan Embassy in London (Fig 1.2, top). By 1794 balloons were being used for military observation at the siege of Maubeuge in France and in that same year the French army formed a special corps of airborne observers or '*aerostiers*'. Strangely, the corps was disbanded only five years later, but from this time onward there has been a repeated interplay between the military and civilian uses of balloons, airships and eventually aircraft which continues to the present day in the guise of airborne and satellite-based **remote sensing** of various kinds.Ground-based photography was well established by the middle of the nineteenth century. The cameras of the day were of course very cumbersome, and the exposures long. It is all the more remarkable, therefore, that in 1858 the first aerial photographs were taken (from a tethered hot-air balloon) above Paris by the floridly named writer, draftsman and photographer Gaspar Felix Tournachon, working under the more economical pseudonym of 'Nadar'. Two years later, above Boston on the other side of the Atlantic, aerial photographs were being taken by J. W. Black and S. A. King.

Balloons of various kinds were used for military observation and signalling throughout the second half of the nineteenth century, for instance in 1859 at the battle of Solferino, so important for the unification of Italy shortly afterwards. It was in Britain, however, that '*… a significant step forward was taken in the 1880s when Major H. Elsdale … combined free unmanned balloons with automatic cameras designed to expose several plates successively, the balloon subsequently emptying itself of gas and returning to the ground. Shortly after these experiments, a proposal was made to use similar equipment to photograph the ruins around Agra, India, with the ultimate purpose of using the photographs to make a map of the ancient cities. Although the scheme was officially approved and the equipment sent out to India, it became entangled in bureaucracy and no photographs were taken*' (DOWNEY 1980, pp. 3-4).

The first successful use of aerial photography for archaeological purposes had taken place a little earlier, in 1879, when the German excavator Franz Stolze used it to record his excavations at Persepolis (STOLZE *1882*). Two decades later, just before the end of the century, a tethered balloon was used by the *Brigata specialista del Genio Militare* (which had been taking aerial photographs since at least 1894) to record Giacomo Boni's 1898/99 excavations in the Foro Romano, in Rome (Fig 1.2, left). The first aerial photographs of an archaeological monument in Britain, the great ritual circle of Stonehenge on the Salisbury Plain, were taken from a military observation balloon in 1906. A decade after Boni's pioneering work in Rome excavations at Pompeii were photographed from the air in 1910, this time from an unmanned balloon. By this time, too, photographs from balloons were being taken for mapping purposes, along the Tevere near Rome in 1902-3 and 1908 and then in and around Venice, first from a tethered balloon, then in 1913 from a dirigible.

By this stage, however, the next chapter in the story had already begun, the Wright Brothers having made their first flight in a powered aircraft in 1903. Six years later Wilbur Wright was the pilot when the first airborne movie film was shot, over the Italian countryside near Rome. Soon afterwards it was an Italian army officer who first realised the potential of the aircraft-camera combination in times of war.

'[*As*] *in so many other matters it was the result of personal initiative; Italy was at war with Turkey over control of Libya when, in October 1911, Captain Carlo Piazza was involved in reconnaissance of Turkish positions. He realised the benefit of recording these flights, and requested a 'Bebe Zeiss' camera for use in the air. His request failed so he borrowed one from the Engineer Corps, fitted it below his aircraft and was thus able to take one photograph per sortie'* (DOWNEY *1980*, pp. 5-7).

Fig 1. 3
O. G. S. Crawford
Crawford was the first Archaeology Officer of the Ordnance Survey in Britain, the national body for survey and mapping – the equivalent of the Istituto Geografico Militare (IGM) in Italy. In the 1920s he defined and used most of the methods that are still fundamental to archaeological air photography today – the use of light and shade, cropmarks, soilmarks etc. He also tested the aerial evidence through observation in the field and, with others, by excavation.

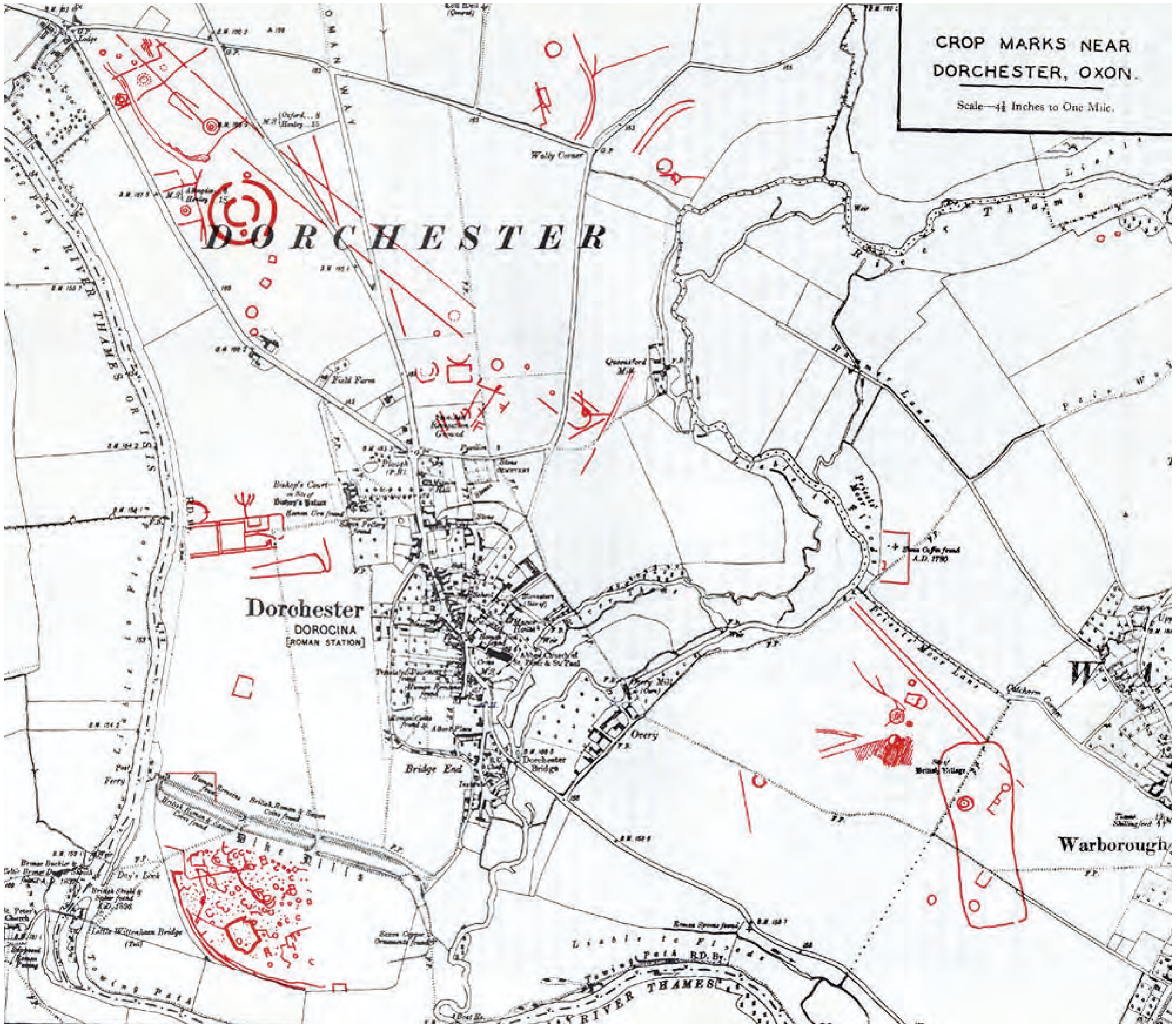

Fig 1. 4 Major G. W. G. Allen

Major Allen (above), another pioneer of exploratory aerial survey in Britain, bought his own aircraft in the 1930s, made his own aerial camera and carried out regular exploratory flights. He often re-visited sites to compare their appearance with what he had seen in previous years or at different times of year. He interpreted and mapped the evidence that he saw, the extract on the left being part of one of his published maps.

Fig 1. 5 Fyfield Down, Wiltshire, England

Photographed by Major Allen on 3 June 1934. Low light has been used to emphasise the pattern of rectangular ‘Celtic fields’, of pre-Roman or Roman date, overlain by the narrower ‘ridge-and-furrow’ ploughing from the 13th century AD or later.

World War I and the inter-war years

The Great War gave a huge impetus to the development of aircraft, cameras and films, and to their use in photo intelligence by all of the combatants. By the end of the war British military photographers, for instance, had collected over half a million photographs, though most of them were destroyed soon after hostilities ceased. The war had, however, introduced a number of pilots and observers to the archaeological potential of air photography. In Britain one of these was O. G. S. Crawford (Fig 1.3), who in 1920 became the first Archaeology Officer at the Ordnance Survey, the state body responsible for national mapping. Three years later Crawford was able to deliver a lecture on ancient field systems near Winchester that was based almost entirely on evidence mapped from military air photographs (*Crawford 1923*, *1924*). The photographs in this case were all verticals, but a few obliques were taken and subsequently published when Crawford and his financial backer Alexander Keiller arranged a number of specifically archaeological flights in 1924. The vast potential of exploratory aerial photography was established in this decade, and the main principles of the technique (shadow and highlight, **soilmarks** and **cropmarks**) were codified over the following few years in three seminal publications (*Crawford–Keiller 1928*; *Crawford 1928*, *1929*). These were the principals that the British archaeologist John Bradford, thirty years later, declared entirely suitable for aerial exploration in the countries around the Mediterranean (*Bradford 1957*, 5).

The next major advance in Britain, again the result of individual initiative, came from Major G. W. G. Allen (Figs 1.4, 1.5), an enterprising Oxford businessman who bought an aircraft in 1929 and from 1932 to 1939 used his own hand-made cameras in a regular programme of oblique (and occasionally vertical) aerial photography, mainly over the gravel terraces of the Upper Thames Valley in southern England (*Allen 1984*). By the time Allen died in a motorbike accident in 1940 he had exposed over 2000 glass plates, recording many well-known monuments and discovering over 150 new sites and **complex**es of almost every date from the Neolithic to medieval. Allen returned time and again to the same sites to record the changing appearance under differing conditions of weather and crop development, and transcribed his discoveries onto maps to start reconstructing the ancient landscape. He also checked many of them on the ground, and refined some of Crawford's observations about cropmarks and **soilmark**s. Both men took part in excavations to test the below-ground evidence for things first seen or recorded from the air.

Even before Crawford's time others had been taking an interest in the archaeological potential of air photography. A Frenchman, Léon Rey, examined air photographs of ancient sites in Macedonia as early as 1916, and the German archaeologist Carl

Schuchardt did the same when he was studying the Roman border wall in Romania. But the first archaeologist to actually commission aerial photographs for archaeological purposes was probably Theodor Weigand. During the Great War Weigand persuaded the German High Command to let him set up a special unit for the protection of historical monuments in the Near East, and in 1920 he published air photographs taken for this unit over Late Roman and Byzantine ruins in the Negev and Sinai deserts (*Weigand 1920*). Meanwhile, and still under war conditions, Lieutenant-Colonel G. A. Beazeley, of the British Royal Engineers, realised how many **trace**s of the past he was able to see during his flights over Mesopotamia, and then applied aerial photography to the recording of the ruined ninth-century city of Old Samarra, in the desert northwest of Baghdad (*Beazeley 1920*). On these and later flights Beazeley would often land his aircraft to examine the **feature**s that he had just seen from the air. He was the first of many to remark that things which were clearly visible from the air vanished altogether when viewed from ground level. He was also one of the first to register the importance of 'landscape' features such as canals and irrigation systems, as distinct from individual 'sites' such as forts and towns. In this sense, like Poidebard and Baradez after him, Beazeley was a precursor of the 'landscape archaeologists' of the present day.

Still in the Middle East, one of the great innovators was Pére Antoine Poidebard (Fig 1.6), a French priest, soldier and aviator, who was for many years a missionary and then soldier in Armenia. In 1924 he moved to French-administered Lebanon as a professor at the Jesuit University of Beirut. A year later he was surveying the economic potential of northern Syria, using both ground-based and aerial survey (he had been a keen aviator since his first flight over Persia in 1918). This first phase of work on the Syrian steppe showed him the importance of climate and terrain, and he studied these in detail when in 1926 he began to investigate the Roman and Byzantine remains that he had seen during his earlier flights.

Poidebard, realising that terrestrial survey alone would not meet his needs, embarked on a long series of flights with pilots of the French air force, using both vertical and oblique photography in the identification, mapping and interpretation of the roads, forts, camps, towers and irrigation systems of the shifting border zone at the eastern edge of the Roman Empire (Fig 1.6). Here, in 550 hours of flying, first in upper Mesopotamia and later in western Syria (*Poidebard 1934*, *1945*), he developed techniques of observation, interpretation and photographic recording that, in their use of low light and **vegetation mark**s, broadly matched those developed by Crawford in southern England (Poidebard, in addition, developed some special techniques for the arid landscape and sand-laden atmosphere of Syrian steppe).

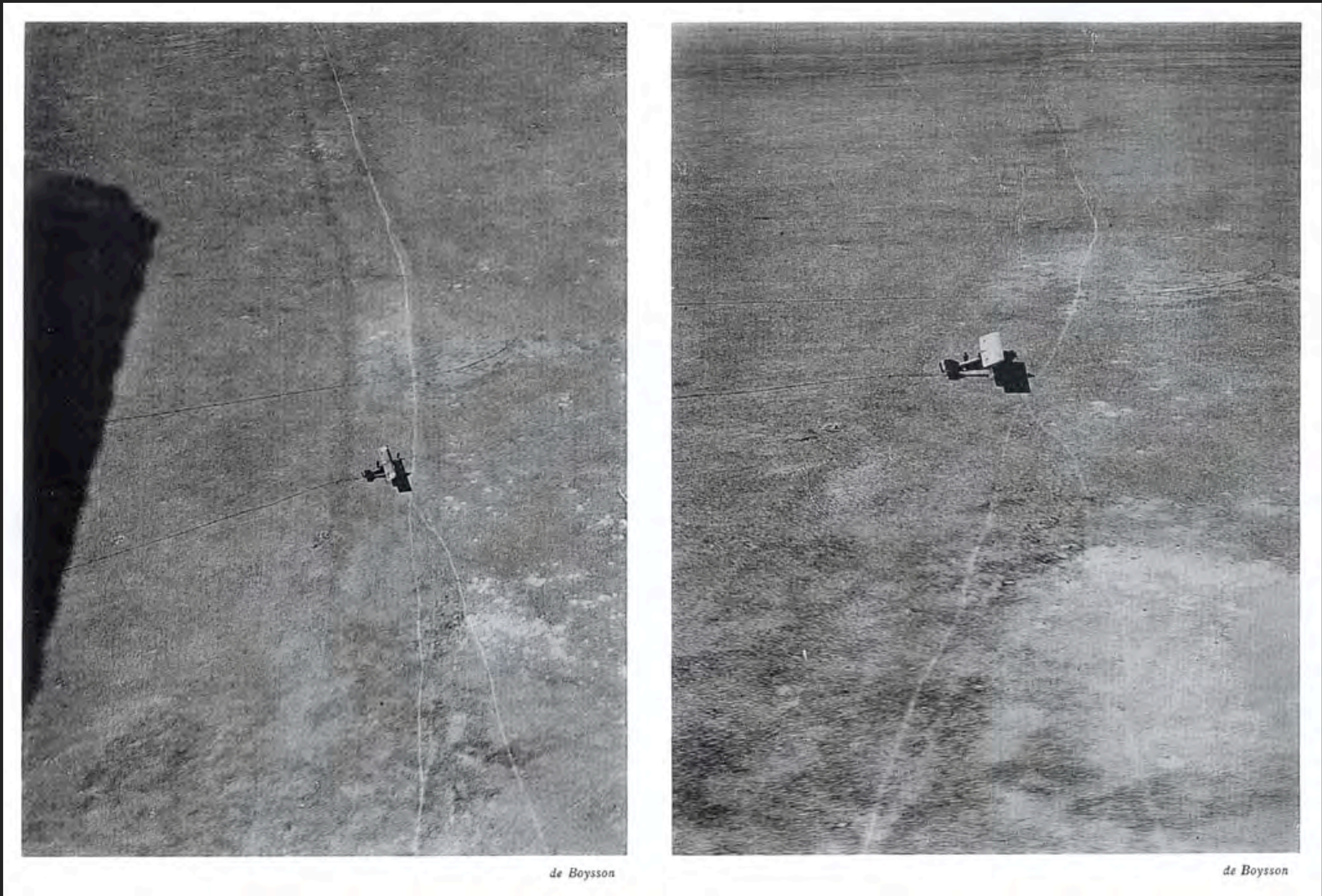

Fig 1. 6 Père Antoine Poidebard in Syria

Paired photographs taken by Poidebard's team of pilots and photographers to show that a Roman road, clearly visible from the air (left), became progressively less discernible as one approached the ground. At ground level it was quite undetectable. One of the aircraft has landed on the road to provide a scale.

Fig 1. 7 Giuseppe Lugli in the Forum at Rome

The coordinated programme of aerial photography started by Lugli in 1939 was sadly cut short by the outbreak of World War II and was never resumed.

Poidebard's 1934 description of the first part of his campaign took the French academic establishment by storm, but it did not inspire any matching growth of aerial exploration in France itself, despite the developments taking place by this time just across the water in England. Back in Lebanon, in 1934-6, Poidebard pioneered yet another new technique in the air, this time exploring the under-water remains of the Roman and Phoenician harbours at Tyre, and later Sidon (*Poidebard 1939*, *1951a*, *1951b*). In 1935-37 Poidebard's work in Syria was matched in Persia, to the northeast, largely for an earlier period of remains, by Erich Schmidt, a German-born archaeologist lavishly sponsored by the University of Chicago. His discoveries of walls, roads, forts and literally hundreds of other sites were as startling as Poidebard's in Syria, and were achieved by a similar combination of exploratory flights and frequent ground checking (*Schmidt 1940*).

In Italy the inter-war years saw the full-scale use of **vertical air photographs** in national mapping programs, a technique taken up more slowly by other countries. But there was no flowering of exploratory work like that in Britain or the Middle East. At the end of the 1930s, however, an important initiative was taken by Guiseppe Lugli (Fig 1.7), of the Istituto di Studi Romani in Rome, who had used a dirigible as long ago as 1919 to obtain views of a villa that he was then working on in the Colli Albani. He was convinced that aerial photography could make a major contribution to Italian archaeology, especially so after his 1938 study of the information available on existing vertical photographs for four study areas in central and southern Italy (*Lugli 1939, 1940*).

Sadly, the ambitious programme of flying and photography that he then proposed fell victim to the Second World War. Another factor in the abandonment of the project, and in the failure to revive it after the war, may have been the legislation introduced in July 1939 on the taking and use of air photographs over Italy or any of its possessions. Everyone – citizen, company or state concern – had to conform to an impenetrable regime of permits, inspections and military censorship in the planning, collection and use of any photographs taken from hired aircraft (*Piccarreta–Ceraudo 2000*, pp. 198-203).

In effect, the window which Lugli had been just about to open had been slammed securely shut again. It remained so, for any project that did not have military blessing, for the following sixty years.

World War II

The Second World War, like its predecessor, produced rapid technical advances in aircraft, cameras and films. It also introduced pilots, observers, photographers and ground-based intelligence officers to the potential of archaeological air photography. Several would take leading roles in aerial exploration after the war. Millions of photographs, mainly verticals but also some obliques, were taken in all theatres of the war. Many were destroyed soon afterwards but vast quantities still survive in archives across Europe, Russia and America. They are an immensely rich source of archaeological data, barely exploited as yet and in some cases now at risk of loss or obscurity through inattention or lack of funds for their cataloguing and preservation (*Bewley–Rączkowski 2002*, p. 329).

Aerial archaeology did not entirely cease during the war. For instance in Britain several military pilots were noticing, and even reporting on, the archaeology that they saw below them (see, for instance, *Riley 1942*, *1944*, *1945*). Poidebard, while serving in the French High Command, continued his researches in Syria, while in Algeria from 1940 onwards Jean Baradez, a former officer of the French air force and already a skilled photo interpreter, took up a task which Poidebard had been contemplating just before the war. Starting from the analysis of 120 high-level vertical photographs, but later undertaking his own low-level flying and photography, Baradez identified the half hidden **trace**s of the Roman transformation of the Sahara rim, complete with its walls, ditches, forts, camps, roads, irrigation systems and widespread centuriation (*Baradez 1949*). Similar work was done in neighbouring parts of North Africa both before and after the war by British and French scholars.

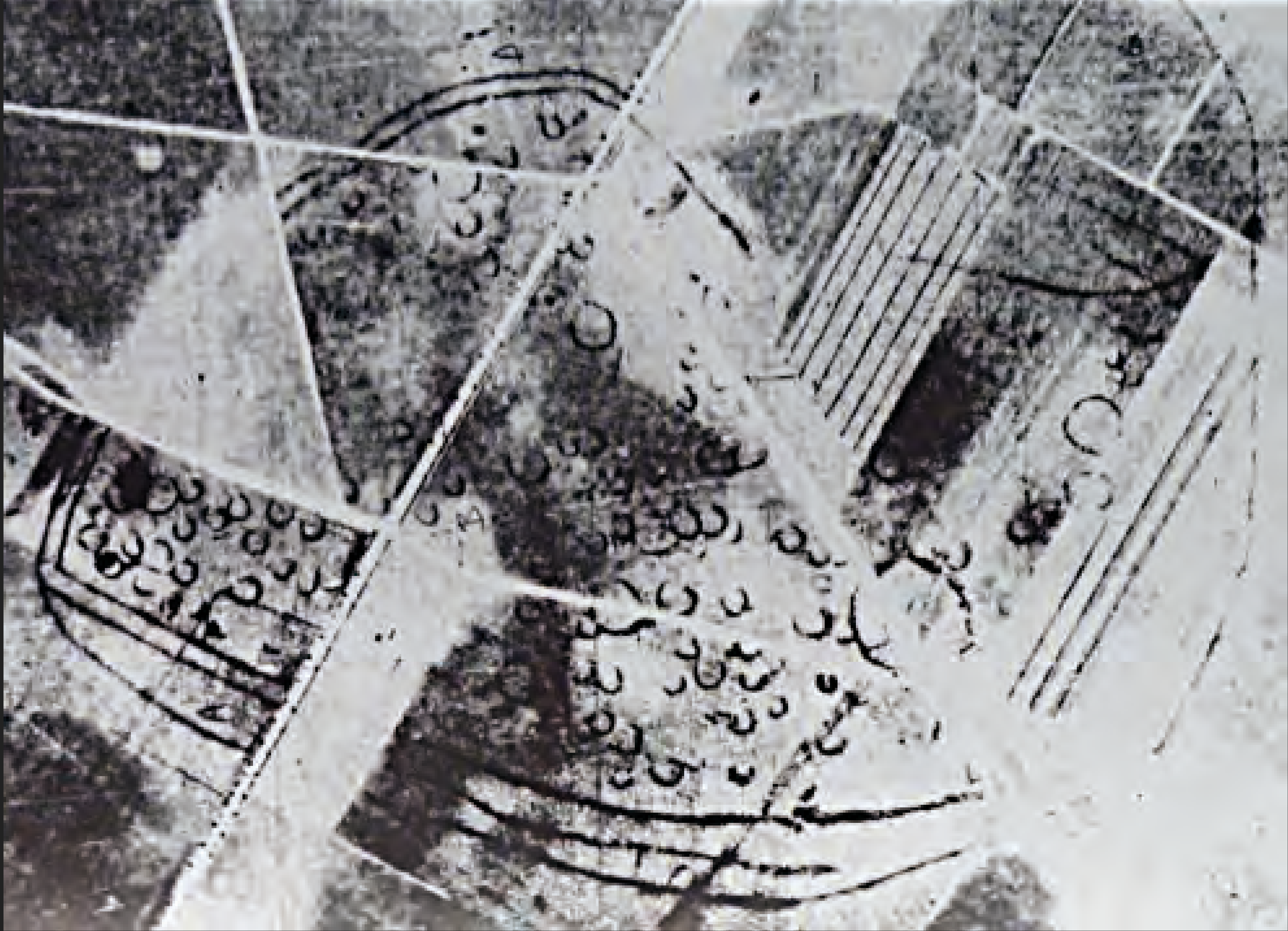

Fig 1. 8 Ditched Neolithic village on the Tavoliere, Puglia, Italy

One of the Neolithic villages photographed and mapped in the pioneering work of John Bradford and Peter Williams-Hunt in May and June 1945. Working first from vertical air photographs taken for military purposes during the war, the two British Army officers then photographed some of the more important sites through both oblique and (as here) vertical photography, mapping and codifying the results.

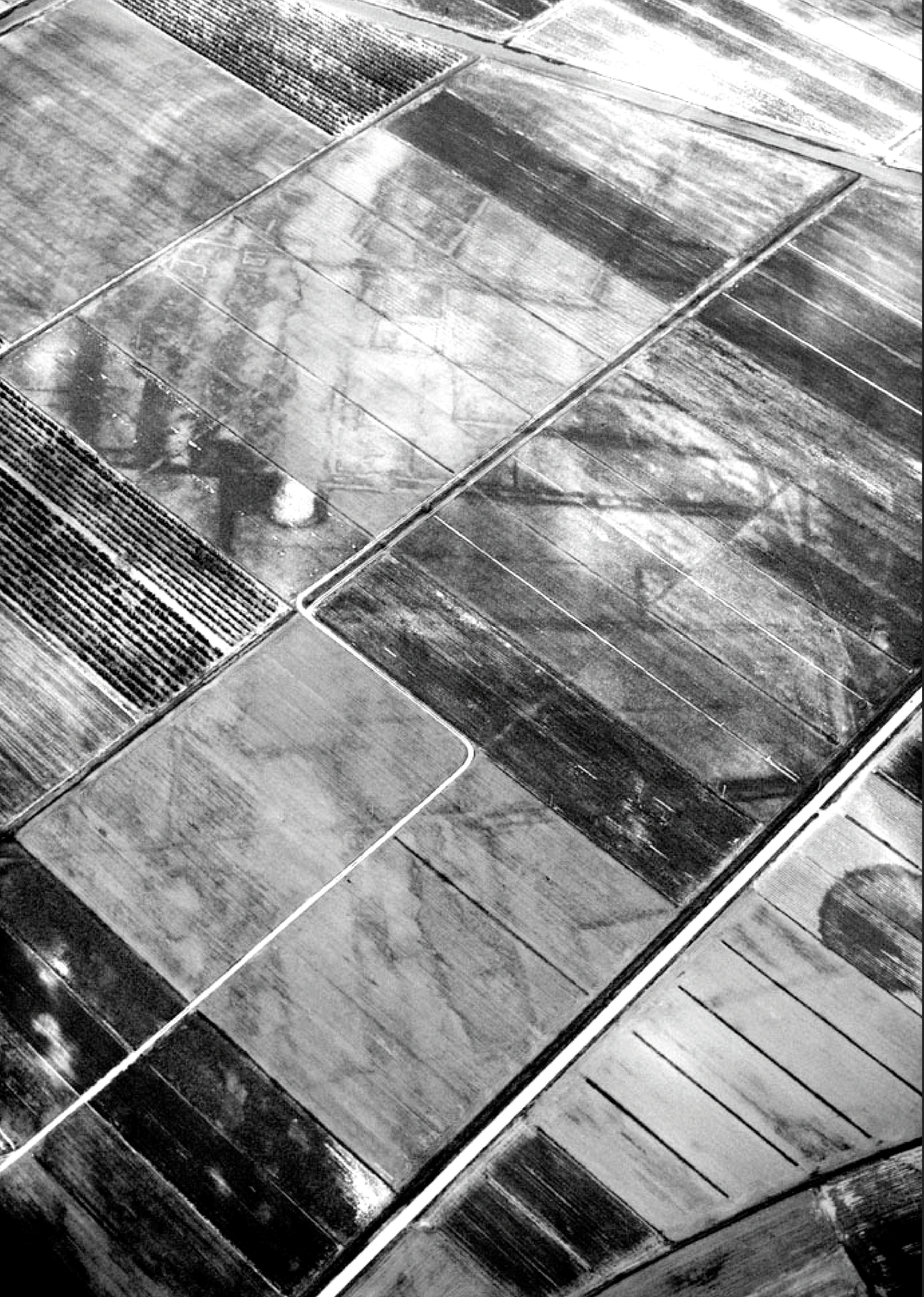

Fig 1. 9 Nereo Alfieri and discovery of the Greco-Etruscan city of Spina

In the early 1950s Nereo Alfieri and Vitale Valvassori used both vertical and oblique air photography through their connection with the military authorities. By means of aerial observation and photography they were able to re-discover the lost city of Spina, in the Po Valley delta near Ferrara. Plans by Alfieri for wider-ranging aerial photography and mapping in the Po Valley unfortunately never came to fruition.
Top: Alfieri, on the right, with his pilot, Ugo Cassigoli, after a survey flight. *Bottom*. Cropmarks near Spina in a photograph from 1959.

The post-war years in Italy

Wartime intelligence photographs taken by the British Royal Air Force (RAF) in southern and central Italy prompted the next great story of discovery and interpretation, on the wide-spreading arable land of the Tavoliere delle Puglie, on the 'heel' of Italy. Here, starting from the analysis of 1943 and 1944 reconnaissance photographs, two British army officers, John Bradford and Peter Williams-Hunt, in two months of frantic activity in May and June 1945, identified literally hundreds of previously unsuspected sites, appearing as cropmarks in the ripening grain of this dry but fertile plain around Foggia. They had seen these and other marks during their official duties and now persuaded the military authorities to let them examine the wartime photographs, and even to undertake limited oblique and vertical photography from RAF aircraft. With its relatively thin soil above a hard calcareous layer ('*crosta*'), itself overlying sandy subsoil, the Tavoliere presents ideal conditions for the development of cropmarks. Working at remarkable speed, Bradford and Williams-Hunt identified and mapped over 200 ditched settlements (ditched villages) up to 800 x 500m in extent, most of them with smaller circular or penannular **enclosure**s or 'compounds' in their interiors (Fig 1.8). Excavations in 1945 and later showed these remarkable enclosures to be Neolithic in date. The cropmarks had revealed a whole 'landscape' of Neolithic villages, with overlying systems of Roman fields and villas and medieval sites of many types. All despite the almost total absence of visible remains above-ground (*Bradford–Williams-Hunt 1946*; *Bradford 1949*, *1950*, *1957*; *Jones 1987*; *Guiitoli 2003a*, pp. 103-27; *Radcliffe 2006*, *2007*; *Musson–Radcliffe 2010*).

Bradford, some years later, used his interpretative skills to identify hundreds of Etruscan tombs in central Italy (*Bradford 1947*, *1957*) and to map Roman centuriation and gridded town plans of various ages in Italy, France, Greece and along the Adriatic coast. Bradford's discoveries on the Tavoliere, however, remain the outstanding achievement of this energetic and perceptive scholar, sadly lost to illness soon after publication in 1957 of his magisterial book on this and his other studies. Bradford's investigations were, of course, only the start of work on the Tavoliere. Excavations and fieldwork have continued over the years, as has analysis of the aerial photographs, both in Italy and Britain. The number of identified ditched settlements had risen to 566 after examination of post-war Italian vertical photographs along with the results of flights in 1987 and 1989 by Derrick Riley and Otto Braasch (*Brown 2004*; *Riley 1992*). Even further sites have been added in the years since 2000 through flights by Otto Braasch, Valentino Romano and tudents and tutors at the Foggia training schools of 2003 and 2007 (*Musson 2004*).

In spite of these discoveries Lugli's pre-war plans for archaeological air survey were not taken up again after the war, though Bradford (as noted above) was sure that the techniques developed in Britain were equally applicable around the Mediterranean rim. Presumably the 1939 law was one of the reasons – the regulations would have daunted the most determined of archaeologists, and no doubt discouraged university departments and research institutes from contemplating such an exercise. This did not stop John Ward-Perkins, Director of the British School at Rome and an avid pursuer of Roman roads through **aerial evidence**, from urging his Italian colleagues to take to the air, while Crawford bemoaned the lack of aerial activity in Italy from his distant chair as editor of the British journal *Antiquity*. 'Every sort of excuse was made for doing nothing', he wrote, 'the soil was unsuitable because under cultivation; or archaeologists moaned that they could do nothing because they were forbidden to fly and take their own photos.' (Editorial note by Crawford in *Anti-quity*, March 1949, p. 1.)

Despite these urgings, the aerial work of Italian archaeologists continued to focus on the analysis of existing (or occasionally specially commissioned) vertical photographs, for instance in the researches of Adamesteau noted above. Important studies were also produced by Ferdinando Castagnoli on patterns of centuriation and gridded town plans in various parts of Italy (*Castagnoli 1956*, *1958*, *1961*, *1969*; *Piccarreta–Ceraudo 2000*, pp. 81-84; *Ceraudo 2004*, *2005*, *2010*; *Tozzi 2004*). Another outstanding exception, involving special photographic missions in partnership with the Italian air force, was the rediscovery in the 1950s by Nereo Alfieri and Vitale Valvassori of the Greco-Etruscan city of Spina, long lost in the marshlands of the Po delta near Ferrara (Fig 1.9; *Alfieri–Valvassori 1957*; *Guaitoli 2003,* pp. 239-44).

Existing vertical photographs provided the source material for much research in the post-War years into the roads and land-management systems of the Roman period. Low-level air photographs taken by commercial survey companies were used alongside existing verticals by P. Tozzi, M. Harari and A. de Guio, of the Universities of Pavia and Padova, in their studies of sites and landscapes in the Po Valley and other parts of northern Italy (*Tozzi–Harari 1984*, *1990*). Other 'aerial' researches were conducted by R. Compatangelo in Campania and Salento (*Compatangelo 1986*). Mapping projects, often aimed at the better management of important heritage sites, have since the late 1970s in Italy reached new levels of sophistication through the use of analogue and digital **photogrammetry** by a number of specialist organisations, including units at the universities of Bari, Lecce (Salento), Potenza and Roma 'La Sapienza' (for a fine example of such work see Fig 1.10). Various aspects of air photography, photogrammetry and landscape analysis are taught at each of these universities, as also at the universities of Siena, Foggia, Pisa, Padova and Bologna.

Finally, in this brief look at post-war Italy, two men and two institutions deserve special mention. The first is Giulio Schmiedt, for many years Director of the archaeological section of the Istituto Geografico Militare (IGM), founded in 1882 to deal with aspects of the national mapping programme. In the inter-war years IGM also took over responsibility for systematic coverage of the country by aerial photography. This responsibility continued in the post-War years, notionally through re-survey at five-yearly intervals from the date of the first complete national coverage in 1954-45 – the so-called GAI or '*volo base*' (low-level) survey, at a scale of 1:30,000. Unfortunately the five-year interval was an aspiration that has not been consistently achieved in practice. At its offices in Florence IGM holds a vast collection of vertical aerial photographs, dating from 1908 to the present day. The organisation, and Schmiedt himself, also produced a steady stream of synoptic and methodological papers from the 1950s onward, along with three of the five intended volumes of the magisterial air-photo atlas of human settlement in Italy, *Atlante aerofotografico delle sede umane in Italia* (Fig 1.11, *Schmiedt 1964*, *1970*, *1974*).

A second celebrated name is that of Dinu Adamesteanu, a Romanian expatriate whose researches in Sicily and Basilicata in the 1040s and 1050s have already been mentioned. Adamesteanu was one of the leading lights in a campaign to secure preservation and study of the large quantities of **vertical air photographs** by then being taken for mapping and other purposes throughout Italy, including those relating to his own studies of Sicily and Basilicata in the 1950s (*Adamesteanu 1957*). When the idea finally resulted in the formation of the Italian national air photo archive, Aerofototeca Nazionale, at the end of 1958, Adamesteanu became the organisation's first Director. Since then its Rome-based archives have become an essential source for all aspects of environmental and historical research in Italy, and it has published and inspired a steady stream of synoptic studies based on the photo collections in its care (including, most recently, the magnificent collection of studies presented in 2003 in *Lo sguardo di Icaro* (*Guaitoli 2003*). Aerofototeca has also undertaken specifically archaeological sorties in the air and has provided training in photo interpretation for university students and the national heritage agency, the Soprintendenza Archeologica.

A useful description of the organisations holding accessible air photo archives in Italy, or carrying out analytical work based on air photos, can be found in *Piccarreta–Ceraudo 2000,* pp. 189-98*;* see also *Alvisi 1989,* pp. 144-49*; Guaitoli 2003,* pp. 23-26, 37-42*; Ceraudo 2003; Tozzi 2004*.

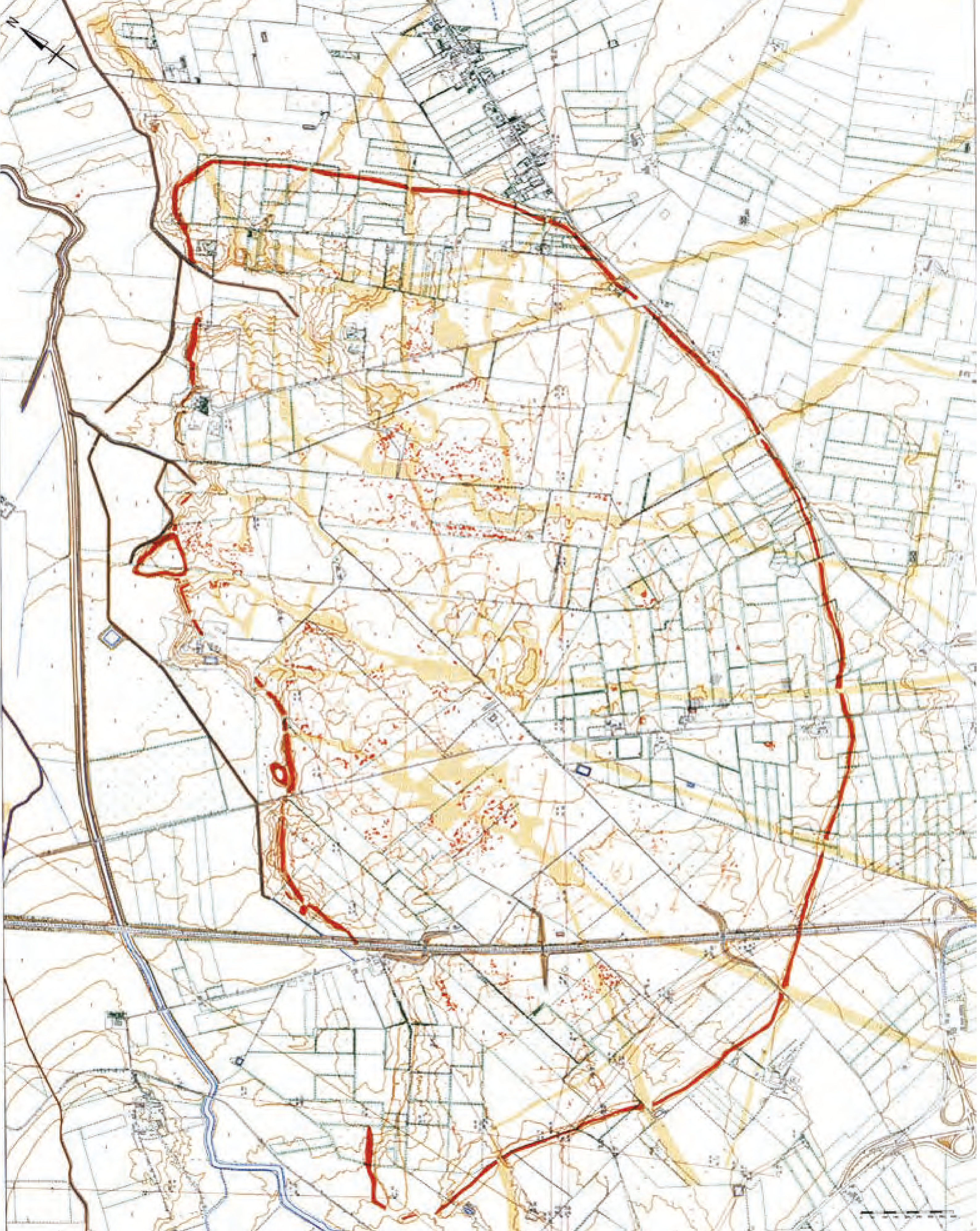

Fig 1. 10 The ancient city of Arpi, Foggia, southern Italy

A fine example of air photo interpretation and mapping from the Ancient Topography Laboratory of the University of Lecce (now Salento).
The city's fortifications and internal features are shown in red, with tracks abd streets both inside and outside the city in stippled orange.

Mapped by Fabio Piccarreta and Giuseppe Ceraudo

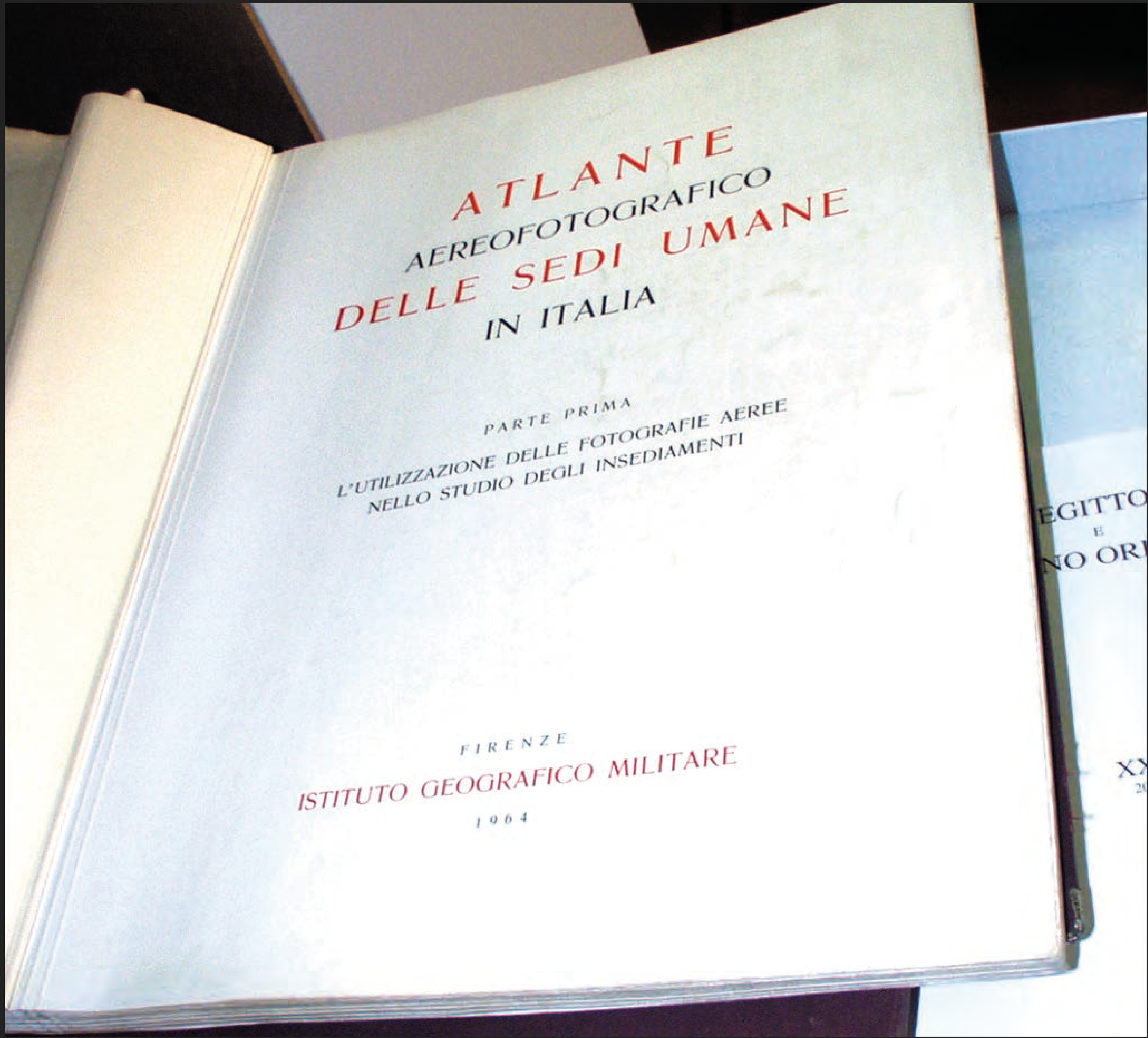

Fig 1. 11 Giulio Schmiedt and the Istituto Geografico Militare (IGM)

Two volumes of the magisterial *Atlante aerofotografico delle sedi umane in Italia* ('Air photo Atlas of Human Settlement in Italy'). Five volumes were planned but only three were eventually published.

Fig 1. 12 Dinu Adamesteanu and Aerofototeca Nazionale

In 1958, when Dinu Adamesteanu took up his post as first head of the newly created air photo library in Rome, now known as Aerofototeca Nazionale, he could not have imagined the riches that would be revealed in the organisation's 2003 exhibition and accompanying book, *Lo Sguardo di Icaro* (GUAITOLI 2003A). Without parallel in Europe, the book, shown here with its cover photograph of Dura Europos in Syria, brings together studies of a host of sites and landscapes in Italy and beyond, mapped and analysed through the use of vertical air photographs.

Fig 1. 13 Four pioneers of aerial survey for archaeology

From left to right: Dr Derrick Riley, Dr Otto Braasch, Professor J K S StJoseph and Jim Pickering, photographed during a chance meeting when undertaking aerial survey in Central Europe. All four made huge contributions to aerial archaeology in various parts of Europe. Riley and Braasch, in particular, flew over Italy in 1987 and 1989. Braasch, who also visited the country every year from 2000 to 2007, was Senior Pilot-Instructor at four aerial archaeology training schools at Siena, Foggia and Grosseto between in 2001 and 2007.

Post-war developments in Britain

Britain was the first country to take up aerial exploration after World War II, and has since carried this activity to new levels of effectiveness and sophistication (for a general account of developments and results in England, for instance, see *Barber 2010*). Though many other European countries make wide use of archaeological air photography the integration of the technique into the fabric of public archaeology (and to a lesser extent into academic studies) is at its most developed in Britain. Whereas mapping and topographical studies were the driving force behind post-war developments in Italy, the impetus in Britain came in the first instance from the irresistible lure of exploration.

Dr (later Professor) J. K. S. St Joseph (Fig. 1.13) first began aerial exploration before the war with O. G. S. Crawford. During the war, amongst other things, he undertook intelligence work and flew as observer on a number of Royal Air Force (RAF) missions. Through his wartime contacts he persuaded the RAF to take him on further flights in the post-war years as passenger and photographer, recording whatever archaeology or other subjects he could. In 1948 he began survey work for the University of Cambridge, the position being formalised in 1949 with the establishment of the Cambridge University Committee for Aerial Photography (CUCAP) to provide air photographic material for all departments of the university. For many years, therefore, St Joseph photographed topographical, geological or geomorphological features as well as archaeological sites (he was himself a trained geologist).

In 1965 the Cambridge unit acquired its own aircraft and began free-ranging flights in response to requests or in pursuit of particular research interests, notably, for instance, the surviving (or still hidden) evidence for Roman military campaigns in various parts of Britain. Exploratory campaigns were also undertaken in other countries, for instance in Ireland between 1951 and 1973 as well as in Northern France (1961, 1973-74), Denmark (1966-70) and the Netherlands (1970-73). By the time the unit drastically reduced its work on oblique aerial photography in the early 1980s (in favour of commissioned vertical photography for a wide variety of purposes) the number of oblique photographs in the Cambridge collection amounted to some 300,000 (not all of them archaeological), covering most of Britain as well as parts of Ireland, France, the Netherlands and Denmark. The discoveries made over the years revolutionised the content and understanding of the Roman occupation of Britain, and brought vast quantities of new data (and new interpretations) to almost every period of British antiquity from the Neolithic to the rapidly changing rural and industrial scene of the twentieth century (see, for instance, *Norman–St Joseph 1969*; *Beresford–St Joseph 1979*; *Frere–St Joseph 1983*; *Hudson 1984*). The unit was later absorbed into the university's Department of Geography as the short-lived Unit for Landscape

Modelling. The photo collection can still be consulted in person or over the internet through its computerised catalogue (*www.geog.cam.ac.uk/cucap*).

In the post-war years British aerial photography also benefited from the efforts of a small but energetic band of 'private flyers', notably Arnold Baker, Jim Pickering and from the 1970s to his death in 1993, Derrick Riley (Fig 1.13). These dedicated researchers used aero club aircraft and their own funds to scour the countryside, and of course to integrate their discoveries into the archaeological concepts of the time (for some of Riley's work see Figs 9.4 and 9.6). Later, when limited funds became available from public sources, these few pioneers were joined in the air by others whose daytime jobs lay for the most part in museums, local authorities and university departments. For a time, as a result, Britain had an informal pattern of 'regional flyers' who covered those parts of the country not adequately dealt with by the national survey organisations.

The biggest players on the national scene are now the state-backed survey bodies known as the Royal Commissions, in the case of England now subsumed within a larger body, English Heritage. The English Commission was the first to take up aerial survey, establishing an Air Photographs Unit in 1965 and beginning its own flights two years later. The Scottish Commission followed suit in 1976 and the Welsh Commission in 1986. All three bodies undertake their own survey flights, using hired aircraft both for exploratory work and for a variety of other functions in the fields of recording and conservation. English Heritage also provides part-funding for the work of a small number of county-based regional flyers. All of the photographs produced at national and regional level are on public access through county, regional and national archives. All three Commissions (and a number of other bodies across Britain) hold substantial archives of 'historical' air photographs, both vertical and oblique, derived from a variety of sources, notably the vertical coverage created from the mid-1940s by the RAF and from the mid-1960s to the late 1980s by the Ordnance Survey. After that date most of the Ordnance Survey's mapping work was done directly from negatives; both these and the digital images acquired in place of negatives from the early years of the new century, have to be printed before public access can be provided.

The emphasis on topographical analysis and mapping which still dominates aerial archaeology in Italy found its counterpart in Britain in the policy of John Hampton, the first head of the Air Photography Unit in the Royal Commission in England. He insisted that as many photographs as possible should be converted into 'cartographic statements', at a variety of scales, so that they could be read like any other mapped or documented information used by archaeologists. This led in the late 1980s to pilot studies that developed from 1992 into a

National Mapping Programme for England (NMPE), the aim being to create maps and written records for all disused features of the landscape that can be seen on vertical or oblique aerial photograph over the whole of the country (Fig 1.14; *Bewley 2001*; *Horne 2009*, *2011*; *Winton–Horne 2010*; web reference *NMPE*). Projects within NMPE invariably increase the number of known 'sites' in an area, with particular gains in the medieval, post-medieval and recent periods. Often the 'new' sites represent 60-70% of the records at the end of a mapping exercise. The Welsh and Scottish Commissions have taken rather different lines, their mapping projects being more closely related to survey work on the ground or to the transcription and description of the individual sites recorded during exploratory survey.

Britain has no institution specifically devoted to aerial **photogrammetry** for archaeology, though photogrammetric mapping was in the 1980s and 1990s carried out on a selective basis by English Heritage, mainly for sites which had special management needs or which were the subject of complementary analytical survey on the ground. In most of Britain, however, the concentration is on the fairly rapid interpretation and computer-based transcription of archaeological information, at a basic scale of 1:10,000, from both vertical and oblique photographs, so as to create 'landscape-scale' rather than 'site-based' maps for incorporation, along with related text records, in GIS systems providing information on all aspects of the archaeological resource.

To an extent this policy can be traced back to the realisation, especially in the early 1970s, that vast amounts of archaeological information were being lost to construction works, industrial development, road building, afforestation and the like. From this growing public and political awareness of the need for 'rescue archaeology' there came a rapid growth in the number of archaeologists working within county and municipal authorities to document and map the known archaeology so that it could be protected (as far as possible) through the development control and other planning procedures. A necessary tool was the municipal, county or regional Sites and Monuments Records (SMRs), more recently expanded in scope to form so-called Historic Environment Records (HERs). From the outset these consisted of basic maps and text descriptions of all the archaeological sites and finds, of all dates until relatively recent times, that could be identified in the available sources (aerial photographs included). The creation of these records from the mid 1970s onwards, and their progressive transfer to GIS-based systems in recent years, has shown how important it is to have basic information about all known sites, rather than just detailed data on a favoured few. One upshot of this approach, and of its reflection in policy for air photo mapping, has been the regular use of **aerial information** to identify the implications of development proposals, especially those involving large tracts of

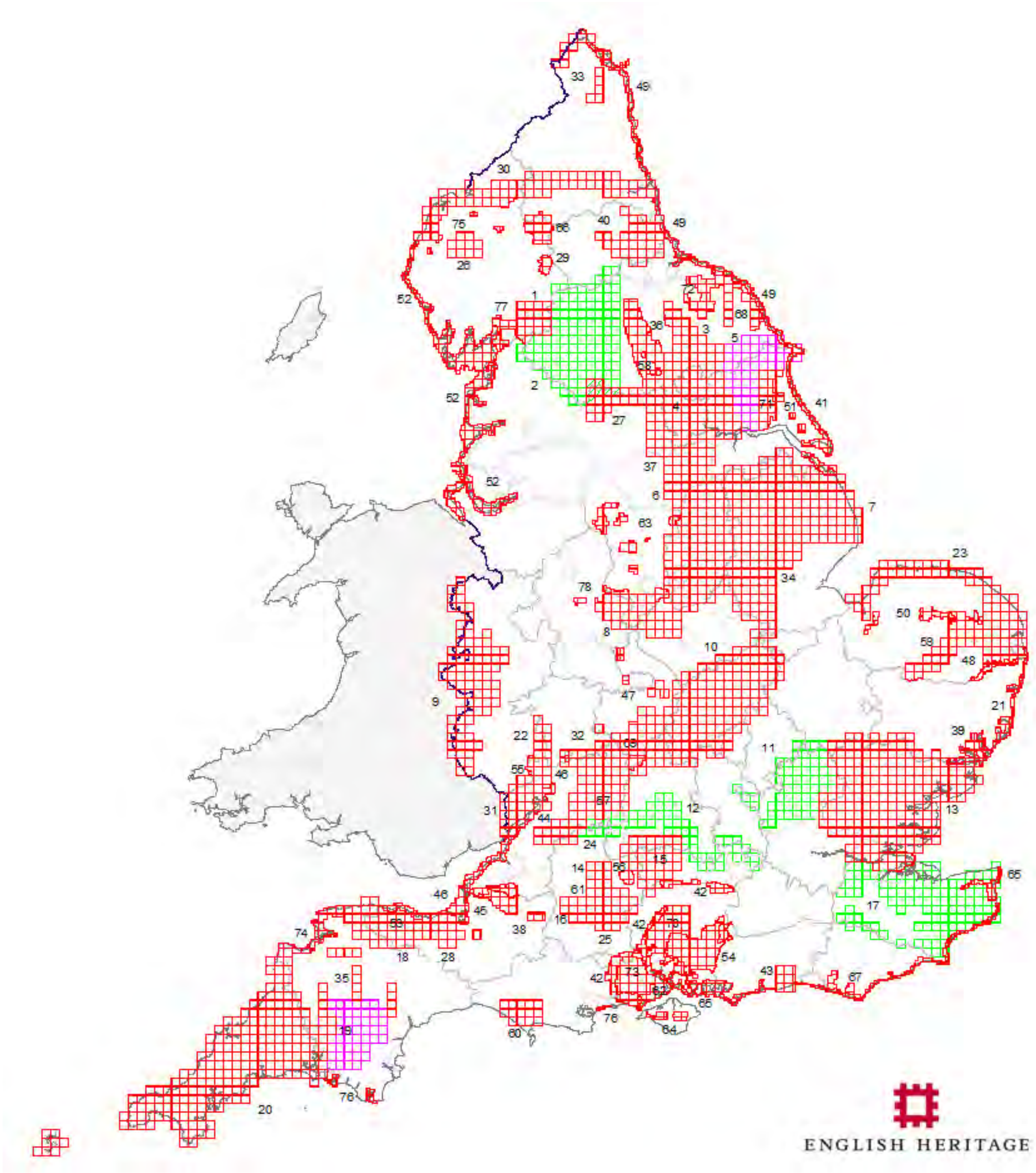

Fig 1. 14 **The National Mapping Programme for England (NMPE)**

The state of completion, at the beginning of 2013, of the English Heritage project for the (now digital) mapping at 1:10,000 scale of all traces of archaeological significance observable on readily available vertical and oblique aerial photographs of England.

In recent years the focus has been on parts of the country that are considered most at risk from archaeologically damaging factors such as coastal erosion, heavy agricultural activity or industrial and urban expansion.

The results of the work in the individual study areas can be consulted on the project website at english-heritage.org.

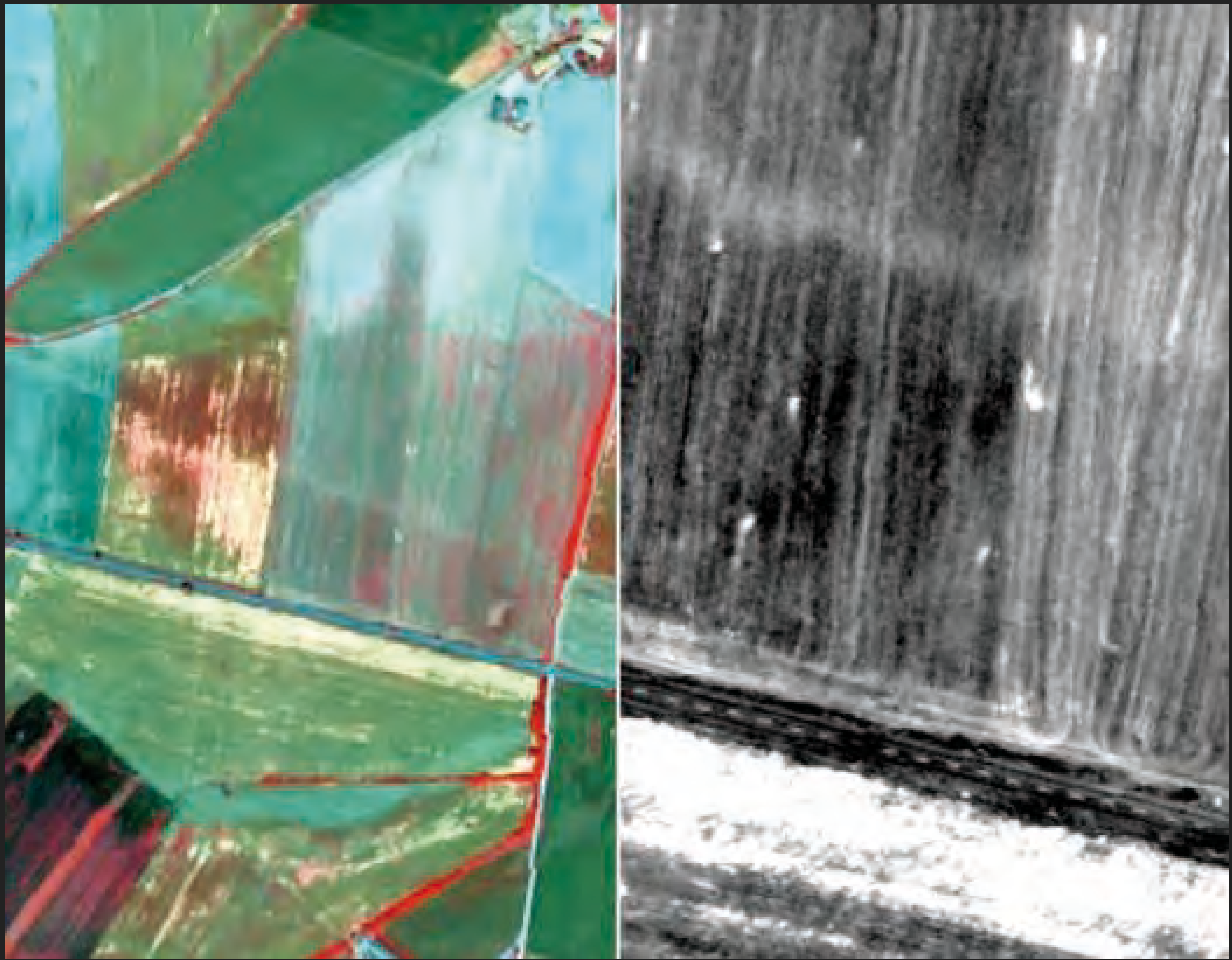

Fig 1. 15 Satellite imagery

On the left is a detail from a multi-spectral image acquired by the QuickBird 2 satellite near Pienza. On the right (printed here at a larger scale) is part of the same area recorded by the satellite's panchromatic sensor. In both images it is possible to make out a linear mark oriented WNW-ESE, a diversionary route of the Via Cassia. In the image on the right the level of recorded detail is good enough to show the white line along the centre of the road near the bottom of the picture.

Fig 1. 16 Interpreting and converting photographs into maps

Cathy Stoertz, of English Heritage, with the 'red boxes' which contain the 35,000 individual images which she used in creating the series of interpretative maps presented in her study of the chalk downland of the Yorkshire Wolds, in northern England. See also Figs 9.8, 9.9 and *Stoertz 1997.*

projects or pipeline construction. Both existing and newly commissioned aerial photographs, and their analysis and transcription at varying map scales, have become regular tools in the conservation process, the mapped information often providing the broader context for detailed excavation evidence where salvage work still proves necessary (Fig 2.21).

Aerial archaeology: the struggle for acceptance

The appreciation – and acceptance – of aerial archaeology, and especially exploratory aerial survey, is clearly far wider in Britain than it is in many other countries of Europe. Aerial studies in Britain suffer little from the 'tyranny of technique', as distinct from the practical evaluation and implementation of the information gained from their application, both aerial survey and its outputs being reasonably well integrated into professional archaeology and heritage conservation. Aerial exploration and mapping both of landscapes and of individual sites have become commonplace tools in a wide range of archaeological work, whether combined with ground-based fieldwork or not. The academic community, however, with honourable exceptions, has remained strangely reluctant to embrace aerial information and the insights that it can produce, perhaps because the body of new data is so vast and so relatively difficult to access through traditional publication channels.

In the first instance there is the sheer quantity of data, the hundreds of new sites that have to be absorbed, often of types never seen before. Except for limited areas of interest, too, the process of absorption cannot really begin until the thousands of individual photographs have been interpreted, mapped, analysed and published – in one form or another – in morphological or landscape studies (Figs 1.16 and Chapter 9). In practice it is easier to pick out a few photogenic discoveries than to master the great mass of new information, easier to illustrate well-known sites from the air than to ask new kinds of questions about the ones that have just been discovered.

Moreover, archaeologists accustomed to working with information derived from excavation, ground survey or surface collection tend to want aerial archaeology to address the same questions that they themselves have been grappling with for years. This may be reasonable for such things as Roman roads, campaign forts (in Britain) or centuriation (in other parts of Europe) but many traditional archaeological concerns are drawn more widely or more narrowly than this.

The new information provided by aerial survey also allows – indeed demands – entirely new approaches to analysis of the ancient landscape. Regrettably, aerial survey does not 'work' in all parts of the landscape, whether in Britain or elsewhere. Nor will it necessarily say anything about an individual site with which the enquirer is concerned – it usually says more about adjacent sites, or previously unsuspected ones, than about those which were the focus of the question in the first place. But, given the chance to develop its own dynamic, aerial archaeology can open entirely new lines of enquiry, especially about such things as settlement distribution or patterns of landscape exploitation.

At another level, many archaeologists in the countries of mainland Europe seem to feel that aerial evidence, whether represented by cropmarks, soilmarks or previously undetected **earthworks**, cannot really be trusted until it has been measured on the ground or 'confirmed' in some way by excavation. British archaeologists, perhaps because of their longer familiarity with **aerial evidence** and with the numerous 'confirmations' by excavation that have already been published, seem more ready to accept that a **ring-ditch** or **enclosure** appearing only as a cropmark or soilmark on an aerial photograph is just as much a 'site' as is an upstanding mound or embanked enclosure, the physical remains of which say little more, of themselves, about questions of dating or function.

These, in a sense, are conceptual problems. But there are – or have been – more practical impediments too. For many decades, of course, there has been the objection that aerial survey, in Italy and some other countries of Europe, was illegal – or virtually so because of remaining bureaucratic or military restrictions. No longer so. Some archaeologists, too, see aerial survey as expensive. But it is vastly less costly and more wide ranging in its coverage than excavation, and no more expensive than some kinds of field survey or surface collection. Perhaps there is a suspicion that allocating *any* money to aerial exploration may mean less for these more well established techniques.

Then there are misconceptions or half truths. To follow Crawford's tetchy editorial from the 1950s and to return to the case of Italy, it has sometimes been argued that the techniques which are so successful north of the Alps will not work on Italian soils and geology, that they only work for a small proportion of the landscape, that they will not work because the ground is under cultivation, or the wrong *kind* of cultivation – the latter is true to a certain extent but in general it is the very act of cultivation that reveals the archaeology as cropmark or soilmark evidence. Complaints have also been made that free-ranging survey will simply produce more sites, thereby demanding more conservation, that cropmarks reveal little about the function or date of the sites they represent, that analytical field survey and surface collection are more effective. And so on, and so on.

All of these objections are true to one extent or another, but similar things can be said about every other method of archaeological investigation. In reality no individual technique gives us better than 'peepholes on the past'. Excavation deals with only a miniscule part of the landscape and recovers only a tiny proportion of what was originally there. Field survey, including geophysical prospection, can verify the physical existence, size and shape of surviving monuments, but without costly excavation or close resemblance to better understood sites elsewhere the date and function of *any* archaeological feature (whether upstanding or levelled) remains pretty much a matter of conjecture. Surface collection tells us about the existence and perhaps the extent of *some* kinds of site but says little or nothing about their physical form or what is actually buried beneath the soil. Documentary sources tell us about things that we often cannot reconcile with the evidence available in the field. And so on, and so on.

Against these objections there are positive arguments. For instance that recording from the air, at regular intervals and especially for areas at greatest risk, is the only realistic means of documenting the traces of the past (or even present) landscapes that are in the throes of rapid and irreversible change. It is true in almost any country that some aspects of landscape exploitation or land management (such as irrigation schemes or land division) can only, or best, be explored from the air. Or that some kinds of ancient sites survive almost exclusively as traces visible only from abobe (ritual and ceremonial sites of the Neolithic and Bronze Age in Britain, for instance, or the Neolithic villages in southern Italy or on the plains of Poland).

What we must surely do is to use every technique available to us in the search for a more broadly based and perceptive archaeology. Far preferable to seek new methods of access to tangible archaeological evidence than to retreat into fact-free speculation about gender roles, mental constructs or psychological motivations in the distant and irrecoverable past. The basis of all archaeological speculation, in the view of the present authors, is the surviving physical evidence of what happened (or existed) in the past. In the identification of this basic information aerial survey has an indispensable role to play, not only in providing new evidence in areas where it *does* work, but also in showing us what may be missing in adjacent areas where it does *not*.

Flights into the future

Aerial archaeology, like archaeology as a whole, has a rapidly expanding field of application, not just for the more distant past but also for the archaeology of the industrial age and for the rapid landscape change of recent decades. It serves functions in exploration, recording, mapping, interpretation, presentation, conservation and of course research. But it will only ‘take off’ in, in a real as well as a metaphorical sense, when archaeologists in a country new to its use take to the air *themselves* and find how they can *make* it work in their own landscapes, townscapes and industrial zones. Some re-alignment of attitudes and funding may be needed, and progress may at first be slow and geographically uneven over Europe as a whole. But the history of aerial archaeology in Britain shows how much can be achieved through the efforts and enthusiasm of a few individuals. The techniques involved are not particularly complex or arcane, and there is a vast body of experience to be drawn upon, through published material and through the experience and of members of the world-wide Aerial Archaeology Research Group (www.univie.ac.at/aarg) and of the pan-European ArchaeoLandscapes project (www.archaeolandscapes.eu). The potential gain for European archaeology is surely worth the risk of occasional disappointments along the way. It is for the archaeologists of each country, and each region within a country, to test the idea and its execution in their own particular context, but it is as certain as the dawn that for many there will be revelations to match and surpass every disappointment that they might encounter along the way.

Postscript, 2012: aerial archaeology in other parts of Europe

Since this version of the book is aimed at Europe as a whole it is fitting to round off this introduction with a brief account of aerial archaeology in each country for which it has been possible (in the summer and autumn of 2012) to gather information from correspondence and conversation. Where countries are not included no information has been forthcoming. In an internet publication of this kind it may be possible to update the text if further advice or differing views are reported to the authors. The following paragraphs should be read in conjunction with the Supplementary Bibliography at the end of the book, which gives basic references for each country for which it has been possible to compile information.

As in Britain and Italy many countries experimented with archaeological air photography in the early years of the last century, or between the two World Wars. But for the most part these initiatives were not followed up until the 1950s, or in many cases much later. In the 'semi-military' context of the former Soviet zone practically nothing was done until after the political changes of the early 1990s, and in many countries there have been (and in a few cases still are) problems with obstructive bureaucracy and difficulties of access to reliable maps or collections of historical air photographs. The present account, which broadly runs from north-west to south-east across Europe, concentrates on the past few decades but references to earlier initiatives (as well as more recent work noted in the following paragraphs) can be found in some of the country-by-country lists in the Supplementary Bibliography at the end of the book.

In **Iceland** archaeological applications involving the capture, analysis and heritage uses of aerial photographs have only emerged in any significant way over the last 20 to 30 years, and only in the last decade or so has the technique achieved any significant following. The character of Iceland's landscape and archaeology puts a premium on the recording of preserved **earthworks** rather than cropmark or soilmark evidence. Recently, however, aerial photographs have begun to emerge as a research tool for understanding the relationship of individual or groups of sites with one another and with their broader landscape context. Several projects have demonstrated the potential of the technique and the use of aerial survey and historical air photographs would surely be more widespread were it not for financial pressures on the country's provision for other aspects of heritage work. Nevertheless, Reykjavik played host in March 2010 to an important gathering of archaeologists involved in heritage management, aerial photography, **remote sensing** and landscape studies, later reported in print as *Cowley 2011*.

The use of air photography in **Norway**, **Sweden** and **Finland** has been similarly restricted, despite attempts to encourage survey and mapping work through an apparently well-received conference and workshop at Helsinki in 2004. All three countries have large areas of woodland and relatively restricted zones of arable cultivation. These two factors may have persuaded the countries' archaeologists that aerial techniques will have less to offer here than further south in Europe.

Despite this, some remarkable cropmark sites were reported a few years ago from central **Norway**, suggesting that further work there, on both earthwork and cropmark or soilmark sites, could produce useful returns. Apart from this, and from a few individual uses of aerial photographs in archaeological reports in the 1970s and 1980s, aerial techniques have yet to attract any substantial following in Norway despite the enthusiastic participation of archaeologists from the Norwegian Institute for Cultural Heritage in the activities of the *ArchaeoLandscapes* project.

In **Sweden** some very effective aerial exploration and illustration was done by Jan Normann and others in the 1980s, recovering additional information on known sites and identifying potential occupation sites in otherwise inaccessible contexts along the country's long and rugged coastline. Unfortunately, after Normann's sadly early death in the early 1990s his post at the National Museum in Stockholm fell into abeyance, and with it any effective use of aerial techniques in the exploration or illustration of the country's archaeology.

In **Finland** aerial archaeology in any substantial form has yet to 'take off', despite the warm reception accorded to the Helsinki conference. The country's excellent and readily accessible range of current and historical maps may also have lessened interest in the use of vertical or oblique air photographs in to illustrating topographical or geological features of the countryside. An important innovation, however, and one which may prompt some 'desk-based' analysis and archaeological mapping in the coming years, has been the release for free download from the internet of the vertical air coverage acquired over the years by the National Land Survey of Finland.

The position in **Denmark**, and in particular on the open landscape of the Jutland Peninsula, is very different. Summer visits by Cambridge University air photographers between 1966 and 1970 produced an impressive collection of photographs, recording nearly 300 known and previously unrecorded earthwork, soilmark and cropmark sites and **complex**es, the cropmarks being especially numerous and varied on the sand-and-gravel soils in the western part of Jutland, while earthworks were more numerous on the clay soils and pastureland to the east. In the last three decades Danish archaeologists themselves have taken to the air with enthusiasm and success, often combining aerial exploration with the study of earlier vertical photographs, old maps and active survey in the field. Particularly noteworthy is a four-year research programme which started in 2009 at the Holstebro Museum, to explore the ways in which systematic aerial work could make a contribution to Danish archaeology. This is one of the countries where traces of individual timber buildings, marked by their **pattern** of structural postholes and wall lines, can often be made out from the air, resulting in a tendency, noted by visiting tutors at a training school in 2011, to ‘fly low’ during the cropmark season; the related communication routes and field systems, by contrast, appear more strongly as soilmarks during spring and autumn, being best observed and recorded from a higher altitude.

In **Lithuania**, **Latvia** and **Estonia** the application of aerial archaeology has been restricted by a severe lack of funding and limited opportunities for the kind of cropmark and soilmark discoveries that have attracted attention elsewhere. In the heavily wooded and largely pastoral landscapes of these countries the main attention of their very few aerial enthusiasts has been concentrated on the recording and illustration of known earthwork sites, principally for descriptive and heritage-management purposes. That said, conferences or workshops in all three countries in recent years have raised general consciousness of the potential value of aerial photographs, and there has been an important innovation in the foundation of a postgraduate course in aerial archaeology at the University of Klaipeda in western Lithuania. Institutions from all three countries have also been long-term participants in the aerial archaeology projects of the European Union’s Culture Programme. An encouraging development in Estonia has been the recent provision on the internet of lidar data for virtually the whole of the country. Combining this with aerial photographs will hopefully open up exciting new possibilities for the future.

Further south, the **Netherlands** benefitted from exploratory work by the Cambridge University photographers in the early 1970s. Renewed recording was done by Willy Metz and others in the 1980s and 1990s but little has happened in the decade or so since they turned their attention to other things – the loss of a single enthusiast or employee can often bring the study to a halt.

There is now a revival of interest in remote sensing at the University of Leiden but this has tended to focus on other aspects of remote sensing rather than the capture or analysis of aerial photographs. However, since 2007 there has been a specialist group attempting to revive interest in aerial work in Holland (and in the Dutch-speaking areas of Belgium) by holding meetings and exchanging ideas under the title of DECARS, the Dutch Expertise Centre for Archaeological Remote.

Belgium saw its first experiments with aerial photography almost a century ago but the 'modern' era was initiated by the pioneering enthusiasm of Charles Leva from the 1960s onwards and by Jacques Semey from the late 1970s. From 1997 there has been a steady programme of aerial exploration and analysis by teams associated with the Universities of Leuven and Ghent but there is still no government support for such work. A noteworthy development at Ghent in recent years has been the cataloguing, analysis and interpretation of historical air photographs from the First World War, a specialism that has produced remarkable detail on the character and surviving remains of the Western Front in the years from 1914 to 1918. This work has illustrated very clearly the potential value of military air photography, in this case from almost a century ago.

The history of aerial archaeology in the **United Kingdom** has already been told in the preceding pages. A key feature over the past three decades has been the significant state support provided through the national heritage organisations in England, Wales and Scotland, both for exploratory flying and – with variations in practice – for the mapping, analysis and publication of sites and landscapes form both vertical and oblique imagery. There has, however, been little similar work in Northern Ireland.

In the **Republic of Ireland** pioneering initiatives in 1920s and 1930s were followed between 1951 and 1973 by summer visits by Professor St Joseph and colleagues from Cambridge University. The photographs taken during exploration in the 1970s to 1990s by Dr Leo Swan has recently been scanned and rescued from relative obscurity through a programme sponsored by the Heritage Council. A programme of analysis and mapping work on hugely successful cropmark surveys carried out by Dr Gillian Barrett from 1989 onwards has also reached completion (though as yet without scanning of the images). Various other institutions and individuals have undertaken aerial photography in the last two decades for research, recording or pre-development survey. The history of aerial archaeology in the Republic, with a generous bibliography and recommendations for the future, was described in a report prepared by George Lambrick published in 2008 and now available on the internet (see Supplementary Bibliography). New and historical air photographs, along with **photogrammetry** and intensive lidar survey, are now used regularly in the country's heritage management work, and in the activities of the government-backed Discovery Programme which brings sophisticated modern techniques to the recording and presentation of the Republic's archaeological sites and landscapes.

In **Germany** flights in the 1950s and 1960s by Irwin Scollar have been succeeded by far more extensive work by Otto Braasch, Klaus Leidorf, Ralf Schwartz and others from the late 1970s onwards, the quantity and quality of their work being unsurpassed in Europe, not least in their attention to the opportunities represented by winter flights over the frozen countryside. Not all parts of Germany have been intensively covered but others, such as Bavaria, Baden-Wűrttemberg, Rhineland-Palatinate and Saxony-Anhalt, have large and archaeologically invaluable archives of aerial photographs. In the Palatinate there is also a flourishing voluntary group which carries out aerial survey and related activities (see www.archaeoflug.de). On the other hand the fragmented nature of German central government and its sixteen semi-autonomous federal states, has (with a few noteworthy exceptions) prevented the consistent integration of the results into photo-interpretation and mapping projects equivalent to those of the National Mapping Programme in England, or any kind of coordinated national policy for exploration, recording and analysis. With the exception of the intensive teaching by Dr Baoquan Song at the University of Bochum, and short courses and training by Otto Braasch and Ralf Schwartz at various universities over the years, the technique – whether in active aerial work or in the analysis of existing photographic archives – receives only limited attention in the academic sphere. That said, some use has also been made in recent years of air-photo interpretation (and even specially-commissioned vertical and/or oblique photography) to identify potential archaeological losses along new motorway routes or in other infrastructure projects.

In **France** the exploits of Jean Baradez and Antoine Poidebard in North Africa and the Near East in the 1920s and onwards made little impact on the domestic scene. However, there was a flowering of exploratory aerial survey in the years after World War II, with a number of local flyers (the most notable being Raymond Chevallier, René Goguey and above all René Agache) taking to the air from the late 1950s onwards out of their own enthusiasm or as a supplement to their duties at local or regional museums, universities or other institutions. It is less clear, however, to what extent this enthusiasm or any kind of national or regional coverage has been maintained or developed in the last two decades, despite the holding of a major conference on aerial archaeology at Amiens in 1992. Participants from France have been few and far between in the activities of the Aerial Archaeology Research Group and it has been impossible to secure any significant information about the present situation for aerial archaeology in France, whether in the state service for pre-development archaeology (INRAP) or within the country's other heritage and academic institutions. It is sad that a country with such an illustrious record in the past seems to have 'dropped from the international scene' in this way.

Austria has taken an individual approach to archaeological air photography and in particular to the integration of air-photography with geophysical prospection and other forms of remote sensing. This has been achieved from 1979 onwards under the leadership of Michael Doneus, Wolfgang Neubauer, firstly through the Institute of Pre- and Proto-history in Vienna (now the Department for Prehistoric and Medieval Archaeology) and more recently through the newly-formed Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology. The level of technical expertise in the Institute's investigative work and in the subsequent interpretation and presentation of the results is unrivalled in Europe. A special feature for many years has beeb a very effective cooperation with the Austrian military, who – after limited light-aircraft flights by the archaeologists to test the state of the crops – carry out vertical surveys in an sample area of landscape in eastern Austria at ideal times for the recording of cropmark information. The sophisticated use of lidar survey now forms a key part of the Institute's continuing explorations, both in Austria and with international partners in other parts of Europe. That said, much of Austria, outside the chosen sample area, lacks similar attention apart from periodic vertical survey for essentially non-archaeological purposes.

In the former soviet zone of Central and Eastern Europe the pattern of development in the decades since the political changes of the early 1990s has been fairly varied. As already noted, problems with bureaucracy and access to maps or air-photo archives have persisted in some countries, while in others it has been difficult to convince fellow archaeologists about the potential value of this 'new' technique of exploration and study.

In **Poland** the outstanding champion of aerial archaeology over the past two decades has been Włodzimierz Rączkowski, of the Adam Mickiewicz University in Poznań. But he and a few colleagues elsewhere have been struggling against two structural, or rather intellectual, problems – an ingrained supposition among fellow archaeologists that cropmark and soilmark photography simply will not 'work' in a landscape largely dominated by forests and clay, along with a long-term commitment of the archaeological establishment to field-walking survey as a key method of archaeological investigation, especially through a comprehensive national programme (AZP) that is now nearing completion for the whole of the country. In reality, of course, aerial and ground-based survey, as Rączkowski's regular discoveries have shown, complement one another, each acting as a check on the shortcomings of the other. An opportunity was also lost a decade and more ago when Zbigniew Kobyliński, then head of the state archaeological service and a convinced supporter of aerial archaeology, lost his job as a result of political changes shortly after trying to create some kind of general policy for aerial work amongst his otherwise unconvinced staff. Fortunately, Rączkowski's regular flow of aerial discoveries in recent years, including Neolithic houses and (most spectacularly) a ‘lost’ medieval town, have been attracting growing public interest, so aerial work may be expected to continue and develop in at least some parts of Poland in the coming years.

Hungary was one of the countries visited on a regular basis from the early 1990s by Otto Braasch, from Germany, especially through contacts with Zsolt Visy and his colleagues at the University of Pécs, a relationship which led in 1996 to the holding of the first European training school in aerial archaeology, at Siofok Kiliti, alongside Lake Balaton in central Hungary. More recently, in the years since 2005, the Culture Programme of the European Union has been fostering programmes of combined aerial survey, photo-interpretation, mapping, geophysical prospection and trial excavation by Gábor Bertók of the Baranya County Museum in the south of the country. Aerial studies have also received attention at the University of Budapest, initially through cooperation in the 1990s with Otto Braasch and then René Goguey, from France. In the autumn of 2012 Zoltan Czajlik and his colleagues at the University acted as hosts to the 2012 annual conference of the Aerial Archaeology Research Group and the plenary session of the ArchaeoLandscapes project.

In former Czechoslovakia archaeologists quickly took to the air after the political reforms of the early 1990s. The key proponent in the **Czech Republic** has been Martin Gojda, initially through the Institute of Archaeology at the Czech Academy of Sciences (which bought its own aircraft for the purpose) and more recently through the University of West Bohemia in Pilsen. In **Slovakia** Ivan Kuzma has taken the lead through the Archaeological Institute of the Slovakian Academy of Sciences, his work having a particular focus on the Neolithic ‘rondels’ which figure strongly in the aerial archaeology of Central Europe. Gojda, in particular, has produced a steady stream of publications with an aerial perspective and has trained his own and other students in the principles and practice of aerial archaeology, both in the air and on the ground. With help from colleagues across Europe he also created a fine exhibition at the National Museum in Prague in 2007, along with an accompanying video-film.

In the **Balkans** the lead has been taken by **Slovenia**, not only through the development by Darja Grosman, of the University of Ljubljana, of approaches that combine aerial survey with ground observation and the analysis of vertical photographs to counter the difficulties of the Slovenian landscape, which is so deeply dissected and heavily wooded that anywhere else it would have been considered ‘marginal’ to the development of effective aerial archaeology. Grosman has also undertaken partnership work in Croatia and Greece and has also been an inspiring tutor at workshops and training schools across Europe, including in Serbia and most recently in Turkey. In **Serbia** vertical photographs were used by archaeologists in the 1930s and 1950s for investigating and mapping prehistoric, Roman and medieval sites, and in later years to assist rescue archaeology along the Roman limes. They were also key sources in studies of Roman defences and road systems along the Danube in the 1990s, and articles advocating the wider use of aerial information were published at about the same time. Both Serbia and Croatia are now taking their own first steps in active aerial work, not least through participation in the ArchaeoLandscapes project. **Montenegro** has recently undertaken its first regional **air photo interpretation** work, based on historical (vertical) material. In **Bosnia** and **Herzegovina** a course on air photo interpretation has been established at the University of Sarajevo.

In south-eastern Europe only **Romania**, in the face of much official indifference, has joined the move to introduce aerial archaeology into its heritage work, in this case through exploratory flying and related record and database work initiated by Irina Oberländer-Târnoveanu, with the help of Rog Palmer from the UK, at the Bucharest-based Institute for Cultural Memory (CIMEC, recently re-constituted, to no perceptible advantage, as part of the National Heritage Institute). From 1998 onwards visiting archaeologists from the UK, Bill Hanson and Ioana Oltean, have also been carrying out aerial and related ground survey in other parts of the country. It seems likely, however, that it will be some time before 'home-grown' aerial work can find a secure place in Romanian archaeology. In Bulgaria there have been some 'expressions of interest' but bureaucratic and other restrictions are still in force and 'interest' does not yet appear to have been translated into positive action.

Turning to the Mediterranean world, **Spain** and **Portugal** have seen little use of aerial archaeology in the past. An impetus to future activity, however, has hopefully been provided by a week-long meeting in Spain during June 2012, under the auspices of Merida Institute of Archaeology, along with the ArchaeoLandscapes and Radio-Past projects of the European Union. There are indications from geophysical work by Helmut Becker (pers. com.) that aerial survey could make a significant contribution in some parts of Spain, a suggestion echoed in a preliminary assessment by post-graduate students at the University of Siena, looking at the topography, climate and agricultural patterns of the country in terms of the potential for the aerial discovery and recording of both surviving and buried archaeological remains.

Italy has already been covered through the bibliographical references listed in the earlier part of this chapter. Some publications, however, can be found in the Supplementary Bibliography at the end of the book.

In **Greece** the use of free-ranging archaeological air-survey is virtually excluded by still-extant military-bureaucratic restrictions similar to those which, as described earlier in this chapter, inhibited this kind of work in Italy from 1939 to 2001. Most of the entries for Greece in the Supplementary Bibliography therefore relate to the use of balloons and more recently kites and a radio-controlled helicopter in the low-level photography of known sites and excavations. References to the systematic examination of such images are indeed becoming more frequent, perhaps indicating a change of perception in Greek archaeology, to some extent offsetting remaining restrictions on access to existing archives of vertical air photographs. The landscape of Greece has been radically changed by mechanised agriculture, levelling and terracing since John Bradford, in 1957, pointed to the potential value of examining historical aerial photographs for this and other parts of the Mediterranean world. As yet there appears to have been no light aircraft survey for archaeological purposes in mainland Greece or on Crete, though the publications by Kaimaris and his collaborators cited in the Supplementary Bibliography mention the identification of 'hundreds of buried and upstanding monuments' during an examination of existing vertical photographs and satellite data for Eastern Macedonia. Taken at face value this reinforces what Bradford wrote over fifty years ago and suggests a growing appreciation of what such archives might offer in the present day.

In **Cyprus**, as part of the EC-supported ArchaeoLandscapes project the Science and Technology in Archaeology Research Center (STARC) of the Cyprus Institute is in the period 2010 to 2015 exploring, through a number of case studies, how to store, manage and use a vast amount of WWII aerial photographs recently made available for free. This will involve a series of comparisons with more recent imagery and tools for manipulating the images. Raising awareness in the heritage community is also part of the project activities.

Finally, in **Turkey**, otherwise devoid of any known aerial work, there has been an encouraging first step in the mounting by Kocaeli University of an aerial archaeology training school in the summer of 2012, at least partly as a spin-off an ArchaeoLandscapes event in France a year or so earlier (see Appendix C for a description of the ArchaeoLandscapes and earlier initiatives within the Culture Programme of the European Union).

A patchwork of provision, or a launch-pad for the future?

The pattern that emerges from this short review is very varied, with relatively good provision and active aerial work in some countries and an initial or continuing struggle to create any kind of impact in others. There are also major variations in funding, official support and organisation, the United Kingdom (as described in this chapter) being the only country which has relatively generous state support through the public service, though with limited activity and mostly-elementary teaching in the university sphere. By contrast, Italy has a thriving presence in the university field but virtually none in the public service, while in Germany support comes mainly – and unevenly – through regional museums, without any overall coordination or funding at the national level. Elsewhere the technique is being promoted, or kept alive, by single or at the most small bands of enthusiasts in a variety of different organisations. For these, as well as for the more established practitioners, the pan-European sharing of ideas and experience promoted by the Aerial Archaeology Research Group (AARG) and by a series of projects within the Culture Programme of the European Union (Appendix C) has been invaluable. This kind of international cooperation and encouragement will continue to be a strength – and a spur – in the years to 2015, and beyond that if the ArchaeoLandscapes project achieves one of its primary objectives in the creation of a self-supporting international network across Europe to provide coordination, encouragement and support in the field of archaeological air photography, remote sensing and landscape studies.

2. MERITS AND LIMITATIONS

Aerial photography, aerial survey and aerial archaeology

Aerial photography is the technique which allows us to ‘fix’ the results of aerial survey, which in turn is just *one* of the techniques which we use (along with photo interpretation, **mapping** and **record creation**) to pursue what we loosely call ‘aerial archaeology’. Aerial archaeology is not in any sense a subject in its own right, though it offers its own special capacities and insights. Its results become vastly most informative when combined with other sources of archaeological information such as excavation, ground-based survey, geophysical prospection and topographical analysis, or with the newer forms of remote sensing discussed in the final part of this book.

In this chapter our main concern is with free-ranging aerial survey rather than the analysis **vertical air photographs** taken largely for non-archaeological purposes. As explained in the previous chapter, Italian archaeologists have tended to concentrate on the latter, though there have also been notable successes through specially commissioned archaeological flights, as in the search for the lost city of Spina, in northern Italy (Fig 1.9).

In Britain, by contrast, aerial archaeology has tended to draw its inspiration, along with much of its data, from free-ranging exploratory survey undertaken by archaeologists themselves, using oblique rather than vertical photography. Britain’s huge archives of vertical photographs have been heavily exploited as well, especially in recent years. They constitute an indispensable source (along with oblique photographs) for air photo mapping both at local and national levels. But the more detailed and archaeologically informed view offered by **oblique aerial photographs** has had a profound effect on data and ideas about almost every period of British history and prehistory.

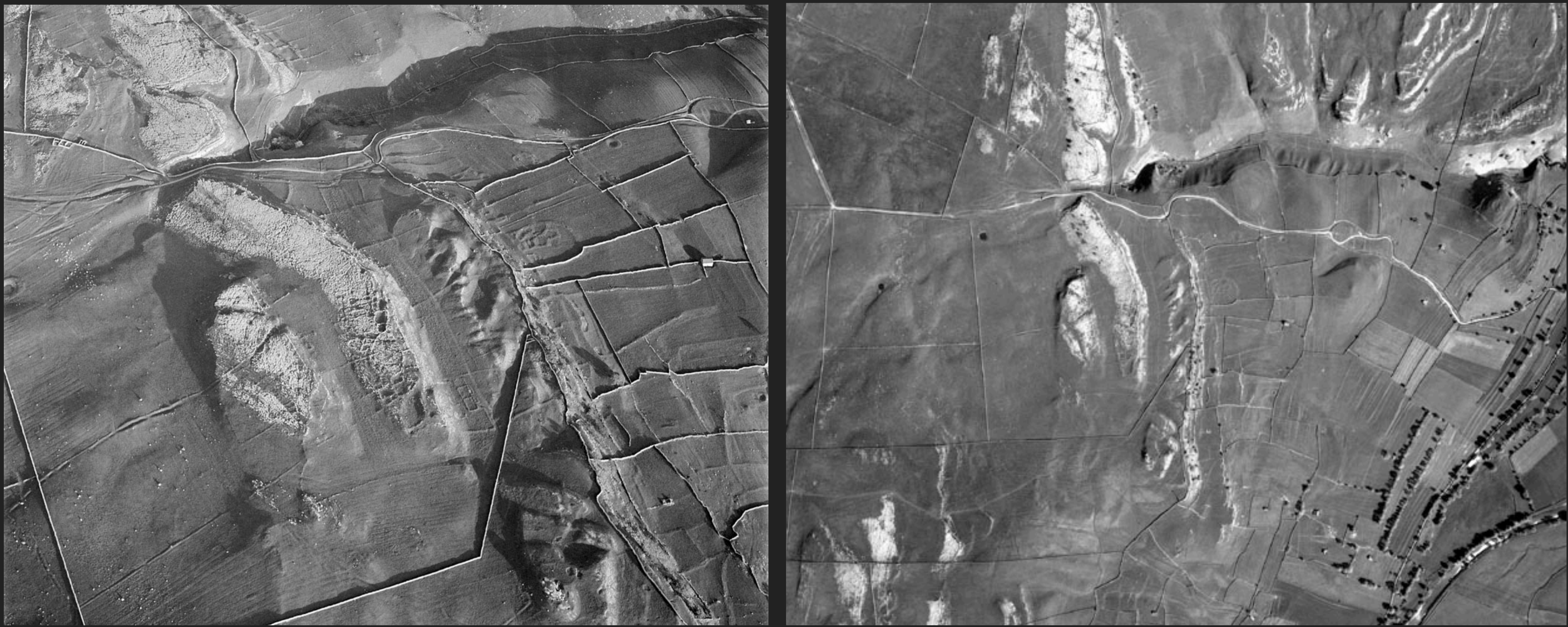

Fig 2. 1 Wharfedale, Yorkshire, England

An oblique view (left) and vertical view (right) of an area of upland landscape mapped and enhanced by ground observation in Fig 9.12.

is recorded on thousands of individual photographs. Most of these are – or should be, in whatever country – accessible to archaeologists and the general public in open archives, well catalogued and in the future perhaps consultable over the internet (at least so far as their catalogues and key images are concerned). The photographs themselves have many direct uses but they will only achieve their full potential if they are also converted into the kind of mapped and written records that are the stock-in-trade of archaeological communication generally. Hence the second part of this book.

Vertical air photographs

Vertical air photographs (or simply 'verticals') are for the most part taken from specially equipped aircraft using sophisticated cameras that point vertically or near vertically downwards (Fig 2.1, right). But several air photographers have adapted their non-specialist light aircraft so as to take vertical as well as oblique air photographs (see *Warner* et alii *1996*, reviewed in AARGnews *15, 1997*, pp. 36-7). In the past vertical air photographs have been taken mainly for mapping or military purposes, but they are now widely used for such things as monitoring plant growth, prospecting new communication routes or documenting the progress of major infrastructure projects. The aircraft flies systematically across or along the survey area on predetermined and parallel flight paths, taking photographs with one or more cameras at automatically controlled intervals so that each frame overlaps its neighbours in both directions, giving total coverage of the surveyed area (Fig 2.2). Because of this overlap the photographs can be viewed in three dimensions through stereoscopes of various kinds (Fig 7.8). Rectified maps can also be made of the whole or parts of the surveyed area using desktop computers (Chapters 6-9) or higher level analog or digital photogrammetric equipment (*Piccarreta 1987*; *Alvisi 1989*; *Piccarreta–Ceraudo 2000*; *Ceraudo 2003*; for an English-language introduction to digital **photogrammetry** in the recording of **archaeological landscapes** see *Corns–Shaw 2008*).

Because it usually involves specialised aircraft and cameras, which cannot be called into play at a moment's notice when the archaeological conditions seem right, vertical photography is only occasionally commissioned by archaeologists for their own purposes. The costs can be relatively high unless the work is coordinated with other commercial work being undertaken by the survey company. For this reason archaeologists usually make use of pre-existing vertical photographs taken for mapping or other non-archaeological purposes. These are available in large quantities, though they are not always easy of access and some are at too small a scale for realistic archaeological use. Moreover, archaeology appears in the photographs more or less 'by accident', few of the flights having been undertaken at times

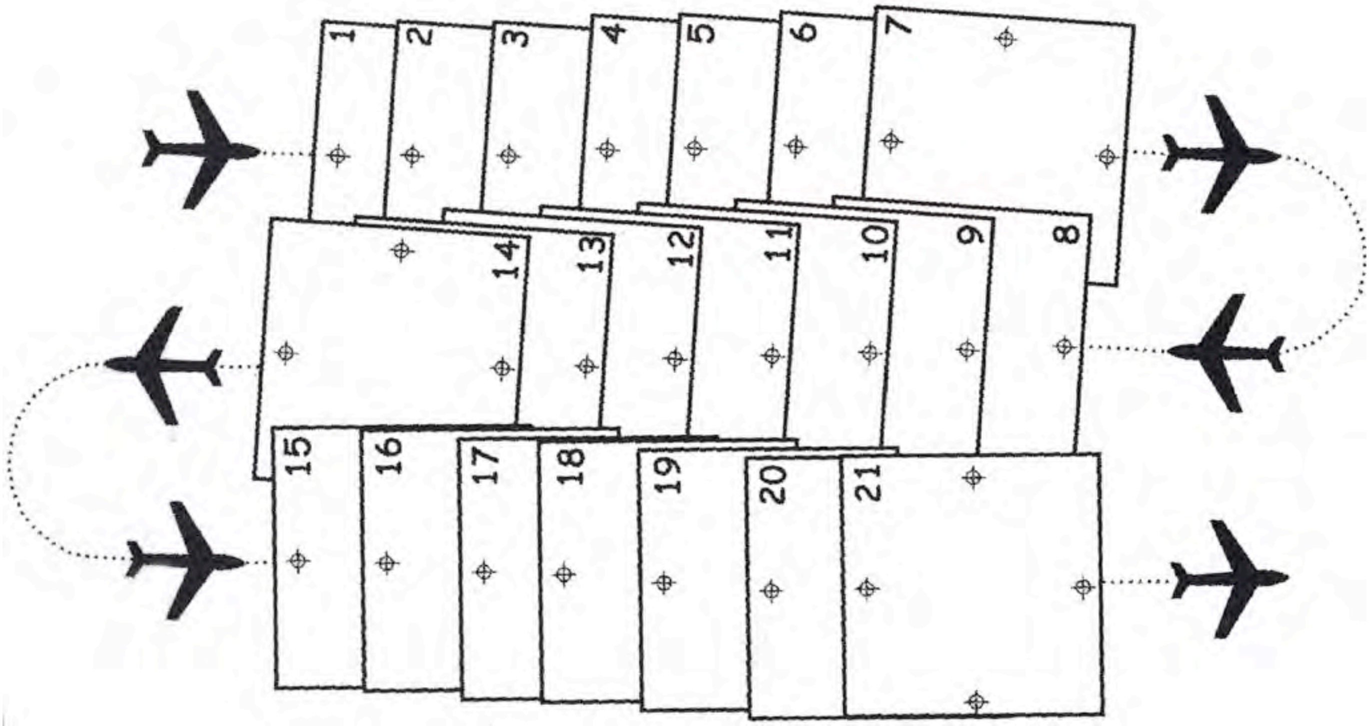

Fig 2. 2 Vertical survey: flight paths and stereo photography

Vertical photography provides total coverage of the survey area by taking photographs along overlapping runs so as to produce images that can be viewed in three dimensions using a portable or mirror stereoscope of the kind shown in Fig 7.8.

Adapted from PICCARRETA-CERAUDO 2000*, fig 14*

that specifically favour the recording of archaeological and related information. For instance, the lighting is often too bland to give the full effects of light and shade, though stereoscopic viewing can reveal the basic terrain and sometimes even archaeological detail. Relatively few flights, taken overall, fall within the period when cropmarks or **soilmark**s are showing to best effect. Moreover, the comprehensive examination of vertical photographs for a large survey area, perhaps involving a number of different archives and several thousand images, can demand resources of skill, time and money that are not always available. Nevertheless, vertical photographs are an indispensable source of archaeological information, pinpointing the location and existence of at least *some* types of **site**s and showing the *whole* of the **landscape** in various stages of development over time.

Oblique aerial photographs

Oblique aerial photographs (or just ‘obliques’) are taken at an angle to the ground, giving perspective views similar to those obtained from the top of a hill or from a high building (Fig 2.1, left). For this reason they are readily understood both by archaeologists and by non-specialists, their high viewpoint giving them a special novelty. By contrast, many people find the ‘plan’ view presented by vertical air photographs difficult to read. Oblique photographs can range from ‘near verticals’, taken at around 80 degrees to the ground surface, to more horizontal views with the camera pointing at a shallow angle to the ground surface, sometimes with the skyline in the frame (in the latter case they are sometimes called ‘panoramas’).

Obliques from free-ranging aerial survey are usually taken by archaeologists themselves, or by aviators who have turned their hand to archaeology. They are for the most part consciously selected views, taken to record something that the observer has identified as having a clear or potentially archaeological significance. What the photographer fails to see – or does not recognise as being an indication of some past activity – does not get recorded, except by accident. Obliques, for this reason, cover only a tiny fraction of the **landscape** compared with verticals. On the other hand every picture, in theory at least, is taken from a point of view, in a kind of lighting and at a time of day or year that favours the recording of archaeological or related information.

Because this kind of photography is done from non-specialist aircraft, using ordinary hand-held cameras, it is fairly inexpensive and relatively easy to organise – the overall cost of an hour of flying, covering perhaps five to twenty **site**s, is likely to range between £200 and £400 including support costs of various kinds (at 2004 prices – not quite as much more in 2012 given that photo-processing and film costs have come down considerably following the switch to digital photography).

Finally, aerial photographs taken by archaeologists are records of things *understood* at the moment of photography to be of heritage significance. The original photographer, if not personally carrying out the subsequent cataloguing or **mapping**, should therefore be consulted if at all possible during interpretation, mapping and text creation of the recorded information.

A partnership of merits

Verticals and obliques each have their merits and limitations, neither being a substitute for the other. They are at their most effective when used in combination, each offsetting the limitations of the other (see, for instance, Fig 2.1). What Italy and various other European countries have lacked in the bureaucratically or militarily restricted decades since the Second World War, is the archaeologist's capacity to seek out information at the right time of day and year, improvising in an archaeologically informed way during flight in response to the unfolding landscape below. One of the aims of this book is to give a basic understanding of the techniques involved in that search. For the moment, however, we will concentrate on the phenomena which the **aerial archaeologist** exploits in exploring the landscape below him.

Phenomena exploited by the aerial photographer

The following paragraphs follow a pattern developed over many years by the present author. Many others, however, have discussed various aspects of the subject (see the first part of the Supplementary Bibliography at the end of the book). The most comprehensive treatment of **soilmarks** and **cropmarks**, in Britain at least, is in *Wilson 1982*, *2000*. There are also useful comments in *Riley 1987*, *Kennedy 1989* and by Colin Shell in Chapter 14.

High viewpoint

The high viewpoint is an essential factor in all aerial recording. It widens the range of view until it includes the whole (or nearly the whole) of individual sites or landscapes and so allows **patterns** to be recognised that would be difficult or impossible to see or understand from ground level (Figs 2.3, 2.8). When the whole of a site or a group of sites can be seen and recorded in a single view the relationship between the parts often becomes clearer, as does the interplay between sites and their topographical setting.

A minor disadvantage is that the high viewpoint, particularly in single (non-stereoscopic) views, can sometimes 'flatten' topographical variations and mask the subtleties of slope or level that mark out the best places for settlement, cultivation or communication routes. The lower the angle of view, the less this applies, though the comprehensiveness of the view then tends to suffer. Ideally, both near vertical and lower angled photographs would be taken of each **target**, though this is rarely practical in terms of economy. The best protection, of course, is to examine the topographical setting of newly discovered sites through subsequent visits on the ground or by stereoscopic viewing of matching vertical photographs.

Light and shade, 'shadow sites'

All photographers use light and shade, or highlight and shadow, to capture the form of the objects they are photographing. In the hands of a skilled aerial photographer highlight and shadow can reveal the presence of sites which, recorded in poor lighting or from the wrong viewpoint, would be virtually invisible (Figs 2.4 and 2.5). By and large, the lower the angle of the sun and the stronger the resulting highlights and shadows, the greater will be the photographer's chance of recognising and recording **features** degraded by ploughing or erosion. There are limitations, of course – *very* low sun can confuse rather than reveal **patterns** and bright sunlight when photographing buildings or substantial **earthworks** may hide important detail in the shadows. Subdued directional lighting beneath a slightly overcast sky can be very effective in these situations.

Fig 2. 3 Flying high for landscape recording

For this Cambridge University view of fields and open pasture in the Black Mountains of South Wales a particularly high viewpoint was adopted on a day of perfect visibility. Note the contrast between the enclosed land in the valleys and the open ground on the hilltops and ridges.

Fig 2. 4 Discovery through the use of light and shade

Flights in late evening, early morning or in low winter sunshine can reveal earthworks that have previously escaped detection. Here, in the hills of north-east Wales, the dark stone rampart of a known Iron Age hillfort occupies the peak of the hill. However, both the rectangular enclosure slightly below and to its right and the double-ditched enclosure in the foreground were unknown until this photograph was taken. More correctly, they were unknown until their existence was declared in readily available written (and now computerised) records based on the air photo evidence.

Fig 2. 5 Using light and shade to reveal low earthworks

Contrasting views of two earthwork enclosures in eastern Wales. In the left-hand photo only the well-preserved embanked enclosure at upper right can be seen with any clarity. In the right-hand view more oblique lighting and a different viewpoint reveal a heavily degraded second enclosure crossed by a hedge line at centre left.

Some of the key ways of using highlight and shadow are illustrated in Figs 10.2 to 10.4. There are also comments on photographic techniques in many of the other captions throughout the book. The prime lesson is that the fledgling aerial photographer should cherish the chance to fly early in the morning or late in the evening, or in the winter months when the sun is low in the sky throughout the day (the obscuring effects of trees, shrubs and other ground cover are also at their lowest in wintertime). Needless to say, both highlights and shadow will be more clearly defined when the visibility is good and the air free of water vapour, dust or industrial pollution. For this and other reasons a basic understanding of weather patterns, along with the regular use of internet and other weather forecasts, become essential tools for the archaeological air photographer.

Soilmarks

It is a truism of aerial archaeology (and of archaeology in general) that once the soil has been disturbed, or overlain by another material, it can never be exactly restored to its original state. There will be greater or lesser changes in the texture, physical content, water retention or nutritional value of the deposits that have accumulated in ditches or pits; there will more stone or excavated subsoil on the line of degraded banks; and stone or clay walls will change the texture of the soil even if all upstanding **trace** has been removed by ploughing or erosion. The impact of these below ground differences, or the remnants of superimposed material, will in the right circumstances still be visible to the **aerial archaeologist**.

This happens in a variety of ways, one of them being the appearance in recently ploughed or harrowed fields of differences of colour, reflectance or dampness of the kind shown in Fig 2.6.

Known as '**soilmarks**', or in some cases 'dampmarks', these can be fairly fleeting in their appearance, depending on the interval since ploughing or harrowing, or on changes in the dampness of the soil in response to sun, wind or temperature. There is an added problem that in many countries ploughing now takes place at almost any time from late summer to early spring, so that in areas with a relatively low proportion of arable cultivation the chance of arriving over fields at the moment when they show intelligible **soilmarks** is fairly low. Where the whole or virtually all of the landscape is under arable cultivation, however, soilmark survey can produce very worthwhile useful results.

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Fig 2. 6 Typical Italian soilmarks

Left. The traces of relatively recent ploughing strips, perhaps of two different dates to judge by the overlap in the upper part of the photograph. *Top right*. An ancient road in the form of a lighter mark cutting diagonally across the modern ploughing strips. *Bottom right*. A small enclosure in southern Italy. Note how the plough has ‘dragged’ the soil in opposing directions on successive transits across the darker mark of the buried ditch.

Cropmarks

In their most typical form **cropmarks** are represented by variations in the colour, height or density of grain and other arable crops, especially in the weeks immediately before harvesting. They are one of the most productive sources of new discoveries. The principles underlying their formation are illustrated in Fig 2.7 but there are many subtleties, only the most obvious of which can be mentioned here. Comments on other aspects of cropmark formation can be found in captions throughout the book.

Cropmarks fall into two main categories: 'positive' and 'negative' (Figs 2.9, 2.10). Positive marks, which typically appear in grain crops as green marks against a yellow background, usually denote greater nutritional or moisture content in buried ditches, pits, foundation trenches or areas of deeper natural soil. Negative marks, appearing as yellow marks and stunted growth in still-green crops, usually result from reduced nutritional value, thinner soil or impeded drainage above buried walls, roads or other impermeable surfaces. Both positive and negative cropmarks can sometimes survive as yellow-on-yellow marks in the ripened crop, as illustrated at bottom right in Fig 2.9. In certain conditions cropmarks can be 'reversed', ditches or water courses appearing along part or the whole of their course as negative rather than positive marks. The mechanisms involved here are not entirely understood but for most purposes this is of little importance – the *meaning* of the cropmarks is usually quite clear in terms of the buried ditches or other **feature**s that they represent. (It may, on the other hand, be important to try to work out the precise mechanisms when analysing an individual site in detail, perhaps as a preliminary to excavation.)

While cropmarks appear most typically in grain crops just before and after ripening, they can also be seen at other times of year. For example, variations in the temperature, dampness or nutritional content of the soil in early spring may accelerate (or delay) growth above buried archaeological features, producing so-called '**germination marks**'. These differences may persist throughout the following weeks, producing stronger or weaker areas of growth (but no change of colour) long before the classical time of cropmark appearance, which may vary from mid-to-late May around the Mediterranean rim to early early August in northern Europe. These dates are liable to quite wide variations, however, since cropmarks are a response to the weather patterns and planting regimes of individual years (as well as to the local soils and geology – clay in Britain, for instance, for the most part only shows cropmarks in very dry seasons). For these reasons the timing or appearance of cropmarks may be significantly different from year to year or place to place within any country, region or locality. In this sense there is no 'average' year, no 'normal' **pattern** of cropmark development and no fixed or 'ideal' time for cropmark survey.

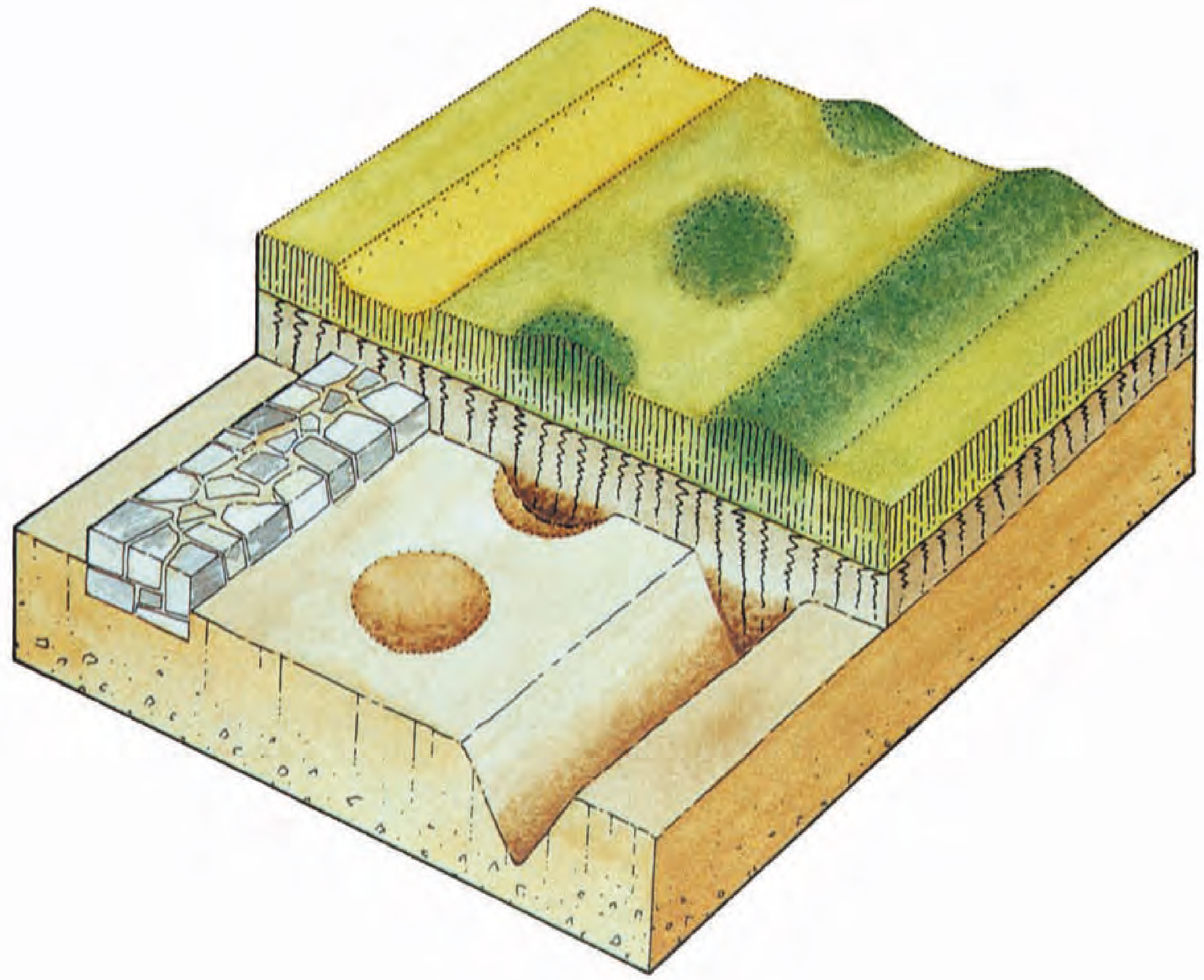


Fig 2. 7 The formation of cropmarks

Crops grow taller and ripen later over the deeper, more nutritious and damper soil of a buried ditch or pit. Growth is stunted and the ripening of the crop earlier in the shallower soil above buried walls or other impervious deposits. Ditches and pits create green marks in the yellowing crop ('positive' cropmarks). Walls and similar features give yellow marks in the green crop ('negative' cropmarks). Both can persists as 'yellow-on-yellow' marks in the ripened crop (Fig 2.9, bottom right).

In addition to grain crops (wheat, barley, oats and rye) other deep-rooting crops such as peas, beans, carrots, clover, lucerne and alfalfa (*erba medica*, Fig 2.10), along with a variety of root crops (notably beets of various kinds), can produce cropmarks at various stage in their growth, some of them startling in their clarity (Fig 2.9, *top*). Shallower-rooting crops (such as mustard, kales and cabbages) rarely produce cropmarks since they lack the capacity to seek out water or nutrients at deeper levels when they come under stress; but the flowers of oil-seed rape and linseed (and very rarely potatoes) can also produce useful cropmark evidence on occasions. In general the coarser the spacing of the plants, and the greater their individual leaf area, the more 'blurred' will be the cropmarks. Interpretable marks are therefore rarely seen in maize (apart from the more recent and shorter growing varieties) and cropmarks will only rarely occur in vineyards or orchards, except as **weedmarks** in the ground *beneath* the trees or vines. Poppies in abandoned or temporarily dormant arable fields can sometimes produce cropmarks that are startlingly beautiful as well as archaeologically useful.

Fig 2. 8 Soilmarks and cropmarks in Wales

Three views of a complex of ritual and funerary monuments first discovered through aerial survey in eastern Wales.

Top. Two Bronze Age burial mounds appear as slightly lighter patches of soil in the upper part of the field. In the lower left corner the external bank of a Neolithic ritual monument or 'henge' also appears as a lighter mark where the plough has cut into subsoil originally thrown up from the its now re-filled internal ditch.

Centre. When seen as cropmarks both the burial mounds and the henge appear as dark green ring-ditches, the latter with a narrow entrance gap on the left-hand side. Note how the lighter soilmark in the top photo takes a wider circuit than the darker-coloured ring-ditch, showing that the marks in each photo represent different parts of the monument.

Bottom. The same cropmarks can be clearly seen at ground level, but without the coherence of overall pattern provided by the aerial view.

Fig 2. 9 Positive, negative and ‘yellow-on-yellow’ cropmarks

Top. Positive (dark green) cropmarks above the filled-in ditch of a Roman temporary camp in England, showing in sugar beet, a crop widely grown in some parts of Italy.
Lower left. The walls of a Roman building in Tuscany show as negative marks where the stunted crop has ripened more quickly above the buried stone foundations.
Lower right. Previously dark green marks above a complex of pits and ditched in Hungary now show as light yellow marks on the darker background of the fully ripened crop. Low sunlight accentuates the extra height of the plants over the buried ditches and pits.

Fig 2. 10 Roman villa showing in a crop of alfalfa in September 2012

Some of the walls show as clear ‘negative’ marks, where prolonged dry weather has led to parching of the stunted crop above remaining stone foundations. Others walls show less clearly, though still as light green (therefore ‘negative’) marks, probably where there is a mixture of soil and stonework in the partially-robbed wall foundations.

Fig 2. 11 Grass-marks and weed-marks

Top. The ditches of a defended enclosure with a long ditch-defined entrance show as green marks in yellowing grass after a long dry spell on the Welsh borderland. The site, which has a Welsh place-name (Cloddiau = banks or ditches) which suggests the former existence of an enclosure, was watched for ten summers before this mark appeared in 1989. It has been seen very rarely since. *Bottom*. Light green 'negative' cropmarks above the buried walls of a small church in southern Italy are here emphasised by the scarlet poppies that have taken over parts of the field. The eastern apse of the church is just visible at its far end. See also Fig 10.14.

Cropmarks can sometimes be seen in grassland, as so-called '**grassmarks**' or '**parchmarks**'. They usually occur, often quite suddenly, at the end of a prolonged summer drought. Grass above stonework or other hard surfaces parches out first, giving brown or yellow marks against a green background. Later, when almost all of the grass has lost its colour, the parts that lie above buried pits or ditches may stay green for a little longer, giving well defined cropmarks. On chalk, and for instance above the '*crosta*' of the Tavoliere in southern Italy, the effect may be reversed, the shallow rooting grass turning brown first above ditches which have acted as drains rather than reservoirs. Grassmarks may fade rapidly after rain but they are of particular value to the **aerial archaeologist** because they occur less frequently than cropmarks in cultivated fields and thus give access to parts of the landscape that are generally impervious to cropmark survey.

Grassmarks of even greater clarity can occur when the harvesting of hay or silage is followed by a period of hot and dry weather. The cut grass quickly withers to a whitish colour, except above ditches or other reservoirs of underground moisture. In these conditions the grass and weeds (if not eaten by grazing animals) may put on rapid growth, producing remarkably clear cropmarks in fields that normally reveal nothing.

Cropmarks of a different kind, sometimes referred to as '**weedmarks**' or '**vegetation marks**', are caused by minor differences in moisture content, nutritional value or microclimate which favour one plant over another, or give an advantage to plants in one position compared with their neighbours alongside. Poidebard, on the Syrian steppe, for instance, noted how tiny variations in ground conditions resulted in differences in vegetation which were difficult to see from the ground but clearly visible from the air. A similar thing can happen with weeds of cultivation, such as poppies in stands of corn (Figs 2.11 and 10.14) or the re-growth of weeds amid the stubble of harvested grain crops. Commenting on the prospects for cropmark survey in Mediterranean countries, and particularly in southern Italy, Bradford (*1957*, pp. 24ff) noted how wild plants and flowers can create cropmarks in sun-scorched pasture at almost any time from July to October. The grass itself may also show patterns when the first rains of autumn bring the summer drought to an end. Along with similar effects of flowering plants earlier in the year this could give the drier parts of Italy and other Mediterranean countries a wider range of opportunities for recording cropmarks than applies in the more temperate zones of Europe.

Extreme conditions: frost, snow, ice, flood and drought

Winter flights, in addition to providing low sunlight for shadow photography, offer extra opportunities through the effects of frost, snow and ice, though in these conditions it can sometimes be difficult to reach the airfield or to take off from a frozen runway (helicopters, with their vertical take-off, can prove useful at such times, though they are less commonly available and are at least twice as expensive to hire as light aircraft).

A heavy coating of frost or a light fall of snow can remove the distracting colours of winter vegetation and make ideal conditions for shadow photography, whether of individual sites or of whole landscapes (Figs 2.12, 5.11, 10.16 and 10.17). Deep or drifting snow can hide as much as it reveals but a thin covering of wind-blown snow can show up changes of level that are barely perceptible in other conditions, even in low winter sunlight. The differential melting of frost or snow on slopes facing

Fig 2. 12 **Snow and low light in combination**

Low winter sunlight and a light covering of snow pick out the earthworks of a typical pattern of ‘ridge and furrow’ cultivation on the Welsh Borderland, with beyond it the distinctive layout of a managed water-meadow of medieval or post-medieval date.

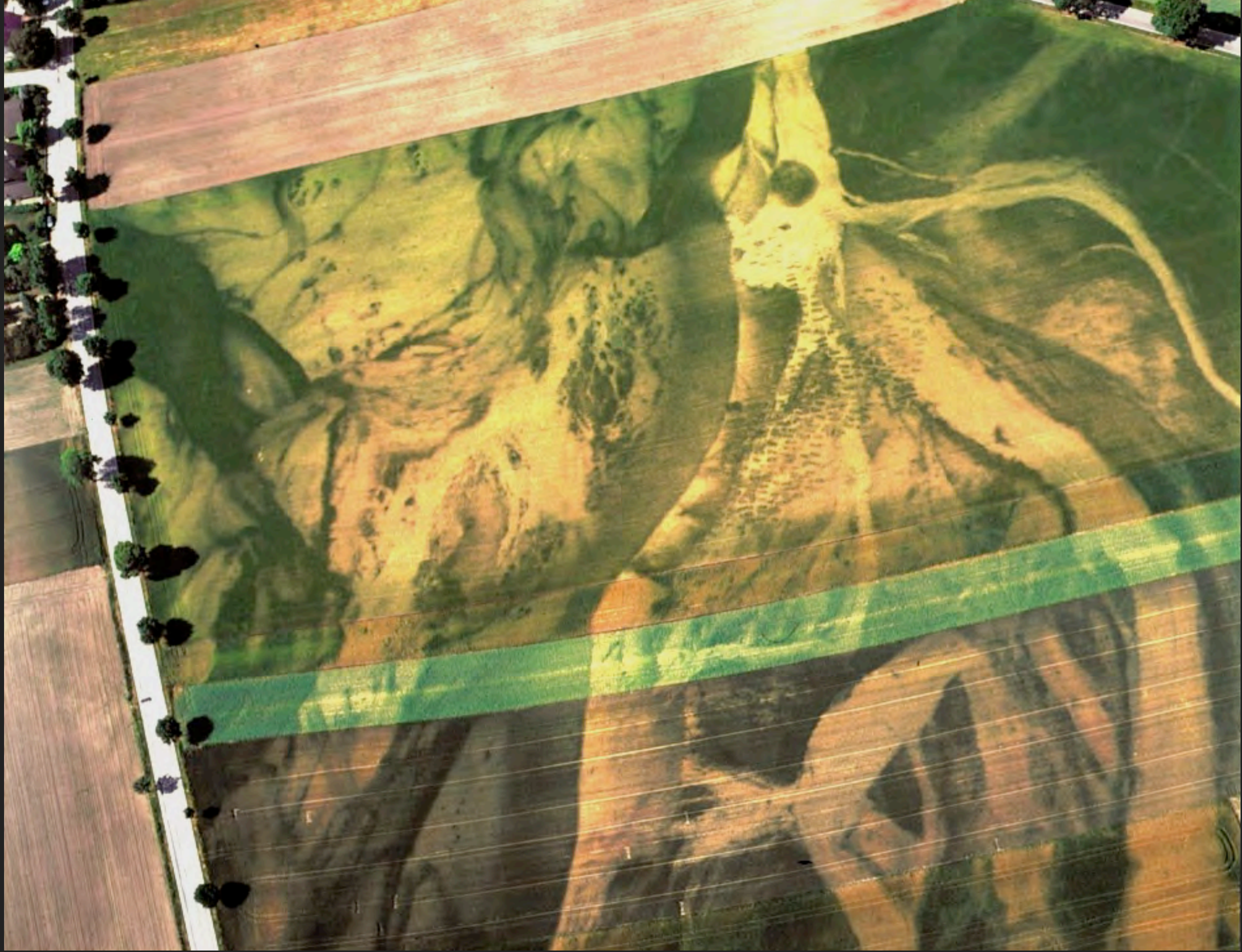
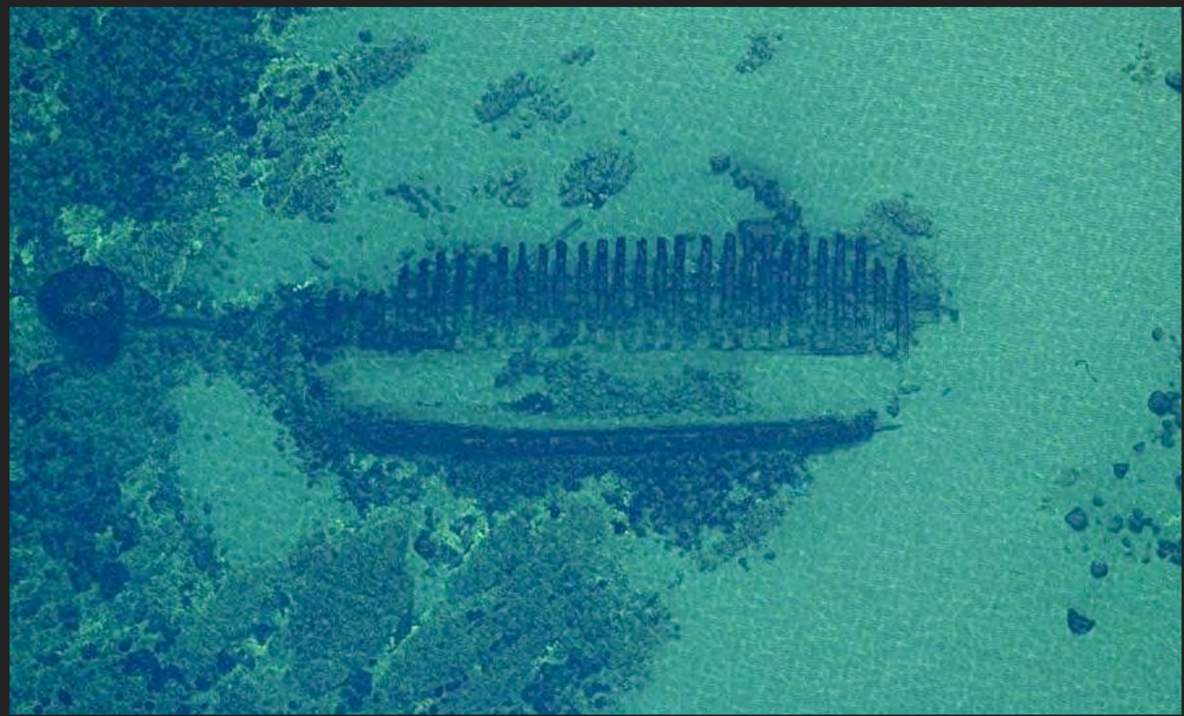


Fig 2. 13 The results of drought at Awaren, Austria

Fossil river courses and an extensive inhumation cemetery (just right of centre) are revealed by drought conditions during a long hot summer.

Fig 2. 14 Flooded and under-water subjects

Left. The same earthworks that appear in Fig 2.11 are in this picture emphasised by the effects of winter flooding, the ponded water making clear the slight changes of level that would be almost invisible if seen at other times of year, in dull weather or ‘flat’ lighting.
Below. The remains of a wooden ship photographed through shallow water on the Baltic coast of Germany.



freezing soil of a buried ditch. The opposite may happen at the end of a long period of cold weather, when the now deeply-frozen ditch, and the frost or snow above it, thaw out less quickly than the surrounding areas (*Braasch 2005*).

Flooding can show up minor differences of level in low-lying areas, explaining the location of ancient sites, outlining ploughed-down **earthworks** or revealing earlier courses of rivers or streams (Fig 2.14, left). Drought can have an equally dramatic effect in revealing abandoned river courses (Figs 2.13, 10.39) or the parched fairways of ancient roads, whether in grassland or in arable crops.

Recording of submerged features

During the 1940s and 1950s experiments were carried out by both Italian and British military authorities into the aerial photography of submerged features. Films, filters and other aspects of photographic technique were tested, apparently with success at depths of up to 13m in coastal waters. The wooden piles of Swiss lake dwellings were mapped with the aid of air photographs in the 1930s and have been photographed again more recently. In Italy the remains of the Roman *Portus Iulius* were recorded by military air photographers as early as the 1950s, submerged deep in the Gulf of Pozzuoli near Naples (*Guaitoli 2003*, fig 878 and pp. 485-92). More recently underwater archaeologists have shown a renewed interest in the use of aerial photography in their branch of study. Wrecks in shallow water have been photographed along the Baltic and other coastlines (Fig 2.14, right), while fish-traps and other features in the inter-tidal zone have been recorded on numerous occasions in recent years around the British coastline, for instance along the Severn Estuary which has been studied as one of the project areas within the National Mapping Programme for England (see web reference *NMPE*).

Fig 2. 15 **‘Patterns of survival’**

Two examples of ancient patterns partially preserved to the present day.
Left. The oval shape of the Roman amphitheatre still visible in the streets and building of modern Florence.
Below. The gridded pattern of Roman centuriation survives with relatively minor divergences in the modern agricultural landscape near Imola, in northern Italy.

Patterns of survival

Sometimes it is the very 'shape' of the past which can still be seen in the present-day landscape. No airborne observer could fail to be see the bold line of the an ancient boundary earthwork (such as the Roman *limes*) tracking across the countryside through the present-day fields, even though it might here and there be shrouded in trees or eroded by modern agriculture. Centuriation in the Po Valley of northern Italy (Fig. 2.15, right) is obvious from the air but seems like nothing but more than modern tracks and fields when visited on the ground. Sometimes only part of the pattern survives – the suspiciously curving hedge-line in an otherwise rectilinear field system, for instance, that on ground examination proves to be the last surviving **trace** of an ancient settlement or ritual **enclosure**. A striking example of a Roman amphitheatre persisting in the street pattern of present-day Florence is illustrated in Fig 2.15, left and on the title page of the book. The eye and camera of the **aerial archaeologist** can sometimes restore such survivals to the archaeological record.

Putting the photographs to work

Aerial survey and air photographs have a multiplicity of uses, frequently overlapping with one another. The discovery of 'new' sites – really the re-discovery of old ones – can radically change the perceived density or distribution of ancient settlements and prompt fresh ideas on their interpretation. Photographs originally taken for **mapping** or management purposes can be used in publicity and education – in Britain, for instance, vertical as well as oblique photographs have been used in school exercises aimed at giving children a better appreciation of their local environment.

Discovery

The most potent application of **exploratory aerial survey** lies in the discovery of 'new' sites, or of new information about already known ones. Sometimes the same information is actually visible at ground level but has simply escaped recognition until seen from a higher and more intelligible viewpoint during aerial survey. This may be so with low earthworks of various kinds (banks, ditches, trackways or field divisions) or with stone-built features which have become partly obscured by erosion or plant growth.

In other cases aerial survey may be the *only* realistic means of discovery and recording, though even cropmarks or soilmarks can sometimes be seen, but not so readily understood, from ground level (Fig 2.8). The important point is that the aerial

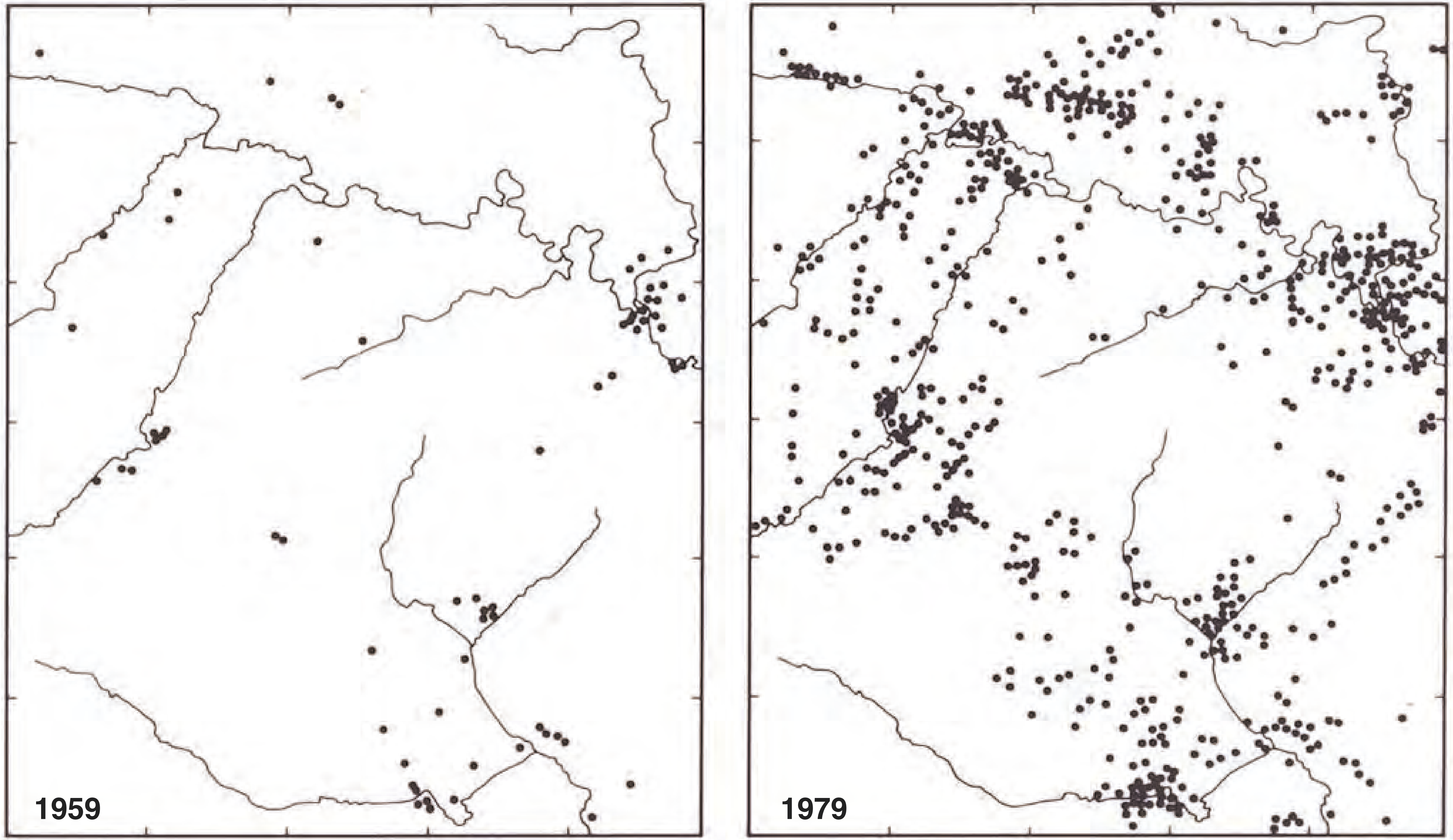


Fig 2. 16 Discovery through cropmark survey

The left-hand map of a 60 x 50km area of river valleys and low hills in eastern Wales shows the distribution of known cropmark sites in 1959. The starkly different density after a further 20 years of sporadic cropmark survey is shown on the right. New cropmark sites continue to appear each year (Fig 5.6) so long as the weather is dry enough to prompt the formation of cropmarks. Discoveries on this scale are bound to influence ideas on the settlement history of the area, and to question the reliability of interpretations in areas where cropmark evidence is not available.

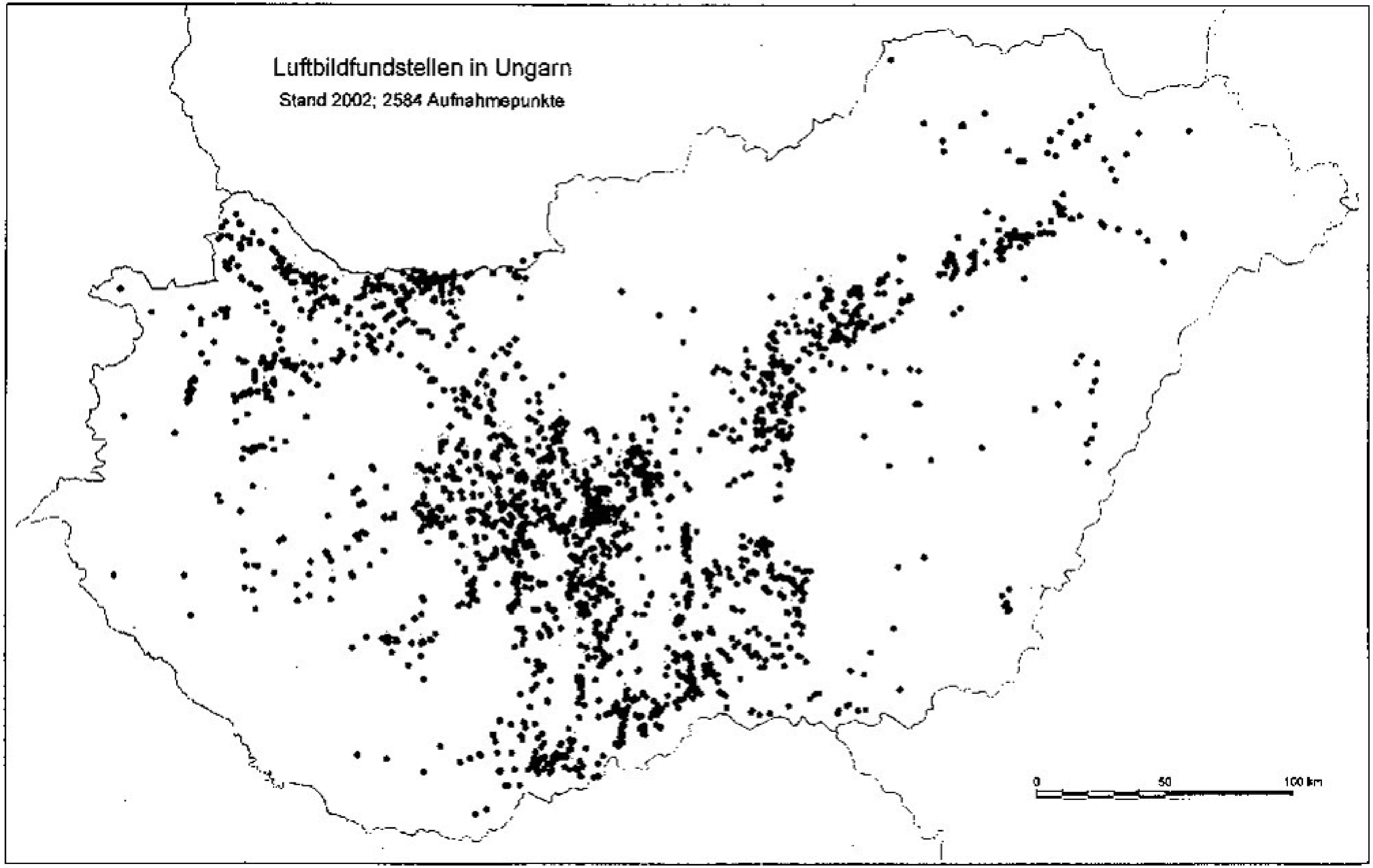


Fig 2. 17 The impact of oblique aerial survey: Hungary

In a landscape that has been little studied through the analysis of existing vertical air photographs the impact of carefully targeted oblique aerial survey can be profound. This map shows the 2584 features, mostly cropmark sites, recorded in the river valleys and lowlands of Hungary by Otto Braasch during summer visits in the decade to 2002. Experience suggests that the vast majority of these will have been unknown to Hungarian archaeologists working from ground-based evidence.

perspective, and the capacity of the aerial archaeologist to recognise the significance of what is visible from the air, provides an effective means of identifying and recording features which have not yet been recognised as legitimate parts of the the archaeological record. The impact of such discoveries on the interpretation of settlement patterns or military dispositions can be quite radical, not only in suggesting new interpretations where **aerial evidence** is available but also in hinting at what may be missing where it is *not* (Figs 2.16, 2.17, 2.20 and 2.25).

Record

Because of their high viewpoint air photographs (whether vertical or oblique) can provide an objective and intelligible record of the whole or large parts of an archaeological site or landscape, only parts of which are visible from any single point on the ground. In oblique photography the quality of the record will vary with the viewpoint, lighting and in some cases with local crop development – and of course with the skill and archaeological perceptiveness of the photographer. The record is not *complete*, however. It cannot in most instances reveal the date or function of the features recorded, except by analogy with the appearance of better-explored sites elsewhere.

On the other hand the photograph is an *objective* record, in that it does not of itself contain any bias of description, interpretation or representation, as does a map or plan drawn by a ground-based surveyor. The photograph can of course have bias projected onto it at a later stage, during the interpretation and mapping of its content for comparison with data derived from other sources, including other air photographs. There is an element of bias, too, in the aerial archaeologist's choice of where to go and what to photograph. It is difficult to avoid this when the resources available do not allow all areas to be given equal attention. The aerial archaeologist should guard against such distorting factors as far as possible, both in the original exploration and in reporting the choices and omissions made in the collection of the **aerial evidence**.

Sometimes existing or so-called 'historical' aerial photographs represent the *only* available record, for example of sites or other archaeological features that have subsequently been destroyed by agricultural terracing, mineral extraction, road construction or urban development. The same applies to abandoned urban or industrial sites (Fig 2.18) and to many rural sites which have been partially destroyed by mechanised farming or the re-allocation of formerly open spaces to 'obscuring' crops such as olive trees, vines or fruit trees (Figs 2.19, 10.40, 10.41). The air photographs taken during World War II or in the post-war surveys of the whole of Italy, for instance, constitute an irreplaceable record not only of these lost archaeological sites but also of the Italian landscape before both town and countryside were transformed by the 'economic miracle' of the 1960s. The same applies, to one extent or another, in many other European countries. Every photograph taken today, in this sense, becomes an immediate historical record. The writer, in lectures in the mid 1990s, used to show an aerial photograph of

Fig 2. 18 Oblique aerial survey as a means of record

This picture of Hanley, in the West Midlands of central England, is one of many contemporary scenes photographed by J K S St Joseph for Cambridge University in the late 1940s and 1950s. Many of the industrial and urban contexts that he photographed then have been radically changed by later developments. At Hanley few if any of the brick-built kilns of the then thriving pottery industry now survive. Photographs like these quickly become historical documents in their own right.

a British steelworks, describing it to the audience as an example of “the industrial archaeology of fifty years hence”. Barely five years later the steelworks were taken out of use and its furnaces and strip-mills were demolished, soon to be replaced by plans for a massive retail shopping complex.

Mapping

Air photographs are taken in great numbers throughout Europe every year, mostly for national or regional **mapping** programmes or crop monitoring but also on rare occasions for archaeological purposes. The individual photographs are primary records which must be consulted directly in many cases, for instance in the detailed examination of a site prior to excavation. For most uses, however, their content is best communicated by summarising it (perhaps from many photographs) in drawn plans, maps and written descriptions similar to those created when recording the

Fig 2. 19 Oblique aerial survey for recording landscapes

This ‘traditional’ landscape of managed pasture defined by walls, tracks and stone-clearance heaps was photographed by Otto Braasch near L’Aquila, in central Italy, in 2001. Many such landscapes, for example in the Murge Hills south of the Tavoliere plain in the far south of Italy, are losing their traditional pattern under the impact of mechanical stone clearance and the heavy use of chemical fertilisers (see for example Fig 10.41).

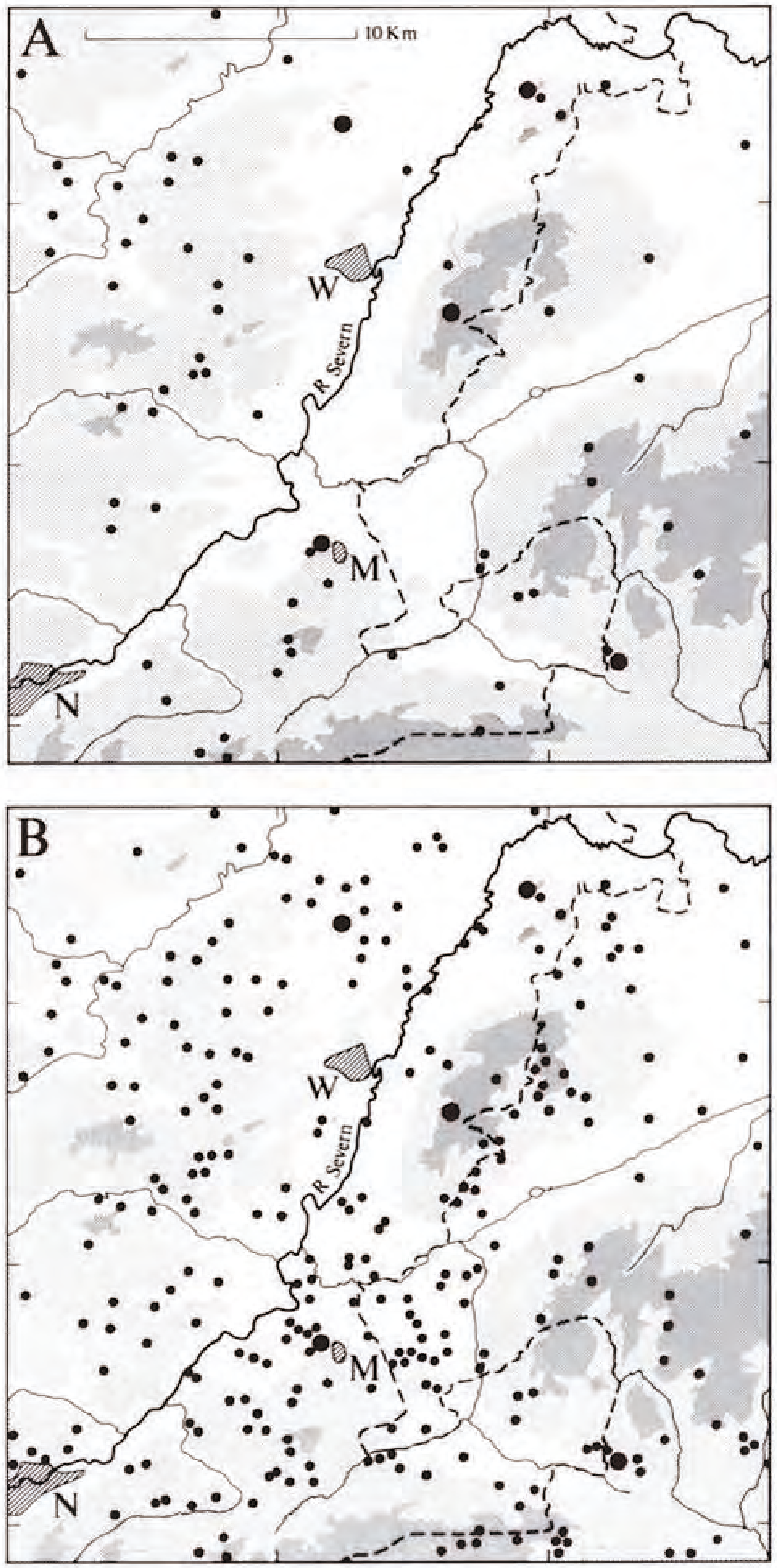


Fig 2. 20 'Small enclosures' on the Welsh Borderland

These drawings summarise the aerial evidence for small defended enclosures of probable Iron Age to Roman date in part of the area shown in Fig 2.16.

Top. Surviving earthworks, mostly occurring on the higher land (stippled in this diagram).

Bottom. The radically changed pattern when aerial evidence is added, especially for the lower land where few earthworks have survived the effects of centuries of ploughing.

Any archaeologist trying to analyse the landscape on the basis of the earthwork evidence alone would be using only a fraction of the potentially available data and thus would be prone to erroneous interpretations on the use or otherwise of the valley areas.

results of ground-based survey. In many instances, especially with cropmark and soilmark evidence, direct mapping from oblique or vertical photographs is the *only* way of achieving this transition. In other cases, with low earthworks or wider areas of preserved landscape, it may be the most *economical* method of creating an initial record, for subsequent checking and elaboration by ground-based survey where resources allow (see, for instance, Figs 2.19 and 9.13).

Research

Aerial survey, when combined with air-photo interpretation and mapping, has a host of applications in the field of research. Newly identified sites can give rise to totally different interpretations of settlement patterns and landscape exploitation, or prompt fresh lines of enquiry to be further pursued through ground-based survey, geophysical prospection or excavation. Aerial photographs can illustrate the topographical or archaeological contexts of sites or areas already under study, and facilitate morphological analyses that would otherwise be difficult or near-impossible. By showing the precise shape, extent and location of sites or linking features such as roads or field systems, maps made from aerial photographs can suggest the most effective strategies for research or rescue excavations (see, for instance, Fig 2.23). Working together with terrestrial survey and surface collection, aerial survey can contribute to a more rounded view the ancient landscape – the sites seen from the air, for instance, are often quite different from those identified through ground survey or surface collection (Figs 9.12, 9.13). Aerial survey has even been used for predictive purposes in advance of fieldwork in America, Australia and Sweden by identifying topographical settings or kinds of terrain which elsewhere are known to support settlements which would not in themselves be detectable from the air.

Interpretation

The high viewpoint and wide coverage of air photographs can help in the interpretation of complex sites or **archaeological landscapes**. Continuities or contrasts with adjacent or other parts of the landscape pattern may be readily picked out and ideas generated for testing against other photographs, or against the results of ground-based survey, field walking or excavation. Indeed, such comparisons are almost essential if reliable interpretation is to be achieved – air photographs should rarely be used as the *only* source of information, especially where the pattern is at all complex, either internally or in its relationship to the local topography, land use or vegetation.

Conservation and monitoring

In Italy detailed air-photo mapping by **photogrammetry** has been widely used in the management and conservation of nationally important sites and monuments. Similar work is done for special sites in Britain, though less frequently than in Italy. At a more general level, the rapid inclusion of aerial discoveries in national and local heritage registers can influence planning decisions, reducing or preventing unnecessary damage by development proposals. In a broader context, anything which creates a better appreciation of the historic environment also helps indirectly in its preservation. Oblique aerial photographs often have a dramatic effect in emphasising the importance of individual sites or landscapes, especially in the eyes of the general public, and they are used widely used in Britain and other parts of Europe for this purpose. Oblique air photography can also be used for monitoring potential risks to state-protected monuments, as illustrated in Fig 2.22. For similar work in Denmark see *Olesen 2012* in the Supplementary Bibliography. In Britain aerial survey is also regularly used in assessing the archaeological implications of major development proposals and in illustrating the broader context of rescue excavations where these prove necessary (Fig 2.21).

Fig 2. 21 Aerial survey and rescue archaeology

Air photo mapping, and sometimes new vertical or oblique air photography, are used on a regular basis in Britain to assist understanding of sites subjected to rescue excavation in advance of road building or other damaging development projects. Here, the fragments of 'aerial landscape' plotted in red help to establish the context of the much smaller excavated areas (in black) in a major road development in the English Midlands. See *Deegan 2001.*

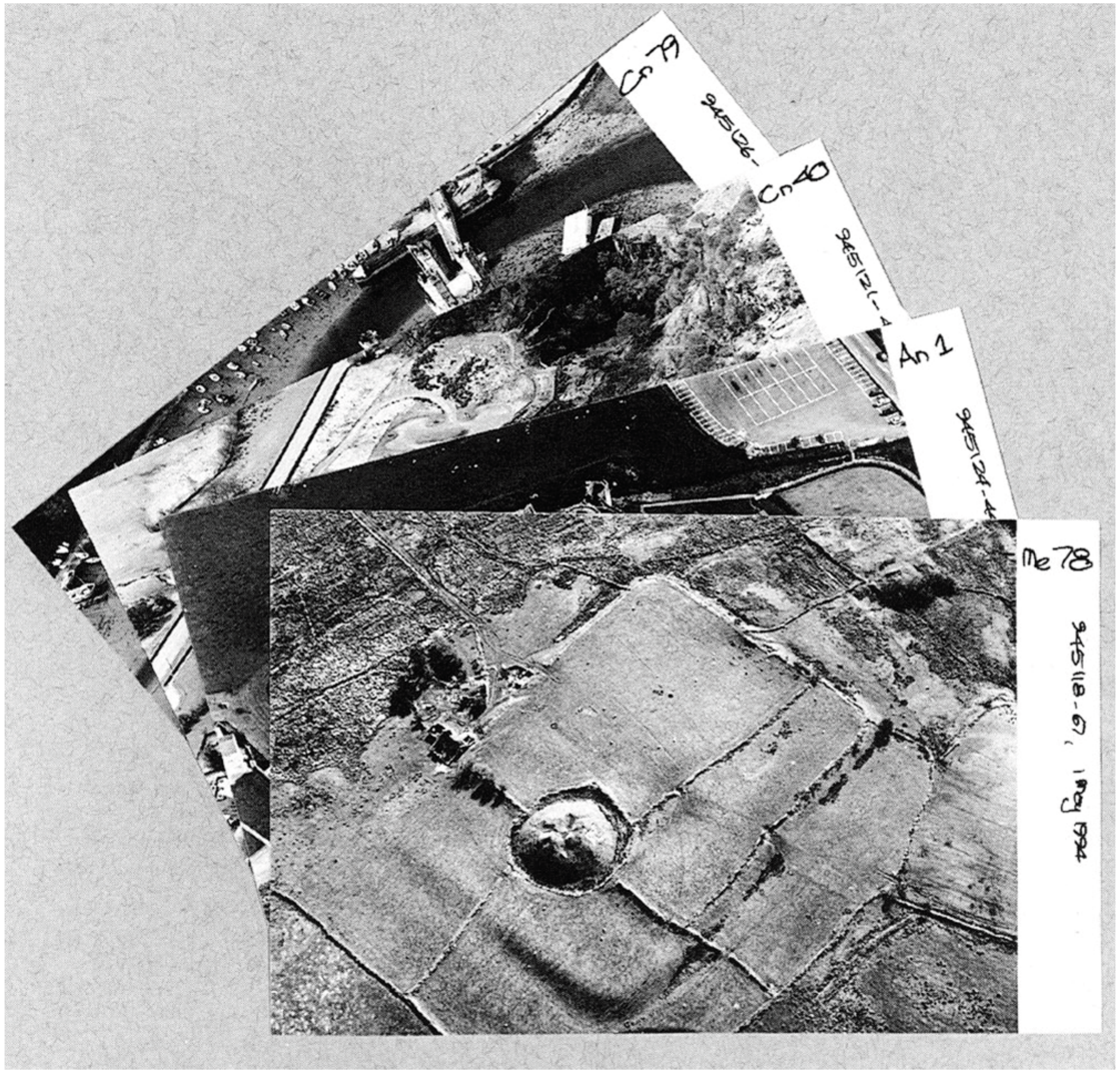


Fig 2. 22 Oblique aerial survey and monument monitoring

In Wales and more recently in England oblique aerial survey is used for the regular monitoring of legally-protected monuments in private ownership, with special attention to potentially damaging land-use within or around the monuments. The resulting photographs are taken by ground-based ‘field monument wardens’ when visiting land-owners and tenants to enlist their help in the sympathetic management of these nationally important sites.

Illustration and education

Oblique air photographs are simply perspective views taken from a novel angle. As such they have an unrivalled capacity for illustrating and describing sites, **complex**es, landscapes, buildings and built-up areas, both for the specialist and for the general public. Taken from the right angle and in appropriate lighting they can explain the form and setting of an embanked settlement, a castle or a village more effectively than a page of words or a host of ground-based views. They are widely used throughout Europe in educational or general interest books and in the tourist industry. With an eye on these kinds of uses archaeological air photographers should always be on the lookout for views that are striking as well as informative. The contribution of eye-catching images in communication with the general public cannot be over-emphasised (Fig 2.26).

The merits and limitations of archaeological air survey

One of the great merits of aerial survey is its capacity to reveal the existence and character of sites, land management systems and communication routes that are invisible (or nearly so) from ground level. This applies both for cropmark and soilmark evidence in lowland situations and for better preserved 'earthwork' sites on higher ground. Aerial survey allows large areas to be covered in a relatively short time, and gives at least partial access to parts of the landscape that are difficult to survey on foot. Chronologically, aerial photographs have a wide variety of uses, from early prehistory to industrial archaeology and beyond. Vertical photographs, given the attention they deserve, are an inestimable source of new information, though England is the only European country so far to have initiated their analysis and mapping on a truly national scale (Fig 1.14).

Specially commissioned vertical photography, undertaken at times appropriate for the recording of archaeological information, is fairly difficult to organise but oblique aerial survey presents fewer problems, as long as archaeologist can put up with the disappointments of flights cancelled because of bad weather, or of summers that begin well but later fail to produce the hoped-for cropmark evidence. The interplay between ground-based and **aerial evidence** can multiply the effectiveness of field survey, especially if air photo mapping is done before the fieldwork starts. The excavator, too, can often be shown the broader context of excavated areas through air photo mapping or specially commissioned flights, and whole new concepts of 'minimalist excavation' can be developed when the detailed mapping of the air photo evidence has suggested the critical places to dig (for stratigraphical relationships or potential dating evidence, for instance, as might be desirable for the pair of sites illustrated in Fig 2.23).

The gains from free-ranging aerial exploration can be enormous (Fig 2.20), but they will not accumulate uniformly across the landscape (Fig 2.25) nor will they necessarily be quick to materialise (Figs 2.16, 2.17). Some kinds of soilmarks, for example, appear so fleetingly that their recording, except during special flights to locations and at times where they are known to be likely, is more or less a matter of chance.

There are similar limitations on the occurrence of cropmarks, which can be irregular and unpredictable. On gravel terraces or in areas of light and well drained soil, some arable crops regularly develop cropmarks in times of restricted rainfall. The gains in these areas may come quickly and continue for years or even decades into the future (Fig 5.6). But on heavier, even-textured or highly eroded soils, where there is less contrast between the natural soil and the filling of features dug into it, cropmarks may appear only occasionally, in times of extreme

Fig 2. 23 Aerial photography and 'minimalist' excavation

This picture records a pair of overlapping cropmark enclosures on the Welsh Borderland, where a single trench could reveal the stratigraphical and perhaps dating relationship of the two. The double-ditched enclosure at lower left has a form which is typical of Iron Age sites in the area. The single-ditched enclosure in the central part of the picture, with the narrow foundation trench for a palisade set back a short distance from the ditch, would from details at the intersection appear to be the later of the two. It might perhaps belong to the Early Christian period when very few sites of any kind are known from Wales. The name of the adjacent farm (Court Farm) might support this conjecture. In such cases, however, the cropmark evidence must be checked by excavation. In this instance 'minimalist' excavation would probably produce the necessary answer.

drought for instance. Some areas may at first seem too wet or too homogeneous in their soil texture for soilmarks or cropmarks to develop in any profusion. Even in these areas, however, there may be small 'islands' of susceptible soil, or summers of exceptional drought, which will allow the occasional recording of cropmark evidence. In such areas it is important to record this evidence when it *does* occur, as a corrective to ideas based on its absence in photographs taken at less favourable times.

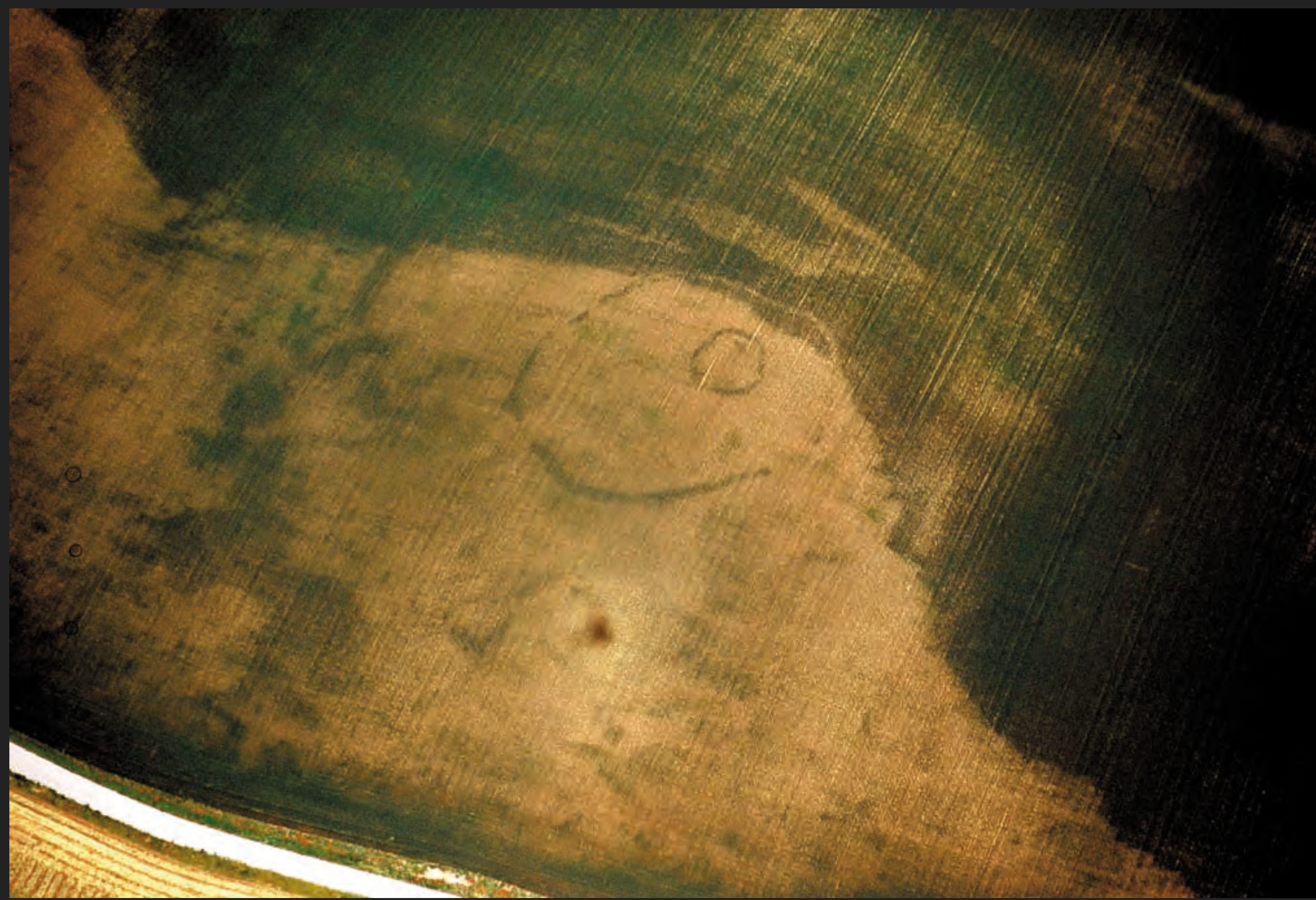
Present-day land use can 'close the window' on some parts of the landscape, though it is the very act of cultivation that produces cropmark and soilmark evidence in the first place. The cultivation which reveals the sites is simultaneously destroying them, making aerial photography and air photo mapping the only practical means of 'preserving' them where rescue excavation or removal from cultivation are not realistic possibilities. Except in times of drought, cropmarks are unlikely to occur in upland areas where there is little or no arable cultivation, though there is an added chance here of recording upstanding archaeology through shadow photography. Both earthworks and eroded sites can be masked by alluvium or colluvium, of whatever age or agency. Vineyards, orchards and natural or planted forests will remove other parts of the landscape from 'aerial visibility', as will reservoirs, roads, railways and built-up areas of the present day (though air photographs can be a potent tool in the study of historic towns and villages). Other areas may be inaccessible because they lie within restricted military zones, or because they are too far from the airfields that can be used by local archaeologists.

There are also difficulties of dating and interpretation. Some of the sites seen and recorded from the air will reveal their probable date and function by analogy with well explored sites elsewhere. In other cases the interpretation may be far more speculative, though in reality this applies just as much to most sites recorded through ground-based observation. Especially with cropmark sites of indistinct or undistinctive morphology there may be little that can be said about dating or function, though again this differs little from similar sites recorded by field survey.

Finally, only some types of sites reveal themselves through aerial survey. Where there has been no disturbance of the ground, or no significant deposition of extraneous material, archaeological sites or features are unlikely to show as cropmark or soilmark evidence, and by definition will not be visible as **shadow sites**. Unenclosed settlements, lacking ditched or walled perimeters, will remain difficult or impossible to detect from the air, unless they contain pits or are located on slopes which require terracing for the individual building. For the most part, too, cropmark photographs reveal only the *major* features of sites. The smaller pits, postholes and foundation gullies register on the photographs only when the conditions are particularly favourable (Fig 2.24, left).

Fig 2. 24 **Major features and minor details**

Oblique air photographs tend to show only major features, such as enclosure ditches (below, in Puglia) and sometimes larger pits or graves. Post-holes and narrower linear features, ubiquitous during excavation, are infrequently seen from the air, an exception being the post-built Neolithic long-houses on the left, at Harting in Germany.



Despite these limitations aerial survey, properly applied, provides a very effective means of establishing the existence and general form of sites or contextual features, which may then be further investigated through ground-based survey, geophysical prospection or excavation, each technique giving a progressively finer but more expensive means of access to the surviving archaeological evidence. Archaeology builds its concepts from impossibly fragmentary evidence, like a crossword puzzle with only parts of the grid and just a few words from the clues. Whatever its limitations *any* technique which helps to reveal other parts of the pattern should be welcomed and put to work in partnership with the more established investigatory techniques.

The potential impact of aerial survey

Figs 2.16, 2.17, 2.20 and 2.25 show some examples of the impact of free-ranging aerial survey in Britain and other parts of Europe. There is little doubt that parts of Italy and many other European countries could benefit in similar ways. In Britain, for instance, much of the data about field monuments, from the Neolithic to the Roman periods in particular, is drawn primarily from **aerial evidence**, and in the more arable parts of the country up to half or more of all known field monuments have been recorded in the first instance through aerial evidence. In many countries of Europe the best part of the landscape for cropmark and soilmark survey have yet to be identified through properly targeted reconnaissance flights, or through the study of thematic maps of geology, soils, climate and land use. In Britain upland areas that have been relatively little affected by recent agricultural activity have provided rich returns from aerial survey, especially in winter conditions when the sun is low in the sky and the shadows cast by ancient earthworks are long. On the evidence of recent flights in central and southern Europe, too, there is a vast amount to be recovered on hillslopes and in upland areas, with whole landscapes of terraces, fields, **enclosures** and trackways capable of rapid recording from the air, whether through oblique or vertical photography (Figs 2.19, 10.15, 10.40, 10.41).

But the real gain for Italy, and across Europe as a whole, will only come when free-ranging exploration is matched by mapping and interpretation of the kind described in Chapters 6-9. It is hoped that the examples described here from Britain will show what can be achieved when aerial survey becomes more widely used as an everyday part of archaeological exploration, mapping and interpretation.

Fig 2. 25 The varying impact of aerial survey in different parts of Wales

Only certain parts of any country are likely to respond positively to aerial survey though all will probably produce at least some worthwhile returns from aerial recording. This figure shows the varying 'aerial visibility' across Wales, situated as it is on the wetter and more mountainous western side of Britain.

1. Areas with arable cultivation and rich cropmark evidence.
2. Areas where cropmark evidence is less dense but still significant.
3. Upland areas characterised by permanent pasture and the good survival of earthwork evidence.
4. Areas with surviving evidence of 'industrial archaeology'.

Fig 2. 26 Striking patterns

Aerial archaeologists should never be afraid to photograph unusual or aesthetically pleasing patterns. Striking or amusing images can capture the attention of an audience or enliven a printed publication. All of the photos were taken over Tuscany.

a) A modern hospital
b) A carefully designed vineyard
c) Grain-crops beaten down by summer storms
d) An anti-nuclear ‘crop
e) A castle in silhouette
f) Imaginative use of a confined urban space

3. PLANNING A PROGRAMME OF AERIAL SURVEY

Attention in this chaper turns to the planning of a survey programme and in Chapters 4 and 5 to the resources and procedures needed to make it a success. The advice has been structured on the assumption that few countries will have – for some years at least – a state funded national flying programme like that in Britain, nor large-scale regionally-funded aerial survey like that in some parts of Germany. More probably the pattern will resemble that of local and regional aerial survey in Britain, with regionally based flying programmes of 10-30 hours a year supported by a variety of academic and other funding. In reality, 10 hours a year barely qualifies as a ‘programme’, though it might meet limited local needs or keep a long term project ticking over. Around 50 hours, on the other hand, would provide reasonable coverage for a region the size of Tuscany or Wales, or for a relatively small country such as Holland or Belgium. Of course, useful work could be done on less, and there would be no shortage of worthwhile projects if more air time could be made available.

A medium-scale operation of this kind would almost certainly use locally hired aircraft and be carried out in the first instance by archaeologists and pilots who are ‘learning on the job’. With this in mind the advice offered here has drawn especially on the present author’s own experience, starting with a few hours of flying each summer in the 1970s, then rising to several years of involvement in a ‘local’ (county-based) programme of 20-30 hours a year, and finally to a decade or so of flying for 60-70 hours a year across the whole of Wales. The advice – addressed directly to the reader – will be resolutely practical, with the focus on common problems and everyday experiences rather than unusual happenings or specialist applications.

The best single piece of advice, of course, is to seek some kind of formal training in aerial survey, like that offered at the training schools that have been organised in various parts of Europe since the mid 1990s. If this is not possible, try to fly first with – or take advice from – someone who is already carrying out archaeological air survey, whether at home or elsewhere in Europe. In this context the members of the international Aerial Archaeology Research Group (AARG) and of the ArchaeoLandscapes Europe project will be more than willing to help through internet or other forms of contact (www.univie.ac.at/aarg and www.archaeolandscapes.eu). Thereafter the best advice is to remain an eternal student, learning something from every mistake and every new experience, both in the air and on the ground afterwards.

Firstly, though, a few words of caution. Almost any programme of aerial survey will take years to mature, demanding both patience and perseverance. Worthwhile results may come quite quickly in some areas, especially in countries where aerial survey has yet to establish itself as a regular part of the search for archaeological information. But those initial gains will not continue to come, or the exploration may fail to achieve its full potential, if the programme is not supported by clear and realisable objectives, matched to the characteristics of the study area and of course to the resources available. The cost of equipment and facilities may be substantial – cameras and photographic accessories, navigational aids, computers and related harware and software, along with computer equipment and related storage and library space. Plus of course the direct and indirect costs of flying – the hire of aircraft and pilots, the cost of films and processing (or nowadays of memory cards, high quality computer screens and related software for processing and archiving of the mass of digital data now being collected each year). But 'resources' must also include skill, time and attention to the planning the work, and to the post-flight processes which give wider meaning to the few hours of excitement in the air.

Aerial research should be matched to the area being studied – its size, geography, geology, soils, climate and land use (all of which affect the aerial visibility of sites), and of course to its known archaeology. There may, for instance, be ways in which aerial survey could test existing archaeological perceptions about the area, or open up entirely fresh lines of enquiry. Aerial recording might be able to help in the presentation, management and conservation of the area's archaeological **site**s. Advice on such things should obviously be sought from archaeological colleagues and from existing heritage records and record keepers. Time should also be allowed for feeding information and ideas back to those who have provided this kind of help.

The lesson here is to form links and partnerships from the very outset. If you can help other people or organisations with *their* concerns, perhaps in having informative aerial views for publication or publicity material, you may win their support and goodwill for *yours*. The more 'useful' your work can be (for other archaeologists, of course, but also or for those working in related field such as **landscape** studies or the promotion of tourism) the more widely it will become known and the more likely you will be to accumulate at least small amounts of money to finance your aerial work. Even so, you may need to put real effort into fund-raising, by applying for academic grants or sponsorship, or by cost sharing where your own work can be made directly useful to others. Be aware, however, that direct 'commercial' activity, as distinct from research, may run counter to aerial regulations in your own country – for the past decade and more in Britain, for instance, official flights for aerial photography can only be made with pilots holding a Commercial Pilot's License (CPL) and through aircraft contractors holding an Air Operator's Certificate (AOC).

Naturally, the more links you can form with archaeological colleagues on the ground, the more ideas or **target** areas they are likely to suggest and the more productive may become your precious hours in the air. The more 'rounded', too, will become both your own and your colleagues' archaeology.

It is not particularly difficult to get into the air, nor to take acceptable aerial photographs. But the wise beginner will want to learn the 'mysteries of the art', doing things in the right way and above all at the right time – for instance catching low light in the winter months or at the start or end of the day in summer. One of the first lessons is that summer cropmarks occur sporadically and often unpredictably, so that it is necessary to return day after day, week after week, year after year in order to realise even a fraction of any area's potential. You must learn to improvise when the weather turns against you in the middle of a flight, when the sun refuses to shine, or when one year's observations seem to another. You must train your eye and mind to recognise, year after year, *more* things which may be of archaeological significance while filtering out those which are not. You must retain the intuition and sense of enquiry to seek out – to *expect* – new things every time you go into the air. And you must have the determination and perseverance to carry the task through on the ground and in the office afterwards, however tedious that post-flight work may seem at times.

Fig 3. 1 A 'portfolio' of potential targets

The aerial archaeologist can maximise the benefits of time in the air by having a range of target types to photograph as opportunities arise.

a) Cropmarks in spring and summer (a Romano-British settlement).

b) Earthworks in low sunlight (a deserted medieval village).

c) Monitoring of legally protected sites (a hillfort and overlying medieval castle).

d) Landscapes an archaeological sites under snow in winter.

e) Towns and villages, in this case with a surviving medieval street pattern.

f) Country mansions with their gardens and stables etc.

g) Early field systems surviving in the countryside.

h) Industrial sites, in this case an endangered cider brewery.

A ‘portfolio’ of targets

Several different *types* of survey might be involved within a well-organised flying programme. Firstly, of course, there is exploration, the discovery of new **sites** or **landscapes** elements, or of new information about known sites or **features**. This is in some senses the most exciting kind of survey but also the least predictable, especially if concentrated largely on cropmark evidence. There can be years when wet weather leaves little to be recorded by way of cropmarks. But there may still be upland (or even lowland) areas that can be explored for **shadow sites** in low light. In any country that has been devoid of free-ranging aerial survey in recent decades there will be much to be done in the basic recording and illustration of sites, landscapes and townscapes for a variety of purposes, including education, **mapping** and **record creation**. Important sites and landscapes could perhaps be monitored from the air to help their management or conservation. There may be excavation sites, field survey areas or other individual **targets** that could be photographed for colleagues in academic and public-service archaeology.

In combination, these types of recording can create a ‘*portfolio*’ of objectives or targets, any or all of which might come into play on a particular flight (Fig 3.1). The more targets or target areas there are on the archaeologist’s flying maps, the more cost-efficient will be the flying and the more useful the programme’s output.

Stages of exploratory aerial survey

Within **exploratory aerial survey** there tends to be a progression over time. First comes *primary reconnaissance*, testing the area to see what might be recordable, when and where. This grades into consolidation, the systematic collection of data in those areas where it is now known to be available. Thirdly (or at any stage in the process) there is *problem oriented survey*, the testing of particular hypotheses or the close examination of particular sites or areas, including those which have failed so far to produce worthwhile **aerial evidence**. These are useful concepts to bear in mind when planning a long term programme primarily focused on exploratory survey.

Summary

A programme of aerial survey must have clear objectives, sensibly related to the chosen study area and to the financial and other resources available. Otherwise it will not repay the time and money invested in it, and will risk discrediting the whole idea of free-ranging air survey.

Choose your study area with care. Do not make it too big in the first instance – it can always be expanded later. On the other hand you may decide to 'scan' a large area first and then select a smaller area for intensive study.

Think about the area's location in relation to the journey time from home or workplace to the airfield, or from airfield to the study area. There is obvious economy in using an airfield close to the study area. Travelling time on the ground is less wasteful – and less expensive – than long transits in the air to a distant target area.

Choose objectives that are realistic in relation to the topography, geology, soils, climate and land use of your study area – or choose a target area where these factors allow you to address the problems which you wish to explore.

Do not necessarily try to replicate the kind of aerial archaeology that you have seen elsewhere – you must be true to your own area. If you do not have light soils, permeable geology and a reasonable amount of arable cultivation you will be unwise to focus on cropmark survey. You may, on the other hand, have opportunities for upland exploration or for searching out **earthworks** in permanent pasture. You may have a mixture of soils and topographies. React to what is actually available to you.

Do not be overly ambitious. In your early flights new experiences and new demands will crowd in on you from all sides. You can only absorb a certain amount at a time. Do not rush things, take time to think about what you have done and to study the results, not least the effectiveness of your photography.

Be realistic about the post-flight commitment – in Britain it has been estimated that every hour in the air requires a full day on the ground for pre-flight planning and immediate post-flight tasks – without even *beginning* to think about photo processing, **mapping**, academic assessment and publication.

Recognise from the outset that if you do not give these post-flight activities the time and resources that they demand you will communicate little of value to your fellow archaeologists, other than a pile of photographs and paper records which nobody can realistically utilise.

Enlist the support of fellow archaeologists and record keepers. Find out how you can draw on their advice and how you can offer them photographs, information and ideas in return.

Form a small 'steering committee' to advise on the project but make sure that you (and perhaps a few close colleagues) retain executive control – there is nothing worse than a swiftly moving project *managed* by a committee, rather than *advised* by it.

Try to look at least three years ahead. Set realistic objectives and targets and review them at six-monthly or yearly intervals. But also be prepared to react to experience and results as they come in.

Engage the interest of others in the project, and in the concept of free-ranging archaeological air survey. Write progress reports for academic and general interest publications. Give lectures to archaeological colleagues and to the general public.

Make sure that you have the pictures that will allow you to do this effectively – general views of landscapes and townscapes, of aircraft and cameras, maps and computers, and of the processed results of your survey work.

If you can do all of these things you will in time bring to your area data and ideas which will enormously enrich the understanding, appreciation and conservation of your country's material past.

4. THE TOOLS OF THE TRADE

Introductory Note

Some of this chapter is out of date now that digital cameras have attained a quality that fully satisfies the needs of aerial photography. 'Traditional' cameras and films are now rarely used during aerial survey but many of the general lessons from earlier times still apply in the digital age. For this reason the text is retained more or less in its original form, comments on the advantages and remaining problems of digital photography being discussed more fully in Appendix A. Additional advice on camera equipment and the handling of digital data can be found in Appendix B.

The archaeologist

The right archaeologist for aerial survey is one who understands its potential but is realistic about its limitations, seeing it as only one of several techniques that can be used in the search for a more rounded archaeology. He (or she, of course) should want to fly because he sees the long term gains for archaeology, not just for the excitement of the chase. He should be confident in the air, though practice can bring confidence even to those who have an initial fear of flying. He should be a careful planner who can also cope with tedious post-flight procedures. He should have intuition and a sense of enquiry but also patience and determination. Specific pieces of advice are as follows.

Fig 4. 1 Flying maps

The archaeologist's flying maps are a precious part of his equipment, marked up with target areas, notes from previous years and routes both planned and completed. The extract shown here, from one of the author's well-used 1:50.000 maps of the Welsh Borderland, is marked in red for known sites, yellow for legally protected site, blue for cropmarks and soilmarks, pink for industrial targets and green for country houses and gardens.

The inset at top left, of an area of chalk downland in northern England, shows the cropmark evidence from previous years of flying by English Heritage, for comparison with the current season's marks so as to identify new discoveries.

Read everything that you can about aerial archaeology. Make contact if you can with people, in your own country or elsewhere, who have experience of aerial survey and air photography. Join the Aerial Archaeology Research Group (AARG) so that you can correspond with people throughout Europe who share your interests in aerial survey and air photography.

Study the specialist maps for your area – topography, geology, soils, climate and land use. Try to work out what they might tell you about the aerial potential of your area. Try to understand which parts, if any, are likely to produce **cropmarks** or **soilmark**s, or where there might be well preserved **earthworks** evidence.

Familiarise yourself with the different topographical and land use zones on the ground, travelling around them if you can. Then do the same from the air (for the surrounding areas too) as an early part of your flying programme. Photograph typical **landscape**s and make notes on them when you land. 'Terrain study' is a *sine qua non* of effective aerial survey and **air photo interpretation**.

Learn all that you can about photo interpretation and **mapping**, so that you are familiar with these too. At the very least this will help you to become a better air photographer.

The pilot

Without a pilot, or pilots, you can achieve nothing. The pilot is your means of getting where you want to go, safely and in good time, and then getting back home again. But he (or she, again) is not just your chauffeur, he is also your second set of eyes in the air – some pilots, of course, have become **aerial archaeologist**s in their own right. The pilot's interest and commitment must be enlisted if you are to coordinate your own and other flight bookings when the weather is right and you need an aircraft and pilot to be available.

Your pilot should be experienced, with several *hundred* hours of aerial experience if possible. He should be calm, not a buccaneer – if you feel the least unsafe with him, you should fly with someone else. If he is not already interested in archaeology, try to foster his interest – show him what you want to do, why and where you want to do it and what you are looking for. This is the most crucial partnership in the project team – if lose your pilot once you have become a real team you will bitterly regret the loss.

The aeroclub or aircraft contractor

In general you will have to hire your aircraft and pilot either from an aero club or from a commercial operator. As with your pilot, you should try to engage the interest of the aircraft contractor or the president and members of the aero club. Explain to them the potential of archaeological air survey. For them, as for the pilot, it will be something novel to engage their interest when they are in the air. Talk to them about insurance and any aspects of aviation law (or any aspect of your national law) that you or they think may be relevant to your activities.

In Britain, for instance, all air photographic flights of the kind for archaeology are deemed to be commercial flights taking place under Public Transport Rules; so the aircraft must have an up-to-date Certificate of Airworthiness (which involves mechanical and other checks after every 50 hours of flight), the aircraft contractor or flying club must hold an Air Operator's Certificate (which entails stringent testing of maintenance, safety and other procedures), the aircraft operator, passengers and third parties must be covered by up-to-date insurance policies, the flights must be undertaken under Visual Flight Rules (VFR) with take-off and landing only at properly licensed airfields, the pilot must hold a valid Commercial Pilot's License – and so on.

It is your responsibility, or that of your employer, to check that all of these arrangements are in place. You should, for instance, ask to see the insurance documents and maintenance logs for the aircraft, which (as noted above) should fly no more than 50 hours before a standard maintenance check. If there is any reluctance to show you **any** of the documentation, you should arrange to fly elsewhere. When discussing the kind of flights you want to make, you should of course explain that you need good visibility and relatively calm air for the kind of survey and photography that want to undertake – you will need forbearance at a later stage when you have to cancel flights because the weather is not what you had hoped for or expected.

The aircraft

Most archaeological air survey is done from single-engined light aircraft, providing either two seats (for pilot and archaeologist/photographer) or four seats (for pilot, archaeologist and one or two others). When the archaeologist is also photographer he usually sits in the front seat alongside the pilot. When there is a separate photographer, as has been the case for a fair amount of state funded survey in Britain, he may work from the rear seat behind the archaeologist, who sits alongside the pilot and directs the operation.

The aircraft itself may be of the low-wing or the high-wing type. High-wing aircraft, such as the venerable Cessna series, give a

Fig 4. 2 **Airfields, aero clubs and aircraft**

An aerial archaeologist using hired aircraft must seek a close and supportive relationship with an aero club or commercial aircraft operator, at an airfield as close as possible to the intended survey area. Both high-wing and low-wing aircraft can be used, though high-wing types like that at extreme left provide a less obstructed view of the landscape. Small helicopters – far more expensive to hire than fixed-wing aircraft – can be used in circumstances such as winter days when normal runways are blocked by ice or snow.

more or less unobstructed side-view of the **landscape**, save for the diagonal wing strut which is common to most of high-wing craft (Fig 4.2, bottom, far left). Low-wing aircraft such as the Rallye Sport (Fig 4.2, bottom centre) are less easy to use because the wing obstructs a large part of the lateral view during level flight. In both types the land immediately below the aircraft is hidden from view, except when you bank the aircraft to make a turn or to describe a circuit around a **target** that you have spotted. In almost all aircraft the engine cowling obstructs the forward view on the line of flight. It is better to work from a high-wing aircraft if at all possible, but a low-wing aircraft (with certain limitations) can be perfectly serviceable if you have no choice in the matter – better low-wing than no wing.

Equally important, especially for the quality of the photography, is the presence of an opening window. Most but not all high-wing aircraft have one on the right-hand (passenger) side which can be opened to allow photography unimpeded by the perspex of the canopy (Fig 5.1, bottom). Sometimes there are windows on both sides, in other cases only on the left side alongside the pilot. In many instances the opening window has a diagonal 'stay' which restricts opening to a limited gap at the bottom. With permission, however, this can usually be removed and taped against the window frame so that the window can open fully against the underside of the wing (the stay, of course, must be replaced at the end of the flight).

Many low-wing aircraft have perspex canopies which slide backward to provide access for the pilot and passengers. These can be partially opened in level flight but not in the tight turns that are necessary to keep the low wing clear of the photographer's line of sight. In such aircraft there is little option but to photograph *through* the perspex. This complicates the photography, and reduces its quality to a certain extent, though there are ways of overcoming most of the problems (Chapter 5 and Figs 5.1, 5.8). Some aircraft have small rotating or sliding openings in the perspex of the canopy, only 15cm or so across. These require very skilful teamwork by the pilot and photographer to keep the subject in view long enough for the photographs to be taken. In such cases it may be better to learn how to take photographs *through* the canopy.

Survey can also be done quite effectively from ultralight aircraft, which have a fabric skin over a light metal or wooden frame. There are obvious limitations, however, in the cold of winter. Microlights, with an open or partly open cockpit and the engine and propeller behind the crew, can also be used, though they provide little or no storage space for maps and supplementary equipment and none at all from the slipstream, making the handling of cameras, lenses, films and maps more difficult (if not impossible in winter conditions).

Small helicopters like the one illustrated at bottom right in Fig 4.2, can also be used though they are less commonly available and cost at least twice as much per hour to hire. They have a shorter flight endurance (usually about two hours compared with three or three-and-a-half hours for a typical fixed-wing aircraft). Helicopters of this kind have wrap-around perspex canopies which give a virtually unobstructed view of the landscape. In most models the side-doors can be removed to give an unrivalled view for photography, though frustratingly not in the cold of winter when the helicopter's vertical take-off may provide the only means of getting into the air from otherwise snowed-in or ice-bound airfields. If traditional aircraft **can** take off under such conditions it is often better to take the photographs through the perspex, so long as precautions are taken to reduce the risk of flare (Chapter 5). Operating in this way at least prevents the abandonment of the flight because the photographer's hands or camera equipment have become frozen.

Cameras and lenses

See Appendix B for comments on digital cameras and zoom lenses etc. The following notes are addressed at traditional film-based photography which is little used nowadays but which nevertheless relied on some basic principles that still hold true in the digital age.

The handheld 35mm or medium-format (6x6 or 645) cameras used in free-ranging aerial survey must be sturdy, reliable and of good quality. Both types, with some of their matching lenses, are shown in Fig 4.4. Poor-quality cameras, or cameras without the facilities mentioned below, are a false economy for aerial work. The exposure metering should be automatic and the lenses of high quality, with as large a maximum aperture (f-stop) as the buyer can afford – preferably f1.4 or better for the standard lens of a 35mm camera and f2.8 for a medium-format camera. This allows more light to reach the film emulsion – a big advantage when operating in poor light during winter or late-evening flights.

The autofocus facility now available on medium-format as well as 35mm cameras is of no particular value in aerial work, where almost all subjects are far enough away to be photographed at 'infinity' setting. There is an exception with very long-focus lenses, of 200mm or more when mounted on a 35mm camera; these may need some focus adjustment, either manual or automatic, when photographing at full aperture. Autofocus can in fact create its own problems when photographing *through* the perspex or from low-wing aircraft because the camera will occasionally focus on the perspex or upon another part of the aircraft rather than on the scene below. Before the advent of digital cameras and high-quality zoom lenses it was often the practice in Britain to disable the autofocus facility and work in manual mode, taping the lens at infinity setting with insulating tape.

An essential requirement for effective aerial photography is a fast shutter speed so as to reduce the risk of camera movement during exposure (producing so-called *camera-shake*), a common cause of blurred images in aerial photography. The effect of camera-shake can be particularly severe with long-focus lenses because of their narrow field of view. Some expensive modern lenses and cameras have mechanisms that compensate for camera movement and greatly reduce the risk of blurred images, even with long-focus lenses. The camera should have 'shutter-priority' as one of its metering modes, allowing the shutter speed to be set at 1/500 or 1/1000 second, the camera then automatically adjusting the lens aperture (f-stop) to give consistent exposure. Many 35mm cameras now make use of plastic rather than metal so as to reduce the overall weight. This is not necessarily an advantage in aerial work since weight helps to dampen vibration and reduce the risk of camera-shake.

For aerial work with 35mm cameras, suitable interchangeable ('prime') lenses are 28 mm or 35mm focal length for wide-angle views, 50mm for general photography, and 100mm or thereabouts for narrow-angle shots (the medium format equivalents are 45-55mm, 75-80mm and 150mm). On 35mm cameras a focal length of about 85mm can also be useful for general photography when flying at a height of 600-750 metres during the rapid scanning of a **target** area. Lenses of greater focal length than 100 or 135mm, being physically longer, are more prone to camera-shake but can have their own particular uses in the air, especially when photographing urban scenes with a great deal of relevant detail. This range of lenses allows the photographer to, in effect, move closer to or farther away from the subject without incurring the time and cost of changing flying height.

The rapid changing of fixed-focal length lenses takes time to learn and it may be more practical in the first season of flying to use a good quality zoom lens (though medium format zooms are bulky, expensive and prone to camera-shake). The emphasis here is on quality since zoom lenses exchange some of the sharpness and contrast of prime lenses for the capacity to vary their focal length. Typical small-format zooms for aerial work are 28-85mm and 35-100mm or more. Zoom lenses are bulkier and for the most part have significantly smaller maximum apertures than lenses of fixed focal length, allowing less light to reach the film and thus performing less well in poor light. Again it is sound policy to seek the largest maximum aperture within the resources available. In terms of physical dimensions a zoom lens for aerial work should be as short as possible when focussed at infinity and should not lengthen significantly when the focal length is varied – the longer the lens, physically, the greater the risk of camera-shake.

Lenses should be protected from damage, and enhanced in their penetration of atmospheric haze, by the use of a UV (ultra-violet) or 'skylight' filter (1A or 1B). For normal black-and-white photography of **cropmarks** in summer these should be replaced by a 2x yellow filter to accentuate the tonal contrast between the cropmarks and the background vegetation. A 4x orange filter is even better, though it reduces the amount of light reaching the lens and may therefore cause problems when photographing in poor light. A few very experienced air photographers sometimes use circular polarising filters, which significantly improve the contrast of the images. To obtain their effect, however, they have to be rotated on the lens barrel until light of only one polarity passes through the filter, a technique which requires a fair degree of mastering.

Lenses can – or in the view of the present writer, should – also be fitted with lens hoods to mask off unwanted light and reduce the risk of 'flares' when photographing into the sun. This applies especially in low-wing aircraft, which tend to reflect unwanted light into the lens off the wing (whereas high-wing aircraft provide useful shade in the same circumstances). Lens-hoods should be of metal or plastic rather than rubber, which can too easily distort and partially block the lens. They should also be properly matched to the focal length of the lens – too long a hood will risk masking off the corners of the picture.

Many air photographers use only 35mm 'film' cameras, which produce negatives or colour transparencies measuring 36 x 24 mm. In Britain, however, much of the black-and-white photography (the ultimate 'archival' record) is taken on medium format cameras, giving notional image sizes of 60 x 60 mm or 60 x 45 mm (a little less in practice). The square and rectangular picture shapes each have their devotees. There is in practice little to choose between them except that the 645 format gives 15 or 16 shots on a normal-length (120) roll of film compared with 12 shots for the 6x6 format (the numbers are doubled with the longer 220 film, though this is available in fewer types of film). Medium format cameras, at least when using 120 film, thus require more frequent film changes than 35mm cameras, which give 36-38 frames per film. In practice the use of pre-loaded inserts or cassettes allows films to be changed even more quickly in medium format than in their 35mm counterparts.

The prime advantage of medium format cameras is the larger size of the image, so that a smaller proportional enlargement is needed to produce the same size of print. But the quality of 35mm lenses and of modern films means that there is otherwise little to choose between them, save perhaps that medium format negatives are less susceptible to degradation as a result of scratching or other forms of physical damage. There is therefore less impact on the resulting prints if the negatives are in any way mishandled during processing or darkroom work.

Fig 4. 3 Relative sizes of film types and digital sensors (below)

An enlargement from a medium-format 645 negative involves a magnification of about half that required for a 35mm negative. Digital sensors come in various sizes, in most cases considerably smaller than a 35mm negative.

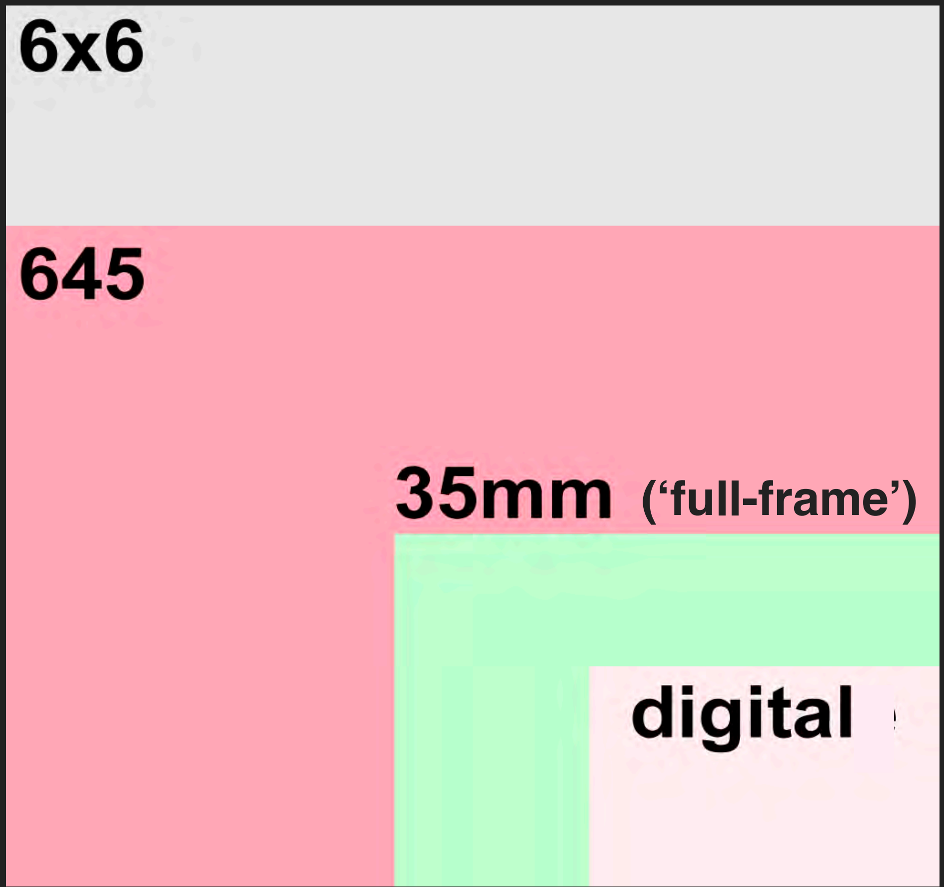


Fig 4. 4 The author's camera kit (in 2005)

In addition to the padded carrying case there are matching pairs of 35mm and medium-format cameras and a range of interchangeable lenses, lens hoods, filters and spare camera batteries. Also shown are supplies of spare film, cleaning brushes and tissues, a GPS unit for navigation and flight recording, a headset in case one is not supplied with the aircraft, and a knee-pad for making notes during flight. Still in the bag are soft pencils, erasers, marker pens and various other accessories, including re-sealable sick bags for passengers who may not be used to flying in light aircraft.

The air photographer's camera kit

It is unwise to take to the air with less than two cameras, one for black-and-white recording, the other for colour (or in the case of digital photography one equipped with a short and the other with a long zoom lens, as described in Appendix B). This provides back-up in case one of the cameras fails, though in the case of film-based photography this mens that either the colour or black-and-white recording then has to be sacrificed for the rest of the flight. Taking every subject in both monochrome and colour (or with both digital cameras) will ensure that a record will survive even if one of the cameras fails without showing that it has done so, as occasionally happens.

The cameras and related equipment used for aerial work should ideally be kept together as a single 'kit' (Fig 4.4), used only for this purpose and meticulously cleaned and checked after each flight so that they are ready at a moment's notice when next needed. The kit should contain an ample supply of spare batteries (which should be kept warm when you are flying in cold weather). There should also be impregnated tissues or cloths and a blower-brush for cleaning lenses and camera bodies. For traditional black-and-white photography both UV/Skylight and yellow or orange filters should be carried when cropmarks seem even remotely possible. There should also be soft pencils, a knife or pencil sharpener, a soft rubber/eraser and spirit-based marker pens for use on film cassettes etc. Seal-top sick-bags should also be carried, along with anti-sickness sweets or chewing gum. And of course there must be readily available supplies of films or memory cards.

Digital cameras and their implications

The advantages of digital photography, and some of the remaining difficulties, are discussed in Appendix A. Digital cameras and digital data are dealt with in Appendix B.

The over-riding advantage of digital photography is that the images can be transferred directly to a digital environment, where they can be subjected, without the tedious scanning of prints or negatives, to all of the manipulations that are available through modern image enhancement software. Contrast, brightness, sharpness and colour balance can be adjusted to reveal extra information without in any way infringing the integrity of the original data (traditional negatives and prints can be scanned to give the same facility but at the cost of considerable extra work). There are, of course, remaining problems, especially in the need to keep abreast of advancing technology so that images committed to a particular recording medium today are still readable in fifty years' time. But these problems are not any greater than those involved in the long-term archiving of traditional photographic images.

The use of prints as a major means of storing and communicating aerial images may continue for a long time yet, especially in existing archives with large numbers of traditional prints. But as digitisation programmes in the major archives make it possible to see a future in which the images are only made available, in the first instance, via the computer screen. This may, indeed, be a more effective and economical way of retrieving suitable images from an archive, with hard-copy prints or digital files only being provided to the user once the final choice of images has been made.

The archaeologist or institution just embarking on a programme of aerial survey will naturally take the digital path, though this was not so clear when the original text was being written in 2004. At that time the authors were themselves divided on the issue, so strong was the feeling of security with traditional methods but so seductive the possibilities of the new.

For more up-to-date comments on digital photography, digital camera equipment and the handling and storage of digital data see Appendixes A and B at the end of this book.

Film types and their uses

Tenses have been changed in this section but the text otherwise remains essentially unchanged. It will hopefully act as useful background information for those work will bring them into contact with negatives and transparencies etc in 'traditional' archives. For comments on digital memory cards and related matters see Appendix B.

Four main types of film were used in the past, and occasionally are still used today, in archaeological air survey: black-and-white, colour reversal, colour negative, and false-colour infra-red.

Black-and-white

Black-and white (panchromatic) films, using traditional silver-based technology, were estimated to have an archival life, when properly processed and stored, of at least a hundred years. In Britain, therefore, black-and-white photographs (or more correctly their *negatives*) were seen as the ultimate archival record, colour films having a less secure life span. Black-and-white prints were (and are) treated as working documents, re-printable if need be unless the negative has been lost or destroyed (in which case the print becomes the 'archive' item).

Panchromatic films were sensitive to a slightly different range of the spectrum than the human eye, giving a different tonal rendering of certain colours – green and red could appear quite similar, for instance, so that a green cropmark in scarlet poppies might be poorly represented in a panchromatic image (another reason for recording in colour as well as black-and-white). Black-and-white films for aerial photography needed to have good contrast and fine or ultra-fine grain, especially for 35mm work. With medium-format negatives, where the scale of enlargement was likely to be smaller, there was less need for ultra-fine grain (the same of course applied with colour films). To cope with poor light at the end of the day the archaeologist was advised always carry an ample supply of both standard and high-speed films (80-100 ISO and 400 ISO, for instance).

Colour reversal

Colour reversal films were used to produce 35mm colour slides and medium-format transparencies without the intermediary of a negative. The slides or transparencies were themselves the 'archive' item and required processing and storage to to a high standard if they were to achieve the promised life of thirty to fifty years before suffering significant deterioration of the image. Prints could, however, be provided by many laboratories as part of standard processing packages, though archival-quality printing paper had to be specified (at considerable extra cost) if the prints needed to have a long life in a photo-library.

Duplicate slides could and still can, of course, be made for lecturing purposes either digitally or by traditional methods, with some slight loss of quality, but a cheaper and better solution was to expose two slides in the air, keeping one for the archive and the other for lecturing purposes. Some makes of film were said to be more tolerant of projection, others more stable in the longer term. The colour rendering varied significantly from one brand of film to another. It remained an matter of personal opinion, however, which was deemed the most suitable for aerial work. Colour reversal films had a relatively narrow exposure latitude, over-exposed or under-exposed frames often being too pale or too dark for projection or for high-quality publication work. As with black-and-white film the prudent **aerial archaeologist** always carried ample supplies in speed ratings of 50-100 ISO (for normal light), 200 ISO (for poorer light) and 400 ISO (for very poor light).

Colour negative

Colour negative film was used for making colour prints, the negative being treated as the archive item and the prints as working documents. The archival stability was considered by many to be better than that of colour reversal films. Colour negative film was also more tolerant of over- or under-exposure. Acceptable colour slides for lecturing purposes could, and still can, can be made from either negatives or prints. With the appropriate scanning equipment both colour negative and colour reversal films were considered equally suitable for publication work. Colour negative film came in fine-grain versions at 100 and 200 ISO and in slightly coarser grain at 400 ISO.

False-colour infra-red

False-colour infra-red film is no longer (in 2012) obtainable in any format that is likely to be used for archaeological air photography. In the past it was sometimes used in aerial work, employing a medium yellow filter on the lens to create the colour effect (Figs 6.2, 10.55 and 10.62, top). Its sensitivity extended some way into the infra-red range, invisible to the human eye, but not so far as to register temperature differences which might (theoretically) reveal such things as stone **feature**s half hidden in vegetation. The main use was to provide striking images for lecturing or publication purposes. However, by changing the expected colouring of everyday objects such as trees, rivers and roads false-colour infra-red seemed (and still seems) to focus the eye and mind on the **pattern***s* represented in the picture, rather than the everyday objects themselves. In this sense it may helped, at least sub-consciously, in the reading of cropmarks or similar **feature**s, though the same marks were almost always present and readable in traditional colour shots of the same scene. The film's extreme sensitivity to over- or under-exposure made it difficult and potentially wasteful to use in the air, and both film and processing were expensive. (Similarly dramatic colour effects can now be achieved by the manipulation of digital images, as in Fig 10.61, bottom, for instance.)

Headset (ear-phones)

The aerial surveyor will preferably carry his own headset (ear-phones). Headsets come in various costs and qualities. Their relative merits, and compatibility with the aircraft to be used, should be discussed with pilots, aircraft contractors and the suppliers of aviation equipment. In addition to providing protection against engine noise and sudden changes of air pressure when the window is opened they allow easy communication with the pilot (and perhaps with other passengers if the aircraft is fitted with four-way intercom). They also enable the archaeologist to listen to the pilot's conversations with ground control and to discuss any resulting implications for the rest of the flight. Wherever possible extra passengers should also use headsets even if they cannot be connected to the aircraft's intercom system.

Maps

Properly marked up maps are an essential part of the aerial surveyor's tool kit (Fig 4.1). For general navigation the pilot uses aeronautical charts which show major landscape features at a scale of 1:500,000 along with information about controlled or prohibited air space (around military bases, training areas and civilian airports, and along airline routes etc). The archaeologist needs a larger-scale colour coded map showing features that can be readily identified in the **landscape** below – topography, roads, railways, rivers and streams, lakes and reservoirs, forests and other wooded areas, buildings and urban areas. In Britain there are excellent 1:50,000 maps of this kind, overprinted with the the kilometre squares of the national grid, making them ideal for aerial work. Other countries, including Italy, have maps at a similar scale but with colouring that is less distinctive and therefore less easily 'read' in the air. Denmark has maps that are very similar to British maps but at a scale of 1:100,000. The situation will vary from country to country and archaeologists must find the best solution for their own particular context. Maps at a scale of 1:25,000 or thereabouts can be useful on occasions, especially for detailed survey in target areas of limited extent; for general survey work, however, the flight path can often very quickly 'run off the edge of the map'.

Before flying begins the maps for the whole of the study area should be marked up with all of the known archaeological **site**s that are likely to be visible from the air. This can be a tedious task but it quickly repays the effort in making the archaeologist aware of potential targets wherever he may be within the study area. Maps of this kind can in some organisations be printed from digital files of 'potentially aerially visible sites' extracted from the local archaeological record and printed against a 1:50,000 digital base-map. Needless to say, all new discoveries should be marked on the maps in their turn, as should priority target or areas chosen for photography in future flights. Two examples of marked-up flying maps from Britain are shown in Fig 4.1. The maps for the whole of the study area should be carried on every flight in case the expected route has to be changed at the last minute.

Global Positioning System (GPS)

A near-essential aid now carried by almost every aerial surveyor is a GPS unit, which receives signals from an array of orbiting satellites and indicates the present position of the unit to an accuracy of 50 metres or less against latitude and longitude or a variety of national grids (the accuracy may be less, or the signal absent, near military stations, which have the capacity to degrade or block the satellite signals in their vicinity). GPS units also offer a range of other facilities that assist route-finding and flight timing, sometimes with on-screen moving maps.

The archaeologist's GPS unit has two main uses. One is the recording of a continuous flight 'track' (perhaps at 20-second or 200 m intervals). The track can later be downloaded and displayed on-screen against the map base to show which parts of the study area have been visited in the air (Fig 4.5). Cumulative flight tracks also aid future planning by showing which areas have not yet been visited, or perhaps not visited sufficiently often.

The second use of the GPS unit is to record the location of photo-points or **sites** in the manner described at the end of the next chapter. The archaeologist's GPS unit does not have to be particularly sophisticated but the capacity to carry out these two procedures is essential, with 2000 or more track-points (enough for 10 hours or more of flying) and 500 site or photo locations (waypoints). Information on suitable GPS units, at a wide range of prices, can be obtained from suppliers of aviation equipment. Ideally, two GPS units should be carried, and set to record the flight track at the beginning of each sortie. If one fails the other will still preserve essential information about the flight.

Fig 4. 5 GPS unit and flight tracks

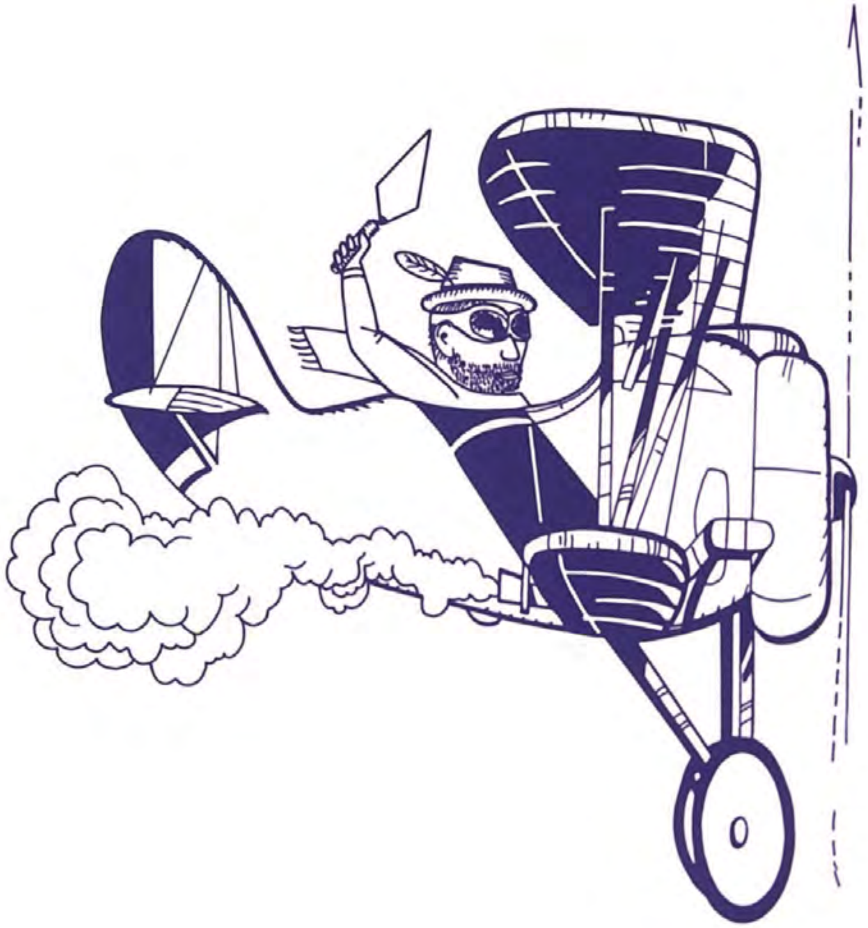
Most aerial archaeologists now carry a GPS unit which stores an automatic reading of the aircraft's position at perhaps twenty-second intervals, along with (in some cases) numbered waypoints for the positions of sites – or rather, the points from which photographs were taken. The underlying maps in this picture show past flight paths for selected years of work over Wales.

The value of experience, and checking on the ground

An essential part of the **aerial archaeologist**'s preparation for work in the air is a secure understanding of the way in which archaeological evidence makes itself visible on the ground and the kinds of agricultural or other activities that help to create the marks seen from the air. When confronted by an uncertain interpretation (for example whether marks represent the walls of a recently demolished farm building or those of a Roman villa) the only way to understand the **aerial information** fully is to check it on the ground (Fig 4.6, left) or even to test it by excavation, as suggested in relation to the two **enclosures** represented by overlapping cropmarks in Fig 2.22.

Fig 4. 6 **'The flying trowel' and observation on the ground**

Below. The 'aerial archaeologist' is an archaeologist like any other, but one who takes his experience and academic insights into the air. The wider his background knowledge, the more perceptive will be his appreciation of the landscape that he sees from above, and of the features within it that might be worth recording.
Right. Aerial understanding will be improved by examining sites on the ground, studying their topography or trying to discover exactly what is producing the marks seen from the air. In this case students at a training school in Italy are checking the site of a cropmark complex recorded earlier in the day during their own exploratory flights.



5. AERIAL SURVEY IN PRACTICE

Getting into the air – and safely down again

Flying, and airfields, can be dangerous. You must not place yourself or others in danger. Before your first flight ask your prospective pilot or a member of the aero club to show you round the airfield and explain the functions of the people, facilities and signs that you see there. Talk to him about safety in the air. He will tell you some elementary rules that you should follow to the letter.

On the ground

- Report at the office when you arrive at the airport so that your presence and purpose is known.
- Always check in with your pilot before you go to the aircraft. On the first few occasions approach the aircraft only in the pilot's company.
- Once you are on the airfield it is good practice to wear a brightly coloured visibility jacket over your normal clothing
- If your pilot tells you to do something, do it. Instantly.
- Look for and respect all warning signs, including those painted on the ground.
- Never walk onto a runway or aircraft taxi-way. Be very careful on all hard-standing areas.
- Never approach an aircraft that is in motion or has its propeller turning.

- Always walk behind parked (or apparently parked) aircraft, not in front of them.
- Never smoke or use a mobile telephone near an aircraft or anywhere near the fuel pumps.
- Offer to help the pilot if the aircraft needs to be moved by hand, but follow his example or ask him which parts of the aircraft you are allowed to touch.
- Never touch any of the moving parts of the wing or tailplane.
- Beware of the rear edge of the wing in high-wing aircraft. It is sharp, malicious and (for most people) at about head height.

Before you fly

- Remember that your main purpose is to photograph archaeological **sites** and you can only do this effectively when you have good visibility and reasonably calm air.
- With your pilot, always make a final check on the weather reports in the office before you fly. Also check any advisory notes or warnings on the notice board.
- Do not fly if there is any risk of bad weather, either in your **target** area or at the airfield before your expected return.
- Develop a network of ground-based contacts around your survey area so that you can check by telephone on local weather conditions, visibility or cloud cover.
- Do not be afraid to cancel or abandon a flight – unfavourable conditions may place you at risk but will *certainly* waste precious flying time.
- Never drink alcohol before a flight or take pills that might cause drowsiness. They may endanger you during the flight or when you drive away afterwards.
- If you are planning to fly over any large body of water, or even over the inter-tidal zone, take a life jacket and be sure to put it on before you enter the aircraft.
- Ensure that you have re-sealable sick bags in the aircraft, and bottled water. In a busy period of aerial activity, with several flights in succession, it is all too easy to become dehydrated and this can produce long-term health problems.

Getting on board

- Do not step on any part of the aircraft that should not be stepped upon. Check this with your pilot the first time you use the aircraft.
- Check that your window opens and remove the stay if necessary as described in the notes on aircraft in Chapter 4.
- Store your GPS, maps and pencils etc in secure positions where they will be available to you during flight but cannot escape and obstruct the aircraft's foot-controls.
- If you want to have spare cameras, lenses or films on the floor in front of you, place them in a bag that is wedged

behind your feet and that can be securely closed during take-off and landing.

- Once aboard, fasten and adjust your seatbelt and check that the door is closed and locked. The pilot will help with this if need be (doors can be difficult and some seatbelts can be confusing).
- Before take-off put on your headset (ear-phones), connect the leads to the sockets on the dashboard or elsewhere in the aircraft and check two-way communication with the pilot.

During flight

- The pilot is in command at all times. Do not try to make him do anything that he does not want to do. He probably has good reason.
- Do not try to over-ride any advice or instructions from ground control.
- Listen to the pilot's communications with ground control. Do not interrupt or distract him while he is in contact with the ground. Make sure that you are familiar with your own aircraft's call sign – this will help you to understand what is being communicated
- Do not distract your pilot during take-off, landing or approach to landing. Just sit quietly, hold onto your cameras and let him get on with his job.
- Keep cameras on their neck straps at all time, even when changing films, batteries or memory cards.
- If you do drop any equipment during flight tell your pilot immediately so that you can make sure it does not obstruct the aircraft's controls.
- Check with the pilot before you open the window, so that he can reduce speed if necessary (a safe and suitable speed for photography is 80-90 knots or less).
- When you open the window hold it carefully and let it move gently up against the wing. The slipstream will hold it there.
- When you close the window, secure the catch properly before you let go of it.
- Do not wear a wristwatch or bracelet that might blow away and damage the aircraft when you put your hand out of the window.
- Keep spectacles on a neck strap or securely wedged beneath your headset.
- Keep the window closed when handling any loose equipment and when changing lenses, films, memory cards or batteries.
- Store the map that you are using so that it cannot blow about the cockpit or get sucked out of the aircraft when you open the window.

- If you begin to feel sick, tell the pilot and chew one of the anti-sickness sweets that you should be carrying. Have seal-top sick bags available (and seal them after use!).
- If you do have to be sick, remember to move the headset microphone out of the way first.
- Never continue a flight if you feel you have ‘lost control’ through sickness, heat, cold or uncertainty. To do so will just waste valuable flying time.

On landing

- Wait until the aircraft is stationary and the engine switched off before you remove your headset, release your seatbelt or unlock the door.
- Do not leave the aircraft in a hurry. Check your footing and step only where you are supposed to step. In high-wing aircraft beware of the rear edge of the wing.
- Flights can be stressful. Never drive away from the airfield in a hurry. Relax in some other way until you can give your full attention to the journey home.

Getting started: first flights and basic aerial manoeuvres

If at all possible you should get basic experience by flying first with someone who is already doing aerial survey, or try to take part in one of the aerial archaeology training schools that have become part of the European scene in the past decade or so. If this is not possible you will have to learn 'on the job' – as will your pilot for *this* kind of flying.

Either way, you should start modestly. A common saying among aerial surveyors is that when you first take to the air you will carry only half of your brain with you. If you stay up too long, or try to learn too many things too quickly, you will risk making mistakes and will not be able to absorb and analyse all of the new experiences that crowd in on you. This applies both to the first flight and to the first 'season' of aerial work. Treat this very much as a learning experience, examining everything you do and being self-critical about your performance in the air and about the quality of the photographs that you take.

Immediately after each flight complete a Flight Report form as described later in this chapter, if you have not already done so during the flight. If you are using film-cameras, take or send the photographs for processing. If possible, talk to the laboratory staff about the kind of work you are doing and the standard of processing that you need. When the processed films are returned, do the basic cataloguing and photo-filing without delay, while the flight is still fresh in your mind. This will make you understand from the outset how much time and attention these processes demand. Follow similar disciplines if working with digital photographic equipment, downloading and backing-up the collected images as soon as you can after the flight. If you are starting on your own, a first flight of forty-five minutes or an hour will be ample, getting used to the sounds and sensations of flight and observing the **landscape** below. For this flight leave your cameras and maps on the ground. Ask the pilot to fly gently but to show you the standard manoeuvres of level flight, wide turns, climbs and descents. Get him to fly at heights of 150, 300 and 600 m (about 500, 1000 and 2000 ft) so that you can see the difference in the length of your view and the speed with which the landscape 'moves' beneath you. Ask him to make a gentle circuit round a village or archaeological **site** that you know well on the ground and watch how the light and shadows change as your position moves in relation to the sun. With the pilot's permission, open the window so that you can feel the force of the slipstream when you put your hand (or any other part of you) 'outside' the aircraft. Compare the clarity of the view as you circle the site with the window open and then with it *closed*. Notice the halation caused by the perspex when you are looking directly into the sun.

Fig 5. 1 Practical aspects of aerial photography

a) Discussing routes and targets with the pilot before a flight.
b) Preparing to board the aircraft.
c) Black clothing worn to reduce reflections from the plastic canopy when using an aircraft without an opening window (but don't put this gear on until you have passed through airport security!).
d) Studying flying maps in flight.
e) Photographing from inside the aircraft through the open window.
f) The open window on the photographer's side, with the wing-strut which has to be kept out of the picture when taking photographs.

On later flights, taking your maps and camera(s) with you and gradually increase the flying time as you get used to the new environment, concentrating first on the variations in the **landscape** below. Make a tour of areas which have different geology, soils or land use (you should already be studying these through maps and written sources). Take a few photographs of typical landscapes, and continue this throughout your flying career.

From your second or third flight onwards make a practice of following your route on the map by comparing distinctive features in the landscape with what you see on the map – a lake or reservoir, the curve of a river, a railway line or major road junction for instance (Fig 5.2). But in essence ask your pilot to do most of the navigation at this stage. As you become more adept at map reading you will gradually be able to take over the control of the route. Remember, though, that your pilot is always in ultimate command, especially when deciding where *not* to go and when it is time to return to base.

When you first start taking photographs, do so sparingly, using a single camera and a 'standard' (50mm) lens or a short zoom lens. Make sure, by practicing beforehand, that you are thoroughly familiar with the camera's functions and controls, especially with the changing of films, memory cards or batteries. A good camera for air photography is a camera that you *know* well before you ever step into the aircraft. On your first few photographic missions (unless you are already an experienced photo-grapher) try to restrict yourself to a limited number of shots or a single film – it is too easy to make a mistake when changing films after you have been concentrating hard on other things.

Do not try to start exploratory work right away. Learning essential skills is best done by visiting and photographing known sites. Your first real photographic sortie should be to a representative selection of sites – perhaps a castle, a group of buildings, a village and a well preserved earthwork. Mark these, along with your intended flight path, on your flying map and discuss the route and purpose of the flight with your pilot. Then work your way calmly from site to site. At each site make a complete circuit to study its appearance. Only start taking photographs – sparingly – on the second (or third) circuit, when you have thought about the most informative angle, or angles, of view. At this stage, however, take both the 'best' view and shots from other directions – between four and eight exposures at intervals round the circuit. Later, when you have the resulting photographs to hand, study how the direction of the light affects the rendering of the archaeology – some views which look quite intelligible in the air will be disappointing or uninformative in two dimensions.

On subsequent flights practice standard aerial manoeuvres. Ask your pilot to fly *slowly* round the sites that you are photographing (at an air speed of 80-90 knots, not the 100-110 knots that may be more appropriate *between* targets). This will cut down

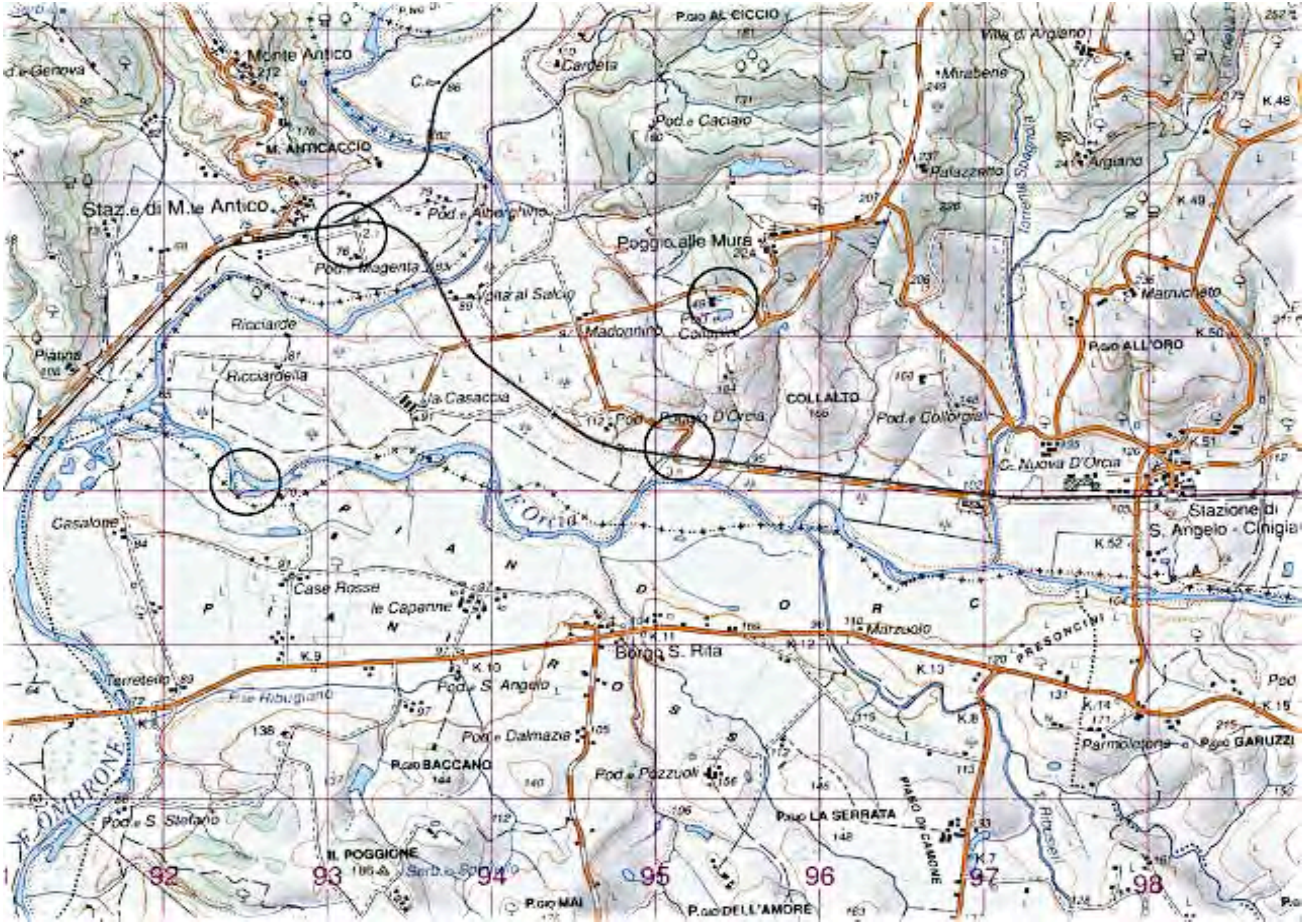


Fig 5. 2 Identifying locations on the map

In relating the schematised map to the real landscape that you see below you it is important to identify distinctive topographical or modern features – a steep hill, a small lake, an unusually shaped road junction or a bend in a river, as ringed in this extract from a 1:50,000 map of Val d'Orcia in Tuscany.

vibration and reduce the danger of blurred images due to camera-shake. Practice making exactly the same circuit again so that you can take a photograph from a position that you identified first time round.

Always let your pilot know what your **target** is, and where. Talk to him over the intercom or use hand signals if you think you are getting too close or too far away. From the very outset train yourself to think about the inclusion of **control point**s of the kind needed for **mapping** work (*Chapter 7*). Ask the pilot to climb or descend if you want a different angle of view. Notice, in particular, how long it takes to gain height. When you add a second lens to your photographic kit, make it a telephoto lens of say 85 or 100mm focal length, or a longer zoom lens. Notice how this seems to take you closer to the site without changing height (if you have have been using a short zoom lens from the outset you will have appreciated this already this already). Later, add a wide-angle lens (28 or 35mm) and use this to photograph landscape view or large **complex**es without having to climb to a greater height. When using a wide-angle lens you may have to ask the pilot to 'raise the wing' so that you can keep it out of the picture. Begin to think, both during flight and in planning your route beforehand, about the direction and height of your approach to known sites. If the next site is a large one, climb before you reach it, or change to the wide-angle lens. If it is a small one, reduce your height or switch to the long-focus lens.

When you are making fairly tight circuits round your target, remember that your pilot, on the other side of the aircraft, will not always be able to see what you are photographing, especially if the target is almost below you. Use the intercom or hand signals to tell him when or how hard to bank round the site. When you want to point out a line of flight or a feature in the landscape, use the imaginary hands of the clock ('one o'clock', 'three o'clock' etc) or describe a distinctive feature (not 'over there', pointing, but 'just in front of the triangular orchard' or 'two fields beyond the big road junction').

Train yourself to stay calm. If you are lost, ask your pilot to fly slowly in a straight line or to circle gently while you check with your map or consult your GPS. Do likewise if you need to change films or memory cards, solve a camera problem or make notes. Do not hurry – inefficient operation costs far more than spending time to sort yourself out. As your experience grows, so will your speed of operation.

Practice these procedures fairly close to the airfield, on known sites or on locations where you *suspect* there may be sites. Do not waste time going to distant sites or target areas, however interesting they might be. Concentrate at this stage on learning basic skills and on improving your teamwork with the pilot (always the same pilot if possible – you cannot develop really close teamwork otherwise).

Operating efficiently

Because of the costs involved you should make efficient and effective use of every moment in the air. Flying maps marked up with all known or newly discovered sites (Fig 4.1) will allow you to take useful photographs 'in passing', especially on otherwise unproductive traverses to or from distant parts of the survey area. They will also help you to plan efficient flight paths for basic recording and will allow you to photograph extra targets even when your main objective is exploration. You should never fly past a photographable site unknowingly. Keep the maps up to date – essential if you *and your successors* are to know what is new and what is already known. Your maps should also be marked up with priority targets, or target areas, which require survey for one reason or another. The 'portfolio' approach discussed at the end of *Chapter 3* should ensure that you have ample targets on your maps, so that every flight will produce at least *some* useful photography.

Even in exploratory work it pays to plan your flight path beforehand, marking an intended route on the maps with a soft pencil, and ensuring that you enter each area at a point which allows you to search it efficiently. In exploratory work you will probably diverge from the planned route but the very act of planning will have made you think about your objectives and the ways in which you *might* diverge or should *not* diverge from your original plans. You will probably plan more for each flight than you can actually achieve. So always head fairly quickly to any distant targets, ignoring closer things and then working your way back towards your starting point. Better to make a second flight to the nearer areas than to risk another long traverse to far-away targets that you did not reach or had to leave too soon on your first visit.

It is good policy to have several possible flights paths marked on your maps, to different parts of the survey area. You can then use one of these ready-prepared routes if for any reason you cannot go where that you originally intended. You can leave the traces of recent flights on the maps as reminders of where you have been, at least until the maze of lines becomes more confusing than helpful.

Before any flight you should spend a few minutes talking about the day's objectives with your pilot and looking over the intended route and its possible variations. Talk to him during the flight, too, about any changes of plan.

Searching out the archaeology

The recognition of archaeological **patterns** relies on the trained eye and mind of the observer. A motte-and-bailey castle or a **hillfort** may be easy to recognise, though less so when only part of it survives. Other things may be more obscure – a partially preserved field system, some indistinct **soilmarks** or a few metres of linear cropmark. The trick lies in being able to see the human intent behind the **pattern**, even when only part of it is present. The **aerial archaeologist**'s capacity to recognise these patterns is little different from that of the excavator with below-ground evidence. The importance of reasoning and experience is the same in either context. The observer must argue with himself about the human or other causes of the pattern that he sees in front of him, and the more logically he does this the more sharp his eye will seem.

Equally, the more things the photographer has already seen, and been able to ascribe to human intervention, the more things he will be able to recognise on later occasions. The power of recognition, of course, has something to do with the observer's general knowledge of archaeological sites and features. The **aerial archaeologist** must be familiar with the form of ditches that characterise a Neolithic **enclosure**, the shape of **soilmarks** that represent a Roman farmstead, or the jumble of 'humps and bumps' that were once an ecclesiastical site or a medieval village (see, for instance, Figs 3.1, top right, and Fig 5.11). He, like the rescue excavator, must be a generalist, recognising the hand of man in a **pattern** – or a discontinuity – even if he has little idea about the feature's date or function. So, what general advice can be offered?

- Look at the landscape as a set of *patterns* – the modern field and farms, of course, but are there also things which do not seem to 'fit', which conflict with the shapes of the present day? (Fig 5.3 right centre and bottom.)
- If so, do they resemble an archaeological **pattern**, or *part* of an archaeological pattern, that you have seen before, in books, in air photos or in reality? (Fig 5.3 top left.)
- Do they relate in a meaningful way to the topography, like pits above a stream or a piece of bank around the top of a hill? (Fig 5.3 top right and centre left)
- Are there patterns that continue over a substantial distance, ignoring the modern landscape? If so, are there signs that might tell you whether you are looking, for instance, at an ancient road or at a modern pipeline? (Figs 5.3, centre right; Figs 10.53, 10.54).
- Are there shapes *within* the modern pattern which might be survivals of something older, centuriation preserved in modern trackways, for instance, (Fig 2.14) or medieval town defences fossilised in the street pattern of the present day (Fig 10.72)?
- Might patterns which initially seem archaeological relate to the topography in a way that suggests that they might be of geological origin (Fig 7.4 top left, top right; Fig 7.5)?
- Could some of the patterns have a modern derivation, such as 'envelope' patterns or the colour changes caused by fertilisers or artificial irrigation? (Fig 7.4 bottom right, centre left.)

Fig 5. 3 Seeking out the archaeology

The aerial archaeologist must constantly seek out likely topographical situations and patterns in the landscape that might have an archaeological meaning. Some, of course, will be ‘false traces’, caused by underlying geology or quite recent events, as in Fig 7.4.

a) An eroded motte and bailey castle.
b) Pits above a stream in Hungary (all the other examples are from Italy).
c) A bank round the top of a hill, an obvious place for a defended enclosure or fort.
d) A linear cropmark, probably an ancient road since it cuts across the modern field boundaries.
e) A pattern that looks at first glance like a building but is shown by its conformity with the modern field pattern to be the result of recent crop trials.
f) A ring-ditch or enclosure of unknown date and function but clearly earlier than the modern road.

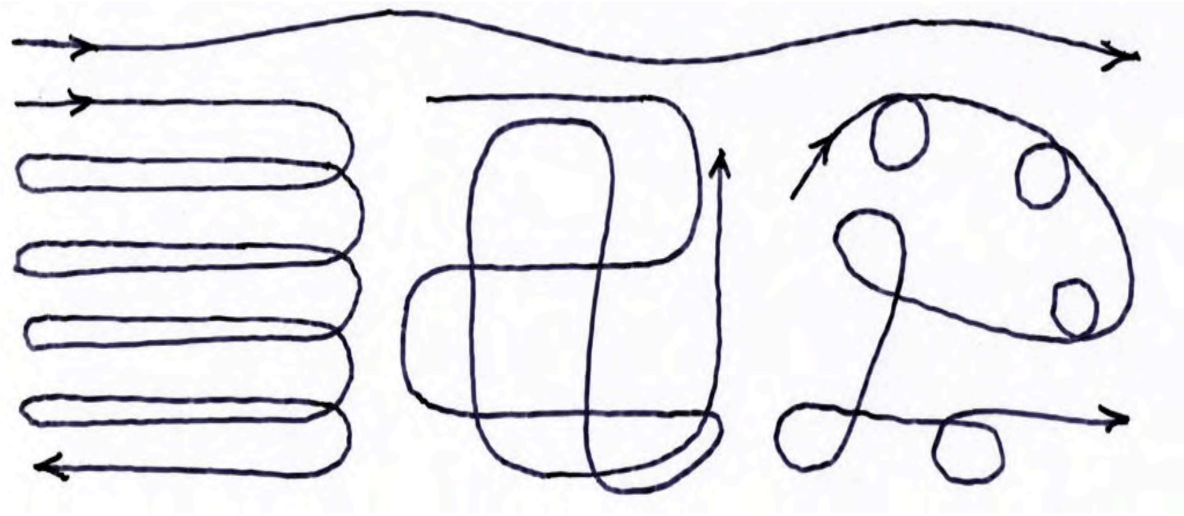


Fig 5. 4 Typical search patterns for exploratory aerial survey

Top. A gently 'weaving' path which presents the archaeologist with at least distant views of areas that would otherwise lie out of sight directly beneath or ahead of the aircraft.
Left. A pattern of overlapping parallel runs, again aiming to ensure that no part of the landscape remains unobserved beneath the aircraft.
Centre. A series of parallel flight paths, first along one axis and then along another at 90 degrees to the first.
Right. A 'field-hopping' pattern often used at the beginning or end of a cropmark season, moving from one 'likely' field to another in response to the colouring of the crops.

These are the *kinds* of observations and reasoning that you should go through before photographing something that may not be archaeological. Half of the art lies in *rejecting* things. But if there remains a doubt, it is better to take a photograph anyway. The pattern may make more sense, as either modern or ancient, if seen on a later flight, in different lighting or different conditions of crop development (Fig 5.12). Or even in the cold light of your comfortable office!

The search, of course, has to be conducted in an orderly way, choosing flight paths and flying heights that will place the greatest amount of the landscape before the observer's eyes with sufficient clarity for the patterns to be recognised. Flying at 600 m (2000 ft), or even higher, may be fine for unravelling whole landscapes (Fig 2.3) but 300 m (1000ft), or even less, may be more appropriate if the targets are small. Often, when it is unclear what type or scale of site might be seen, the flying height must be a compromise, around 450 m (1500ft) perhaps. Below about 200 m (650ft) small detail may be more visible but the landscape seems to move so quickly past you that it is difficult to scan it comprehensively. Some typical search patterns for exploratory work are shown in Fig 5.4. A useful stratagem is to divide the landscape into smaller topographical zones, bounded by a group of roads perhaps, or defined by a river and a range of hills. You should then fly around or across each zone in turn, using whatever flight pattern seems most likely to give the desired degree of coverage for that particular area. Another procedure is to react to cropping patterns, looking at arable crops that are likely to produce **cropmarks** but excluding vineyard or maize that predictably will not. In the early or late stages of the cropmark season it may be permissible to 'hop' from field to field, looking only at those which have achieved or which still retain a colour which seems likely to reveal archaeological patterns.

Fig 5. 5 Returning day after day, week after week

Cropmarks change in appearance day by day or week by week throughout the ripening season. It is important to return to sites that were not showing at their best or in their entirety on an earlier visit. In these views of a Roman building complex in Tuscany the right-hand picture was taken two weeks later than that on the left. Parts of the complex have now become indistinct but an extra building has appeared beyond the left-hand end of the main range.

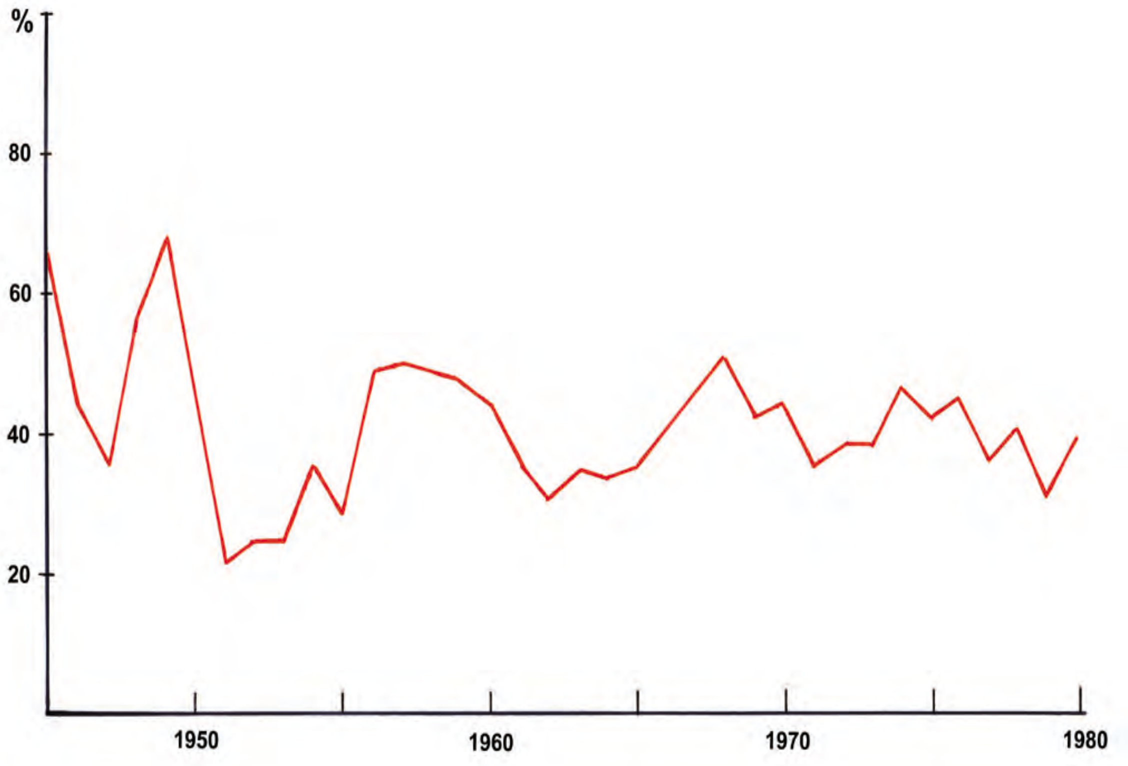


Fig 5. 6 Repeat photography and new discoveries

In a landscape of mixed pasture and arable cultivation the incidence of new discoveries compared to 'repeat' photography can remain high for decades. In the Upper Severn Valley on the borderland between England and Wales the proportions vary from one year to the next but the 3-year average stayed near or above 40% from 1945 to 1980. Thirty years later the ratio is somewhat lower but up to a third of cropmark sites photographed each year are still new to the record.

The importance of timing, return visits and perseverance

Timing and perseverance are of critical importance. The uses of shadow and highlight have already been explained in *Chapter 2* (see also Figs 2.4, 2.5, 2.9, bottom, 10.2 and 10.4), along with the need to time flights so that the sun is low in the sky, early or late in the day or at almost any time in winter. If you fly in the middle of the day in spring, summer or autumn you may see nothing, despite the presence of features that would be perfectly obvious when the sun was lower in the sky.

It is with **cropmarks** that the matter of timing is most critical and the need for return visits most strong. Different crops in adjacent fields, or the same crop sown a few weeks after one another in spring or autumn, will ripen at different times over a month or more in May, June, July or even August, so that only some of the fields will be showing cropmarks at any one time, making only parts of the pattern visible. To catch a significant part of the evidence it is necessary to return, if possible, at intervals of a few days or a week throughout this period, and to do so again in following years when the cropping pattern, the influence of the weather and the appearance of the cropmarks may be different (Figs 10.30, 10.62, 10.63, 10.64). It may be decades before the incidence of new discoveries declines significantly (Fig 5.6). Remember that root-crops and various kinds of weeds can develop cropmarks at quite different times of year (Chapter 2). For cropmark evidence there is no *dies* or *annus mirabilis* when all can be recorded in a single magnificent flight. Only perseverance, week after week, year after year, decade after decade, will produce real success.

Soilmarks, in terms of their clarity or brightness, are quite varied in their response to the moisture content of the soil, the stage of cultivation (after ploughing but before or after harrowing or rolling, for instance) and the direction from which they are photographed (looking away from the sun is often but not always the most effective; *Wilson 2000*, pp. 39ff). In the search for **soilmark** evidence good timing may be a matter of luck as much as judgement since ploughing, harrowing, rolling and seeding are now spread so widely across the year.

Photographing the landscape below

Aerial photographs are not particularly difficult to take but basic skills and 'tricks of the trade' have to be learned if consistently good results are to be achieved. The main object is to photograph archaeological information. So first *look* carefully at any pattern that has attracted your eye, secondly assess whether it is (or might be) archaeological, and only when satisfied about this take the photographs – sparingly. Do not be afraid to take several – even many – photographs of a site (including stereo pairs) if its quality, complexity or 'mappability' justifies this. If a cropmark, soilmark or other kind of site is showing *poorly* when you first see it, photograph it even if you feel it may appear more strongly on a later flight – this may be your only chance to do so and the photo interpreter will thank you for giving him more than a single frame to work on.

On the other hand, do not flood the archive with pictures taken from every possible angle in the hope that some at least will be useful. Choose photographic angles carefully and do not be profligate with the exposures – every frame costs time and money to examine, catalogue and store later in the office, laboratory or archive. The same applies to the identification of 'sites'. Satisfy yourself that what you are seeing is – or seriously might be – archaeology. Do not burden the photo library and record system with material that is actually not archaeological, or has only a faint chance of being so.

On the other hand it is always worth taking general views of landscapes, topography, geology and 'non-archaeological' cropmarks or soilmarks that may be useful in lectures or other educational work. In a few cases, too, you may want to place photographs in the archive (and an entry in the record system) to show that in your opinion what you photographed was not an archaeological site but the product of some other phenomenon.

Preparing for photography

Cameras, lenses and filters should be cleaned after each sortie and re-packed for the next flight. The whole kit should be checked again before leaving for a new flight, to check that everything is present, including maps, draft Flight Report forms, films or memory cards, spare batteries, filters, pencils etc. The shutter speed setting and metering mode on each of the cameras should be checked (generally 1/500 or 1/1000 second, shutter-priority and centre-weighted or multi-point metering). If you wish, insulating tape can be placed across all controls that could be accidentally altered during flight. Likewise, lenses can be taped at infinity (except those of 180mm or greater focal length, which may need some focussing adjustment when used at full aperture).

In film-based photography the film-speed setting should be checked against the speed rating of the film (modern 35mm cameras set the speed rating automatically but some medium format and older cameras do not). Films should be collected from cold store but not loaded until they have had an hour or so to warm up, otherwise condensation may damage the film or camera.

At the airfield films should be loaded if this has not been done already. Time should be allowed for stowing the cameras, films and other equipment in the aircraft for accessibility during flight but safety during take-off and landing. At the end of each flight the aircraft should be carefully checked to ensure that all photographic equipment, maps and other materials have been removed, the cameras switched off and battery packs removed. The whole kit should then be cleaned and packed away for the next flight.

Photographic procedures in the air

Some essential procedures have already been mentioned – approaching sites in a suitable direction and at an appropriate height, and using interchangeable or zoom lenses to avoid unnecessary climbs or descents. Before reaching the site it is sensible to check the number of frames left on the film or memory card and to re-load if need be – better to waste a couple of shots than to run out of film or card space in the middle of the next piece of photography.

The circuit round the site should be made at slow speed so as to reduce vibration and the risk of camera-shake. For the same reason both cameras and lenses should be kept well inside the cockpit, clear of the slipstream outside. During the first circuit the photographer should check through the camera lens that the circuit is close enough and at the right height, and should ask the pilot to make adjustments if need be. Successive circuits can then be made, in the case of traditional photography first for black-and-white film and then for colour. With greater experience it may be possible to exchange cameras quickly so as to take both colour and black-and-white in a single circuit. The standard lens should be used first for overall shots, and – if necessary – the long-focus lens in a separate circuit for close-ups. Once again, the use of good quality zoom lenses simplifies this operation.

During photography the camera should be cushioned gently against the photographer's arms and body, themselves kept clear of the aircraft's bodywork and its inevitable vibrations. One hand should control the camera body and release-button, the other holding the lens from below and adjusting the zoom-lens (or polarising filter) if this is being used. Cameras should always be tethered by neck- or wrist-straps.

In the case of traditional colour photography it may prove economical to take near-identical second shots in the air for use in slide presentation. There is no such need in digital photography though it may be convenient to take simultaneous RAW and JPEG images so that the latter are available for presentation purposes or emailing to contacts. Stereo-pairs for three-dimensional viewing are useful for cropmark sites and for any earthwork or soilmark targets that are going to be the subject of air photo mapping.

Stereo pairs of archaeological sites can be achieved by taking two or more exposures at one- or two-second intervals, *either* while maintaining the subject at the centre of the frame (during a circuit, for instance) *or* by flying in a momentarily straight line *past* the site without changing the camera's basic angle of view. The first technique gives shots along slightly converging sight-lines, with each image covering the whole of the target area. The second method records the scene along *parallel* sight-lines but only *part* of each image will overlap its successor. Only that part, therefore, will give the desired 3D effect during stereo viewing. Experience at English Heritage suggests that either method can produce acceptable results for 'soft-edged' subjects such as cropmark, soilmark or earthwork sites. 'Parallel' sight-lines, however, may be marginally more effective for buildings or other subjects which have a multiplicity of sharp outlines.

In general it is best to concentrate on one site at a time but the photographer should not be afraid to take occasional opportunist shots if something else comes suddenly into view – a striking landscape scene, another site seen from a novel angle, or something that is simply aesthetically pleasing. The opportunity should not be lost – it may not come again. The same applies when heading home when the light has gone or the aircraft is due back for the next customer. An under-exposed or ill-composed shot taken in passing is better than no shot at all, though the location should be recorded if at all possible to ease photo cataloguing and **record creation**.

Framing the subject

Photographs can be put to a variety of uses and the framing of the shot should respond accordingly. Near-vertical photographs will bring joy to the photo interpreter and mapper (*Chapter 7*) but may be less striking than a more oblique view when used in a lecture or publication. Photographers fresh to aerial work often tend to take views from either too close or too far away – it is better to have both a wide view to show the site in its topographical context and a closer view to show its detail. This applies particularly in the case of air photo mapping, where the necessity to include **control points** (*Chapter 7* and **Figs 7.11** to **7.14**) may dictate an initial view that seems too wide for the rendering of fine detail (though the detail probably will be there in the negative, print or slide if it is enlarged enough). Here again a combination of wide and closer views is desirable to identify both where and what shape the site is *and* what intricacies can be seen in and around it (see discussion of 'secondary control' in *Chapter 7*).

Finally there is the question of aesthetics. There is not necessarily a conflict between utility and aesthetics. Good framing, pleasing composition and dramatic lighting (all matters of personal taste, of course) can enhance a photograph without necessarily reducing its practical utility. Where the two considerations *do* conflict, separate shots should be taken to meet the different purposes that are being served.

Photographic complications

Even with assiduous use of weather forecasts and a good knowledge of local weather patterns the aerial photographer using hired aircraft will sometimes have to cancel flight bookings. Bad weather may arrive unexpectedly and atmospheric haze is a regular problem. Morning haze from evaporating dew may clear quite quickly, but will sometimes persist until too late for the flight to be worth pursuing. Industrial haze may drift in on a change of wind and dust may arrive, predictably or otherwise, on hot winds from the Sahara. In Britain haze often builds up after the first two or three days of high pressure in summer and usually persists until the next rain brings a clearance. In general it is not worth flying for shadow photography if ground-level visibility is less than about 5 km, since into-the-sun and even across-the-sun shots then become practically impossible. But appearances can be deceptive and downward visibility may sometimes be better than expected. Only experience and the urgency of the task can determine whether it is worth flying at such times. Cropmark conditions may *demand* a flight, though the results may be photographically disappointing. Again, less than perfect photographs may be better than none at all.

Scattered cloud can cast heavy shadows on the landscape and make it difficult to achieve correct exposure. Satisfactory black-and-white prints are particularly difficult to make when part of the site is in cloud shadow and the rest in bright sunlight (**Fig 5.7**).

Fig 5. 7 **Problems with cloud shadow**

It can be very difficult to take good photographs, and even more difficult to make good black-and-white prints, when there is a dense scatter of clouds across the sky, casting shadows onto the landscape below. In such conditions the photographer, given the choice, might be better employed in undertaking office-based work.

Waiting for the shadows to move away, or temporarily diverting to other targets nearby, may not be worth the extra flying time if the clouds are too big or too numerous. Again, the urgency of the photography may dictate the decision.

Fading light at the end of a flight, especially in winter, is a common problem. In these conditions the photographer must keep a close watch on the camera read-out when there is a danger of under-exposure. Large-aperture lenses are at a premium at such times. Inexpensive zoom lenses may perform poorly in such circumstances because of their smaller maximum aperture and the optical compromises inherent in their design. One response is to change to a faster film-speed (200 or 400 ISO, for instance) or to up-rate the film-speed to 800 ISO or higher, in the case of traditional film remembering to notify the processing laboratory so that development can be adjusted if need be. To catch the very last of the light it is possible to decrease the shutter speed to 1/250 or even 1/125 second, especially with 'stabilised' lenses or cameras, though this obviously increases the risk of camera-shake (so more than one shot should be taken of each subject).

Fig 5. 8 Photographing through the plastic of the aircraft canopy

Top. Occasionally it may be necessary to photograph through the plastic of the cockpit's window or canopy. In such situations dark clothing for both pilot and archaeologist can help to reduce reflections from the inside of the plastic (see centre left in Fig 5.1). Perfectly acceptable photographs can be taken, however, as shown by this cross-sun view of Marsala, in Sicily. But note the tell-tale reflection from the canopy in the top right part of the frame.

Bottom. There will be a damaging loss of contrast, however, when photographing directly into the sun , as in this case, or when there is any significant amount of atmospheric haze.

Fig 5. 9 Flying ‘with the wing up’

When using a wide-angle lens for landscape photography the wing and its supporting strut can intrude into the frame, as here. If asked to do so, however, the pilot can raise the wing and take it forward without changing course so as to give a clear view behind the strut.

Photographing through the perspex

On occasions, especially in low-wing aircraft, it may be necessary to photograph through the perspex of the cockpit (Fig 5.8). If so, the perspex should be washed and dried (inside as well as outside) before flight, using a gentle liquid detergent, plentiful water and a soft chamois leather. Shooting directly into the sun may be difficult, the perspex creating an increasing 'haze' as the aircraft moves round towards the sun (Fig 5.8, *bottom*) . The problem can be countered, to some extent, by shooting downward from a higher angle, or by switching to the equally effective 'cross-sun' technique (with the sun at the side rather directly in from of or behind the photographer). There will also be problems with light reflected from the *inside* of the perspex, whether from the opposite side of the canopy, from other parts of the cockpit or from the faces and clothing of the pilot and photographer. Both of the crew should therefore wear dark clothes, the photographer perhaps even wearing thin black gloves and a black balaclava. Small 'flares' of light will probably still move across the line of view but with practice it is possible to anticipate most of these and to delay the exposure until they have passed. Even if they remain in the photograph, as in Figs 2.8 and 5.8 (top), they do not necessarily reduce its usefulness. Placing the lens close to (but not touching) the perspex also helps, as does the use of a good lens hood.

Photographing particular kinds of subjects

A wealth of advice about photographic techniques can be found in *Wilson 1982* and *2000*, from decades of experience in Britain and elsewhere. Only the most common of adjustments will be mentioned here.

Landscape views

When taking landscape views with a wide-angle lens it may be necessary to ask the pilot to fly with the 'wing up' (one wing raised and slightly in advance of the other but with no change of direction, technically 'side-slip'). This will keep the wing out of the picture and allow photographs to be taken *behind* the wing-strut, which will otherwise be almost impossible to keep out of the frame.

Buildings

Buildings can produce excessive contrast in bright sunlight, with glaring reflections off roofs or the tops of walls (which then appear blurred) and important detail lost on the shaded faces of buildings (Fig 5.10, left). With the sun almost *behind* the photographer the detail will be retained but modelling and the sense of three dimensions may be lost. One answer, when the opportunity arises, is to photograph these subjects in soft directional lighting beneath thin cloud cover, making the shadows softer and less obscuring (Fig 5.10, right). Successful results can even be obtained in quite dull light.

Fig 5. 10 Problems with shadow and contrast

Photographing buildings in bright sunlight can be difficult, the high contrast producing deep shadows and glaring highlights which may reveal the shape of the building but obscure the detail, as in the castle on the left. A viewpoint with the sun almost directly behind the photographer can reduce the contrast but may lose some sense of form, as in the fortress in the lower photograph. Both examples are taken from central Italy (Vulci on the left. Radicofani on the right). See also Figs 10.32, 10.33 and 10.35.

Soilmarks

Soilmarks may show much better from one direction than another, looking away from the sun usually being the most effective. Soilmarks can sometimes show very high tonal contrasts, requiring double printing or contrast adjustment of the kind described below for snow scenes if the details in the lighter areas are to be properly rendered (Fig 5.11).

Cropmarks

Cropmarks present a range of problems, especially when poorly developed in the spring or during wet summers. There may be little colour difference in these circumstances, the cropmarks being visible only from a relatively low angle and round just a narrow part of the circuit. Many cropmarks may be missed altogether in these conditions but when their presence is even tentatively suspected it is essential to fly a full circuit so as to identify the best angle for photography. Yellow-on-yellow cropmarks, after full ripening of the crop, can also be directional, with the balance of the tones changing or even reversing at different points in the circuit. Cropmarks represented by strong colour differences can usually be photographed from almost any angle but it nevertheless is wise to take photographs from several different directions (Figs 10.24, 10.25). **Cropmarks** represented mainly by differences in the height of the crop, rather than by variations of colour, are best photographed looking into or across the sunlight, turning them into **shadow marks**. This adds an extra dimension to late-evening cropmark photography. So too can the use of stereo pairs for three-dimensional viewing during photo interpretation and mapping. In Britain, for instance, English Heritage recommends stereo pairs for all cropmark and low earthwork sites for this reason, following experience that stereo viewing allows significantly more detail to be recovered in such cases.

Frost and snow

Frost and snow scenes call for adjustment of the film speed and the metering mode. ‘Whole frame’ metering is safer than ‘centre-weighted’ or ‘spot’ because of the very bright highlights that can occur in limited parts of the image. Multi-point metering may be even better if it is available (see *Appendix B*). Metering systems in traditional cameras are calibrated to expect (and reproduce) a mid-tone balance across the frame as a whole and are ‘fooled’ by a scene that is almost entirely white. This results in under-exposure, giving a grey-blue cast to colour slides and muddy grey prints in traditional black-and-white and colour negative work. The usual answer is to reduce the film speed by a stop (from, say, 100 to 50 ISO) or even by a stop-and-a-half (to 32 ISO) if the sunlight is particularly bright. Even then it is difficult to retain the full tonal range in black-and-white work and two prints may be needed from each negative, one printed ‘white’ and the other much darker so as to bring out detail which would otherwise lost in the highlights (Fig 5.11). When half or less of the ground is covered in snow the film speed is best left at its normal rating, or at the most reduced by half a stop. In the case

Fig 5. 11 **Photographing snow in bright sunlight**

In bright sunlight the whiteness of the snow requires the film-speed to be reduced by a stop or a stop-and-a-half so as to avoid under-exposure since the exposure meter of the camera is calibrated to produce a grey rather than a white image. The top picture, of a deserted medieval village and its now-isolated church in central England, is a colour photograph. The other two are black-and-white images. In such conditions it may be necessary to make prints from the monochrome negatives at two separate densities so as to show both the whiteness of the snow (lower left) and the detail of the recorded earthworks (lower right).

Fig 5. 12 Even poor photographs can sometimes be of value

Sometimes even a technically poor photograph can contain valuable information. The top picture is clearly out of focus or suffering from camera-shake but it nevertheless records the existence of an otherwise unrecorded rectangular enclosure and ring-ditch at a noted location in central Italy. The image on the right, with intrusive cloud shadow, shows a lighter mark in the ripening crop, perhaps indicating a degraded mound above a tomb. This was the only photograph of the site, taken in haste during a hurried return to the airfield for lack of fuel.

of digital photography the same adjustments can be achieved by manipulating the Exposure Compensation (EV) setting, taking care, of course, to cancel the adjustment for those parts of the flight not involving snow.

Photographing through shallow water

The photography of submerged structures and wrecks calls for clear and calm water, free of mud and algae and with no more than a light breeze to break up the surface into bright highlight (Braasch, pers com). It also needs clear sunlight from a high angle. A circular polarising filter can be used in such conditions but without considerable practice it is quite difficult to handle and a simple skylight or UV filter may be better in most instances. Metering mode does not need adjustment but water 'swallows' light so that a slower-than-usual film speed, or larger f-stop, may be required (some 'backlight' adjustment of the EV setting represents the equivalent in digital photography). The acquisition of an accurate GPS location for off-shore wrecks is essential since most of them lack distinctive topographical features to which they can be related during mapping.

Reflections and high contrast

Any photograph with water in the frame may cause metering problems, because of bright reflections from the water's surface. The use of spot or centre-point metering may provide a partial defence, making sure that these bright spots do not come into the metering position. So too with scenes containing areas of very contrasting brightness, such as sea-and-foreshore or foreshore-and-dry-land combinations. The metering spot at the centre of the frame can then be placed on whichever part is the more important, separately metered photographs being taken if both are of equal significance.

Bracketing

Bracketing is a technique which can be used when the correct exposure is uncertain or when slightly different densities of image (either in colour or black-and-white) are desired for publication, projection and archiving. Three (or even five) near-identical photographs are taken automatically by the camera in quick succession, at intervals of (usually) a third, a half or full stop either side of the central meter reading. Bracketing is less easy with older film-cameras but can be achieved, after a fashion, by taking exposures at varying film-speed settings (but still the same shutter speed) while circling the site. Bracketing (at up to a full stop in either direction) is recommended when using false-colour infra-red film because of its extreme sensitivity to over- or under-exposure.

Recording flight paths and site locations in the air

It is essential to record both the flight path and the location of sites seen during the survey (Fig 5.13). The flight path and the location from which photographs were taken can now be recorded automatically through the ‘track’ and/or ‘waypoint’ facility of the archaeologist’s GPS unit, the downloaded tracks and waypoints being presentable on-screen or in hard copy against various versions of the national grid or map base (Fig 4.5). The accumulated tracks are a record of past and present work and an aid to future planning.

Marking intended routes in pencil on flying maps has already been recommended as a preliminary to *any* flight. The process can be continued during flight by marking the actual route on the map (and rubbing out the pre-planned one if desired). The site locations can also be marked and given a reference number. This can be used to link the resulting photographs to notes about the site and the relevant and film/frame numbers written onto pre-printed Flight Report forms attached to a knee-pad (Fig 5.13, lower). Experiments with small voice-recorders have been too subject to instrument or operator error, or to unreadability because of aircraft noise, to make them a reliable means of flight recording.

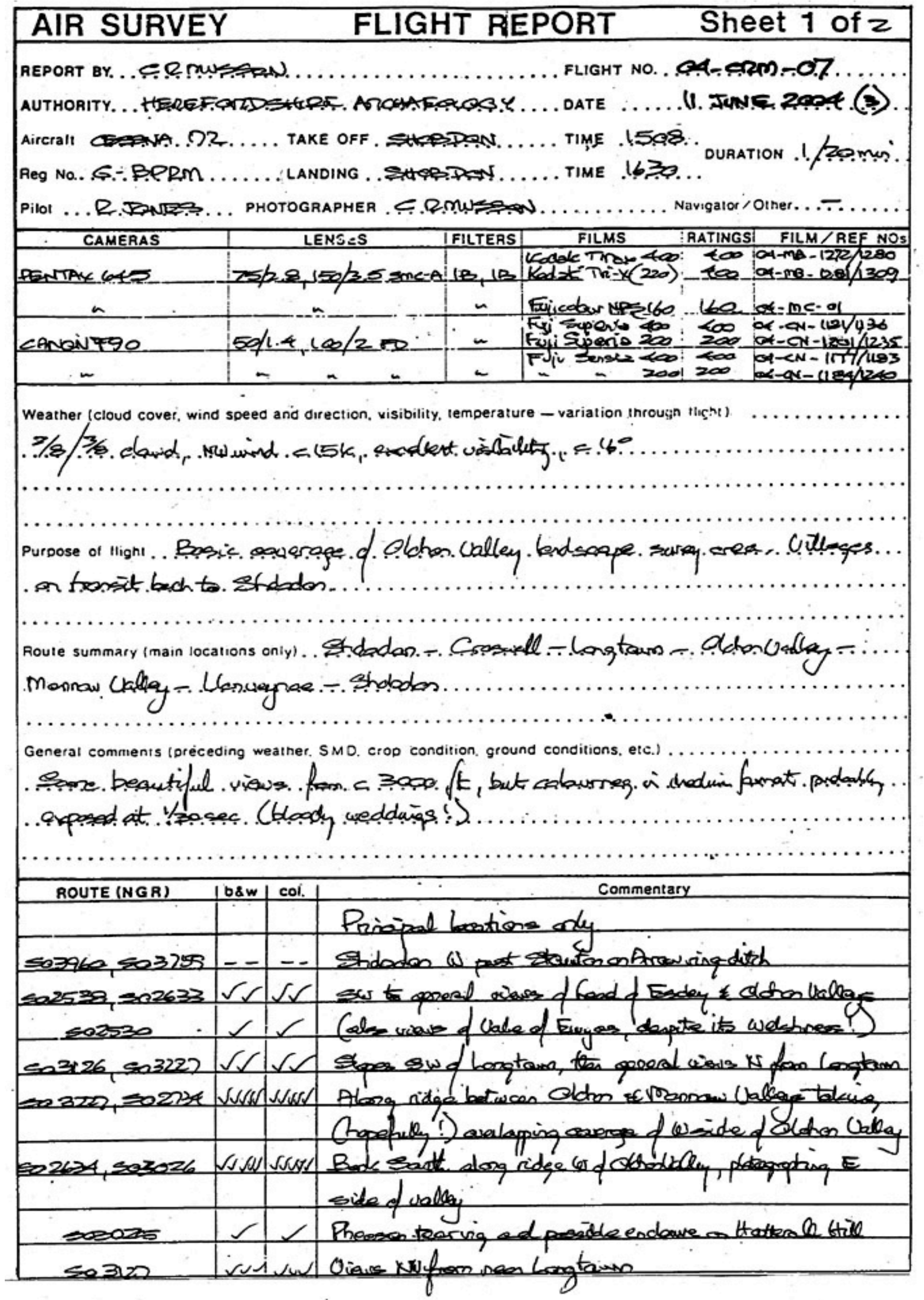
With long practice, a surveyor who knows his area well may make only cursory marks on his map and knee-pad during flight but then be able to re-draw the *actual* flight path and list the sites recorded entirely from memory immediately after landing. This is definitely *not* recommended for those who are new to aerial survey, though GPS records can now offset some of the past risks of forgetfulness. The likelihood of error or omission is greater in the case of free-flying exploratory survey than in flights planned beforehand to photograph predetermined targets.

In manual recording in the air the photographer or another member of the flight crew records an approximate location for each site photographed (say within a kilometre square of the national grid, plus perhaps a mark on the flying map), the precise position being identified later by comparison between the photographs and large-scale maps. With the regular use of GPS units, however, more accurate site positions (as distinct from the positions *from which* the photographs were taken) can now be established during flight by back-tracking directly over the site once photography has been completed and taking a GPS waypoint when the site is judged to be directly beneath the aircraft. A single press of a button on the unit’s keypad will store a waypoint which records the aircraft’s position at that moment. The GPS unit also displays a reference number which can be used to link the recorded locations to notes made on a knee-pad by the photographer or another member of the flight crew. These notes (on pre-prepared forms also giving basic data about the

Fig 5. 13 **Flight Report forms**

A coherent record of the people and aircraft involved, the reasons for each flight, the equipment used, the conditions of weather and crop-development and the targets photographed is essential to orderly exploration and subsequent use of the collected information.

Left. This A4 form follows a format discussed and systematised in the late 1970s and used extensively in Britain ever since, with local variations. In some cases the information is now typed directly into the computer immediately after the flight, using a well-trained memory and brief notes made while in the air – a method not recommended for beginners, who should make a full record during the course of the flight.



AIR SURVEY FLIGHT REPORT Sheet 1 of 2

REPORT BY C R MUSSON FLIGHT NO. 04-CRM-07
AUTHORITY HEREFORDSHIRE ARCHAEOLOGY DATE 11 JUNE 2004 (3)
Aircraft CESSNA 172 TAKE OFF SHOBDON TIME 1508 DURATION 1/20 mins
Reg No. G-BPRM LANDING SHOBDON TIME 1630
Pilot R JONES PHOTOGRAPHER C R MUSSON Navigator/Other —

CAMERAS	LENSES	FILTERS	FILMS	RATINGS	FILM/REF NOs
PENTAX 645	75/2.8, 150/3.5 SMC-A	1B, 1B	Kodak Tri-X 400, Kodak Tri-X (220)	400, 400	04-MB-1272/1280, 04-MB-1281/1309
"	"	"	Fujicolor NPS 160	160	04-MC-01
CANON T90	50/1.4, 100/2 FD	"	Fuji Superia 400, Fuji Superia 200	400, 200	04-CN-1121/1136, 04-CN-1231/1235
"	"	"	Fuji Sensia 400, " 200	400, 200	04-CN-1177/1183, 04-CN-1184/1240

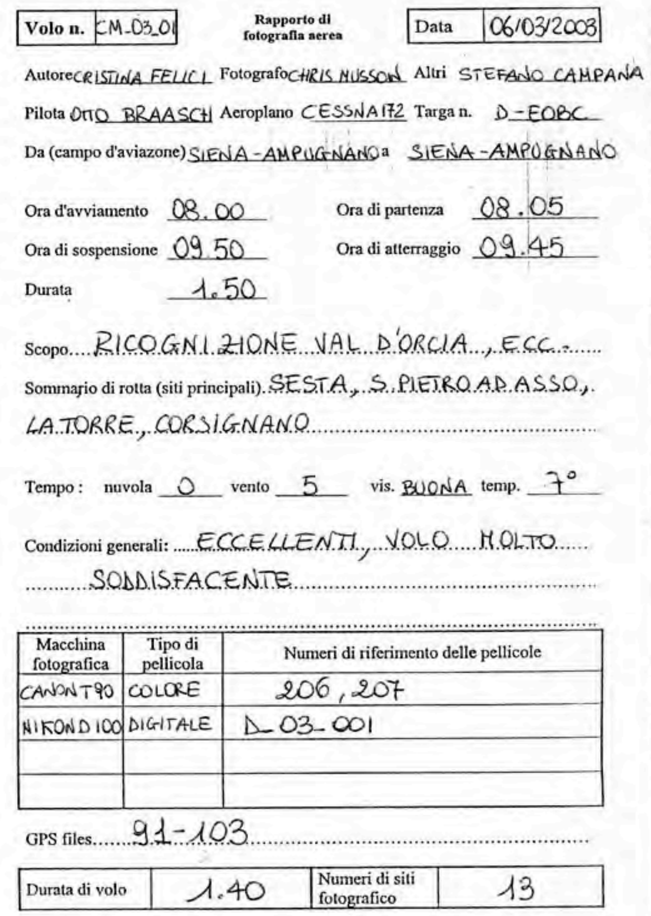
Weather (cloud cover, wind speed and direction, visibility, temperature — variation through flight)
7/8/3/8 cloud, NW wind c 15k, excellent visibility, c 16°

Purpose of flight Basic coverage of Olchon Valley landscape survey area. Villages on transit back to Shobdon.

Route summary (main locations only) Shobdon – Cresswell – Longtown – Olchon Valley – Monnow Valley – Llanveynoe – Shobdon.

General comments (preceding weather, SMD, crop condition, ground conditions, etc.)
Some beautiful views from c 3000 ft, but colour neg in medium format probably exposed at 1/250 sec (bloody weddings!)

ROUTE (NGR)	b&w	col.	Commentary
			Principal locations only
SO3960, SO3755	– –	– –	Shobdon (& past Staunton on Arrow ring ditch)
SO2538, SO2633	✓✓	✓✓	SW to general views of Head of Escley & Olchon Valleys
SO2530	✓	✓	(also views of Vale of Ewyas, despite its wetness?)
SO3126, SO3227	✓✓	✓✓	Slopes SW of Longtown, then general views N from Longtown
SO2727, SO2774	✓✓✓✓	✓✓✓✓	Along ridge between Olchon & Monnow Valleys taking (hopefully!) overlapping coverage of W side of Olchon Valley
SO2634, SO3026	✓✓✓✓	✓✓✓✓	Back South along ridge W of Olchon Valley, photographing E side of valley
SO2025	✓	✓	Pheasant rearing and possible enclosure on Hatterall Hill
SO3120	✓✓✓	✓✓	Views NW from near Longtown



Volo n. CM-03-01 Rapporto di fotografia aerea Data 06/03/2003

Autore CRISTINA FELICI Fotografo CHRIS MUSSON Altri STEFANO CAMPANA
Pilota OTTO BRAASCH Aeroplano CESSNA 172 Targa n. D-EOBC
Da (campo d'aviazione) SIENA-AMPUGNANO a SIENA-AMPUGNANO

Ora d'avviamento 08.00 Ora di partenza 08.05
Ora di sospensione 09.50 Ora di atterraggio 09.45
Durata 1.50

Scopo RICOGNIZIONE VAL D'ORCIA, ECC.
Sommario di rotta (siti principali) SESTA, S. PIETRO AD ASSO, LA TORRE, CORSIGNANO

Tempo: nuvola 0 vento 5 vis. BUONA temp. 7°

Condizioni generali: ECCELLENTI, VOLO MOLTO SODDISFACENTE

Macchina fotografica	Tipo di pellicola	Numeri di riferimento delle pellicole
CANON T90	COLORE	206, 207
NIKON D100	DIGITALE	D-03-001

GPS files 91-103

Durata di volo 1.40 Numeri di siti fotografico 13

Volo n. CM-03-01

numeri delle pellicole iniziali 206 D-003 001

35mm b+n	35mm col	70mm	digit	tipo di sito/descrizione	reticolo/indice numero	carta
	5		6	CENTINE VILLA ROMANA SOIL MARK	91	
	11		11	S. ANGELO IN COLLE CASTELLO	92	
	18		20	SESTA VILLA ROMANA	93	
	24		25	MONTALCINO VEDUTA URBANA	94	
	32		32	S. PIERO MONASTERO MED.	95	
	36		34	VAL D'ASSO PANORAMA	96	
	207					
	4		39	VIGNONI CASTELLO	97	
	6		41	BAGNO VIGNONI NUVOLOSO	98	
	12		48	LA TORRE RECINTO SOIL MARK	99	
	20		53	LA TORRE NECROPOLI CRESCITA GRANO	100	
	22		FINITO	VAL D'ORCIA PANORAMA	101	
	27			CASABIANCA VIABILITA SOIL MARK	102	
	36			CORSIGNANO CASTELLO	103	

RITORNO DIRETTO AD AMPUGNANO

Right. The two sides of this simpler A5 form, originally devised by Otto Braasch, have been used in several training schools in recent years. It is very easy to use in the air but contains less information about personnel, equipment and changes of route – a potential disadvantage for air photo archives drawing material from a number of different sources.

flight) will record the GPS reference number, the film and frame numbers of the relevant photographs and possibly a brief annotation about the type of site involved.

Whatever the method used in the air it is important to complete the process immediately after the flight, marking actual flight paths on the maps, re-writing any annotations that have become illegible, preparing a Flight Report form or completing any final details on the pro-forma report filled in during flight. GPS tracks and waypoints should also be downloaded to computer and GPS units put ready for the next sortie.

Flight Reports

During or immediately after each flight the archaeologist must complete a Flight Report form. This gives the flight a unique reference number and shows when, where and how the flight was undertaken, what equipment was used, the reference numbers of the films or memory cards used, the route followed and the sites or subjects photographed. There may also be entries recording the purpose of the flight, its success or otherwise, weather conditions at the time, and other contextual information. Parts of the form may be filled in before take-off, others during or after the flight. In some cases the archaeologist may prefer to write the information directly to computer. The entry of the information must be done in a consistent and systematic way, and all except little-used items that can be recovered if necessary from the paper records must eventually become available on computer. Two examples of Flight Report forms, based on examples from Britain and Italy, are shown in Fig 5.13.

Photo-processing (film-cameras)

Apart from changes of tense this section has been left unchanged, as useful information on standard procedures before digital cameras and memory cards came into general use in the air. The equivalent processes in the age of digital photography are dealt with in Appendix B.

Standard advice was that exposed films should be processed as soon as possible after flight. Films which could not be dealt with immediately were instead to be double-wrapped against condensation in seal-top plastic bags and returned to cool (not frozen) storage until they could be sent to the laboratory. Before use each cassette or roll of film was indelibly marked with a reference number allocated to it. The laboratory then attached this number to the processed films so as to retain the link with the site-location and film/frame numbers recorded during flight.

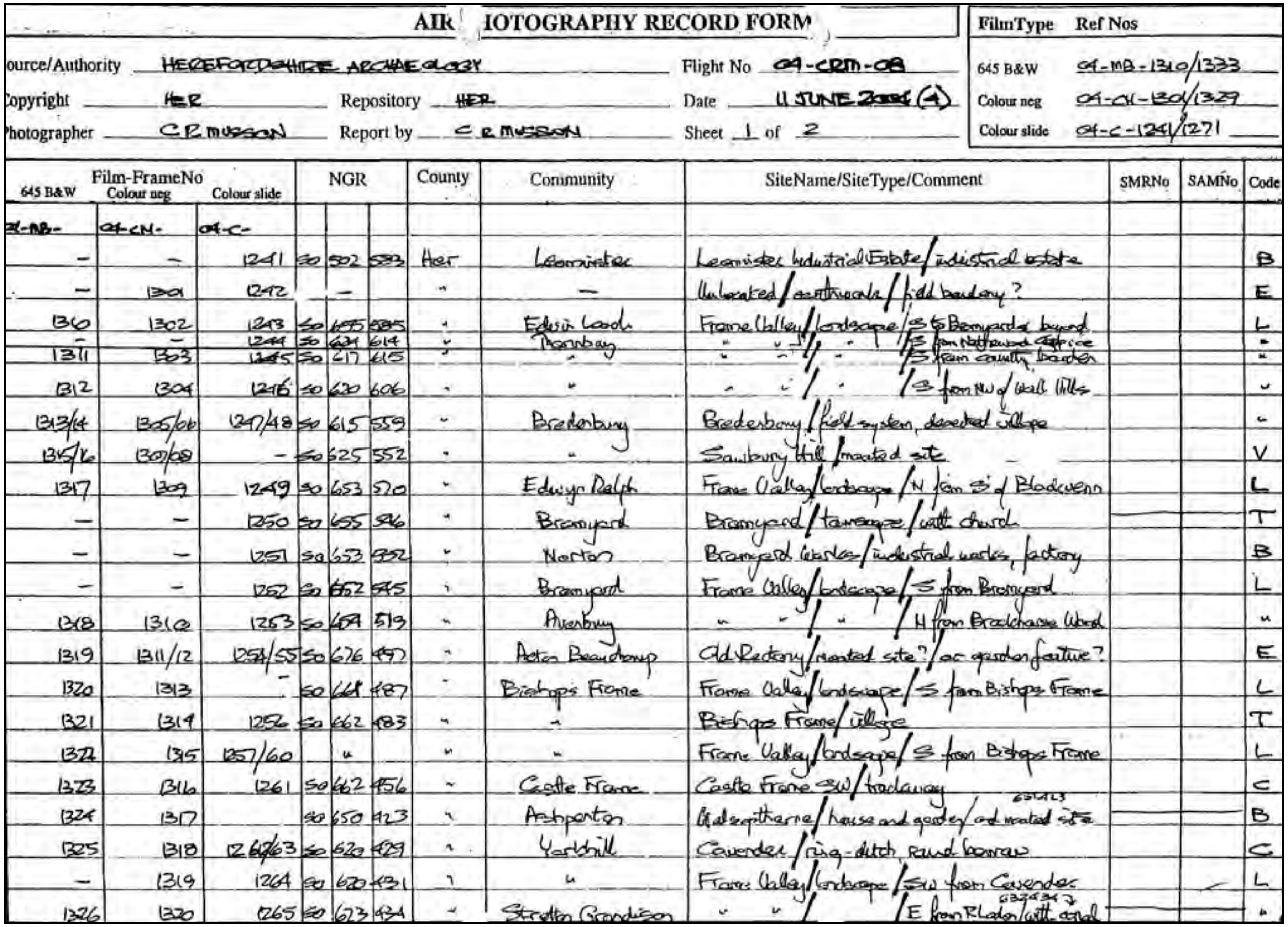
Wise aerial photographers used only top-class processing laboratories. Negatives, slides and prints were to be prepared (and subsequently handled and stored) to archival standards if they were to achieve a life-expectancy of fifty years or more, compared to a decade or so if they were processed in over-used chemicals, with inadequate washing or on poor quality printing paper. Colour material in particular could deteriorate rapidly if not stored in archival filing systems at a reasonably stable temperature and humidity (*Wilson* 1997). In essence, all photographic materials need be protected from exposure to light, dust, damp, scratching, and finger marks. Negatives, colour transparencies and slides, in particular, needed to be placed in environmentally controlled permanent storage as soon as ever possible. Prints had to be handled with respect but were in effect working document, reprintable from the negatives if need be.

Record Forms and Site Records

Once the processed photographs are available on-screen or as prints and colour slides, the sites or locations recorded in them must be given accurate geographical coordinates by comparison with 1:50,000 or (preferably) larger-scale maps, or by comparison with on-screen orthophotos or internet-based systems such as Google Earth. This can be done in a variety of ways depending on the availability of paper maps or the equivalent digital data. In either case the next stage is to complete a Record Form for each batch of photographs, usually all of those taken on an individual flight. The forms will list the location and subject of each photograph or group of photographs, along with other information which may help future searches or relate the sites to information held in local, regional or national heritage registers. A sample Record Form, based on a format widely used in Britain, is shown in Fig 5.14. The same information, of course, could be typed directly into the computer.

Where the sites identified in the photographs are already known they should be cross-referenced to the information held in existing monument registers. Where they are newly discovered they must be identified as such and given a new Site Record – a short summary of their character, location, likely function and date. So far as possible the description should follow the pattern used in existing monument registers for sites derived from other archaeological sources. In this way the **aerial information** can be rapidly assimilated into the existing public or academic record systems. A typical record for a recently discovered site in Britain is shown in Fig 5.15. Many of these newly discovered sites will later be given fuller descriptions following photo interpretation and mapping of the kind described in Part II of this manual.

- Record systems for the results of aerial survey
- In essence three types of information need to be recorded:



AIR PHOTOGRAPHY RECORD FORM

Source/Authority	HEREFORDSHIRE ARCHAEOLOGY	Flight No	04-CRM-08	645 B&W	04-MB-1310/1333
Copyright	HER	Repository	HER	Date	11 JUNE 2004 (4)
Colour neg	04-CN-1301/1329				
Photographer	C R MUSSON	Report by	C R MUSSON	Sheet 1 of 2	Colour slide 04-C-1241/1271

Film-FrameNo 645 B&W	Colour neg	Colour slide	NGR			County	Community	SiteName/SiteType/Comment	SMRNo	SAMNo	Code
04-MB-	04-CN-	04-C-									
–	–	1241	SO	502	593	Her	Leominster	Leominster Industrial Estate/industrial estate			B
–	1301	1242		–		"	–	Unlocated/earthworks/field boundary?			E
1310	1302	1243	SO	695	585	"	Edvin Loach	Frome Valley/landscape/S to Bromyard & beyond			L
–	–	1244	SO	624	614	"	Thornbury	" " / " /S from Netherwood & Tedstone			"
1311	1303	1245	SO	617	615	"	"	" " / " /S from county border			"
1312	1304	1246	SO	620	606	"	"	" " / " /S from NW of Wall Hills			"
1313/14	1305/06	1247/48	SO	615	559	"	Bredenbury	Bredenbury/field system, deserted village			"
1315/16	1307/08	–	SO	625	552	"	"	Saltbury Hill/moated site			V
1317	1309	1249	SO	653	570	"	Edwyn Ralph	Frome Valley/landscape/N from S of Bromyard			L
–	–	1250	SO	655	546	"	Bromyard	Bromyard/townscape/with church			T
–	–	1251	SO	653	552	"	Norton	Bromyard Works/industrial works, factory			B
–	–	1252	SO	652	545	"	Bromyard	Frome Valley/landscape/S from Bromyard			L
1318	1310	1253	SO	659	519	"	Avenbury	" " / " /N from Brockhampton Wood			"
1319	1311/12	1254/55	SO	676	497	"	Acton Beauchamp	Old Rectory/moated site?/or garden feature?			E
1320	1313	–	SO	661	487	"	Bishops Frome	Frome Valley/landscape/S from Bishops Frome			L
1321	1314	1256	SO	662	483	"	"	Bishops Frome/village			T
1322	1315	1257/60		"		"	"	Frome Valley/landscape/S from Bishops Frome			L
1323	1316	1261	SO	662	456	"	Castle Frome	Castle Frome SW/trackway			C
1324	1317		SO	650	423	"	Ashperton	Galsopthorne/house and garden/and moated site 651423			B
1325	1318	1262/63	SO	620	429	"	Yarkhill	Cavender/ring-ditch, round barrow			C
–	1319	1264	SO	620	431	"	"	Frome Valley/landscape/SW from Cavender			L
1326	1320	1265	SO	623	434	"	Stretton Grandison	" " / /E from R Lodon/with canal 632434 ?			"

Fig 5. 14 Record Form

The photographs from each flight need to be catalogued, with grid references for each target and a tentative explanation of the site type and its possible dating. When the cataloguing work is done by someone other than the photographer a coherent Flight Report Form, of the kind shown in Fig 5.13, becomes all the more important. The A4 Record Form shown here has been used by the author for many years in work over Wales and central England. Some people find it easier to make a manuscript record of this kind, using prints or colour slides and paper maps, entering the information into the computer later. Others find it more efficient to do the date entry straight into the computer, using on-screen maps and digital images. New techniques and technology may well streamline these processes, but the essentials are likely to remain the same.

Fig 5. 15 **Site Record**

Every previously unrecorded site should be given a new Site Record, and any new information about already-known sites should be added to the existing records. The photograph on the right was taken on a training flight over eastern Wales with a visiting student from Italy. The Site Record, below, was made in the national air photo library for Wales, where the photographs had been deposited by the original authors for long-term storage and public access.

Name WHITTON BRIDGE *National Reference Number* *306877*
Grid reference: SO26836715 *Map Sheet:* *SO26NE*
Period: Med? Post Med? *County:* *Powys*
Site Status: -
Site Type: POND *Class:* *12D*
Description: Pair of square ponds or reservoirs, sited on flood plain of River Lugg, close to river, SW of Whitton village. Both ponds are cut into the slope on the N side and embanked on the remaining sides. That to the N has an exit or sluice on the S side feeding a series of leats close to which is a smaller, southern, pond. Discovered during aerial reconnaissance by C Musson and E Donati, July 2002. Prints and negatives lodged with RCAHMW, Reference Numbers 2002/5054-50, 51, 52.

- information about individual *flights*
- information about individual *photographs*
- information about the individual *sites* or *subjects* photographed.

In Britain the information is usually allocated to three or more separate databases, related by a limited number of common ‘fields’. The number of databases may vary with the software available, the designer’s skill in implementing it, and the extent to which the information will be integrated into an existing GIS and/or archaeological record system. All systems, however, rely on three assumptions, the linking fields being shown in italics:

- each flight will have a *unique reference number* and a *date* (the date alone is not enough since there may be more than one flight in a day)
- each photograph within a *numbered* flight will have its own *unique reference number* (often the film and/or frame number) and *geographical coordinates*.
- each site or subject will have a *unique reference number* and *geographical coordinates*.

‘Site’ in this context can mean anything from a standing stone to a **hillfort** or relict field system or a cropmark enclosure. ‘Subject’ has been added to cover general landscape or townscape views, or illustrations of natural phenomena such as geology or topography. In forward-looking photo collections there will also be subjects which have only recently become recognised as archaeological – industrial features or wartime relics, for instance. In some archives the reference numbers of individual photographs may be changed as a final part of the post-flight procedures, for instance so as to conform to a fixed pattern for the archive concerned. Where this is done it is advisable, however, to retain the original photo number as part of the background data.

It is important when compiling an aerial record to choose the right range of information items or ‘fields’, and within each field to use a consistent terminology, which should as far as possible follow the pattern used for sites derived from ground-based sources. New or specifically ‘aerial’ terms should be used only after their need has been carefully scrutinised and agreed as a necessary addition to the existing terminology.

The structure of the databases, and of the search mechanisms provided by the chosen software, should allow users to extract standard kinds of information quickly and efficiently. A newly established system should be as simple as is consistent with this aim, taking account of the amount of material likely to be handled in the short and medium term. It may not need to match the complexity of systems used by older organisations with bigger photo collections or a wider range of responsibilities. Nor should it aim to answer, instantly, *any* question that *any* user might *ever* put to it. It should allow relevant photographs or groups of photographs to be retrieved from the archive (whether stored digitally or as prints and slides etc). It should provide enquirers with basic information about the sites or subjects photographed, and it should tell users how, when and by/for whom the photographs were taken. A primary aim, especially if the record is open to non-specialists, should be a user-friendly front end, through which enquirers can seek and receive answers to standard questions without having any detailed knowledge of computers.

Flights into the future

Before turning to photo interpretation and mapping in the next part of the book it is worth repeating a few pieces of advice from the last three chapters.

- Choose your survey area with care. Then study its topography, geology, soils, climate and land use for their impact on what you might see from the air.
- Set clear objectives, in keeping with the nature of the study area and in scale with the resources available to you (including people as well as money).
- Form partnerships. Take advice widely. Disseminate results generously.
- Be as useful as possible to as many people as possible.
- Foster teamwork with your pilot, aero club, aircraft contractor and colleagues.
- Start modestly in the air. Never rush. Never compromise safety.
- Spend time on the basic skills of flying, site recognition and photography.
- Look carefully, assess logically, and only *then* take photographs. Quality is more important than quantity.
- Do not under-estimate the demands of post-flight processes – report-writing, photo- or image-processing, cataloguing, mapping, **record creation** and publication.
- Be prepared to go back to the same areas day after day, week after week, year after year.
- Do not just address traditional concerns or illustrate other people's projects – be aware that aerial survey can open entirely new perspectives on the past, many of them unanswerable through the use of ground-based information alone.
- Be blessed with good luck, patience and perseverance.

PART II

MAPPING THE PAST

Rog Palmer

6. Cataloguing, archiving and access
7. Photographs, maps and mapping
8. Photo-interpretation, transformation and record creation
9. Towards archaeological understanding

6. CATALOGUING, ARCHIVING AND ACCESS

The next four chapters deal with ‘post-flight’ aspects. These range from the initial record-keeping and locating that is necessary for all photographs, through discussion of types of photographs and maps, to photo interpretation. After this, discussion turns to methods of **transformation** and **mapping** the information to produce archaeological interpretations, and then to uses that have been made of mapped data to help pose or answer archaeological questions.

Introductory Note

It should be noted that Chapters 6-9 were for the most part written in 2003 and are reproduced here largely unchanged. Thus there is a considerable amount, particularly in the Chapter 6, which has become somewhat antiquated since digital photography has become the norm and as technological changes have been embraced. Nevertheless, the information will be useful to those who make use of ‘traditional’ air photo archives. There are, more generally, nuggets of sense and indications of good practice among these words.
(RP, September 2013).

The present chapter outlines processes that fall between aerial photography and photo interpretation. Digital images must be downloaded and backed up; traditional films must be processed, printed and numbered; each photograph needs to be located on a map and given geographical co-ordinates; a catalogue or database entry has to be completed; and films and prints or digital files have to be stored and made available for access. Full details of processing and printing ‘traditional’ films belong in photographic manuals – to which some readers may wish to refer. Advice and recommendations relevant to the safe keeping of films and prints can be found in Wilson *1997*. For the post-flight treatment of digital images see Appendix B.

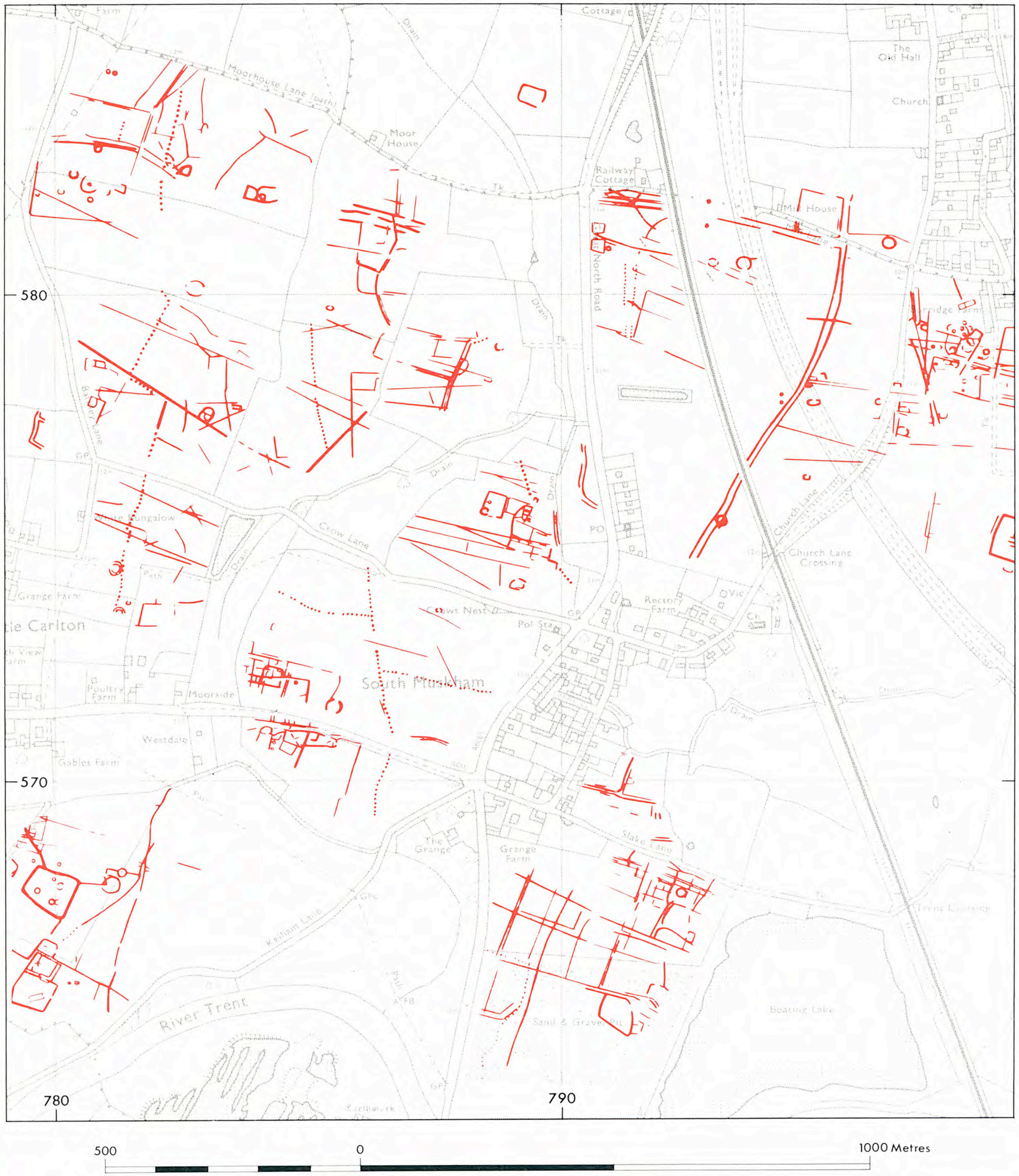


Fig 6. 1 A river-valley landscape

Elements of a past landscape in the Trent Valley in eastern England, mapped to show ditched settlements, fields and tracks that represent fragments of a once extensive system of land allotment of probable Iron Age and Romano-British date. The original mapping was at 1:10,000, possibly amended in places by reference to 1:2500 site plans. The mapped information has been overlaid on a modern map background, explaining many of the apparent 'gaps' in the archaeological record.

For different kinds of landscapes see Figs 9.1, 9.7,

Fig 6. 2 Natural colour film and false-colour infra-red

Two views of a settlement complex in southern Italy. On the left a digital image in natural colour, on the right as seen when using false-colour infra-red film. So as to show two matching images the left-hand photo has had to include the wheel of the aircraft in the corner of the frame, a thing that should normally be avoided if possible.

Processing and printing

After a flight the exposed films or digital files hold a unique record of **features** observed and photographed. Films should therefore be accorded the best processing that is available since the developed films become the primary data. Black-and-white and colour negatives need printing before the results can be used but each frame can be reprinted many times as necessary afterwards. By contrast, colour transparencies can be viewed immediately but are the sole record of the photography unless backed up by matching black-and-white photography. Colour slides or transparencies can also be difficult and expensive to duplicate to a high quality, though nowadays this would most likely be done by making digital copies, for example for use in publications or in Powerpoint presentations. After each flight digital files must be downloaded and copied to hard drive for any further processing and to DVD or other removable media for archiving.

Although all types of film can be processed by the photographer, it is usual for colour material to go to a laboratory. It is normal practice to make enlargements of all negatives taken. In addition, contact prints, especially of medium-format films, can provide a useful means of rapid reference within a collection. Black-and-white films can also go to a laboratory for processing, but some people (including both UK authors) have in the past done their own developing and printing. This is one way to ensure that the resulting prints are of a quality that will show archaeological features as clearly as possible. Prints made from digital files can also vary considerably in contrast and clarity and 'normal' printing may not always suit that required to bring out the best from an aerial view. With most digital files, however, it is a simple matter to increase the contrast before printing.

Express processor, professional laboratory, or film manufacturer?

Most express processors are set up to handle only 35mm colour negative film. Transparency and black-and-white films, if handed to such processors, may be sent elsewhere for processing and may take up to two weeks to complete. Professional laboratories and film manufacturers will usually process both 35mm and 120/220 roll film, though the laboratories dealing with this kind of work have decreased sharply in number since the arrival of digital photography. Express processors, many laboratories and film manufacturers can now also provide digital copies of photographs on CD but some laboratories offer a wider range of services. For example, transparencies can be made directly from negatives, duplicate transparencies can be made (potentially important if these are the only record from a flight), and prints and transparencies may be mounted on card or given data strips for filing in an archive. CD quality and price varies but this may be a useful option for those with digital archives or who use multimedia projectors. These considerations do not apply to in-air digital images but care, manipulation and archiving of the images are equally important (see Appendix B).

Black-and-white films

Most professional laboratories will process standard (panchromatic) black-and-white films and produce prints within a few days. Chromogenic films, using colour dyes rather than silver-based technology, are (or were) developed using the same C41 chemistry as colour negative film but prints must be made on black-and-white paper to ensure adequate contrast. A professional laboratory will do this but an express processor is more likely to make prints on colour paper, with results that will be somewhat grey and lacking in contrast. Your local laboratory will tell you whether it can deal with these or not. Ask about this before you use thoese 'specialist' films!

Colour negative (print) films

If possible, choose a good professional laboratory in your immediate locality. Get to know the people there and tell them about your work, the type of photographs you have taken and any special processing requirements. For archaeological subjects, especially those recorded in crop or bare soil, prints with high contrast should be specified. For buildings and possibly for **earthworks**, the laboratory's 'normal' printing may suffice. Laboratories may also advise a change of film type to help capture the contrast required. Most work will be machine-printed, leaving the option of later hand-printing for any frames that may be required for exhibition or publication. A good laboratory will advise whether there will be any significant difference between a hand-made or machine-made print from any one negative. Machine-prints can be made from only part of the negative if required. For most correctly-exposed photographs, and for file-prints, the additional expense of hand-printing will not be merited.

With an express printer or manufacturer your film is one of many to be processed at speed on any particular day. The machinery is set up to produce the best results from family photographs and, although prints of aerial photographs will be adequate, they may not be at their best. Better prints may be made later (at additional cost) so the choice of processor depends on why you want the prints. For instance, during the first Italian training school at Siena in 2001 all cameras used of were 35mm format. Prints were required by the next day for students to work on so an express printer was used for cheap and rapid turnround. A professional laboratory could possibly have worked at the same speed but the cost would have been more than doubled. As so many photographs had been taken of the same **site**s by different students the cheaper option was chosen. Normal turnround from professional laboratories in Britain is 3-4 days. Use of a film manufacturer (Kodak or Fuji, for instance) for processing will almost certainly mean that your films have to be mailed to a distant laboratory. Even using secure postage there is the possibility of loss or damage during the two journeys involved.

Colour reversal (slide) films and false-colour infra-red

In addition to processing and mounting transparencies, some express processors and manufacturers offer a prints-from-slides service – although this may only be available at the time of processing. This means that the original slides can be archivally stored and prints can be used for interpretation. The total cost (film, processing, printing) is higher than using negative stock, so why use slide film? There are claims that transparency film has higher resolution and definition than the equivalent-speed negative film – but for normal use this will not be apparent to a user.

Certain types of transparency film, notably the Kodachrome series, need to be returned to the manufacturer for processing. Kodak's current false-colour infra-red film can be developed using the normal E6 process or can be sent to the few laboratories still using the E4 process – which will process to the older blue and red false colours rather than to the dominantly reddish colour produced by the E6 process. It is important to check that any laboratory handling this material does not use infra-red sensors in the processing machine. If this is not checked the films may become partially fogged or totally ruined.

(This paragraph has been retained for information but 35mm infra-red film is no longer obtainable. Digital cameras can, however, be modified – permanently and at some cost and inconvenience to capture images in the infra-red range).

Digital images

The now extensive (in reality almost exclusive) use of digital cameras in the air gives rise to a different range of needs and opportunities, both in acquiring the original images and in dealing with their subsequent processing, archiving and use in **mapping** and interpretation studies. To avoid too many changes to this part of the text, however, these matters are discussed separately in Appendix B, the following sections being retained more or less unchanged for the benefit of those still using 'traditional' cameras and filmstock, or those who wishing to understand factors relevant to photographs and prints produced and archived before the widespread use of digital photography in the air.

The importance of good printing

A print that is good for interpretation does not need to show a true representation of reality. This is because the sometimes faint marks of archaeological and related/contextual **features**, in order to be more easily read and understood during mapping and interpretation, require printing at high contrast or, rather less often, to a darker level than normal (Figs 5.11 and 6.3). If a professional laboratory is used, their printers can be asked to boost the contrast but with many express processors or manufacturers there may not be the opportunity to specify such individual requirements. Colour prints are usually of reasonable quality from an express processor but black-and-white prints can be unacceptably grey and lacking in contrast.

Unless a collection is so new as to consist only of digital images photographic prints are likely to be the main source data consulted by users. For this reason alone the prints ought to be of the highest quality that can be afforded, and of a useably large size. This becomes especially important for photo interpreters working at reference collections where all work has to be done on the spot. When prints are examined, the library quality sets the achievable level of perception as there is unlikely to be enough money or time to buy copies of all that may be required. Laser copies or scans (the best of the 'rapid' prints provided by libraries) are not always adequate for identification of fine detail, and scan lines can cause 'interference' when copies are examined stereoscopically.

As well as the quality of printing, the size of the prints affects the level of interpretation that can be carried out. Most archaeological photo interpreters like to work with prints that have dimensions of about 250 x 200mm or 200 x 160mm (or the square equivalent), as these are sufficiently small to use with a pocket stereoscope and large enough for the interpreter to discern and trace interpreted details. Many also prefer to use black-and-white prints as these appear sharper and have higher resolution than colour prints of the same size.

Digital images

Digital images, either originals or those made from film stock, may benefit from simple image processing to adjust brightness, contrast and gamma to an optimum. Adjusted images can be cropped and saved in different formats to facilitate, for example, use on a Web page or in a multimedia presentation. Programs such as Adobe PhotoShop do this and a lot more, and both specialist photo-transformation programs discussed in Chapter 8 include a range of image processing tools. Others can be downloaded from the Internet. A useful paper about digital enhancement of rock paintings (*David* et alii *2001*) includes much that is relevant to the manipulation of aerial images. As with photographic printing, there are two choices available: the final image can represent reality, or it can show the archaeological features to their best advantage. The two may coincide but this is not always the case (Figs 5.11, 6.3).

High quality is also important when offering photographs for publication or for sale. A good print or digital image is more likely to be selected than a mediocre one. Sales of photographs will generate income that can be fed back into your project.

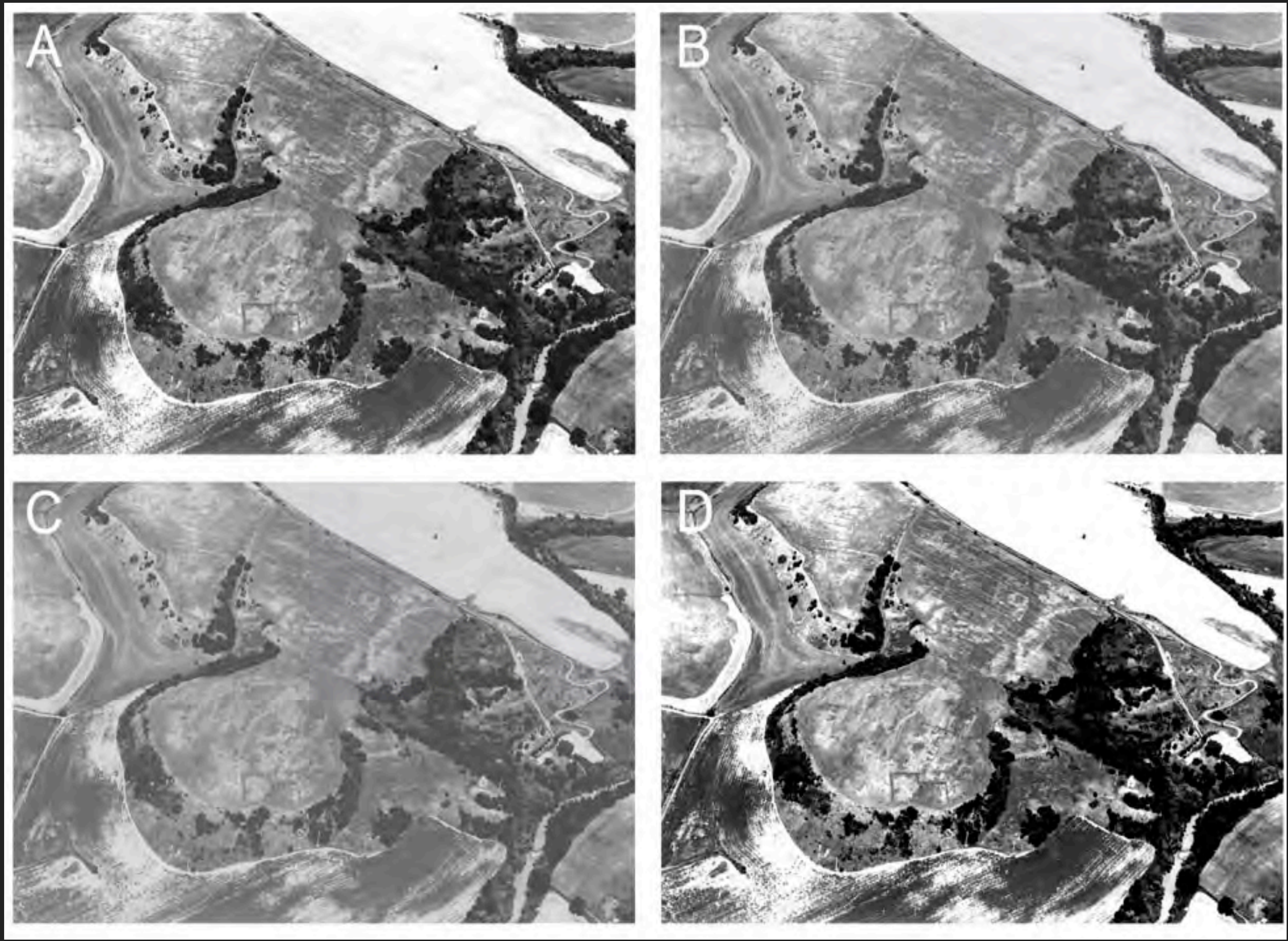


Fig 6. 3 Printing black-and white aerial photographs

Printing at different contrasts can affect the visibility of archaeological features in the resulting prints. The original photograph recorded a group of enclosures, pits and possible buildings visible as dark growth in unripe (green) cereal. The scans here mimic the effect of printing on different grades (contrasts) of paper.

A. The original photograph, printed to show archaeological features clearly and with adequate contrast. B. A print with slightly less contrast, as from an express printer dealing with 'family' photographs. All features remain visible but at lower contrast to their surroundings. C. A print with very little contrast. Some faint features may be difficult to interpret with confidence. The print by now has no true blacks or whites. D. A print with very high contrast, showing the archaeological features well. This kind of print is favoured by most interpreters. There is significant loss of detail in the dark and light parts of the print, however, making it difficult to identify control points in these areas. Knowledge of this kind will help to inform a photo laboratory what is required for oblique photographs of archaeological features.

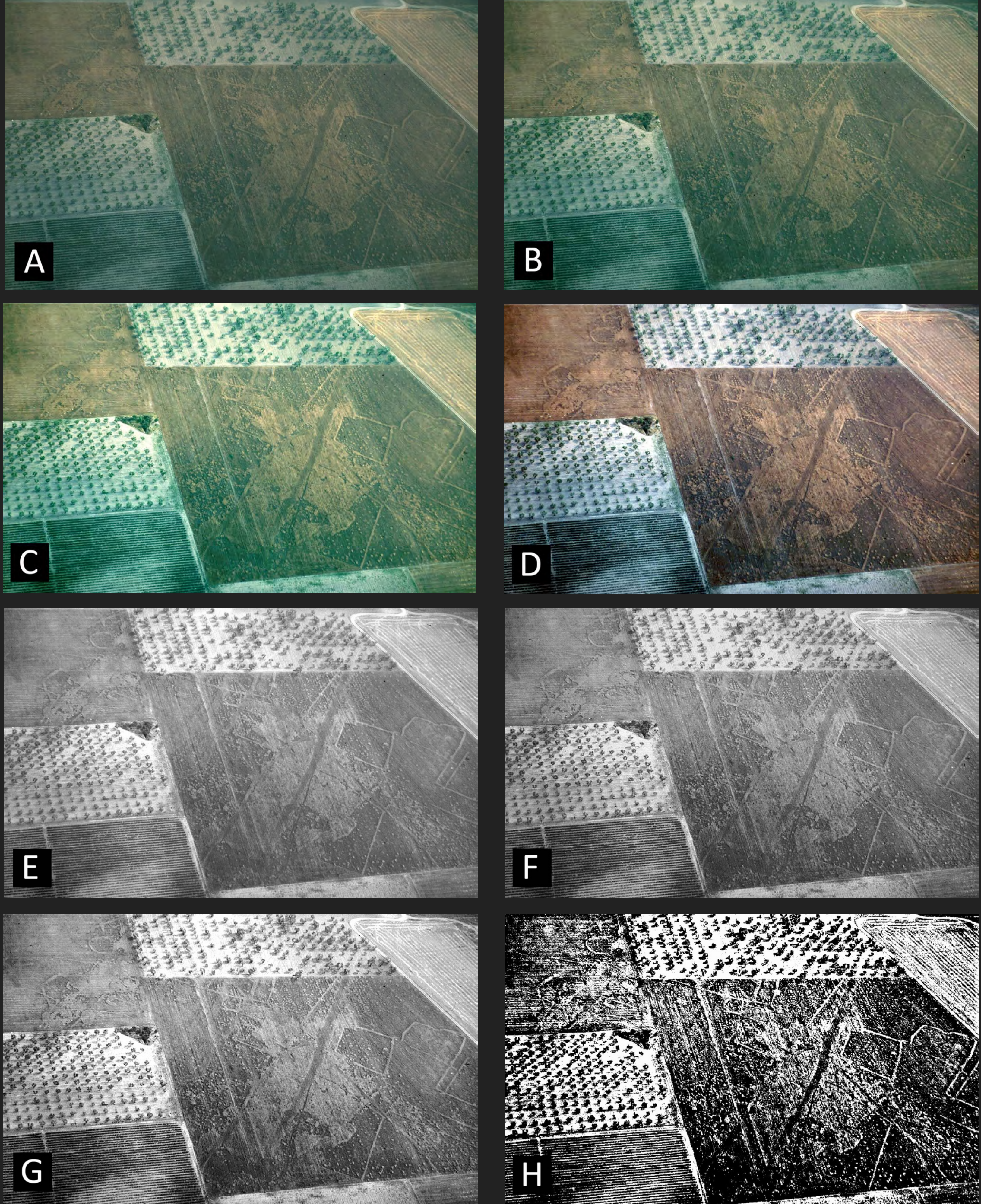


Fig 6. 4 Enhancing a colour image in AirPhoto

A. Default settings for Image Enhancement, with Scan of the original slightly under-exposed colour slide.
B. Brightness increased to 55%. This has produced good results in both dark and light areas.
C. On image B, use of Detail Filter at its default settings.
D. On image B, increase contrast to Fig 1.31, brightness by 5%.
E. On image B, convert to greyscale with brightness increased by 10%.
F. On image E, Image Enhance using default settings.
G. On image E, Image Enhance with Contrast Limit set at 15%.
H. On image G, Image Enhance to Threshold with Contrast Limit set at 15%. inform a photo laboratory what is required for oblique photographs of archaeological features.

These examples may guide manipulation of other prints but experiment is encouraged as each photo is likely to need its own settings to achieve the optimum image for interpretation.

Film and print numbering

Film numbers used during flight may be temporary. Use can be made of self-adhesive numbers on films or cassettes; these should be noted on the flight record sheet in the order of their use. A professional laboratory will retain the temporary numbers which, back at your office, can be exchanged for permanent archive numbers. The latter may take many patterns, perhaps following a numerical sequence (eg beginning with film 001), the order of the alphabet (film A to Z, then AA to ZZ and AAA to ZZZ etc) or the date of photography (09_001 for the first film of year 2009, for instance). The numbering may even include an indication of the film type (09BW001 for the first black-and-white film of 2009, or 07-CS-001 for the first colour slide film in 2007). Each individual photograph also needs its own unique number, which in many cases will be the film number plus the frame number from the edge of the film (eg 001/24, AA25, 09_001_26A, 09BW001/15 or 07-CS-001/34 in the above examples). With mounted colour slides or medium-format black-and-white films an alternative is to number the photographs in a single numerical or alpha-numerical sequence, marking the number with a spirit-based indelible pen on the slide-mount or (with great care) between the frames or on the edge of each strip of negatives (some archives will not allow anything to be written onto the negatives but this method at least has the merit of attaching the number clearly and permanently to the individual image). The archive numbers need to be added to the Flight Report form and should be used as headers on any forms or files that will be created.

Image files from a digital camera may be best written into a directory that could be named using the flight number and/or date of photography in addition to the frame/file number allocated by the camera. An alternative system involving batch re-numbering of the image files is described in Appendix B.

Archive numbers also need to be marked on each film and print. Films are usually returned from processing in transparent or translucent sleeves. The films should be removed from these and placed in plastic sleeves or other storage materials of archival quality (Wilson 1997). If there is no danger of mixing strips of different films it may be adequate to number just the sleeve, otherwise each strip should be marked with the film number. The sleeve may also carry other information such as the date, subject or general location, although this is not really necessary. On 120 or 220 roll film it may be preferable to write each film/frame number on the film edge or between the frames. The number may then be exposed during printing, thus automatically numbering each print. To avoid marking films and unmounted transparencies with fingerprints, they should at all times be handled wearing clean white cotton gloves.

Unmounted transparencies can be treated in the same way as negative films. If mounted, the film and frame number will need to be written on each mount. This may be done using a fine-tipped spirit-based marker pen of the ‘indelible’ type stocked by most office or art suppliers. Decide on a standard place for these numbers, remembering that later you may add a library number, co-ordinates, north point and a ‘spot’ to indicate ‘right way up’. You should always specify plastic rather than card mounts (which may fall apart with time). Mounts, especially those used by film-manufacturers, are often printed on the front face with lettering of various kinds. You should ask the processor to omit everything except the frame number, so that the blank spaces can be used for numbering and labelling to your own requirements.

Prints should come from processing in sequence. Check this by comparing them with the negatives and, using a light touch and a very soft pencil (6B or softer) or marker pen, write the archive film and frame number on every print. This can be on the reverse (near one corner) or on the front on the border. Some processing machines may print the frame number and date processed on the back of the print. In this case, only the archive number needs to be added. This is the minimum of information that is needed to identify a print and it should be added to them immediately the prints are returned from the processor. Later, it may be useful to add the co-ordinates of the **target** photographed, date of photography, and an approximate north point.

Use of a digital database for recording film data makes it seem logical to extend this to print out self-adhesive labels that can be stuck on the back or front of each print or slide. In many data-handling programs such labels can be quickly and efficiently generated at appropriate sizes once the database has been completed. They are tempting to use but while self-adhesive labels may be adequate for marking film cassettes while flying, it is not known how long the adhesive will last on films or prints in an archive. Their use is therefore unwise, as are self-adhesive spots (rather than indelible pens) to mark the corners of slides.

Locating photographs

If a GPS unit was used during flight, its output will need to be downloaded and converted to the user’s national grid, or to some other means by which the track and waypoints can be tied to the map. Numbered photographs can now be referred back to the Flight Record Form which should identify a GPS number and/or co-ordinates for each photographed target. The in-flight co-ordinates will give only an approximate location of the target and the task is now to precisely locate each photograph (or target) and assign co-ordinates. These should refer to the user’s national grid system or some universal system such as UTM and should aim to place each photograph (or target) to within 100m. There has been some discussion in Britain about which point these co-ordinates should indicate, the centre of each photograph or the centre of the target. There are also problems in assigning co-ordinates to very oblique views that may include the horizon. The authors favour reference to the centre of the target or, for general views, to a point about one-third into the centre-foreground of the photograph.

To locate photographs, they should first be sorted into target groups and examined to find that, or those, which show most modern detail as this is what will be matched to the map. A film-to-frame list on paper is a convenient way to link such groups and note their co-ordinates when they have been sited. This record form will provide the basis of any catalogue or database. If there are difficulties in locating any photographs it may be necessary, and is helpful for a beginner, to make a sketch map to combine information from several photos. Approximate north can be determined from the time of the flight and direction of any shadows. Prints or map can be rotated so that both are similarly aligned and then can be compared with the suggested location on the map. This will be done most efficiently using 1:50,000 maps if these are available and are of sufficient quality in the country concerned. Use of these for locating photographs will need a good eye or a magnifying glass, but they are likely to show useful modern features that will enable the work to be done reasonably efficiently. Some photographs will be easily and obviously located, others may require comparison with larger-scale maps – 1:25,000 or 1:10,000 – before they can be confidently located. It may sometimes be helpful to use previously catalogued photographs, obliques or verticals, to finalise the location of a 'difficult' photograph.

GPS data may have been collected in two ways when flying in a light aircraft to take hand-held photographs: an independent and continuous track of the whole flight may have been made using a preset time-lapse, or coordinates for each frame may be written to the EXIF file of a digital camera that logs the location of the camera at the time of exposure. Either, or both, of these are extremely useful when making an index of photographs after a flight. A GPS track can be saved in a format that will open directly in Google Earth and will show the route taken by the aircraft and any orbits made to examine and photograph selected targets. After a GPS track has been downloaded and saved, this is a common second step in the operation. Images in Google Earth are likely to show more detail than a map of any scale that will help locate a photograph. Two windows need to be visible on screen (or by using dual monitors) so that a user can see part of the Google Earth image with the track and the whole of each frame of the pictures to be located. A rapid way of locating new pictures is then to use placemark pins to mark the position of each. These are named using individual frame numbers. There are programs that will read this information and prepare a list without the user having to retype coordinate values (which can be easy to get wrong). These coordinate values will be in the system set by the user in Google Earth and thus restricted to variations on latitude and longitude or in UTM; they may later need to be converted to any local grid system that might be in use.

If a GPS has been used to write coordinates to an EXIF file the whole flight may be opened in a program such as GeoSetter (web reference Geosetter). The screen can be set up in various ways, but the default setting shows, on the left, a series of thumbnail images and a larger view of the one selected, and on the right is a zoomable area of Google Earth (or other internet maps) that, by default shows a pin at each camera location but can also be set to show a track. Once the correct location of a photograph or photographs has been found, a pin can be placed on the map and coordinates can be written to the EXIF file(s) and saved as part of the image metadata. Keywords can also be added if required. If you are working in local coordinates the location can be correlated between Google Earth and a map and the local coordinate values added to a table that is being prepared in a program such as Excel or Access.

Some photographs may never be located, though the conscientious recording of GPS locations in the air may help to reduce this eventuality. If you consistently have problems locating photographs on a map you (or your photographer) need either to fly higher or to use a camera with a wide-angle lens to take a 'siting shot' of each target – a broad view including plenty of modern features that will also appear on maps. If this is not done the lack of modern detail will again cause problems when mapping is attempted. The broad view is essential. Negatives can be enlarged to show archaeological detail that may have been invisible to the photographer during flight but they cannot be expanded to show modern features that were not included at the time of photography. This was emphasised recently by Michael Doneus: *'… the author wants to stress that providing good control information on aerial photographs should be a concern of the archaeological aerial photographer. Even if modern hard- and software may make it possible to correct for a certain degree of neglect, the expenditure of time and money is still high compared with a little responsible thought (and action) while in the air.'* (*Doneus 2001a*, p. 27).

Written catalogue

The amount of elaboration in a catalogue will vary with the expected searches that will be made of any collection. At its most basic, the catalogue may consist of an ordered list of locations (as co-ordinates) cross-referenced to photo numbers. A more detailed catalogue may include dates of photography, possibly named locations, and the main subject or **site** type photographed. Any catalogue can be used to assign multiple descriptions, but use of a relational database (visual or text) eases the compilation of one which will have the versatility to help general enquiries or to answer specific queries.

If the sole purpose of the photographs were to provide data for interpretation and mapping, the list by co-ordinates would be perfectly adequate as the interpreter would use the catalogue only to identify photo numbers that cover the area of interest. If photographs are stored in co-ordinate order, even that basic list becomes irrelevant for searching as the user can go directly to the box (or file) that holds the required prints. However, it is likely that many enquiries will ask for photographs of certain types of site (archaeological or not), and so a subject index – capable of being expanded to add new topics or site types – is necessary. Fig 5.14 shows one solution to that need in paper form (for later transfer to computer). See also the final part of Chapter 5.

Storage and access

Films

Negatives and transparencies are the most valuable part of a photographic collection. Damaged or faded prints can be reprinted, but damage to the original films may be irreparable. This can range from scratches and fingerprints caused by careless handling to complete loss of a black-and-white or colour image due to chemical deterioration. This has already led to losses of some invaluable material (colour and monochrome) in England, France and no doubt elsewhere. Films should be kept in a dark place, protected against extremes of temperature and humidity and secure from fire and flood. To help avoid catastrophic loss they are best stored in a different room or building from the prints and, to reduce the danger from flooding, neither on the ground floor nor immediately below the roof. For further advice on film storage see *Wilson 1997*.

Prints

Prints of **oblique aerial photographs** or short runs of verticals (one to three frames) are best kept in archival-quality box-files or flip-top boxes, in neither case containing more than about 250 prints. The prints themselves may be in paper or card-and-plastic sleeves, each containing the prints from a particular co-ordinate square. If stored in flight or film order no such sleeves are needed. If possible, and certainly in any in-house collection, prints should be made to a standard size or at least kept in standard size pockets. This helps browsing and also means that small prints do not get dropped and scattered across the floor when a handful of photographs is extracted from a box or pocket containing mixed-size prints. Stereo prints must be kept together in a way that facilitates their viewing. Long runs of vertical prints should be kept in film and frame order.

Colour slides and transparencies

Unmounted 35mm or medium-format transparencies should be treated and stored in exactly the same way as black-and-white or colour negative films. Storage of mounted transparencies for easy access may cause problems. Perhaps the best way is to slot them into archivally stable transparent file-sheets that can then be stored in metal filing cabinets or archival-quality ring-binders or box-files. To avoid excessive handling the slides may be kept in film order but will then require an efficient index if they are to be searched for a particular co-ordinate, site or subject. This problem can be avoided if the transparency collection has been scanned and catalogued using suitable image-archiving software. This will facilitate searching and viewing and will also avoid user-contact with the original transparencies. However, the scanned resolution needs to be decided with the end purpose in mind (see Digital data below).

Storing prints: geographical order or flight order?

There are two conflicting approaches to the filing of oblique air photo prints. One maintains that they should be stored in some form of geographical order. The other simply files them in flight (or film) order. Both systems have their supporters and neither has a monopoly of merits.

Most enquirers, including photo interpreters, will ask, “Have you any photographs of place x?” Therefore storage of photos by co-ordinates (in kilometre or five-kilometre squares within the national grid, for instance) provides a simple but effective means of retrieval. This is the method used by most of the national libraries in Britain. It means that a user (or librarian) can go to a single box, or to adjacent boxes, and immediately retrieve all the photographs for a required target or area. Storage in flight or film order, as in some other air photo libraries in Britain, saves time initially because each new batch of prints is simply added to the ‘open’ end of the collection, without re-sorting into geographical order and filing in boxes throughout the collection. But it needs a good and readily accessible catalogue to allow relevant prints to be identified (by enquirers or library staff) when the collection – or the number of enquiries – becomes large. As an example of the problem a representative piece of interpretation and mapping work to examine a small (80 hectare) area required this writer to extract (and later put away) 61 oblique prints taken between 1954 and 1981 from 15 different boxes scattered among about 2500 film-order boxes stored in 14 separate filing cabinets. In another collection, where prints are stored in co-ordinate order, 145 oblique photographs of the same area were immediately available in a single box.

The decision on which system to use lies with the individual needs of the organisation involved and, in particular, its manpower resources at each stage of the process.

The usual way of storing vertical prints is in film and frame order. This does not cause the same problems as with obliques since prints that cover any particular area will consist of a series of adjoining frames. Prints should be kept in archival-quality boxes but should not be put in individual transparent pockets. The latter may provide a quick way of seeing which are missing but makes them tiresome to use as every print has to be removed from its pocket for viewing and for stereoscopic examination – and then put back again. It is unwise to break up runs of vertical photographs and file them by place-name or co-ordinates, as to examine prints stereoscopically can mean that adjacent place-names or co-ordinates have to be identified and additional photographs located.

Digital data

Primary digital data

Primary digital data is that which comes directly from digital cameras which have now achieved such an advanced level of quality and internal systems that they have for the most part replaced traditional film-cameras for aerial work. With the aid of good-quality zoom lenses and large-capacity memory cards they vastly simplify photographic processes in the air. After downloading from the camera, the original and unaltered digital files should be written to removable media, preferably duplicated for safety and with a working copy on an accessible hard disc. Library copies will need to be indexed in a way, or ways, that allow their recall through use of the main catalogue. All archival digital data will need to be maintained over the years in ways that ensure their compatibility with new generations of software and hardware.

Enhanced or manipulated images must be saved using file names that clearly indicate that the file is not the original image. Care also must be taken not to destroy or overwrite an original image file. Many enhancements may be created as temporary files, made for a single use and then deleted. Working files of this kind should only be archived if they are essential to explain how the final result of an enhancement exercise was reached.

Secondary digital data

Secondary digital data can be created by scanning negatives, transparencies or prints. Many vertical survey companies now sell high-quality copies in this format in preference to making photographic prints. Oblique photographs may be required in digital form for a variety of reasons. A digital index can operate successfully using medium-resolution scans from prints (at around 1500 x 1000 pixels). For photo interpretation, higher resolution may be needed. For this it may be necessary to scan the original negatives or transparencies rather than the prints so as to obtain the maximum amount of information. This, however, requires high-tech and high-cost equipment, which may not be immediately available. Specialist bureaux, however, can be used for making occasional high-quality scans (so long as the photo-library will allow the original negatives or transparencies to be removed temporarily from their care). Another advantage of scanning from negatives is that print and negative formats rarely match exactly and useful control information may be cropped from the edge of the frame during printing.

Secondary digital files that are to become part of the archive need to be written to the working disc and copied to removable or external media. Unless a collection is to be wholly digital it may simply be sufficient to note in the catalogue that a digital copy exists. Conversely, in a digital collection, it may be useful for the interpreter to know which files have readily accessible prints that can be examined, for example, as stereo pairs.

Final thoughts

This range of tasks and their organisation may seem formidable at first but it is essential that aerial photography is served by an efficient and effective ground-based system to ensure the best care and preservation of the irreplaceable information that has been recorded. After the expense of flying for aerial survey it is false economy to take precious films to a poor-quality processor whose use of, for example, exhausted chemicals could lead to deterioration or loss of the photographic record. Similar principles apply to the creation and archiving of digital files and their related metadata (see Appendix B).

A hard-copy collection, whether based on film photography or primary digital data, needs to contain top-quality prints, at a reasonable size for the uses envisaged, and must be clearly ordered if retrieval is to be effective. This means that not only must photographs be put in order to begin with, but also that they must be replaced in that order each time after use. The catalogue, whether paper-based or digital, must be accurate and informative and must allow easy access to photographs through various routes of enquiry.

If you are establishing a collection as a reference library do not lend photographs (especially original negatives, colour slides or transparencies) to anyone, however senior. Experience shows that there is a clear risk of loss or damage however much you emphasise that they are irreplaceable. Provide working space, with a range of optical or digital viewers. Make – and keep – rules that prohibit smoking, eating and especially drinking anywhere near the photographs.

Finally, encourage use of the collection by archaeologists and colleagues from other disciplines as well as by the general public. Aerial photographs, even those taken specifically of archaeological targets, include much information that is of interest to others. Geographers, environmentalists, crop specialists and soil scientists have made considerable use of photographic collections in Britain and there is no reason to think that this will be any different elsewhere. Encouragement to others can be done by providing displays of interesting or significant photographs or examples of mapping projects, and may be enlivened by including sites that have been photographed because you do not understand them. A ‘what is this?' picture can attract a lot of attention and may lead people to further investigate a collection. The more use others make of a photo collection, the more 'indispensable' it may become, to the extent of securing continued or supplemented funding to assist your project.

7. PHOTOGRAPHS, MAPS AND MAPPING

Introduction

It is rare in Britain that an aerial photographer follows through the remaining processes of aerial survey to interpret and map photographs that he or she has taken. It is equally rare that an interpreter is more than 'touristically' active in the air. The two jobs tend to attract different kinds of people, who are likely to have different aims for their roles in archaeology. The photo interpreter enjoys teasing out evidence from many small pieces of information in order to unravel and so 'discover' the past. The aerial photographer enjoys the more instant excitement of discovering and recording things from the air. However, there is much to be gained if one person is able to do all aspects of the work or if a close-knit team can be assembled and kept together.

As an interpreter you will probably have to use the work of several or many different photographers. If there is one who works in your local area it is worth spending time with him or her to explain just what is required to assist your work – in particular the need to include **control points** which will relate photo to map during **transformation** and **mapping**. The advice on the following pages, especially if accompanied by practical work on photographs, will begin to familiarise you with different types of photographs and help you to decide what is right for photo interpretation.

This chapter is about the data the photo interpreter works with – maps and photographs – and how the two may be combined. Lessons learned here are expanded in Chapter 8 when these data are used for photo interpretation and **mapping**.

Why map?

Most books dealing with the uses of aerial photographs in the natural sciences show a staged progression from photo reading to photo interpretation. They also stress that the latter has to include **mapping**. This book omits discussion and description of the stages of photo examination but asserts most strongly that photo interpretation must include **mapping**.

A photo interpreter will be working with collections of material that record disparate fragments of past **site**s and **landscape**s. Mapping allows these fragments to be combined into a single picture (Figs 6.1, 7.1 and 7.3). Without mapping, the best that can be done is to make a detailed description of **feature**s seen in the photographs. By making a map we are able to indicate exactly which features we think are archaeological, which natural and which recent, so as to produce a considered interpretation of what are otherwise just marks on a photograph. Mapping a single site enables features to be located accurately on the ground. Plans of different sites can be measured to provide data that facilitate their comparison. As well as recording detail of individual sites, aerial photographs also provide a superb resource for the examination of extensive landscapes from the past, yet this is not in any real sense possible until they have been interpreted and mapped.

Mapping allows the photo interpreter to combine, locate, measure, and build up information that has often been collected on a number of different flights over a time-span of many years. It should be obvious from the first part of this book that the occurrence of archaeological features is irregular and unpredictable. Information on vertical photographs and from satellites will be particularly dependent on the time of year and day when they were taken, even though they have the capability to record everything that was visible at the time of exposure. Oblique photographs tend to be targeted on single modern fields, or parts of them, in which archaeological features have been identified by the airborne observer. Vast numbers of new discoveries are made each year in Britain – often on each flight – despite more than fifty years of reconnaissance by Cambridge University, various official bodies and local fliers.

With both single sites and wider-spreading landscapes, the preparation of a map that also includes natural features can aid archaeological understanding. The relevant information may be contours, to show the topography, or other features such as watercourses and palaeochannels that may have determined or affected the location of settlements and the uses made of the land. An example can be seen in Fig 7.2 which makes clear that this simple addition contributes significantly to any archaeological interpretations that we may make.

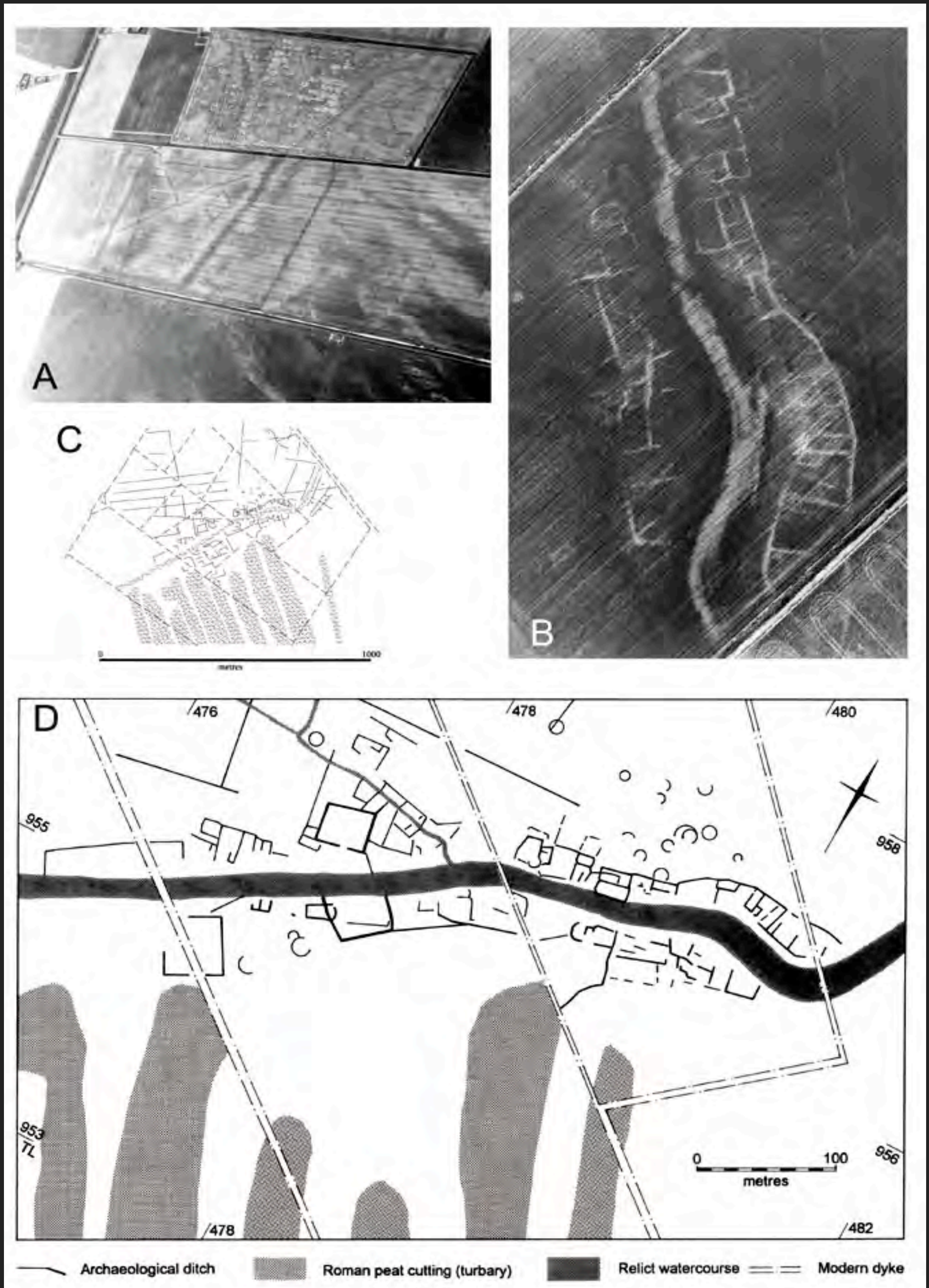


Fig 7. 1 **Combining information at different map scales**

Photo A shows archaeological features in the central field. There are hints of their continuation in the upper field but parts of the crop there have become beaten down by rain or wind, making any archaeological traces unreadable.

Photo B, taken nine weeks earlier, shows the upper field in exceptional detail. By combining interpreted information from these and other photographs maps can be produced that depict different levels of detail and have different uses.

Map C is an extract from a survey of 1400 sq km of the low-lying Cambridgeshire Fenlands in eastern England. Photo interpretation was carried out to produce mapping at 1:10,000 scale as a rapid summary of Fenland archaeology. At this scale sites can be seen in context, relationships with other features can be identified and analysed, and most archaeological features can be depicted with reasonable clarity and accuracy. Interest in the Fenlands increased as new aerial information became available and as considerable field evidence was collected for Roman-period settlement and salt-making.

Map D. After the collection of this new evidence further mapping was undertaken at a scale of 1:2500. This focused on the settlement /salt-making sites but also showed some of the peat-cutting areas (shaded) which provided fuel for the salt-making process. The larger scale allows more detail to be shown. The interpretation adds information from photos taken after the 1:10,000 mapping had been completed.

However complete one phase of mapping appears to be, examination of new or different photographs can add detail and confirm or disprove features previously mapped.

It may be necessary to combine information from two or more photographs so as to complete the plan of a single site. It becomes essential to examine as many photographs as are readily available if the environs of that site, or larger landscape, are to be studied. It is the nature of oblique aerial survey to pick out and photograph those fragments of the past that are visible on the day of photography, and vertical photographs are similarly restricted to recording only what is detectable at the time of their exposure. Therefore a complete archaeological landscape is unlikely ever to be photographed on a single date and the interpreter needs to combine the evidence from a number of flights, often spread over a considerable period of time. This is definitely the case in lowland areas where **archaeological visibility** is dependent on crop growth or farming routines, and is likely to be similar in upland areas where shadows and directional lighting may 'hide' upstanding **features** on steep slopes facing away from the sun. Modern computer software allows a photo mosaic or ortho-photo to be made of all the relevant pieces, but a more intelligible result will be produced by a map that shows and distinguishes between different features interpreted from the photographs (Fig 6.1).

The recoverable landscapes will vary in different terrain and in different parts of the world. For the cultural past to become visible on aerial photographs requires there to have been either earth-moving (usually by digging holes or ditches) or structuring of stones or other material (to form, for example, banks, walls and buildings). Aerial photographs are unlikely to record evidence of past sites which consisted of small fences, tents, or temporary **enclosures**, like those made of thorn and other branches in parts of Africa. Even within hole-digging or stone-moving communities the use of 'civil engineering' will vary from place to place. Examples are illustrated in Figs 6.1, 9.1 and 9.8 from two survey projects that mapped and analysed three different topographical locations: a river valley, a piece of chalk downland and an area of hill country (*Palmer* 1984; *Whimster* 1989). These and other examples are discussed in more detail in Chapter 9.

Mapping, and analyses of the resulting maps, are beginning to raise new questions that require a fresh type of field investigation to help provide answers. Landscape study – aided so much by **air photo interpretation** and mapping – is desperate for approximate dates that can be provided by small-scale excavation at crucial points or intersections. Unfortunately, 'minimalist excavation' of this kind is not currently fashionable in Britain although some useful data have come from projects of field-walking survey.

When compiling maps of past landscapes it is important to try to take account of contemporary features that will not be visible from the air. Crucial among these are areas of past woodland that must have been of considerable importance, and value, in all times up to the relatively recent past but of which there remains little trace in the landscape of the present day. Air photographs may record the former boundaries of now-shrunken areas of woodland, though many of these changes may have taken place in relatively recent times. In Britain, some of these features may have Saxon and medieval origins, but earlier woods are almost impossible to identify definitively on the ground or from the air.

Finally, maps showing levelled archaeological features also need to indicate those areas where no information can be, or has been, recorded from the air. These so-called 'negative zones' include roads and railways, built-up areas (beneath which no **aerial information** will be visible), woodland (which sometimes can mask earthwork features), and bands of deeper soil such as alluvium (which is often too deep for roots to penetrate and enable crop growth to indicate subsoil differences). Knowledge of these negative zones helps archaeological interpretation, which may otherwise read false significance into apparently 'empty' spaces on maps (see for instance Figs 6.1, 9.1 and 9.4).

What shows on air photographs in addition to archaeology?

Many archaeological features are illustrated in the aerial photographs published in this book. However, any single aerial photograph is capable of recording information derived from many causes and spanning many millennia. An archaeologist acting as photo interpreter therefore needs to have broader vision than archaeology alone so as to be able to isolate the archaeological evidence. There are many other kinds of specialist photo interpreters – the geological structure of the earth is examined by those seeking oil-bearing strata, the health of trees and crops can be noted by other specialists, while military interpreters may be able to identify not only the type of factory photographed but also to estimate its production capacity. No one person is likely to have the training or experience to identify everything recorded on an aerial photograph and archaeologist interpreters have their own specialist range of features to identify and explain. Archaeological interpreters work in similar ways to airborne observers but examine photographs, instead of the ground, to sort cultural elements from others (see *Chapter 5*: 'searching out the archaeology'). An advantage is that an interpreter has more time to look and think, and may also be able to examine and compare photographs taken on different dates before reaching a conclusion. The next few paragraphs describe and illustrate some of the more common non-archaeological features that occur on

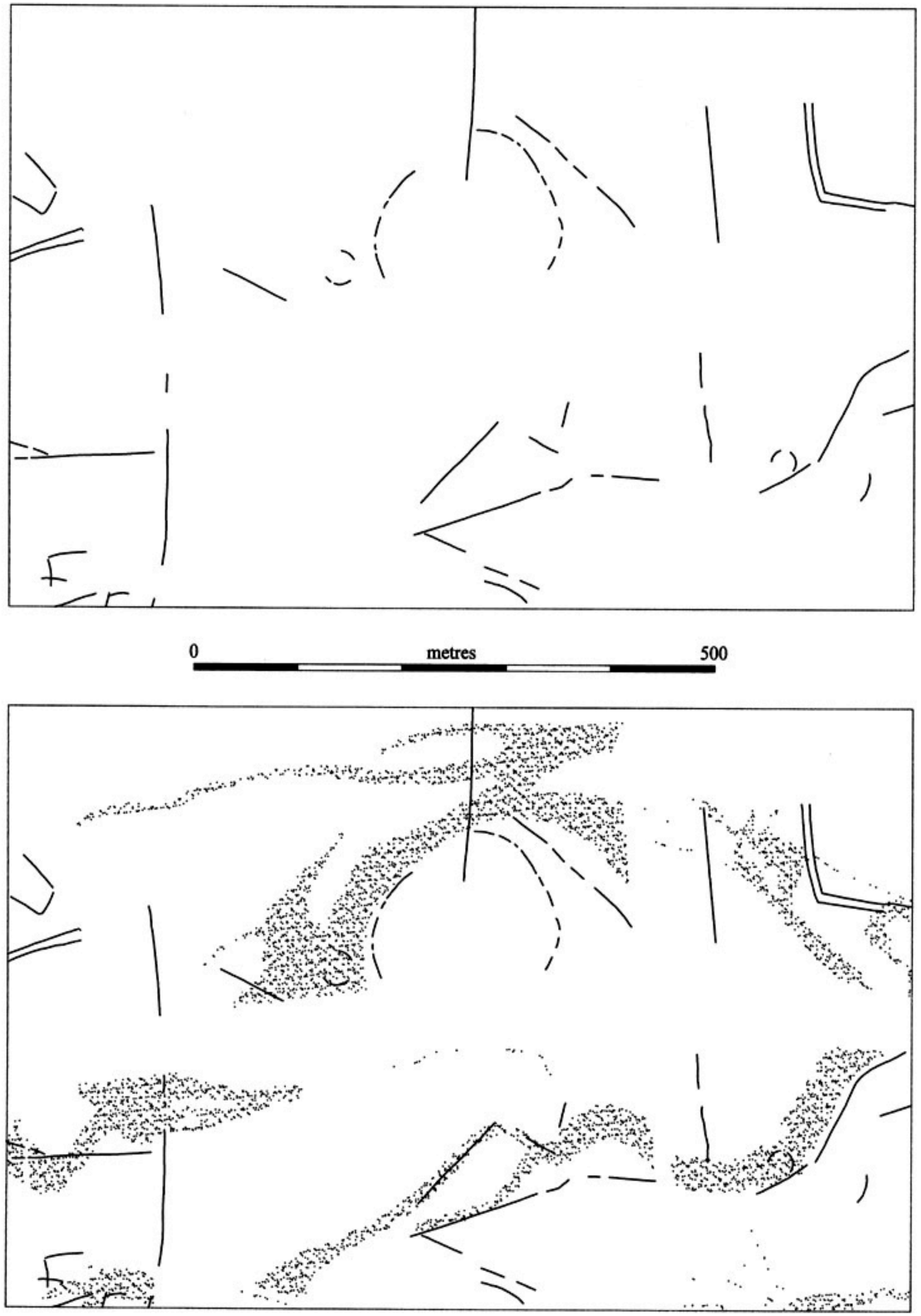


Fig 7. 2 The relevance of natural features

Central to each of these two maps is the ‘dashed’ plan of a Neolithic interrupted-ditch enclosure at Etton in eastern England. The upper map shows only the archaeological features and allows their sizes and relationships to be seen. In this virtually flat landscape their relationship with the micro-topography cannot be seen and may not even be apparent through a closely contoured survey.

The lower figure adds palaeochannels that were recorded on air photographs. These are known to have been active watercourses in the Neolithic. The resulting map shows that the Neolithic enclosure was constructed within a loop of a stream-channel, possibly on a small island, with much of its design dictated by the watercourses. Omitting evidence of such natural features reduces the information-content of the resulting maps (at whatever scale) and handicaps our understanding of the past.

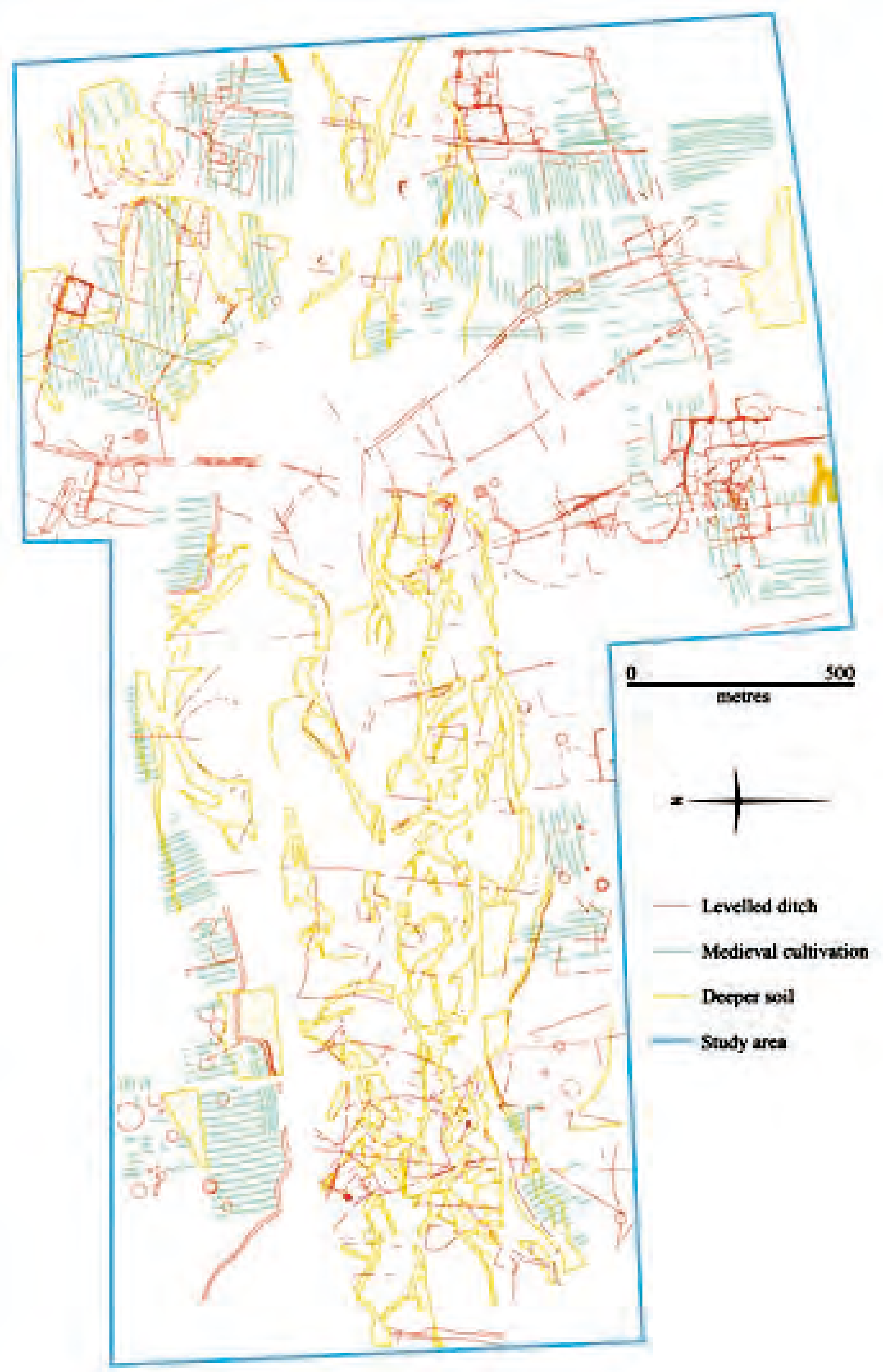


Fig 7. 3 Combining natural and archaeological evidence to map a local landscape

This figure was originally mapped at 1:2500 to record archaeological and natural features within a 400ha study area in the Welland valley in eastern England. More than 500 photographs were examined (about 180 verticals and 325 obliques), from which 26 verticals and 22 obliques were selected as the principal source for the mapping. Ditched archaeological features include the Neolithic enclosure shown in Fig 7.2.

There are also clusters of ring-ditches that probably belong to Bronze Age cemeteries and a linked system of settlements of probable Iron Age and Romano-British date with fields and drove-ways on two different alignments. The ditches of the fields cross watercourses that are known to have been active in the Neolithic, indicating that the streams had dried up or changed course in the subsequent 2000 years.

Parallel green strips represent medieval cultivation, part of which (in the north of the figure) is bounded by a double-ditched track perhaps dividing arable land from pasture. Many of the 'empty' spaces in the map are due to modern features, as would be apparent if a present-day map were used as a background.

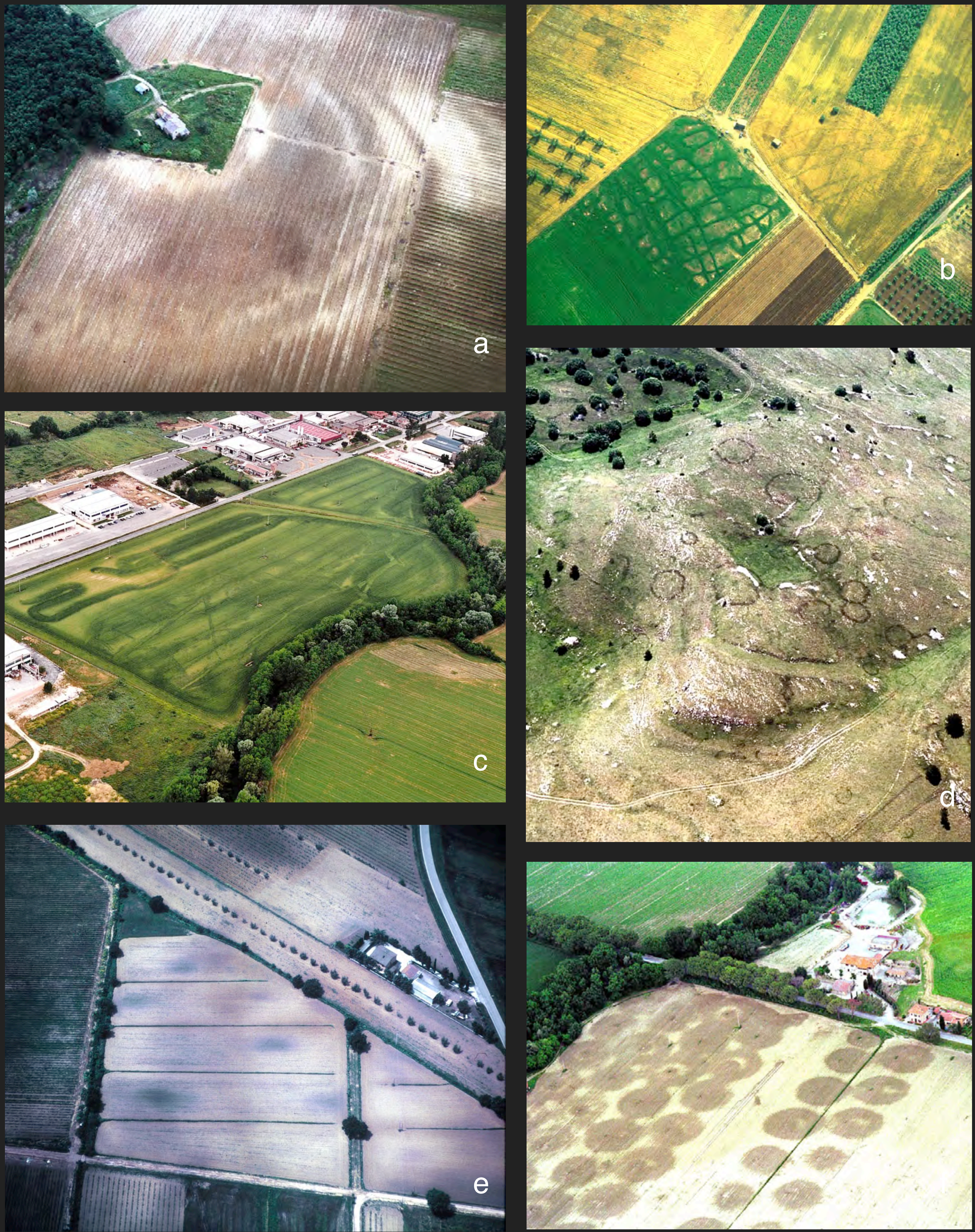


Fig 7. 4 Uncertain interpretations: ancient or modern?

Patterns in the landscape are not always of archaeological origin. Some of the most common non-archaeological phenomena are shown here.

a) Geological marks superficially resembling a multi-ditched enclosure on a slight hilltop or promontory, caused by underling layers of softer and harder rock.

b) Cracks in the bedrock, particularly in limestone, can produce marks which at first sight seem to have a human origin. Again, the cause is entirely geological.

c) These wide and soft-edged lines of darker crop are caused by the spreading of modern fertiliser, with tractor turning circles at either end of the field.

d) 'Fairy rings' are often mistaken for traces of circular huts. Their irregular size and relationships betray their natural origin as wholly natural features caused by gradually spreading rings of fungus growth. Such rings are only ever seen in grass.

e) Isolated black marks in open fields usually denote charcoal burning or the deliberate firing of individual trees in the final stages of woodland clearance.

f) The regular pattern of these circular soilmarks, and their alignment with the modern field boundaries, show that they are not circular tombs but the result of present-day watering with rotary sprays.

different geological formations and that show in soil- or crop-marked form alongside archaeological features. There is no one list of all such features as they will differ in different places and with different modern land-use, but the examples in Fig 7.4 may indicate some types that are relevant to the archaeological interpreter. For a broader range of non-archaeological features, mostly from Britain but commonplace in much of temperate (and perhaps Mediterranean) Europe, readers are recommended to examine the illustrations in *Wilson 1982* or *2000*. For Italian readers there are also useful summaries in *Alvisi 1989*, pp. 83-6 and *Piccaretta–Ceraudo 2000*, pp. 124-8.

Both non-archaeological and archaeological features are recorded as variants of the same phenomena. Thus light and shade helps identify form, whether natural or man-made. Soil colours (or differing tones on black-and-white photographs) can show deeper or shallower soils that may indicate things such as silt-filled natural lakes, recent quarries or prehistoric walls and ditches. Crop growth, photographed as changes of colour, texture, tone or plant density may differ over any type of holes or bumps in the ground, not just those remaining from archaeological features. This means that archaeological interpreters need to know the range of non-archaeological features that are likely to be present – most of them can be, and sometimes have been, mistakenly identified as archaeological features. Terms such as 'cropmark' and 'soilmark' do not in any sense refer only to archaeological features since these are the mechanisms through which a wide range of sub-surface irregularities may become visible.

Geology

Some types of bedrock can be identified by the distinctive pattern that they exhibit when viewed from the air. Limestone, for example, often shows a network of fine fissures (Fig 7.4b). Some natural patterns have been mistakenly attributed an archaeological derivation by the inexperienced or unwary interpreter – and even the 'famous' occasionally make such mistakes. But this is to be expected as any open-minded photo interpreter will learn more each time a new, or old, photograph is examined.

Periglacial features include so-called 'ice wedges' or 'frost cracks' that are found on many gravel soils in temperate and colder countries, as well as in the southern foothills of many mountain ranges. These can sometimes form fairly regular extents of crossing 'ditches' that look similar to ancient field systems, though sometimes on a grander scale (Fig 7.5). Careful examination of the photographs will show that these features lack the coherence of most genuine field systems and are devoid of associated tracks or other means of access. Frost cracks were fissures in the ground which over time became filled naturally with local materials. This gives them the ability to affect crop growth and they are often recorded alongside or beneath archaeological features. Their form on photographs often, but not always, differs from dug archaeological features in that they tend to be less consistent in width, with irregular or ill-defined edges, and to follow a more sinuous course than the majority of man-made ditches.

Periglacial conditions also caused pitting in the substrata. It is difficult, if not impossible, to distinguish a single natural pit of this kind from a deliberately cut one but when they occur in groups and in association with obvious archaeological features it may be possible to draw a distinction between natural and man-made pits. Crop-marked natural pits often appear to have diffuse edges like ice those of wedges, and in places they can be clustered so closely together as to blend into an amorphous dark area on the photograph. Both types do occur alongside archaeological features within or adjacent to occupation sites, so thoughtful and cautious interpretation is required.

Another source of confusion comes from a type of feature that could be called a 'geological **hillfort**'. These can occur on layered geological strata and are known on chalk and limestone in England and for instance in the Czech Republic. A probable example in Italy is shown in Fig 7.4a. The changes of the rock strata or accumulated soils at their junctions can affect crop growth or show as bands of lighter and darker material in winter. To the unwary these can look similar to a ploughed-out **hillfort**. More critical examination will show that on some such sites the 'ditches' and 'banks' just do not make archaeological sense but instead show as a series of irregular and sometimes offset lengths of darker and light marks. Others show a multiplicity of circuits that can cover the whole of a hillside. No genuine **hillfort** would present such a plan.

Recent

Recent features can sometimes appear very similar to archaeological ones. Pipelines buried under the ground can look somewhat similar to Roman roads (Fig 7.6). Sometimes compacted earth left by the pipe-laying operations will be recorded with the same characteristics as a metalled surface, but clues may come from examining the course of such a linear feature. If the feature changes course where it crosses modern boundaries it is likely to post-date them, or if it ends in what is clearly a pumping house or sewage works it can clearly be identified as part of a modern system. Many pipelines have marker-posts at field divisions and these may be seen on air photographs and so identify the nature of the linear feature that links them (Fig 10.53).

On certain soils there will be evidence of hand-dug quarries, of almost any date from early prehistory to the present day. When back-filled and in arable land a quarry will influence crop development in the same way as any other former hole in the ground and will become a reservoir for moisture and nutrients that will encourage crops above it to grow differently. In bare soil the filling of a quarry may be visible as a darker feature

Fig 7. 5 Frost-cracks or field-system?

Crop growth has increased over fissures caused during a periglacial period, now surviving as a network of soil-filled cracks below the ground (known as 'frost-cracks' or 'ice-wedges'). Their regularity has sometimes led to their misinterpretation as ancient field systems, though this can be discounted in the illustrated example. Natural features often have indistinct edges and variable widths compared with the more sharply-defined edges and regular widths of archaeological ditches. The circles in this photograph represent the filled-in ditches of Bronze Age burial mounds.

Fig 7. 6 Modern pipeline or Roman road?

The parched crops above the linear feature running vertically in the picture show they overlie a hard or compacted surface. Unlike a Roman road this feature changes direction at modern field boundaries, suggesting that it is a recent pipeline. This is confirmed by the dark line of the pipe-trench down the centre of the cropmark in the foreground, with lighter marks above compacted soil on either side. Part of the pipe can also be seen in the middle distance where it crosses a stream-bed. Such pipelines often have marker-posts at field-boundaries, as in Fig 10.53, and changes of direction tend to coincide with modern features such as streams, field boundaries or highways.

compared with its surroundings and, on some soils, there may be a lighter rim left by a residue of upcast material from the quarry itself. Small single quarries recorded thus may be mistaken for the hollows and pits that frequently occur within settlements. Hand-dug quarries also occur in groups, sometimes planned and of regular size and form, but more often as a scatter of irregular features that may cluster in or near the corner of a modern field – presumably for ease of access by carts or other means of removing the quarried material (Fig 10.27, *bottom*).

Rows of perhaps of three to six pits are sometimes recorded in the countryside. These may be of archaeological origin but they could alternatively represent a row of bomb craters from recent military conflicts. There is no easy way to distinguish one from the other when they appear in cropmarked or soilmarked form unless one has access to wartime photographs that may show them as craters with a surround of upcast soil. In arable land they were usually backfilled and ploughed level soon after they had been created and there is unlikely to be any surface **trace** other than, perhaps, a scatter of bomb fragments. If there is one pit missing from an evenly-spaced row this could indicate an unexploded bomb – so caution is advised during fieldwork or excavation!

In Britain some features from as recent as the 1950s are now given archaeological recognition (*James* 2002) and it may be necessary on occasions to map (for example) disused military sites. Collections of historical air photographs may allow an interpreter to document the development and decline of such sites. These may have had beginnings in the First or Second World Wars, been altered to meet requirements of the Cold War period, and may now have been restored to arable land.

1. Vegetation and agriculture

A commonly photographed feature is the so-called 'fairy ring', or fungus ring. These only occur in grass and are rings of thicker and darker growth caused when filaments grow progressively outwards from a central point. These rings are rarely truly circular, often uneven in shape, and two or more may be conjoined. Almost any feature in pasture should be treated with suspicion as grass is a poor respondent to sub-surface disturbances except in periods of extreme drought. An interpreter should question the cause of any 'circle' noted in grassed fields. Past explanations have ranged from ancient round houses and burial sites to alien landing sites! An example is illustrated in Fig 7.4c.

Other circles may be due to more recent causes such as a vehicle turning, rotary water sprays (Figs 7.4d and Fig 10.6), animal feeding troughs or horse-riding circuits. A cautious photo interpreter ought to question all features, especially those that occur in grass fields or which relate perfectly to modern field boundaries.

A final feature to be aware of is caused by 'round and round' ploughing in square or rectangular fields. This method of ploughing, in which a tractor is driven in a continuous circuit down the sides and across the ends of the fields, and changes in direction and depth of the deposit due to the turning of the soil as the plough alters direction cause a diagonal 'envelope' **pattern** which in some circumstances can combine to create the impression of an **enclosure** or field system (*Wilson* 1982 and 2000, figs 99-100). Grass or stubble after reaping can show similar envelope patterns but these are caused by the change of direction of the cut crop and hence a change of colour or reflectance when seen from a particular angle.

Using oblique aerial photographs

As described in earlier chapters, oblique photographs are likely to be taken by an archaeological observer to record features that were noticed during flight and thought likely to be of archaeological relevance. Stereoscopic pairs of oblique photographs can easily be taken in the air and these significantly aid interpretation (see Chapter 5 and below). To be able to map accurately from oblique photographs it is necessary for them to have been taken from a sufficient height to include surrounding 'control' information. If obliques have been enlarged to a reasonable size (about 160 x 210mm or 200 x 250mm) they should provide a good working scale for interpretation, in the region of 1:4000 to 1:2000. This enables an interpreter to accurately identify and depict virtually all photographed detail.

Advice on using oblique air photographs

View obliques the right way up, as they were taken (if necessary, rotate the map to suit).

Use prints as stereoscopic pairs whenever possible to enhance your perception. Instruct your aerial photographer to take stereo pairs whenever possible.

Remember that obliques usually have been taken of identified **target**s that will be more or less centred in the picture. Do not waste time trying to interpret and map features in the background unless this is the only record of them. If they were noticed by an airborne photographer they will probably be better represented on other prints.

Scale changes with distance from the camera. Features in the background are at smaller scale than those in the foreground. The greater the obliquity, the more scale differences there will be. This can affect accuracy of mapping, so encourage your photographer to fly higher and to photograph from as near to vertical as possible.

Using vertical air photographs

Vertical photographs are now available for the whole of most European countries, often from a series of different dates. Unfortunately these vertical surveys were not necessarily flown at times of year that were best for the recording of archaeological features either as **earthworks** or as crop or soil responses that might indicate levelled features.

Vertical photographs are taken by a camera fixed inside an aircraft and adjusted to take a series of overlapping views that can be examined stereoscopically. Most verticals are taken using large high-precision cameras that provide negatives (and contract prints) of 230 x 230mm and include a data strip along one edge that shows a range of useful information (Fig 7.7). Smaller-format cameras (6x7, 6x6, 645 and 35mm) can also be fixed to a light aircraft to take verticals and the resulting photographs are likely to be provided as enlargements, possibly sized to achieve a designated scale.

The contact scale of a negative (or digital sensor) is a factor of the height flown divided by the focal length of the lens. This is usually written and s=h/f and can often be calculated from information shown on a photograph's data strip. Cameras, lenses and the methods of photographing strips and areas of land have changed since the Second World War. Many cameras used during that period were fitted with lenses of long focal length, say 500mm, to acquire photographs while flying sufficiently high to avoid enemy retribution. Those cameras continued in use in the years after the war at a time when a lot of survey photographs were flown by the military. As cameras were developed and commercial companies took over survey work, the focal length of lenses became shorter (152mm is a standard focal length for 230 x 230mm cameras) which meant aircraft could fly at lower altitudes to take photographs of medium scale. If nothing else this reduced the effect of haze as there was less air to photograph through. Another, more important, difference because of these changes was that photographs taken with shorter focal length lenses had exaggerated height differences when they were viewed stereoscopically. This enhancement is caused mainly by the longer distance flown between exposures which, in effect, gives a wider 'eye base' between the photographs. Increased height perception also assists photo interpretation as, under ideal lighting conditions, the experienced interpreter is able to perceive differences of a few centimetres in the ground surface

Because library copies of precision vertical prints are usually at contact scale, they are often of relatively small absolute scale (a useful common scale being 1:10,000) and their interpretation requires higher perceptive powers and a more cautious approach than the examination of obliques. Use of small-scale images can also lead to errors of location and size when the photographs are rectified or re-scaled to match a larger map

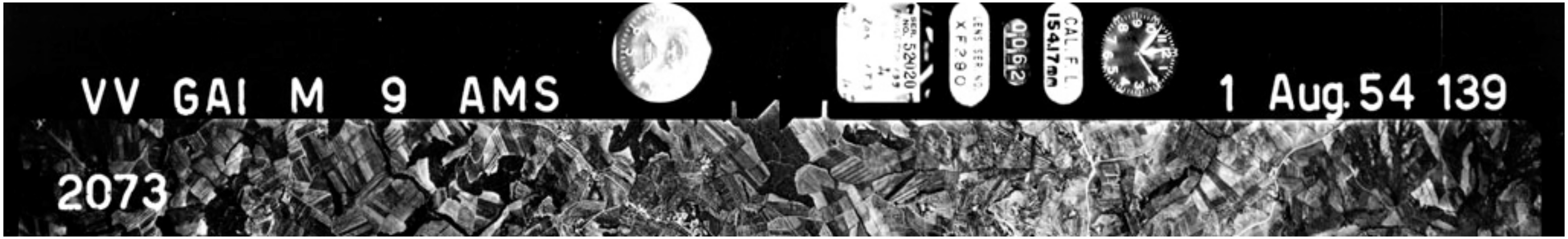


Fig 7. 7 Data strip from a vertical photograph

Information on data strips varies with the type of camera used. All should identify a film and frame number and many will also show the date of photography. In the 1930s and 1940s data strips in Britain were hand-written and often noted an approximate flying height and the focal length of the lens, from which the scale of the photograph could be calculated. Modern cameras may have digital data strips that include a position from GPS and much other information.

The example shown here, from a photograph which formed part of the 1954-1956 ‘*volo base*’, carried out for the whole of Italy by the GAI company (Gruppo Aereo Italiano) shows the information recorded by a Wild aerial camera. From left to right the recorded information is as follows: the project reference (VV GAI M 9 AMS); a circular altimeter; a ‘square’ recording the serial number of the camera; three rectangles recording respectively the serial number of the lens, a frame-counter and the calibrated focal length of the lens; a circular clock (showing the time as 11:52), the date (1 August 1954); the sortie number (139) and, below on the left, the individual frame number (2073).

scale. Enlargements, or part enlargements, can be made but this can be an expensive process, doubly so if a stereoscopic pair is ordered. If ordering prints from old military verticals, try to ensure that these are made from the original negatives (when these survive) rather than from copy-negatives of sometimes poor-quality library prints. Libraries should be able to advise potential buyers on the options and availability of conventional prints and digital copies.

Now that GIS are commonly used for heritage management and research, vertical photographs may be joined seamlessly together to produce a map-like orthophoto which may become one layer of information. When taken on film, these orthophotos began life as individual negatives which were then scanned at high resolution, ortho-rectified and geo-located to form a single mosaic covering (for instance) a modern administrative area. Modern orthophotos may be made directly from original digital images. Seamless verticals may provide a useful layer in a GIS, showing ‘real’ detail (trees and field boundaries etc) with a map superimposed or present as another layer in the system. Through an integrated index they allow rapid viewing of a specific place or easy examination of larger areas. Their value to the archaeological photo interpreter remains to be evaluated although first impressions are not wholly favourable for two reasons: the ability to view the photographs stereoscopically is lost, and eye-and-brain coordination may misread topography and archaeological **earthworks** because the image is installed and viewed with north to the top (see immediately below and Fig 9.11).

Advice on using vertical photographs

View prints with the shadows falling towards you (turn the map to suit if necessary). This is because the subconscious seems to expect the source of light to be from the top of a picture. To place it elsewhere, as can happen if a vertical is viewed with north to the top, can result in apparently inverted topography, with hills appearing as hollows and vice versa.

View verticals as stereoscopic pairs whenever possible. These not only allow perception of height differences but can increase an interpreter’s confidence when, for example, questionable or slight features can be seen on both prints.

Verticals, really, are one state of oblique images and the only truly vertical view is at the photograph’s nadir point. From that point, obliquity increases towards the edge of the picture as can be seen clearly when tall buildings have been photographed.

However, unless ground height differences are great, the scale on a vertical print may be considered constant. Tilt, which occurs when the camera is not pointing directly downward, will introduce scale changes. The degree of tilt can be seen in the bubble level that is displayed on the data strip (Fig 7.7). If tilt is more than about 5o the photograph can be treated and rectified as if it were an oblique.

Obliques or verticals?

The majority of obliques taken by or for archaeologists are targeted on features thought to be archaeological. By circling each site a photographer is able to record it from the best viewpoint and produce a clear photograph of its visible features. It is difficult to improve on a good oblique record of a site as it will generally offer a closer view than a vertical. If obliques have been taken with interpretation and mapping in mind – that is, as stereo pairs from as near vertical as possible and with ample and well-spaced **control points** – they can be a pleasure to work with.

Obliques are excellent for recording individual sites or for photographing **target**s on a field-by-field basis. They are less able to cope with continuous linear features and they are a cumbersome way of recording, for instance, a wide-spreading system of centuriation or the open fields of a medieval settlement. If the density of individual sites is high or if there are 'continuous' archaeological features, it is easy for even an experienced air photographer to 'lose' some parts during the repeated circling to take the photographs (*Cowley* 2002). In such cases verticals taken at an appropriate time may provide a more complete record.

One advantage that verticals have over obliques is that they record all of the ground within the survey area. If they have been taken at times of year when crops, bare soil or lighting are appropriate they can thus offer more information for interpretation than the obliques of inevitably more limited areas taken by an archaeological photographer. For example, in Austria on a survey flight to take oblique air photograps it was apparent that crop conditions were exceptional and the number of sites was too high to be sure of recording them all using conventional oblique tactics. The solution was to commission a vertical survey of a block of land covering 160 sq km at a scale of 1:10,000 to provide photographs that were later examined stereoscopically. It was recognised that lower-altitude archaeological survey might have detected more sites, as they appeared and then faded over a period of weeks, but this was not possible, the only qualified archaeological surveyor being fully occupied at that time with other work (*Doneus 2000*).

On verticals it is often possible to follow linear ditches from field to field as colour or tonal differences. Occasionally these can be extended because they are visible as height differences in the crop when viewed stereoscopically. In such cases there may have been nothing for an oblique photographer to observe (or believe in) unless the sun was low enough to produce a shadow of the taller crop (Fig 2.9, bottom right). The use of verticals allows an interpreter to more closely examine and question features than is usually possible from the air within the constraints of flying costs. A disadvantage of using verticals, especially in the hands of an inexperienced interpreter, is the ease with which the mind can 'invent' features which are not really there. This is especially so with prints which record only a few genuine features and the interpreter may become desperate to find at least something. As Irwin Scollar noted: 'Prolonged examination … usually leads to unwarranted fantasy which often cannot be confirmed by later excavation' (*Scollar* et alii *1990*, p. 27).

In general, a photo interpreter will not be concerned whether the principal source of information is an oblique or a vertical photograph. More important will be the spread of **control points** and the availability of stereo pairs. Magnification can be used as necessary to reveal archaeological and other features and specialist transformation software can handle either type of photograph with equal ease.

Stereoscopy

A single photograph, be it vertical or oblique, provides only a two-dimensional view of reality. This may sometimes be enhanced by the lighting or by viewing verticals with shadows falling towards the observer. But this does not provide the detailed – and slightly exaggerated – view that comes from three-dimensional viewing of stereoscopic pairs of photographs.

A person's eyes, spaced some 65mm apart, allow depth and distance to be perceived because a view is seen from two slightly different positions. Stereoscopic pairs of photographs provide similar information by showing the same scene from two different points so that it may be recreated in three dimensions by use of a stereoscope. In it simplest form a stereoscope comprises two lenses in a frame that holds them at a suitable height for focusing on the pair of photographs placed below them. The lenses direct each eye to see one photograph and, if these are correctly placed, the mind combines the two images to create a three-dimensional view. These so-called 'pocket' stereoscopes, are favoured by most archaeological interpreters in Britain (Fig 7.8, top). They are available with lenses that give either 2x or 4x magnification. Both versions are small and easy to use, and give the viewer a sense of contact with the photographed evidence. The 2x magnification model has legs that are high enough for the interpreter to use a pen to mark interpreted information on a transparent plastic overlay placed over the photographs, as discussed in Chapter 8. The 4x models have shorter legs, making it more difficult to annotate the overlay.

Larger 'mirror' stereoscopes (Fig 7.8, bottom) direct light from photographs to the inerpreter's eyes using mirrors and prisms. Many can be used with a wide range of supplementary lenses and there is at least one model that has an excellent zoom lens. Different magnifications have different uses and most archaeological interpretation of conventional photographs (obliques and verticals with contact scales up to 1:12,000) will not need to use more than 4x magnification. At 1x magnification it may be possible to see a complete stereoscopic view of a photo pair. This can be superb for examining topography on small-scale prints (1:20,000 and smaller) and can be used for a first-stage examination of larger-scale prints (1:12,000 and greater). Use of 2x or 4x magnification, however, will be required for the interpretation of detail.

For an archaeological interpreter stereoscopic examination of prints should become the normal way of working. Viewing stereoscopically aids perception of very slight features and may give an interpreter the confidence to accept them as archaeological. Stereoscopic examination is essential for any work on upland areas where earthworks or upstanding walls of only a few centimetres in height may be perceived and mapped by an experienced interpreter. Stereoscopic perception increases with a viewer's experience. This is both long term –

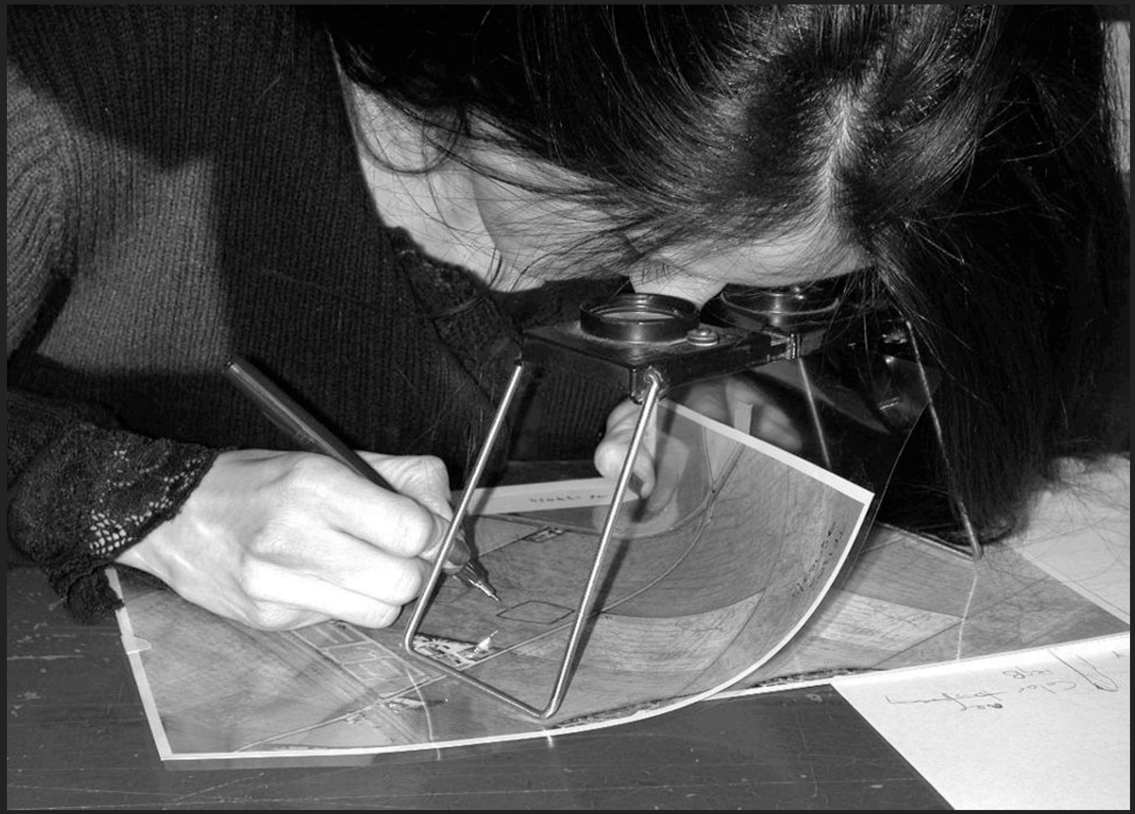


Fig 7. 8 Use of a pocket and mirror stereoscopes

Top. A pair of vertical photographs being examined in three dimensions using a pocket stereoscope that allows 2x magnification. Note how the top print is being curled up so that the area beneath it on the lower photograph can be seen. The interpretation is being drawn on a transparent overlay taped to the right-hand print (as viewed in this photograph).

Bottom. A pair of vertical photographs being examined in three dimensions under a mirror stereoscope that allows 1x or 4x magnification.
The prints do not need to physically overlap one another and there is plenty of room in which to use a pen to mark interpretation overlays. This instrument can be used to ‘scan’ the photographs by using controls which move prisms in x or y direction. Other stereoscopes do this by using a movable baseboard.

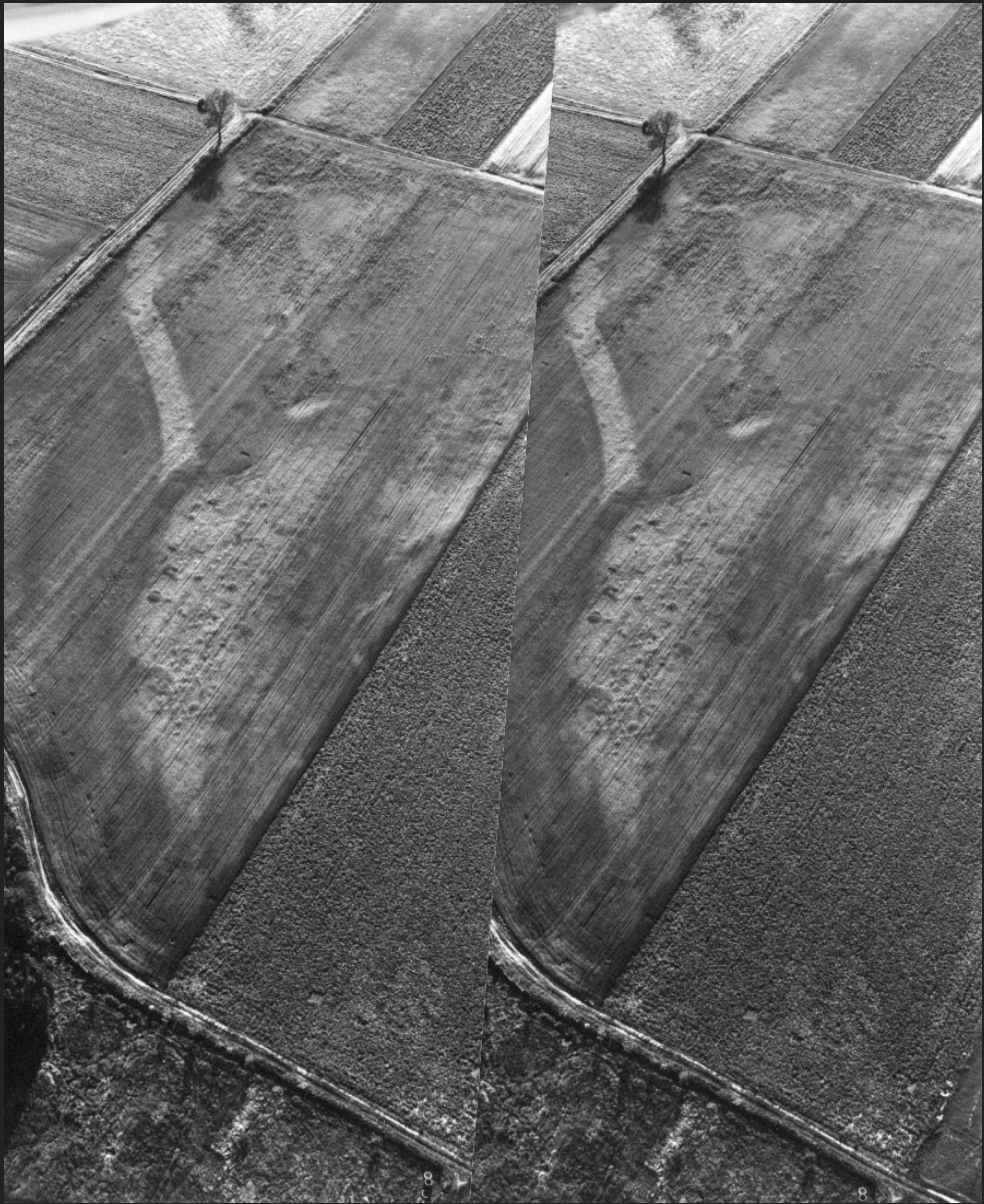


Fig 7. 9 Advantages of stereoscopic photographs

This split view of an oblique stereo-pair, taken about a second apart from an orbiting aircraft, is here displayed for viewing in three dimensions with a pocket stereoscope with a magnification of x2, as in Fig 7.8.
On the light-toned patch can be seen at least one rectangular enclosure and many probable pits. Most of these, and the enclosure, are visible only as height differences in the crop – enhanced by the stereo view which also shows that the lighter area stands on slightly higher ground of the kind usually selected as a location for past settlement. Impressions of height in the photographs are helped by the shadows falling towards the viewer, allowing changes in the height of crops above the enclosure ditches to be seen as highlights and shadows. In overcast conditions or with a higher or different angle of sunlight such features might only be seen through stereo viewing.

over a period of years – and in the short term, when the eye-and-brain may need several minutes to become adjusted to the view through the lenses.

A stereoscopic view can sometimes help distinguish natural from archaeological features because their relationships to the topography will be clearly seen. A small dry stream, for example, may have a deeper or wetter channel that affects crop growth in similar ways to an archaeological ditch and may be indistinguishable from examination of a single print. Stereoscopic viewing usually shows the stream to be in an eroded hollow and so it can be correctly identified.

Film types and photo interpretation

Types of film for taking air photographs have been discussed in Chapter 4. The following paragraphs examine the different film-types from the point of view of the interpreter. Digital images are discussed in the succeeding section.

In theory a black-and-white negative should produce greater resolution and sharpness than any form of colour film as all information is recorded on a single layer of emulsion. Colour films require at least three emulsion layers – red, green and blue – and most modern films have many more because of the inclusion of various filter layers. The end product is a much thicker sandwich of layers of which each and all need to be in exact focus in a photographic enlarger or projector to produce a sharp image. Since this may not always be achieved the result is the 'soft' appearance of many colour photographs.

There is also the archival life of different film types to consider. In summary, properly processed and stored black-and-white films and prints can be guaranteed to last for at least a century while colour material, however well processed and stored, may begin to deteriorate in a matter of decades.

Black-and-white (panchromatic) film

Almost all historical aerial photographs and most obliques can be examined as black-and-white prints. These will be of varying quality depending on the type of film, the quality of processing and the contrast given during printing. In general, prints made for interpretation and mapping of archaeological subjects, especially of crop-marked features, benefit from increased contrast (Fig 6.3). This may not result in a realistic representation of tones but provides a picture from which an interpreter is most able to extract the maximum amount of information. Obliques for photo interpretation are usually printed in this way, but vertical survey material is usually automatically manipulated during printing to eliminate uneven contrast and may sometimes have a 'flatter' appearance.

With experience it is possible to identify a range of types of crop on black-and-white prints, although sometimes there are uncertainties. Often this knowledge will assist interpretation, especially when grass can be identified so that extra care is taken to question any apparent features that may be visible.

Colour negative (print film)

Until recently, vertical surveys were taken on colour negative film with colour prints as the final product. Now they will be captured digitally. Colour negative film is also used in Britain by a number of oblique air photographers using medium-format cameras. Medium-format obliques are likely to be printed by a specialist laboratory that may be prepared to produce prints to the photographer's specification and at a reasonable size (at least 160 x 210 mm). If small-format (35mm) prints are taken to an express or non-specialist printer the resulting prints may be of variable quality and, if costs are cut, too small in size. If prints are too small it makes them difficult or impossible to use for detailed interpretation.

One small advantage of colour over black-and-white is that it may be easier for a beginner to identify features on a photograph as there is one stage less of translation to go through (in interpreting black-and-white tones in place of the original colours). Another is that crops are easier to identify and there is usually no doubt whether a field is grass or not. Some of the more exotic, or colourful, crops such as linseed (which has a purple tint) and flowering oil-seed rape (bright yellow) can be identified and this helps accumulate knowledge of which crops may be affected by changes in soil depth and at which times of year.

At high magnifications colour prints will lack the clarity of definition of black-and-white images. This may be countered to a small degree by asking aerial photographers to use higher speed films which have added contrast. Most photographers believe that increased film speed produces a grainier image, but with correctly exposed modern films there is little noticeable difference in granularity unless huge enlargements are made or only a small part of the negative is used.

Colour reversal (slide film) and false-colour infra-red

Colour slides/transparencies and false-colour infra-red images are excellent for lecturing purposes. They may also provide better copy for published illustrations (Figs 6.2, right; Figs 10.55, 10.62, left) but, until the advent of easy digitisation of images, they were of little use to a photo interpreter. Coming mainly from 35mm or medium-format cameras, their small size makes them difficult if not impossible to examine rapidly to find the most informative frame or to effectively compare one frame with another. However, this is now possible if prints have been made or if slides or prints have been scanned for on-screen examination.

The present writer believes that aerial photographers should be encouraged to make minimal use of transparency film as slides for lectures can easily be made by copying conventional prints and, with the now almost exclusive use of data projectors for teaching and at meetings, all types of material can now readily be scanned for display.

Digital data and photo interpretation

Digital material falls into two types: that taken using a digital camera, and digital images made from prints, negatives or transparencies. With their 10+ megapixel capacity, the latest digital cameras are now able to produce images suitable for conventional publication or Internet use. But at the time of writing the original version of this manual, in early 2003, no digital camera images had been used for serious photo interpretation so no comments could be made about their efficacy for this purpose.

Considerable use has been made by interpreters of digital images made from scanned prints. Normal office flat-bed scanners are likely to have the necessary resolution range and are faster than negative scanners. However, scanning from the original negative is advisable – if appropriately-high technology is available – as it avoids the slight degradation of the image that is inherent in the use of an intermediate print. However, one argument in favour of scanning from a print is that the print itself may have been expertly made and manipulated to produce the best copy from that negative. These considerations may be more important when scanning is being done to create archive material rather than for single use on-screen. Maximum resolution will be desirable for the former but may result in huge and unwieldily files for on-screen interpretation unless they are reduced in size or compressed before use in mapping and interpretation work. Some juggling of pixels and bytes may be required to find suitable file sizes that best suit the needs of on-screen interpretation.

Working directly from negatives or transparencies does not necessarily require use of a scanner with exceptionally high optical resolution. On-screen interpretation may be more easily undertaken with a reduced-size file or with a new scan made at an appropriate resolution using a relatively cheap scanner. For example, satisfactory scans, that allowed fine detail to be seen clearly on-screen, have been made from 35mm material by setting a mid-range scanner to scan at 1200 dpi. Larger-format films will need either a specialist scanner or a flat-bed machine with a light lid. Experimentation may be necessary with each scanner and computer system to find the point at which no extra gain is made by increasing scan resolution.

During work in England it has been found that adequate scans for interpretation of most crop-marked features can be made at 300 dpi from a 200 x 250 mm black-and-white print. When extremely fine detail is sought from part of a print, the resolution can be increased to 600 dpi. Smaller prints, crops from small- or medium-scale verticals, and colour photographs with their inherent softness, may require scanning at resolutions of 600 dpi or more.

Maps

Access to good topographical maps of suitable scales is crucial if accurate maps of past **landscapes** are to be prepared, or plans made of individual sites for measurement, analysis and location of small excavation trenches. If such maps are not available an alternative is to make a new survey of selected **control points** and relevant topographical information. This method may be practical for individual sites but would require a major surveying campaign for the mapping of a landscape. The final choice of working and publication scales depends on the reasons for mapping and the aims of publication. The brief and selective ‘history’ of mapping in Britain (below) may indicate how certain scales were adopted for showing different kinds of information. Traditions may of course be different in other countries of Europe.

Uses of different scales

Maps of scales suitable for locating sites, and providing co-ordinate values for photographs, have been noted in Chapter 6. Here we take a closer look at the maps usually used to provide **control points** for **transformation** and background information for archaeological maps or plans. Much will be relevant to other countries where a similar range of map scales is available.

In Britain the choice of scales for mapping was initially dictated by the available maps. Crawford’s first mapping (1924) was at 1:10,560 scale – the old six-inches-to-the-mile scale then in use for the so-called County Series maps – and he continued to use that convenient scale for later mapping and annotations from field work. This scale later became the basis of the Ordnance Survey’s Archaeology Record and was used for much of the archaeological mapping in Britain until the English Royal Commission decided in 1992 to change to the new metric 1:10,000 series for its National Mapping Programme (Fig 1.14).

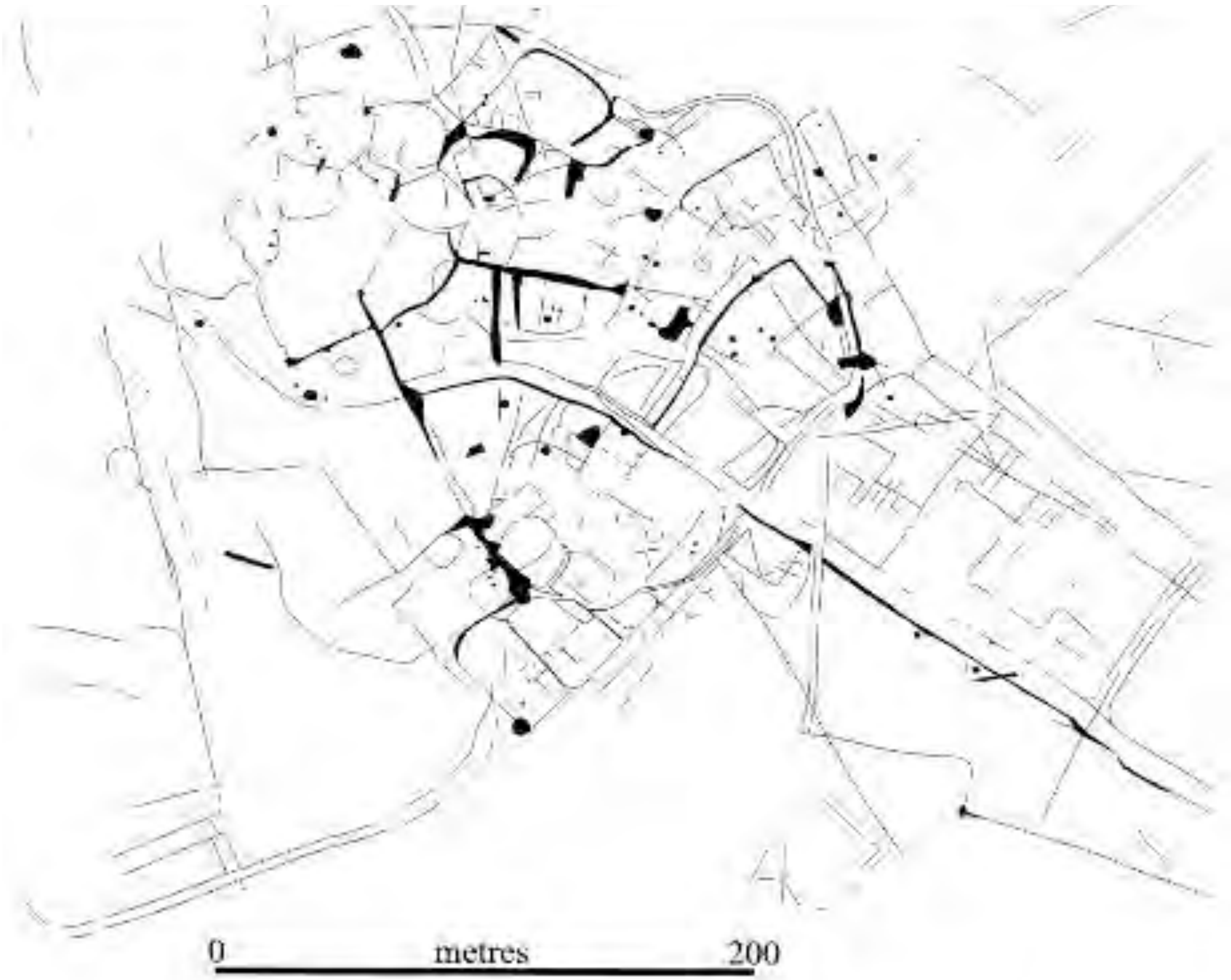
Until the mid-1970s all mapping was done by hand, without the aid of computers (see Chapter 8). This was a slow and tedious process, especially when the maximum level of detail was to be shown. It was one thing to undertake such work on a 1:10,560 base, and to attempt to emulate the ±8 m accuracy of that scale, but to do such work at 1:2500 – with a survey accuracy of ±2 m – would have required high skill, extreme carefulness and a lot of time if the result was to match the accuracy of the base map.

From that beginning, and because of the convenient coverage of a 1:10,560 and 10,000 sheet (5 x 5km), these scales became the natural choice in Britain when areas of land, or landscape projects, were to be mapped. Unfortunately the newer series of 1:10,000 maps make considerable use of conventions and are less accurate than their predecessors (which therefore remain the favoured map of many interpreters). Another argument in favour of using the earlier maps is that there are usually no problems in matching a modern photograph to an old map, even if some changes have taken place since the map was made. Conversely, it can sometimes be impossible to match an old photograph to a new map of an area that has seen recent removals of field boundaries or the building or re-alignment of roads. This is even more the case when using digital versions of maps that take pride in being up to date and so eradicate useful information that is no longer visible on the ground (useful to the photo interpreter, that is).

One outcome of these mapping experiments was the decision in Britain to use 1:10,560 or 10,000 scales for a 'basic' level of mapping that would show an area of land, the relationship of features and also a good representation of the complexity of some of the settlement sites. Use of 1:2500 scale was reserved for individual sites or smaller areas selected for more detailed depiction. By the mid-1980s, after considerable discussion within the air photo community about map scales and conventions, work had been published that showed these in use (*Palmer 1984*) and which also depicted uses of a wider range of map scales (from 1:100,000 to 1:1250) and conventions (*Riley* et alii *1985* and Fig 7.10).

'Improving' maps

Maps at scales of 1:25,000 and larger may be 'improved' by combining them with vertical photographs or satellite data. Vertical photographs usually contain sufficient control to allow them to be transformed on to such maps and the detail they add may provide control points for lower altitude obliques. The accuracy will not be very high if a small-scale map is used as the basis for this work. Improved accuracy should result if geo- and ortho-rectified photographs are used as these should open in their correct place and scale in a GIS. This also saves the additional work of transforming each photo. Similar improvements can be made using high-resolution satellite images, as has been done in Romania with US declassified corona images (*Oltean 2002*) or with higher-resolution geo-located images in Syria (see Chapter 15 and *Beck* et alii *2002*). These methods may suffice for mapping at 1:10,000 and 1:2500 but at larger scales it may be necessary to accurately survey ground control points to match those on the photographs. This has been done in Austria where precision EDM survey provided a base map for work at Carnuntum that combined evidence from aerial photographs with data from geophysical survey and excavation (Chapter 13; *Doneus* et alii *2001*, *2012*).



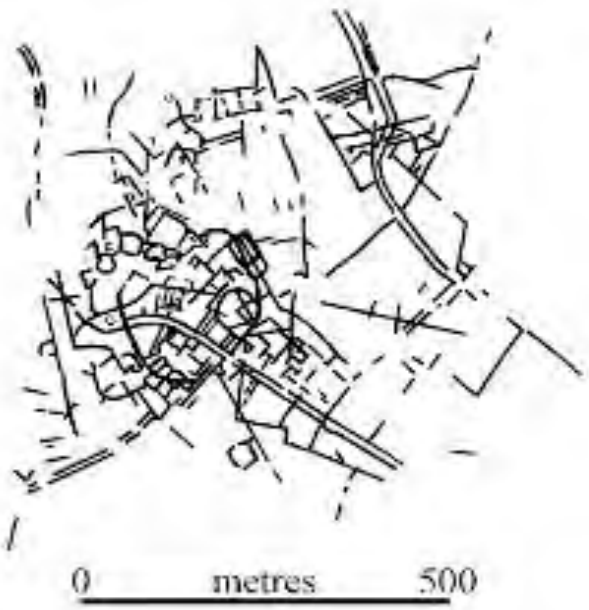


Fig 7. 10 Mapping at different scales

A complex site, originally mapped at scales of 1:2500 (top) and 1:10,000 (bottom). The maps are printed in correct proportions to one another but (as seen on-screen) not of course to the original scales. They show the difference in the level of detail that can be clearly depicted at these two scales.

The 1:10,000 extract (at the bottom) is from a much larger area that was later redrawn for publication at 1:25,000. Line widths were therefore kept thicker than would have been the case for reproduction at the original scale. Additional detail in the 1:2500 plan arises from the higher level of interpretation that can be achieved at this scale.

Paper and digital maps

Before about 1990 all maps and plans published in Britain were on paper. Many of these old maps are now held in libraries or by local authorities. Current Ordnance Survey mapping in Britain, especially at scales of 1:10,000 or greater, is prepared in digital form and can be purchased as printed copy or as raster (1:10,000) or vector files (1:2500, 1:1250). For use with aerial photographs the digital form is often preferred as files can be read directly by software used for image transformation without the need to first scan and then calibrate a paper original. Another advantage is that digital maps require considerably less space for storage than paper maps.

The 1:10,000 raster maps in Britain are not particularly accurate as they use conventional widths for roads and sometimes have thick outlines for buildings which leave users unsure which part of the outline is the edge seen on an aerial photograph. However, as work at this scale is unlikely to be used for accurate and reliable measurement the maps are probably adequate. Vector plans at 1:2500 and 1:1250 are more detailed and accurate and are almost as good as the old paper map series. Lines are thin and details are correctly shown, enabling control points on plan and photograph to be matched to within the tolerances of the original survey.

Control points

A control point is a fixed point that can be clearly identified on both map and aerial photograph. These points are used in the rectification or transformation of photographs and images to match maps so as to provide placement and scale of the photograph or of details interpreted from the photograph. All mapped features are represented at their ground-level position and it is important to try to identify these when placing control points on a photograph. Examples of control points (Figs 7.11, 7.12, 7.13) are corners of buildings, junctions of field boundaries, road junctions (the margins of those meeting at rounded corners will need to be projected to make an intersection), corners of fenced woods and centres of power pylons (identified by diagonally joining the legs).

Photo interpreters are encouraged to spend some time when travelling around the country to look at the landscape and to identify potential control points and decide or check how they will look on a map. Different countries or different regions may have different rules for what is mapped and how it is depicted, so it is important to learn any national and regional variations. Time spent locating photographs and comparing them to a map is not wasted as modern detail on photographs will be constantly compared to the mapped information. This will help photo interpreters to become familiar with their local photo-to-map relationships.

Ideally control points will form an evenly-spaced polygon that surrounds the archaeological features that are to be mapped (Figs 7.11, 7.12, 7.13). Even on level ground inaccurate matching of photograph to map occurs outside the controlled polygon due to distortion caused within the camera and by the direction and obliquity of the photograph. In hilly ground this becomes even more apparent (Fig 7.15) and the displacement of any archaeological features outside the controlled polygon can be significant when attempting to join features recorded on two or more photographs. In most cases control points will come from existing maps but workers in parts of the country with poor maps may have to create their own ground control points or use geo-located vertical photographs or satellite images for this purpose.

Secondary control

The term 'secondary control' refers to control points that have been identified on one transformed photograph and can be used to provide control for another. The first, or primary, photograph may be a vertical that includes trees, fence poles or other features that can be used as control for the transformation of a lower-altitude oblique. Alternatively, two obliques taken on the same day from different heights or with different focal length lenses can provide a high view and a close-up with detail. In this case secondary control points can be such things as intersecting tractor lines, clumps of weeds or distinctive parts of the archaeological features themselves (Fig 8.1).

Final thoughts

This chapter has introduced and discussed the data with which the photo interpreter works. All interpreters will meet a variety of aerial photographs – oblique, vertical, colour, black-and-white, good and bad – and will have to learn to work with them. Flexibility is the keyword. Similarly with maps – some may not be produced at the scales required or may not show sufficient detail, others may be ideal for the proposed task. Often there are ways around such problems and many can be avoided by thinking ahead, being versatile and working as a team member with one or more aerial photographers.

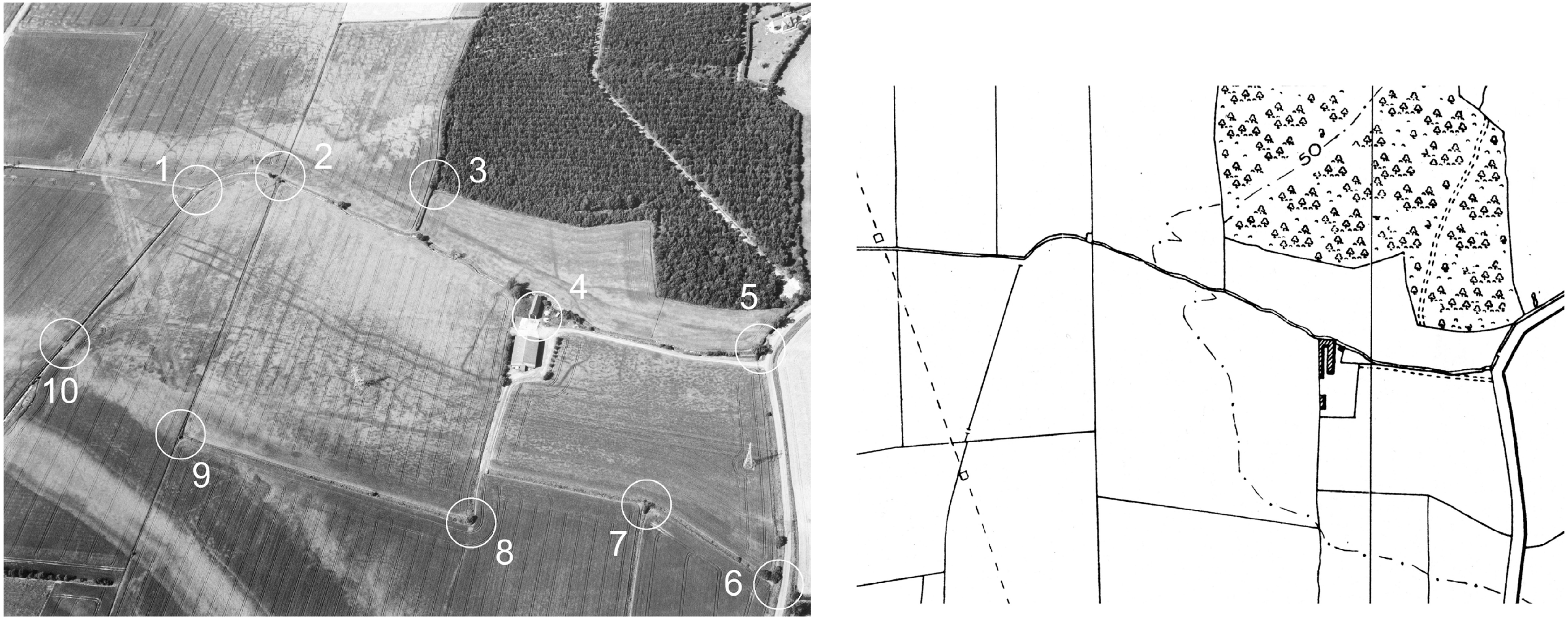


Fig 7. 11 Pairing control points on map and photograph

The Figure shows a complete photograph and an extract of a 1:10,000 map of its location. To map the features shown on the photograph they have been surrounded by a series of ten control points, marked here by white numbered circles. The details of how these are then used to provide accurate control are then shown in Figs 7.12 and 7.13.

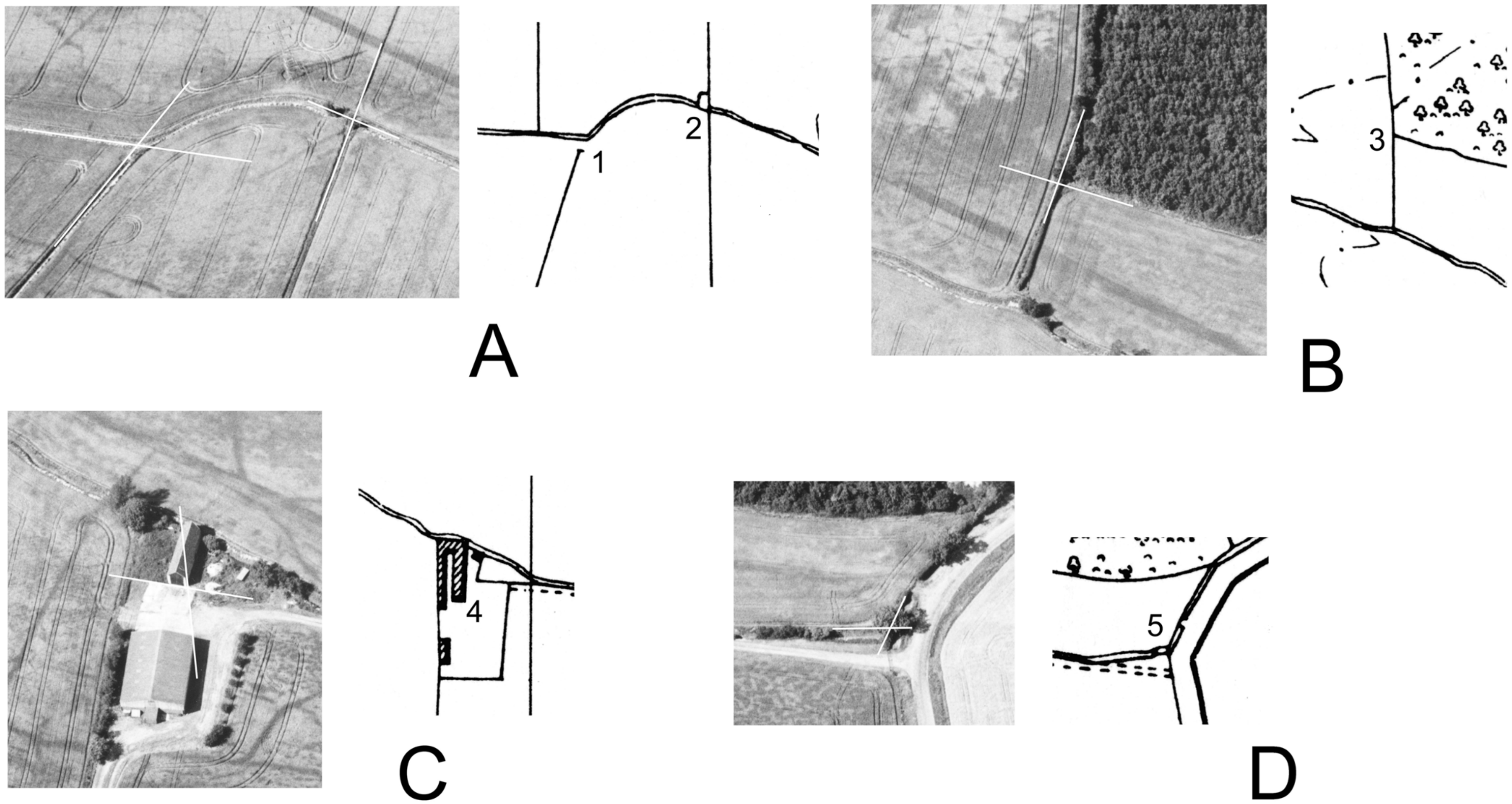


Fig 7. 12 Pairing control points on map and photograph (continued)

A) Control point 1 is at the projected intersection of two ditches, one of which has been extended on both map and photo to create the intersection. Lines on the photo are drawn along the centre of the top of the N-S ditch to match the single line on the map, and along the southern edge of that mapped as a double line. Point 2 is at a real intersection where again lines are drawn as for point 1. There may be slight inaccuracy here as the E-W stream appears straighter on the photograph than on the map. Its ground position may have been.

B) Corners of woods are not usually reliable as control points because it is necessary to estimate where the edge on the map actually occurs on the photograph. In the case of control point 3 there appears to be a fenced boundary along the southern side of the wood. The intersection of this with the N-S hedge has been taken as the control point.

C) This small group of farm buildings has changed between the dates of mapping and photography but one building remains on both. Control point 4 on the photo is made by the intersection of a line drawn along the bottom of the southern end of the building with one drawn ‘vertically’ down its corner post. If the map is accurate this should be the most precise control point in the series.

D) Control point 5 is not easy to locate accurately but is placed where a stream turns at a sharp angle to follow a road. On the photograph lines have been drawn along what are thought to be the northern and western edges of that stream. This is one of the least reliable control points in the set.

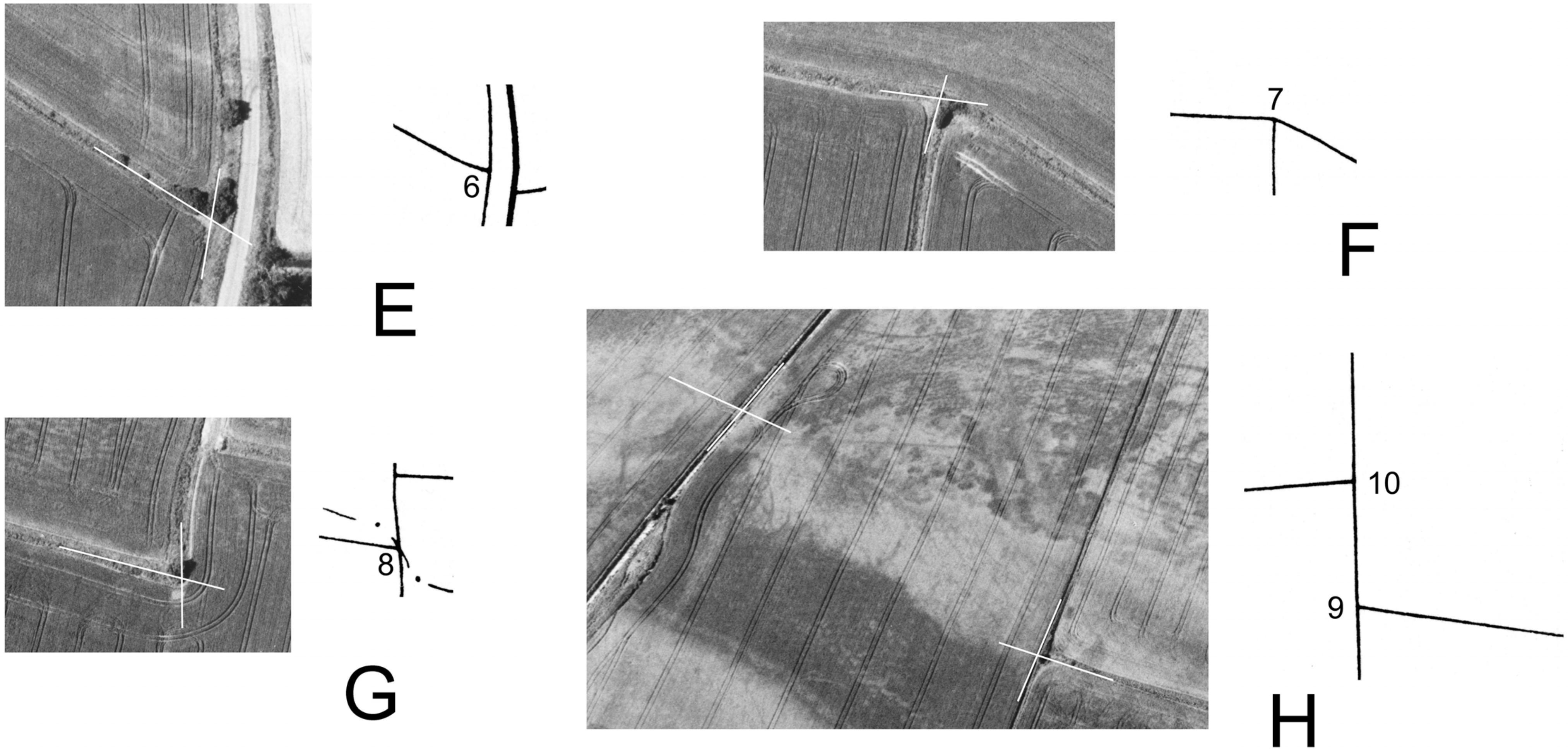


Fig 7. 13 Pairing control points on map and photograph (continued)

E) A more reliable point occurs at 6, which is an intersection of a ditch with a roadside boundary. Note that at 1:10,000 the map shows the width of the road plus the strips of grass along its edges, not the edge of the road's metalled surface. The photo interpreter needs to know about local conventions of this kind when transforming reality into cartography.

F-G Both control points are made at simple intersections of field boundaries. Note that both are also marked by trees. This is a situation that is common in the subdivision of land in Britain. The presence of trees helps to identify former field junctions from which one boundary has been removed between the dates of the photography and the mapping.

H. Control point 9 is a simple intersection of ditches. Point 10, however, is less definite. The map shows an intersection of ditches but one of these has since been removed. However, there is a small bridge crossing the N-S ditch and it is probable that the former E-W ditch made its intersection at one edge of that bridge. Very slight marks in the crop suggest that this intersection occurred on the north edge of the bridge and the control point has therefore been placed in this position. Transformation software that calculates mismatches of control points will show if this decision is correct. If not, it is a simple matter to move the point to the southern edge of the bridge and to re-make the transformation.

Fig 7. 14 Photographing sites to include control points

Two photographs of the same Roman villa, taken from different heights. The upper photograph was taken at a height sufficient to include control points. It could readily be used for interpretation and mapping although it is more oblique than would be preferred. The lower photograph was taken from closer to the ground and shows only the villa. It would be possible to map from the lower photograph by using secondary control taken from the upper print (see Fig 8.1). Examination of the original prints shows, however, that the same information is recorded on both, so this would not be necessary. These photographs emphasise the need to fly high enough to include control points, and to photograph at steep angles to the ground, when taking photographs for interpretation and mapping. The band at the edge of each photo has been caused by double enhancement in AirPhoto – applied first to the original colour scan, then converted to greyscale and enhanced again to improve the contrast of this poorly visible site. Better photographs might hopefully be obtained in a future year.

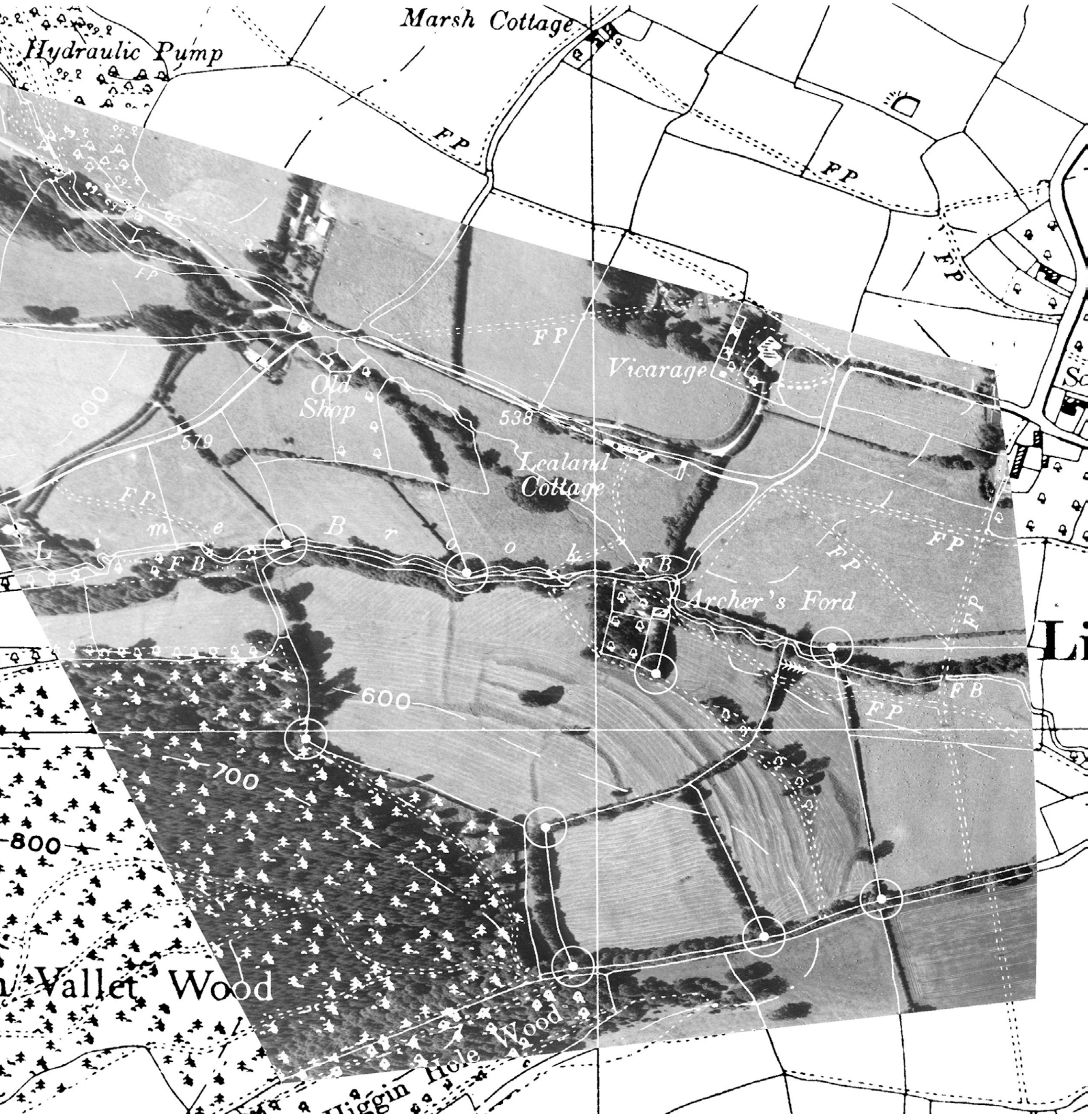


Fig 7. 15 Image displacement on hilly ground

This photograph was selected for mapping ancient fields recorded as earthworks. Nine control points (circled) were identified so as to surround the area of archaeological interest, the rest of the photograph being of no relevance for this purpose. Transformation was made using a digital terrain model to produce low mismatch values. A visual check showed there to be good match of map and photograph within the controlled area. Modern boundaries outside the polygon of control points have ‘drifted away’ from their mapped positions. This is due to the sloping terrain and the relatively low angle of view. Areas outside the controlled polygon will not necessarily be transformed accurately, especially on hilly ground. For normal use, the transformed image would be cropped to eliminate the unwanted area, but the greater part of it is retained here to illustrate the need for well-placed control points.

8. PHOTO INTERPRETATION, TRANSFORMATION AND RECORD CREATION

Introduction

Archaeological photo interpreters in Britain are in general agreement that their method of working from photographs to archaeology can be divided into two inter-linked phases. Firstly, photographs are examined to identify **feature**s of interest and those items of information are combined in a map (photo interpretation). Secondly, archaeological deductions are made using that map (archaeological interpretation). It could be argued that there is not enough information on many single photographs to interpret in archaeological terms, but that it is necessary to join together in map form the items represented on many photos before there is a reasonable amount of information for meaningful interpretation. This chapter outlines some of the methods of photo examination and transformation to produce a final drawing that presents an archaeological **site** or landscape in its natural context. This in turn makes the photographed information available for integration with other data to allow more definitive archaeological interpretation.

Ideally you will be working on a big desk with plenty of room to spread out photographs and maps. Preferably the desk will be in front of a window so that the light falls towards you and you will have an adjustable desk lamp that can be placed best for viewing photographs. The window is also useful to rest your eyes and to allow them to adjust their focus from a few centimetres to infinity – something you are recommended to do at frequent intervals.

Beginning photo interpretation

The previous chapter described the interpreter's main data – photographs, maps and the need to match the two using **control points**. We now put these to use by making a preliminary examination of a collection of photographs so as to select some for interpretation and **mapping**.Choice of photographs

In Britain there are oblique photographs of archaeological subjects from over 100 years of collection (Chapter 1) and vertical surveys dating from the 1930s onward. In Italy, to take a contrasting example from another part of Europe, vertical surveys are in well-managed and easily-accessible collections and have a longer history of use in research projects and in the mapping of major national monuments for interpretation and management purposes. By contrast, oblique photographs result from more recent activity by individual archaeologists who maintain collections of photographs at their own universities or other establishments.

Thus, for many **sites** in both countries, and for many other countries too, there are likely to be collections of photographs from which those most useful for interpretation and mapping can be chosen. For work over a large area an interpreter may need to examine hundreds or even thousands of photographs.

There are two things to seek: first the photographs that show the maximum amount of archaeological or contextual information, and secondly those that include sufficient control information. Most photo interpreters search for these in the reverse order. The ideal print for interpretation and mapping is one that has a regularly-spaced polygon of potential control points surrounding clearly-defined archaeological **features**. At this point a new interpreter will begin to realise that there is more than one way to take an oblique air photograph and that many of these do not provide photographs that can be used for mapping even though they may show clear details. Most currently active interpreters think that **all** aerial photographers should undergo a short course of interpretation and mapping, using their own photographs. This would serve as a reminder for them to fly higher and to include control information. Among the present collections of photographs there are some that have been taken from a sufficient altitude and with the needs of mapping in mind. It can be a pleasure to find these amongst the mass of difficult-to-use prints.

The best print for interpretation

So, how do we sort through a group of photographs and select the most useful? The first thing to do is to find the map or maps, at the chosen working scale, that cover the area. You will need a map to find and indicate your selected control points and it may be useful to make copies of the maps for annotating with notes and working sketches. One thing to note is that photo interpretation, especially in lowland areas, generally proceeds in units of single modern fields. This is partly because soil or crop differences often mean that only one field is at its most responsive in any single photograph, but also because modern field boundaries can provide an ideal surround of **control points**.

Most good obliques will be composed with the main **target** in the foreground, or front two thirds, of the frame. Features seen in the background should, if noticed by the photographer, be the foreground subject in other photographs. But do not rely on the photographer seeing everything as the airborne work-load can be high and observation is broken when changing films or memory cards, reading maps and making notes. Equally, the airborne observer may concentrate attention on one field and not be aware of features in the next. Students and beginners often think it necessary to interpret a whole photograph but, unless there is no choice, this is not preferred practice, firstly because the background of an oblique photograph is at smaller scale than the foreground, making features more difficult to interpret accurately, and secondly because there may not be surrounding control points, making the transformed location and proportions of the background features less accurate.

Sorting through the photographs will also provide some first impressions of the site or area to be mapped. Spread the photos across the desk and take the opportunity to become familiar with the area. Possibly you may roughly sketch the most obvious features on a working map and see how they relate to one another – or at least write the photo numbers in each field that they illustrate. Doing this will also indicate any gaps in the photographed record – perhaps missed during your first look, perhaps a genuine absence of information, in which case it may be worth noting on your map. You should end up by identifying which are the best photographs (‘primary photos’) for each field. Interpretation of these can now begin. Do not completely discard the remaining photographs (‘secondary photos’) as these should be checked during the interpretation and final drawing stages to see if they show information that is not present on the primary photos. This may be added by transforming them using secondary control (see Chapter 7 and Figs 7.14, 8.1). Alternatively, once seen, this additional information may then become visible on a primary photo. Regardless of which, or how many, photographs you eventually use, a list should be compiled and filed with the project archive to identify all the photographs examined. This helps subsequent reference to a specific

Fig 8. 1 Use secondary control points

Many photographs show good detail but do not include control points that match those on the map. This figure shows photographs taken on the same day, one using a normal lens for black-and-white photography. The other used a short-telephoto lens for colour slides; these are usually only used for lecturing purposes so do not need control points. The black-and-white photo was transformed using control points on the 1:10,000 map and was saved as a combined map-photo image. This was then used as a 'base map' on which to transform the colour photo, using control points from intersections of tractor lines, crop-marked features and some of the small pits. The continuity of features in the combined image shows the accuracy of the resulting transformation. Secondary control is often used for photographs of different dates, using such things as posts, pylons, trees, bushes, or recognisable parts of archaeological features.

Fig 8. 2 The relevance of natural features

When mapping is used as an aid to understanding the past it can be important to include natural features. Here, a cluster of small enclosures and parts of a probable field system seem likely to have been located in the bend of the former river that is now visible as a darker area in the crop. The slight curvature in the ‘tramlines’ crossing the field shows that the river-bed survives as a shallow depression, though probably too meagre to be depicted by contours on national maps. Interpretation of the photograph provides an effective way to identify, and depict through mapping, relationships between archaeological and natural features. The missing control point outside the bottom edge of the photograph (trimmed here) can be ‘reconstructed’ by extending the two field boundaries.

photograph and provides a cut-off date after which more recent photographs may provide new information. A list may also help solve the otherwise annoying references to a feature that was ‘seen on an air photo’, with no further indication of which photograph it was. References such as this can be, and have been, impossible to verify.

Questions and reasons for photo interpretation

You should always aim to examine aerial photographs with specific intentions or questions in mind. These will direct attention and affect what you perceive on the photographs and hence your interpretations of them. Also, as your experience and knowledge changes so will your interpretation skills develop. It is perfectly reasonable to expect different interpretations of the same photographs to be produced by different interpreters, to expect your own interpretations to change as you gain experience. Regardless of how experienced you consider yourself to be, never be restrained from asking another interpreter, “What do you think of this?” It will also rapidly become apparent that different **mapping** scales will allow different levels of detail to be shown. So before you begin interpretation of a set of photographs it is important to know or decide what the final mapping scale will be and to plan your work on this basis. It should be clear by now that there is no such thing as a definitive interpretation of an aerial photograph.

If you are engaged in archaeological research your principal questions are likely to be to identify and indicate **trace**s of former structures, but you ought also to be interested in any relevant topographical and environmental evidence that can be mapped from the photographs. For example, stereoscopic viewing may show a settlement to be located on a local high spot that is too slight to be visible on conventionally mapped contours, or your site may be situated next to the deeper soil of a former watercourse (Fig 8.2). These natural features can add understanding to your interpretation of the sites by explaining their location.

If you are aiming to produce specialist reports that aid trench-location or assist rescue excavation, your role is slightly different as you will try to produce a large-scale plan to distinguish the range of sub-surface features that will be uncovered when the topsoil is removed. Thus a typical plan derived from aerial photographs may include ‘recent’ boundaries and drainage, pipelines, areas of deeper natural deposits and geological features as well as any identified archaeological traces.

If your work is in management or conservation you may be interpreting air photographs in order to produce a record of known sites for a national or county record. The aim here may be to isolate only definite archaeological features and to note their basic character and perhaps their state of preservation. You may intentionally disregard natural or recent information – although it will still need to be seen and identified in order to classify it as such.

Mapping produced for these three levels of interpretation may differ and the resulting maps will not necessarily be useful for the needs of the others.

Aerial photographs hold a two-dimensional record of surface and sub-surface anomalies produced by archaeological, natural or recent features. This may be convertible to a three-dimensional record through stereoscopic photography and viewing. Simple **earthworks** such as linear banks, walls or ditches can be relatively easy to identify but the remains of complex earthworks may present problems to an interpreter. Levelled sites, however, may be treated as a series of former holes in the ground – ditches, pits and hollows. These are sometimes accompanied by traces of walls or banks, or by the protected surfaces that once lay beneath them and which have not yet been fully removed by ploughing. They may also include now-filled platforms cut into the slope to accommodate buildings. Air-photo lore has identified the ways in which these different types of feature may be recorded at different times of year. In essence, but not always:

- Dark lines or areas on air photographs indicate deeper soil or holes in the ground.
- Lighter marks indicate raised areas or hard surfaces.

With this simple knowledge we are now in a position to examine an aerial photograph so as to identify within it these basic distinctions.

Photo interpretation by conventional methods

Use of overlay and pens

Most libraries will not allow users to borrow prints or to make their own high-quality scans (scans can in any case be difficult to use in stereoscopic viewing because of ‘interference’ between the pixels of the two scans involved). So if photo interpretation needs to be done reasonably quickly the work has to be carried out on the spot in the library. This is usually done by tracing off the information required onto transparent plastic film (an overlay) that is taped over the photographs. Tracing-paper or plastic drafting film is not sufficiently transparent for easy photo interpretation and ought not to be used for that purpose. Suitable fully-transparent film can be bought from drawing office suppliers, who also sell suitable pens. These can be either fine-tipped (‘superfine’) marker pens or technical pens with nibs finer than 0.25 mm. If using a stereoscopic pair of photographs for interpretation try to ensure that the print with the overlay is the one on the same side (left or right) that you hold your pen, otherwise you may accidentally draw on the uncovered print. To be absolutely sure of not marking a print, overlay sheets could be taped over both prints – but check that you have drawn your interpretation on only one of them before removing the overlays from the photographs. When fixing overlays adhesive tape should be stuck only on the back of the photograph (and very carefully removed afterwards) although some libraries are reluctant to allow even this. Also many reference libraries will not allow the use of ink or marker pens. In such cases a finely-sharpened chinagraph (wax) pencil may have to be used for drawing on the overlay.

Annotate and identify the photographs

As soon as the overlay is attached to the photograph it should be labelled with the original photo number and any reference of your own. Either of these numbers can continue as a subsequent file name for scans and transformations if the data are to be processed digitally. If the original photo has a reference number which includes grid co-ordinates the photo number will also indicate the geographical location of archaeological features without need for an additional reference.

Mark control

A well-chosen photograph will have good control information which needs to be marked on its overlay. Carefully decide which points on the photograph are also identifiable on the map and use a straight-edge to mark them with lines that intersect at the exact position, numbering each point as you go (Fig 8.3). Intersecting lines, so drawn, will be more accurate than, for example, a hand drawn X or a dot. Use of stereoscopic pairs may help to precisely identify certain control points or give confidence in the identification of, for example, the middle of the bottom of a tree at a hedgerow corner. Make sure that each control point is also marked or indicated on the map and identified by number or letter. Be as precise as possible as the 'fit' of control points will affect the shape and position of the rectified archaeological information.

Identify and mark the features to be mapped

If you have stereoscopic photographs, use them. This may seem difficult at first, but the added confidence it will give is well worth the effort of learning to look with a pen in one hand, one photo held curled up, and closing each eye in rapid succession to compare detail on the two photographs (Fig 7.8, top). By allowing a viewer to see each photograph alternately while retaining the other in the mind, this enables comparison of prints and can help identify anomalies that are only on one print of a pair. Stereoscopy can make such points appear to float above or below the surface of the photographs. This draws them to the attention of a viewer and shows that they are almost certainly blemishes on the negative or print rather than genuine archaeological features.

Using this method carefully and thoughtfully ink over the features interpreted, using colour coding if appropriate to distinguish different types of features. This is the stage at which much of the initial archaeological thinking ought to be done. At this stage of the interpretation-and-mapping process you are beginning to show the archaeological features as such and are no longer concerned with how or why they show. Draw in a logical order to identify, for instance, individual **enclosure**s within a complex system and to show any observed chronological sequence. If a photograph shows upstanding as well as below-ground features these may be easily depicted as such, for example, using one colour or type of line for ditches and another for walls or similar upstanding features. But the final mapping scale may make it difficult to draw accurately over very complex or small features and an overlay may have to be simplified to show ditches or walls. Making overlays is a useful way for beginners to produce their own interpretations for discussion with other students and teachers. Overlays provide a considered interpretation that can be compared with the master photograph and with features recorded on other photographs. Such comparisons are less easy to manage on-screen, especially if stereoscopic examination is required during discussion.

It may be useful, especially if control points are few and/or uncertain, to include on the overlay a selection of continuously-drawn modern boundaries. These will provide a check against the map after image rectification has taken place (see for example Fig 8.9).

Although this method of creating a map is somewhat antiquated, use of an overlay drawing is an excellent teaching aid on which students can show their interpretation of a phograph in a form which is easy for others to see and discuss.

Written notes

It is useful, especially for a beginner in photo interpretation, to note any thoughts and uncertainties about the features being interpreted. If you have questions or doubts, make a note or sketch to illustrate them before you forget (because you forget). These notes will remind you of specific points that may be answered when you examine other photographs. For example, one of the most frequent doubts is whether a break in a ditch is a genuine ancient gap (perhaps an entrance in an **enclosure** boundary) or has been caused in some other way. ‘False entrances’ can be due to a range of effects – a recently removed field boundary can cause such a break, for instance. Or sometimes, with crop-marked information, local conditions may not allow the crop to develop and show the **enclosure** ditch. Any such queries can be marked by adding a question mark (using a different colour) on the overlay and may in some cases be resolved by reference to old maps or to photographs taken on different dates. Each interpreter can develop his or her own system. Some may prefer the shorthand of a set of symbols, others may like to write more extensively. Any notes made on paper will need to be clearly referenced to a specific overlay or photograph; they may then be attached to the overlay when collating material for storage after completion of the work.

Need for care and accuracy

The accuracy with which you trace the features on an overlay will be reproduced in the resulting mapping. Try to follow features on the photographs precisely and to show variations in the widths of ditches as appropriate to the mapping scale at which you are working. Mistakes will inevitably be made and may need erasing or marking as 'ignore' by crossing out using a different coloured pen. Ink from technical pens can be removed by use of a licked finger or damp cotton wool bud. Marker pens come with either water-based (temporary) or spirit-based ('permanent' or 'indelible') inks. The former can be erased as described above, the latter require a solvent to remove them and this is unlikely to be permitted in a library.

Use of colour codes

Use of consistent colour coding will avoid the need to write explanatory notes on your overlays and will enable you and others to make sense of them many years later. The colours can be continued through later phases of transformation and can be retained in the final drawing if appropriate. There may of course be good reasons for changing them on some drawings, for instance to colour-code different phases within a multi-period map. Colours are required that easily identify the main local types of feature and can themselves be graded to show different ranks of probability. In Britain there are several colour codes in use by different organisations and no one example can be recommended here. An example of the writer's own conventions can be seen in Fig 7.3. Interpreters, in whatever country, are urged to establish their own system and to employ it consistently, remembering that they may be using it to show natural and recent features as well as a range of archaeological types such as banks, walls and ditches.

The range of depicted natural features is likely to vary with the area being studied and the reasons for mapping. The focus will be on those most likely to have been relevant to the location or visibility of archaeological items. For example, a band of deeper soil may indicate a past watercourse that may have encouraged ancient settlement (Figs 7.2, 8.2). Other areas of deeper soil, such as alluvium or colluvium deposited after archaeological activity, can mask evidence of former structures or inhibit past features from affecting crop growth above them. For this reason their inclusion on maps indicates zones of 'negative information' – that is, areas where we know that archaeological information is not likely to have been visible from the air. These, plus such things as wooded and built-up areas, help to explain apparent gaps in the **pattern** of the past that has been interpreted and mapped from **aerial evidence**.

Fig 8. 3 Marking control points

Control point number 3 has been marked on the photograph by intersecting lines ruled along the top of the middle of two narrow ditches. On the 1:10,000 map these ditches define the edge of the road. Intersections made in this way are more accurate than freehand lines or dots. This should become the standard way of marking control points on overlays.

Photo interpretation on-screen

Photo interpreters employed within photo libraries or using their own photographs have the opportunity to work with digital copies directly on-screen. The selection of photographs will follow the same pattern as above – and scans will have to be made at adequate resolution to ensure that maximum detail is recorded. Work is then carried out in two stages. Firstly the photograph is transformed by adding control points to the map and photograph directly on screen. Use of image processing software or of the monitor brightness button may be needed to see into any dark parts of the photograph, and the prints should be kept readily available so that they can be examined under the stereoscope to help confirm any uncertain positions. Final transformation should be done using the highest quality interpolation within the software being used (see below). This is necessary to retain good detail and resolution in the transformed images since interpretation will be done on these. The use of GIS for interpretation and final drawing is outlined below.

Another type of on-screen examination entails systematic examination of photographs (usually vertical runs or satellite images) to identify possible sites within a pre-defined area. This kind of work also requires high-resolution digital data that can be manipulated on screen and enlarged to an adequate scale. Files may be direct scans of the original material or geo-referenced copies from which topographical co-ordinates can be read directly. Examination of these files may be made easier (for the computer) through the use of compression software and appropriate programs for viewing. Examples of such programs are ER Compressor and ER Viewer, both of which can be freely downloaded from the web (*web reference: ER*).

Transforming to plan

For many uses of air photographs it is necessary to transform them to match ground co-ordinates. This section outlines some methods that are or have been, used to transform information recorded on aerial photographs. In this context verticals can be considered as one form of oblique photograph and all of the following methods can be applied with equal ease and success to both. Readers in Italy will find useful information on long-eatablished photogrammmetric methods in that country in *Piccaretta 1987*, *Alvisi 1989* and *Piccarreta–Ceraudo 2000*.

A range of specialist software is available for digital transformation. Some of this is only for vertical or near-vertical photographs and will not be considered here. Other specialist software has been written to deal particularly with transforming oblique photographs (see below).

The following methods assume that photo interpretation on an overlay has been done before mapping is attempted.

Theoretical note

A critical factor to remember when working with oblique air photographs is that they are perspective views and so the scale will change between foreground and background. This is especially so with the more pictorial obliques which tend to be taken at shallow angles to the earth's surface. From this, two factors become relevant:

It is more difficult to be precise about items in the background of photographs. This may seriously affect the accuracy with which control points can be identified and marked and may also cause errors in the positioning and size of any background features.

Small errors will be magnified towards the background of a very oblique photograph. See for instance Fig 7.15 and the distorted grid lines Fig 8.4.

These reasons help to explain why an aerial photographer taking photographs for interpretation and mapping should not only take them at near-vertical angles but also ensure that the **target** is placed in the foreground two-thirds of the photograph. Interpretations should be made from the background only if no other prints exist.

Historical methods of transcription: by hand

Sketch mapping

Sketching, or sketch-mapping, is nothing more than freehand drawing made by looking at the site on the photograph to mentally rectify and scale features and transfer them to the map. There have been claims of fair accuracy for sketch mapping but this is unlikely to be consistently expected or repeated, especially by beginners in air photo mapping. Sketching may be adequate for mapping isolated features at 1:10,000 or for making small additions from recent or secondary photographs to features already mapped with greater accuracy at an earlier stage. Sketching is often seen as a rapid method of mapping (which it is **not** if the site is in any way complex) so photo interpretation is often lax, with the sketcher probably working directly from an unmarked photograph (ie with no overlay interpretation). This will hinder any comparison between photographs and often means that the finer detail of a site is omitted. Sketch mapping, however, is an art that improves with practice.

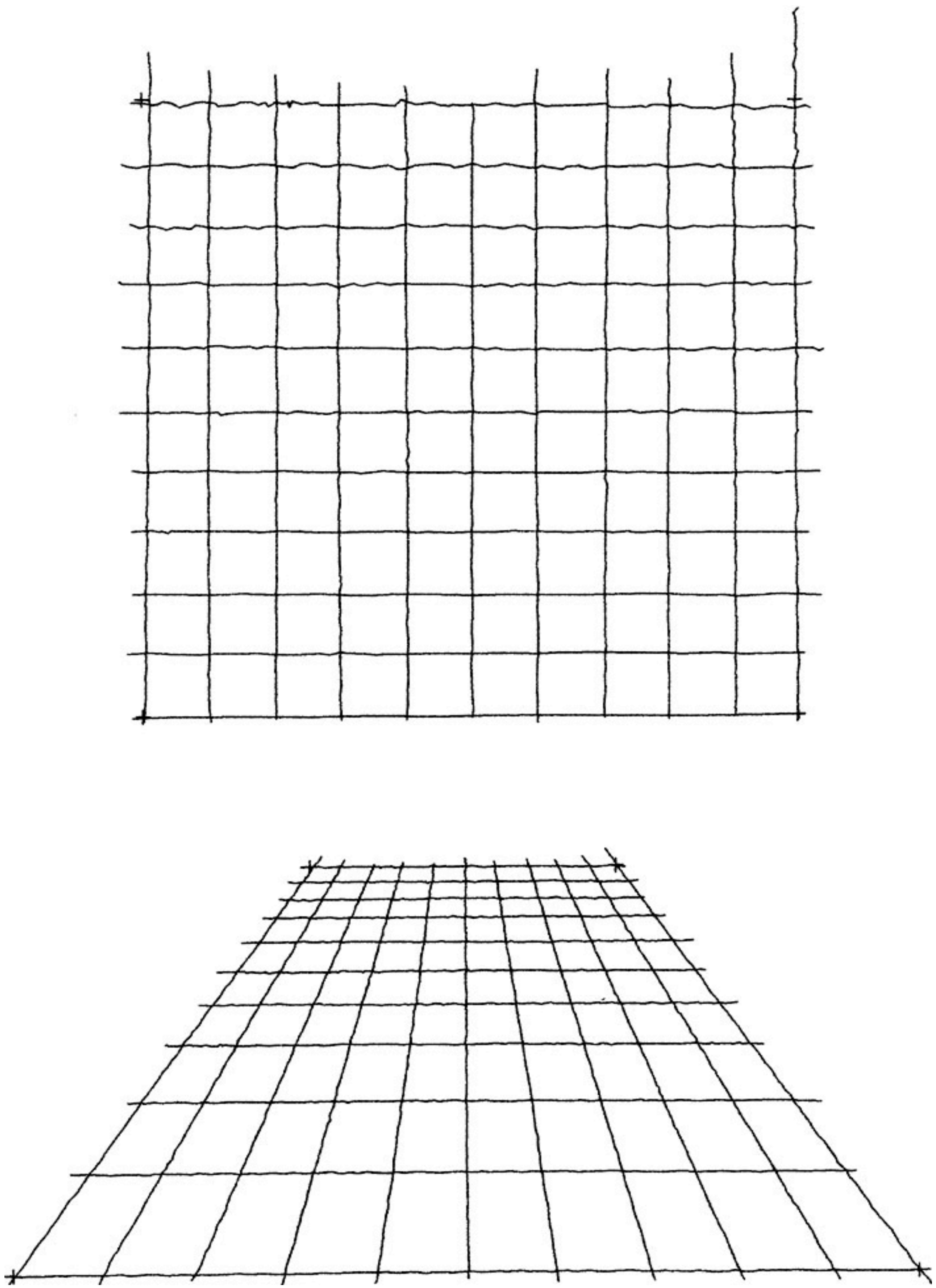


Fig 8. 4 Transforming oblique views to plan

The perspective grid (*bottom*) represents an oblique aerial view. This has been transformed to plan in the top view, using a control point at each of the four corners. Input was freehand-digitised with points being read at fixed distance intervals. The resulting plan illustrates a number of points about mapping from oblique air photographs.

Note that the foreground of the perspective view has been transformed with fair accuracy of position and with lines that are reasonably straight. However, errors in position are magnified towards the background. This is shown by the positions of the back (*upper*) two control points in relation to the lines that should pass through them, as well as by the increasing irregularity of the lines. This shows the problems of accurately pinpointing features in the background and suggests that most interpretation should be confined to the foreground two-thirds of oblique photographs. The best photographs for mapping are those taken from a near-vertical viewpoint.

Network method

Mapping by network (described in detail in Fig 8.5) relies on the fact that by joining matching points on a photograph and a map a series of polygons can be constructed through which detail on the photograph can be transferred to the same relative position on the map. At least five initial control points are required, others being created by intersections or where a network line crosses a mapped boundary. Completed networks will result in two matching irregular grids – one for the photograph (on an overlay, of course), the other on the map. Archaeological information is then transferred from its position within one grid to the same relative position in the other. Lines in a network owe their positions to the mapped and photographed control points, so ideal cover of a site is not always possible. Use of networks will give greater accuracy to hand-drawn mapping.

The network method needs no sophisticated equipment and provides a good introduction to the properties of photographs. It also allows a beginner to become aware of some of the problems encountered when working with aerial photographs (such as matching a boundary – hedge, fence, wall or ditch – on a photograph with a line on a map). It is a useful method for occasional work and is of sufficient accuracy for simple sites mapped at 1:10,000 scale. To achieve the accuracy commensurate with larger scales, or to transcribe complex detail, the use of networks is very slow and tedious.

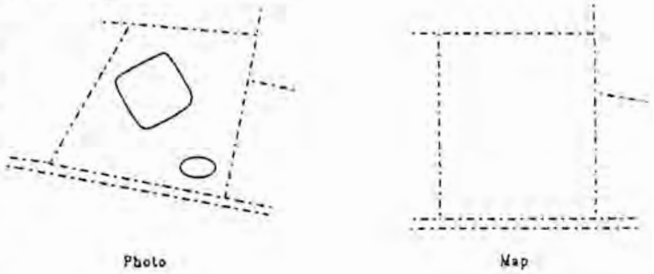
Paper strip

The paper strip method (which is described more fully in Fig 8.6) was developed in the early days of aerial photography. It is a way of creating a network that allows the user to make intersections at points where they are required. This will assist the more accurate transfer of information. Only four control points are needed and a series of rays can then be transferred from photograph to map which enable a simple site to be accurately located and drawn. Lines can be positioned as required to intersect interpreted features and so good accuracy can be achieved. No special equipment is needed but, as with all hand-drawn methods, care is needed at all stages to ensure the precise transfer of information.

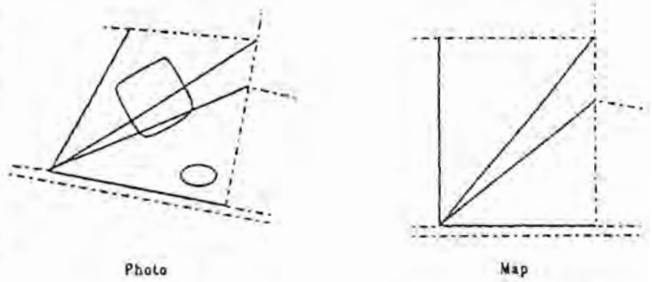
Although computer methods are now commonly used for plotting from oblique aerial photographs, and should be used whenever possible because of the greater accuracy and ease of use, there is still a place for manual transcription in the landscape archaeologist's toolkit. The simplest aids to transcription, requiring no specialist tools are the Network and Paper Strip methods. N.B. In common with the basic computer programs, neither method can compensate for distortions due to height variations and so by preference the photograph chosen should be as near vertical as possible and the site substantially planar (either level or an even slope).

THE NETWORK METHOD provides a simple, quick method of enhancing the accuracy of the manual plotting of information from oblique aerial photographs. The aim is to produce a network of lines that provide a framework to assist the drawing of the archaeological information.

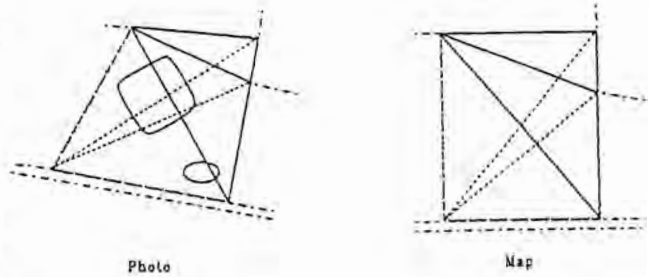
1 The basic requirement is a photograph that contains at least five control points (i.e. points such as field intersections that are visible both on the photograph and the map). If only four points are available then the Paper Strip method should be used.



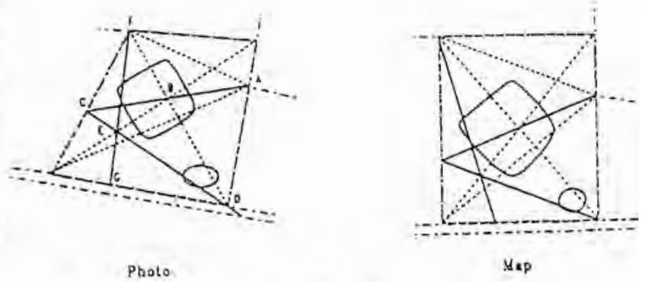
2 On a transparent overlay to the photograph, using a ruler and a fine line, accurately draw lines from one control-point to all other control points visible on the photograph. Now draw the same lines between the same control points on the map to be used.



3 Repeat 2 for each of the other control points, working first on the photo and then on the map. You now have a basic network. N.B. In this example the field boundaries are straight, usually this will not be the case - for network construction purposes always draw the lines joining control points even if they nearly coincide with field boundaries.



4 The network can now be enhanced by using the intersections of the lines already drawn as control points e.g. a line drawn from A (an original control point) to B (a network intersection) can be projected forming a new intersection at C. In turn C can be joined to D forming an intersection at E, which in turn can be used with point F to produce a further intersection at G. The process can be continued until the features to be drawn are sufficiently well defined by the network to enable accurate sketching on the map. N.B. To avoid confusion at this stage always alternate, by first drawing a line on the photo and then on the map.



N.B. If using two photos taken on different occasions, but with the same control visible, the network produced on the map will of course be applicable to both photos.

Fig 8. 5 The Network Method

As explained in a drawing by Pete Horne, of English Heritage.

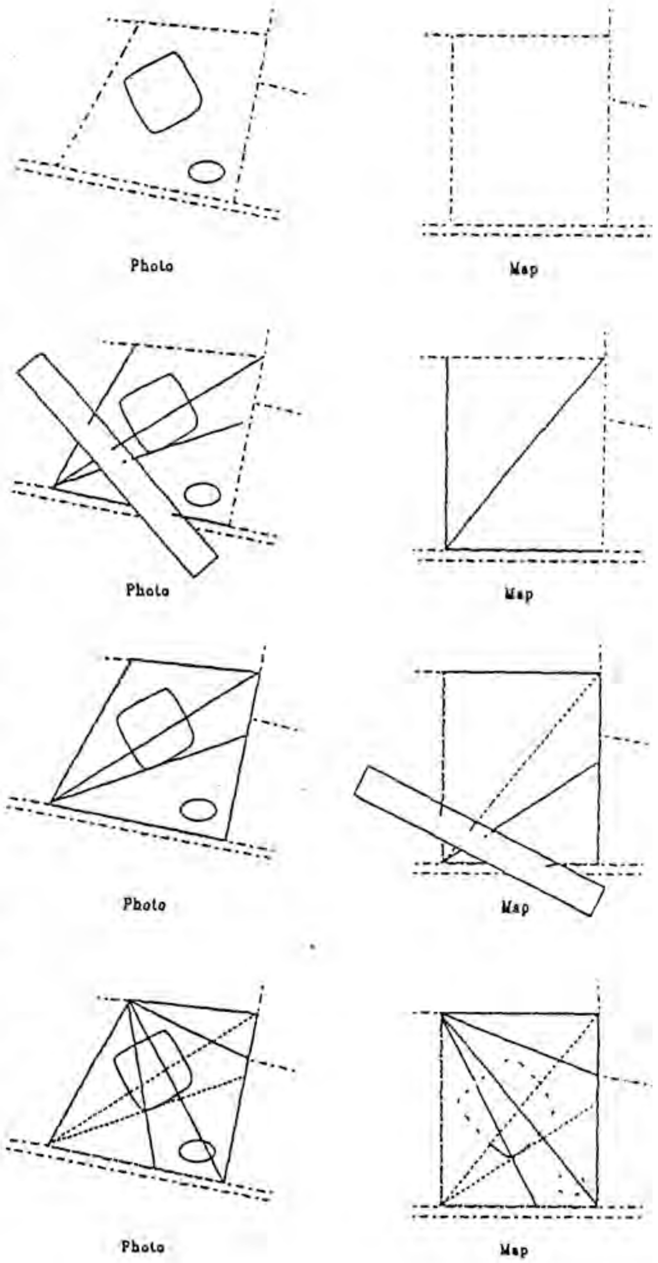
THE PAPER STRIP METHOD provides a way of constructing lines and intersections on photo and map at precisely the points required to define the archaeological features seen on the photograph, but for all but the simplest sites is more laborious than the Network method. The Paper Strip method only requires four suitably spaced control points, though more are preferable. (It is of course possible to combine the methods - and if necessary the Paper Strip method can be used to create the fifth control point needed by the Network method).

1 The basic requirement is a photograph with at least four control points. The example shown here will show how to locate the bottom corner of the enclosure, the procedure should then be repeated to establish other key points required for an accurate transcription.

2 On a transparent overlay to the photograph, using a ruler and a fine line, accurately draw lines from one control-point to three other control points visible on the photograph. Now draw the *same* lines between the same control points on the map to be used. Draw a fourth line on the photo overlay from the first control point and passing through the point to be identified. Now place a straight-edged paper strip over the photo overlay and mark it on one edge where each of the four lines cross.

3 Transfer the paper strip to the map and line up the marks with the lines joining the control points. It is now possible to transfer the mark made for the fourth line to the map; then, by using a ruler to join this point back to the first control point, accurately mark the position of the fourth line on the map.

4 Exactly the same procedure should now be followed working from a second control point so producing an intersection on the point of detail to be transferred. For greater accuracy it is preferable to then repeat the procedure working from a third control point and so confirm the accuracy of the intersection. Having marked all the key points in this manner it is possible to sketch on the detail in between them with a high level of accuracy.



N.B. To ensure accuracy the paper strip should be laid across the lines on the photograph some distance from the control point to be used. Great care should be taken not to confuse lines - use plenty of paper strips and/or coloured pencils to ensure the right marks are transferred for each part of the construction.

Fig 8. 6 The Paper Strip Method

As explained in a drawing by Pete Horne of English Heritage.

Historical methods of transcription: by computer

Development

An outline of the development of computer transformation methods for archaeological use was published some while ago by the present writer (*Palmer 2000*). The major difference that separates 'historical' from 'current' methods is the change in computer processing power that now allows digital copies of photographs to be transformed. The specialist image-transformation software written for this purpose and used by photo interpreters in Britain and elsewhere were designed for PCs. PC emulators can, however, be installed in Macs to facilitate use of some of the software mentioned – **AirPhoto**, for example.

These uses of computers were developed over time from Irwin Scollar's program that transformed single point co-ordinates from a photograph to three-dimensional points on a map (*Scollar 1975*). This was followed by a crude program written by this author to graphically transform digitised input from oblique images to match map co-ordinates (*Palmer 1977*). Both programs were written for mainframe computers. In the early 1980s John Haigh, a British mathematician from Bradford University, was working on software that could use the increasingly commonplace PC as a platform to rectify digitised input to match a map and to output a drawn plan (*Haigh 1993*). His suite of programs, known as **AERIAL**, was used by many British interpreters until the change to image transformation around 1996 broadened the choice of software for this purpose. In a more developed form, AERIAL is still used in the aerial survey section of English Heritage.

AERIAL **4** was the last version of Haigh's software to employ digitiser-input in the rectification of drawn photo interpretations. Input was made using a puck, a small mouse-like device with a clear window inscribed with cross hairs. Control points and interpreted data were traced as a series of points using the puck to input x and y co-ordinates to the computer. Normal use of AERIAL 4 assumed flat and level ground but contours could be input to create a digital terrain model that assisted more accurate rectification in hilly areas. Output was to a pen plotter or could be sent digitally to graphics packages or added to a GIS. Digitiser input has now been superseded by more recent methods, described below.

Specialist software for oblique and other images

Two programs have been written specifically to enable the transformation of oblique photographs holding archaeological information. **AERIAL** 5 was designed in collaboration with a number of national archaeological organisations in Britain and serves the needs of those who use the British grid as a coordinate base (*Haigh 1996*; *1998*; *1999*; *2005*). Grids for the rest of the world are dealt with under a single mathematical system that may not relate precisely to all national grid systems and map projections. This writer has not used AERIAL **5** but has since 1998 been working with, and helping to develop, another program, **AirPhoto**, designed by Irwin Scollar, an American who has been based in Germany since 1959. **AirPhoto** is fully compatible with several dozen national and local grid systems plus latitude-longitude and other co-ordinate systems (*Scollar 1998a*, *b*; *2002*; *2008*). In general terms the two programs are similar: both perform transformations of oblique (or vertical) images to match a map, or map co-ordinates. In practice AirPhoto is more sophisticated, easier to obtain, and a little cheaper – although neither program is costly for the facilities offered and there is now a free, cut down, version of AirPhoto (AirPhotoSE, formerly called PerCor). In 2008 AARG produced a guide to transformation programs that were then available (*Scollar* et alii *2008*) which, although in parts already out of date, may help a reader decide which options are available and necessary for any new work.

Other software for transformation

There are a number of other programs that include image transformation suites. Some are very expensive, others are available as free downloads. The essential difference seems to be that they have been written to deal with vertical images, either from aircraft or satellite, and they do not perform as well as the specialist software does with oblique images which, in some countries, are the main source of archaeological information. Results using the algorithms in these programs can be unsatisfactory. The survey conducted by AARG included two of these programs, Erdas Imagine and ILWIS GIS, in its comparative table (*Scollar* et alii *2008*, 13-18). Since that date, there has been progress in using computer vision and image stitching programs to produce a form of orthorectified output from series of oblique images. This work in still in its early stages but offers exciting prospects for work during the next few years (see *Verhoeven 2011* and *Verhoeven et alii 2012* in the preamble to the Supplementary *Bibliography*).

Scanning maps and photographs

For high-quality output it is essential to make original scans of maps and photographs at adequate resolution to retain the detail required. If a flatbed scanner is used it should be set to at least 300 dpi (300 pixels per inch), or more if it is intended to interpret on-screen. Maps and photographs can be scanned and saved as colour (24 or 16 bit) or greyscale (8 bit) images but large files may cause problems if used on a computer with less than about 4GB of memory. Most black-and-white maps are best scanned and saved as 1 bit files – this keeps files small and retains fine detail. Transparencies or negatives can be copied in an appropriate scanner or by using a light-lid attachment on a flatbed scanner. High optical resolution, of at least 1200 dpi, should be selected when scanning from 35mm negatives or transparencies.

The critical factor when scanning is to ensure that the final image size (i.e. photo transformed on to map) is of sufficiently high resolution to avoid detail becoming pixelated. Irwin Scollar, in AirPhoto Help, suggests using images that are at least 3000 x 3000 pixels if detail is to be retained after transformation. It is easy to adjust the physical size of an image and beginners are urged to experiment with sets of images at different resolutions and to observe how different sizes affect the final product.

Using AirPhoto

As computer programs constantly change and go out of date, the following is a general description that is accurate for the version of AirPhoto that was current in January 2003. The main transformation routines have not changed since then although important additions have been made to the program and these are mentioned below.

Input to the program can be from existing digital files of photographs or maps (raster files or dxf-coded data) or by new scanning of photos, overlays or maps, in black-and-white or colour. Scanning can be controlled from AirPhoto if desired and files may be image processed using the suite included in the program (Figs 6.4 and 8.7). Maps can be calibrated to suit the chosen grid system and, when necessary, may be joined together. Calibration will provide maps with an absolute scale and will allow them to be automatically geo-located in a GIS. It is usual to work with the map and one air photograph in split windows on a single screen. However, with an appropriate operating system and drivers dual monitors can be used. Paired images allow the user to keep track of progress when adding control points, which are usually input by use of a variable-magnification mouse-driven cursor (Fig 8.8). A choice of transformation methods is available which can be combined with three interpolations to help achieve the required accuracy and resolution in the resulting image. One of the transformation methods allows a terrain model and a minimum of three control points to be used. This should provide optimum accuracy and ought to be the preferred method whenever terrain is other than flat and level.

After control points have been positioned and the transformation method selected, transformation can be activated and, when this has been completed, the screen will display a small menu showing '**mismatch**es' of control points (see Glossary). If mismatches are not good the program allows selected points to be disabled or deleted and others to be 'tweaked' (adjusted), a pixel at a time, into positions which give smaller mismatches. When mismatches are acceptable (see below) the original transformation can be undone and the transformation repeated using the improved control information. With the base map superimposed on a transformed image accuracy can also be

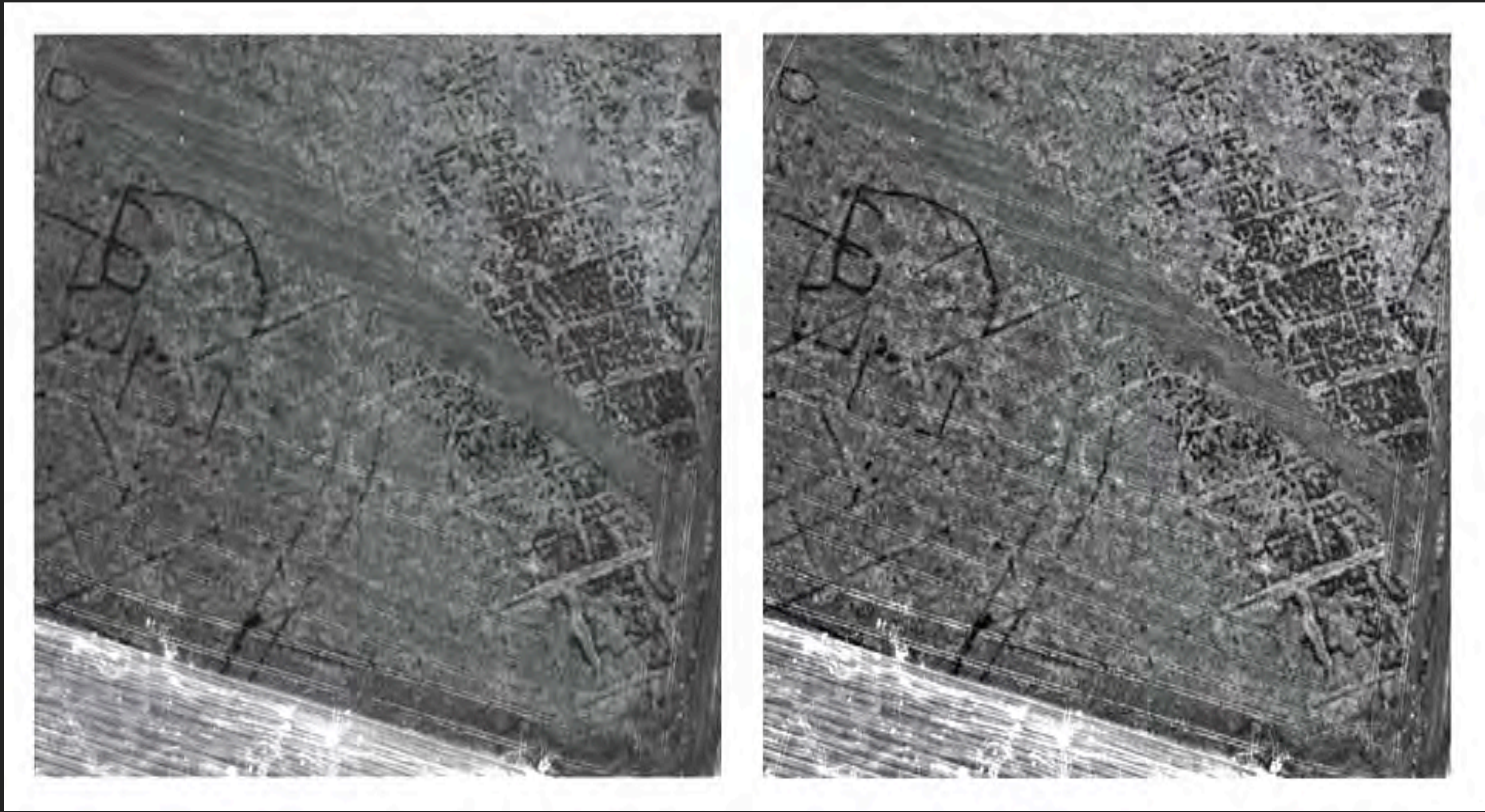


Fig 8. 7 Basic image processing of a black and white print

The original scan is on the left with (on the right) the same image after processing in AirPhoto at the default setting of Image Enhance. This feature of AirPhoto works equally well on colour and grey-scale images and is especially effective at enhancing features on differing backgrounds (see Fig 6.4). Note that features visible as dark-on-light and light-on-dark have been equally well enhanced – something that would not occur if a 'global' contrast change had been used. The method works on the luminance of an image by moving a processing window of pre-set size through the image to continuously compute the mean and standard deviation of the luminance in the window's area. This level of processing is a useful first step after an image has been opened for transformation. The rectangular grid on the photograph shows the structure of the underlying limestone bedrock, with archaeological features on the left.

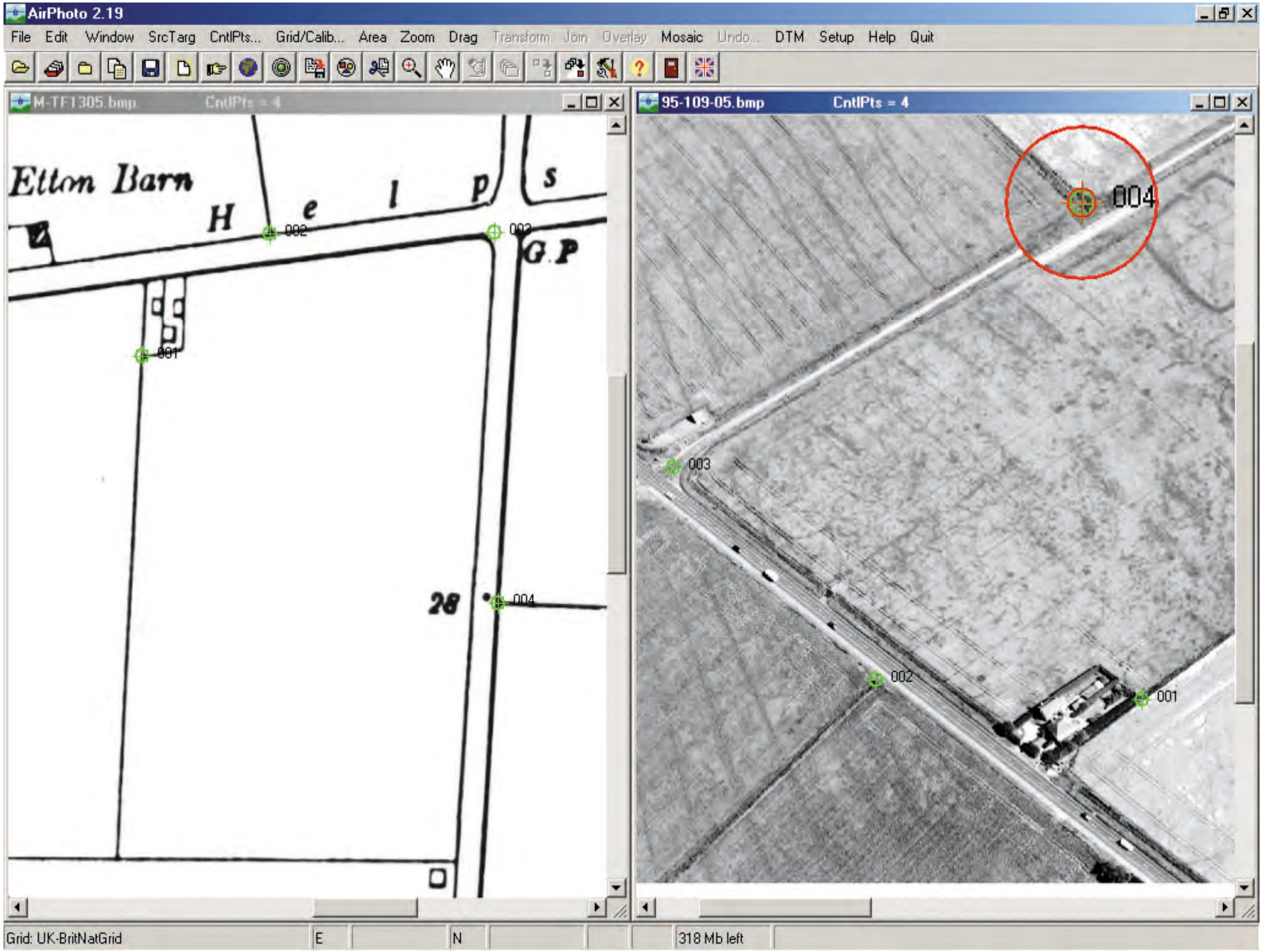


Fig 8. 8 Adding control points in AirPhoto

Inputting control points using paired windows to display the map (left) and photograph (right). A fourth control point has just been added to the photograph using the magnifying cursor. Adding control points alternately to map and photograph helps to keep track of progress and is recommended whenever five or more control points are used.

visually assessed by checking the fit of modern boundaries at and between control points. Transformation to a plain background, or a range of other options, can be selected as appropriate. Plain backgrounds, for example, can be less confusing when the interpreter is over-drawing a combined photograph and overlay in a GIS.

If required, the program allows transformation of a selected part of an image. This can be useful when building up a combined view, or mosaic, of an area from many photographs or interpretations. After transformation a selected part (or the whole image) may be printed to a chosen absolute scale although, in the era of digital records, printed output may only be required in special circumstances. Mosaics can also be made in AirPhoto by successively adding transformed files which wholly or partly overlap the previous ones or which, discontinuously, lie within a selected area. If necessary, irregular polygons can be cropped to enable individual modern fields to be pieced together with no overlap. Completed transformations can be saved in a range of image formats and can be given appropriate header information to enable their automatic geo-location in a GIS.

AirPhoto and AERIAL 5 make no distinction between vertical and oblique photographs so users can work with any photograph that best shows the archaeological features and has adequate control. Photogrammetric software and GIS add-ons, noted below, are primarily for use with precision vertical photographs. As noted earlier, they will not always give satisfactory results when used with oblique air photographs.

Specialist photogrammetric software

Use of photogrammetric equipment requires special training. It is expensive and is not commonly used except in Italy for archaeological mapping although its use can be advantageous in upland situations or where output showing very detailed 3D information is required for conservation or management purposes. One such computer-based system, using Erdas SoftPlotter, is at the Institut für Ur- und Frügeschichte in Vienna, Austria. It allows extremely accurate correlation between **air photo interpretations**, geophysics and excavation data. In Vienna, **photogrammetry** is often one stage in the preparation of an accurate background (combining surveyed ground control and vertical photographs) on which to transform more detailed oblique information (*Doneus 2001b*).

GIS add-ons

In addition to this specialist photogrammetric software there are various add-ons that are supplied with, or can be purchased for use with, GIS platforms. The versatility of these does not compare with the specialist programs and they are intended for little more than transforming small-scale vertical photographs in manners appropriate to their use as background layers in GIS displays.

Metrical accuracy of transformed data

The accuracy of the dimensions, form and location of any transformed information is relative to the accuracy with which the selected control points can be matched on the aerial photograph and the map. This is the basic premise for any rectification. Problems may arise for a variety of reasons:

- due to topographical relief, which can cause considerable errors of location and shape;
- due to the photographs being too oblique;
- due to an inability to match detail on an air photograph precisely with that surveyed on the ground;
- due to inaccurate drawing, or fixing, of control points on map, photograph, or both;
- due to differences in the dates of map and photos (eg boundaries recorded on an old photograph may not be on the latest edition of the map, or may have moved);
- due to the use of unsuitable control points (though sometimes this is unavoidable).

It is necessary to know the largest scale required for output before commencing photo interpretation, and then to use maps of that scale or larger for control. Rectified output or finished drawings can be reduced but ought not to be enlarged as this will also enlarge errors. Reasons for this, related to the accuracy to which cartographers work at different scales, have already been noted in Chapter 7.

These survey standards will be reflected by the transformed output and final drawings, not only in the levels of accuracy attainable but also in the degree of detail that may be expected at each scale. To interpret and depict these different levels of detail the photo interpreter needs to adapt work within each project to meet the expectations of the largest scale of output to be produced. Extreme representation of detail at 1:10,000 can confuse a final drawing and hinder the level of archaeological understanding appropriate to that scale. Some reductions may therefore need editing. On the other hand, badly produced 1:2500 drawings using a standard line thickness give a poor impression and offer little confidence in the work done.

After performing a transformation, AirPhoto and **AERIAL** both display values for **mismatch**es of map and photo control points. As a rough guide, when working to 1:10,000 scale it may be acceptable to allow one control **mismatch** greater than ±7.0m while maintaining a mean of ±3.0m. Occasionally one greater mismatch has to be allowed due to lack of any alternative. At 1:2500, especially if the work is to be used as a guide for the location of excavation trenches or has to link with excavation plans, it is good practice to keep all control mismatches below ±2.0m and to expect the mean value to be well below this. Use of the control point 'tweaker' in AirPhoto is a considerable help in attaining very close map-photo matches. There sometimes will be an aberrant control point, as may be caused when farmers shift a boundary a few metres or when someone erects a new building in much (but not precisely) the same position as a mapped one. Mismatch values help identify such points which, if other well-spaced control points exist in sufficient numbers, can then be disabled or deleted.

Regardless of the mismatch values obtained by careful identification of control points it is perhaps misleading to state that the accuracy of the air photo mapping is better than that of the target map. That accuracy may be applicable when measuring between close points but may not be valid with regard to their absolute position or their relative location over longer distances.

Additional precision in the location and form of transformed features will be gained by use of a digital terrain model (DTM) and the appropriate transformation algorithm. Creating this may be a tedious process but ready-made DTMs may be available through the major cartographic providers. The contour interval and resolution of these may often be less than ideal for depicting the sometimes slight differences in topography that were exploited by past communities but they will often be good enough to provide a surface model that will help achieve better transformation.

Terrain models and other advantageous information is commonly available now (in 2012) from Airborne Laser Scanning (ALS, Lidar or – in this book – lidar). This remote-sensing technique had barely reached archaeological awareness when this book was originally written but has since been applied in many countries and in many varied situations (*Doneus–Briese 2006*; *Doneus* et alii *2008*; *Crutchley–Crow 2009*).

One advantage of image transformation is that transformed images can be overlain by the map and can thus provide a visual check of the locational accuracy of modern, or mapped, detail and so to add confidence in the mismatch values. Even if the photograph itself is not transformed, sufficient modern detail can be added to an interpretative overlay to provide a useful visual check (Fig 8.9).

Fig 8. 9 Uses of interpretative overlays

On occasions an interpreter working with photographs in a library is unable to obtain scanned copies. If modern boundaries are traced on the interpretative overlay these can be compared with those on the map after transformation. This visual check, plus the mismatch values, will indicate the locational accuracy of the transformed image. Note here how the schematically mapped road-edge at a scale of 1:10.000 conflicts with the gentle arc traced from the photograph. Transformation of such an overlay can be a rapid means of making a map of a site. Multiple images can be combined but there may be slight differences in the location of features due to displacements of ground position relative to the angle of view. Any colour-coding used on the overlay can be retained by scanning as a colour file.

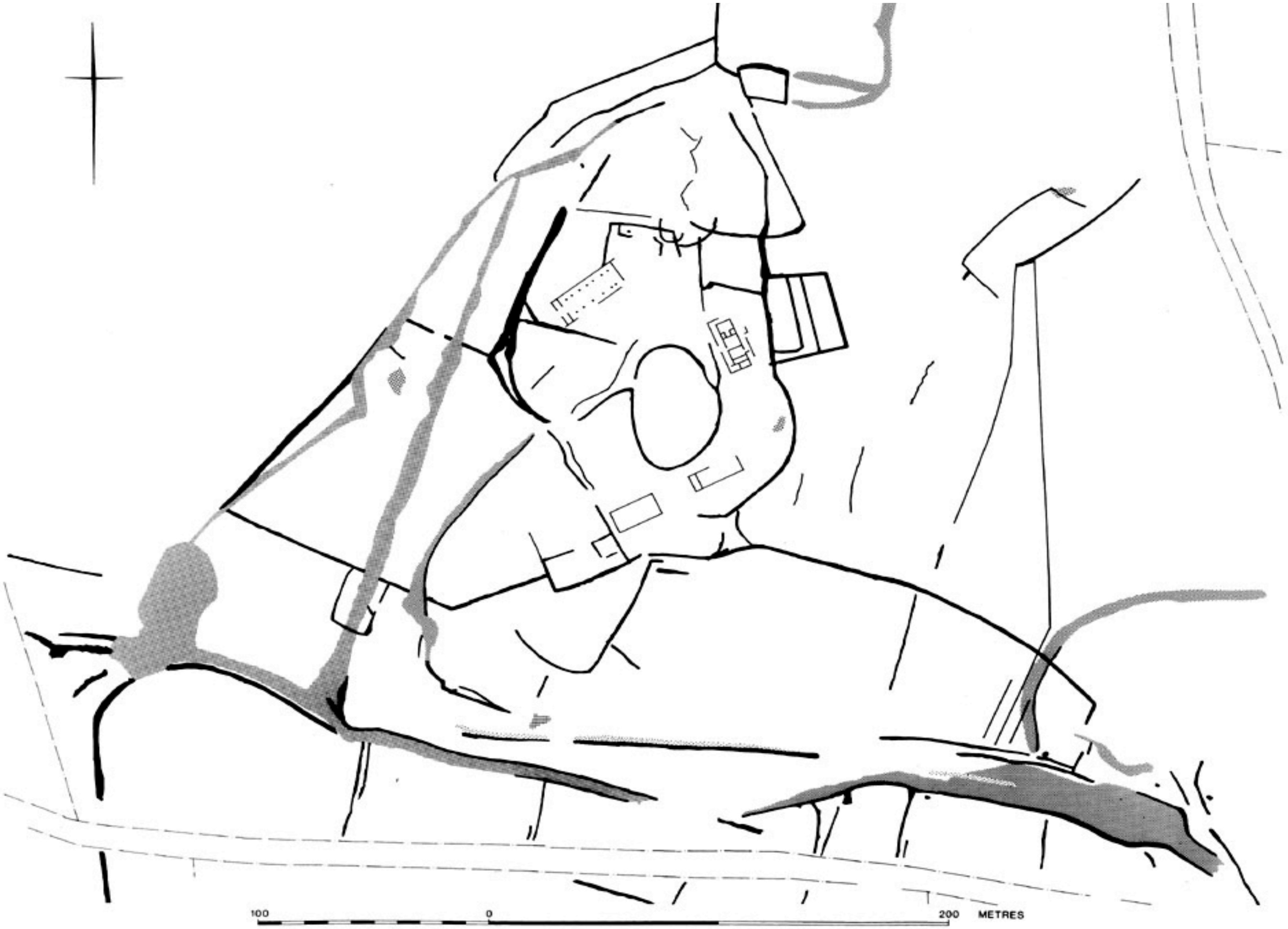


Fig 8. 10 Mapping of a multi-period site at 1:2500

Combined information from many photographs, illustrating a complex site possibly originating in the late Bronze Age. The rectangular Roman buildings, partly known from early excavations, were visible clearly on the photographs at only one date. The plan shows the level of detail and accuracy that can be depicted at this scale. Compare with the map of the same area at bottom right in Fig 9.1, which was drawn at 1:25,000 from reduced copies of original mapping at 1:10,000.

Finishing the drawing

Working scales

The question of map scales, or of knowing the scale of the finished drawing, was raised in discussing the first stages of photo interpretation and is again important in the final stage of the work. The main reason is to allow a drawing to be produced that is clear to read and not overburdened by detail inappropriate to the final scale. This was easier to appreciate in the days when drawings were done by hand as there were limits to what could be drawn clearly in a given space or at a given scale. When working on-screen it may be tempting to over-enlarge (zoom) and so to draw detail that will produce a meaningless blob when it is output at the required scale. No fixed rules can be given and it will be up to individuals to learn from their own experience and by studying the work of others. The basic rules of mapping still apply: work can be drawn at larger scales and can then be reduced but it is bad practice to enlarge from a smaller-scale original. To ensure that this does not happen it may be appropriate to add a caption to each drawing such as: 'Original photo interpretation and mapping at 1:10,000 scale'. In this case the drawing could be scaled down to, say, 1:25,000 but it would be wrong to enlarge it to 1:2500 and expect it to have the accuracy and information content of an original prepared at 1:2500 scale.

Use of digital maps to provide background information in a GIS avoids having to redraw modern features such as woods and built-up areas that can be crucial to the interpretation of archaeological features and landscapes. The common mapping scales for air photo work in Britain are those of the Ordnance Survey maps. Other countries, where work on **oblique aerial photographs** is not yet common, may choose their own scales on the basis of those that are available from their national or regional mapping agencies.

That said, two 'basic' scales for **air photo interpretation** and mapping are now used in a number of other European countries as well as in Britain.

1:10,000 scale can show a fair-sized area with good archaeological detail. Negative areas and natural features, such as soil differences, can also be shown and may provide context for the archaeology. Major recent features, such as old field divisions, pipelines and extents of hand-dug quarrying may be mapped to indicate areas of damage or destruction of archaeological contexts.

For study of larger areas it has become usual in Britain to combine 1:10,000 maps (each covering an area of 25 sq km) and reduce them to 1:25,000 for publication. Archaeological features can be shown over a modern map (as in Fig 8.10) or against a purpose-drawn selective background (as in Fig 8.9).

1:2500 and 1:2000 scales allow fine detail to be shown and precise measurements to be made but are not practical scales for the mapping of large areas. 1:2500 is the largest scale at which rural areas have been surveyed in Britain and it thus provides the largest commercially available background information. Some archaeological area maps in Italy, to give another example, have been prepared photogrammetrically at 1:2000 although the base maps may have been specially surveyed (*Piccarreta–Ceraudo 2000*, pp. 158-182). These scales are used when accuracy is needed for the precise location of protective measures, geophysical surveys or excavation trenches over specific parts of a mapped site. Almost all small features recorded from the air can be mapped at these scales – for example, internal rooms within Roman or later buildings (Fig 8.10). Individual sites can be shown with great detail and precision at these scales. Usually the mapping does not extend beyond a single modern field or archaeological site and study of adjacent features may not be possible at this scale. For that reason many extensive mapping projects may have an 'overall' scale of 1:10,000 and highlight specific features at 1:2500 or 1:2000 (compare, for instance, Fig 9.1, bottom right, with the same features represented at a larger scale in Fig 8.10).

Work at a 1:2500/1:2000 level of accuracy is possible where no base maps exist, as is shown by mapping work on the Roman town of Teurnia in Austria (*Doneus 2001a*). The project team began by identifying control points on photographs and then taking specific measurements of these points to allow the creation of a DTM from a stereo pair of vertical photographs. This provided the basis for photogrammetric rectification of vertical and **oblique aerial photographs**. The process was complicated and required specialist knowledge, skills and software but achieved precision mapping of 23 hectares in a few days. On completion it provided the first concise plan of the large and complex archaeological area since excavations began on the site 150 years ago. This now functions as the basis for continuing investigations in the area.

Contents of a finished drawing

It is useful to know the intended purpose of any finished drawing as this may affect both its contents and the way it is drawn. The addition of recent features may help explain some attributes of an archaeological site. For example, a ditched **enclosure** drawn on a plain background may appear to have a high number of entrance causeways. Some or all, however, may be explained if recent and modern field boundaries are added to the map. Or the unusual shaped of an enclosure may be due to its boundary following a specific contour or the edge of a palaeochannel. If a map is prepared as a guide for fieldwork it is essential that it should include, or be overlain upon, a modern base map of suitable accuracy so that a field team can make measurements and accurately identify areas for specific work, such as geophysical survey or small-scale excavations.

The digital preparation of drawings makes this a relatively easy task as each type of feature – archaeological ditch, recent boundary, modern map – can be assigned its own layer which can be switched on or off as necessary. The feature types and colour codes that were used during photo interpretation will each be given a separate layer in a digital drawing.

Preparing the final drawing: digital

To move from a transformed image to a digital map requires first that a file of suitable resolution has been given an appropriate GIS or CAD header in AirPhoto or **AERIAL**. The transformed image file or set of files can then be imported into an existing or new project where they should automatically be located to scale and in their correct position. Archaeological and any other required content can then be drawn as colour-coded polygons or lines while the interpreter is making reference – if possible – to copies of the original photographs. Different features – ditches, banks, walls, palaeochannels etc – may be kept on different layers but uses of these programs are many and varied and individual users may develop their own preferred way of working. One suggestion that could be made is to keep a layer for doubtful features. The writer often has (for example) a 'possible ditch' layer that contains features that may be archaeological ditches or may be natural fissures or the result of more recent activities. There will almost always be some doubt when photographs are interpreted and it is useful to identify and keep these uncertain elements if only because one day they may become more certain. Such doubtful items also make good points for discussion when learning and teaching.

Interpreting and drawing on-screen

This is a method of preparing a drawing directly from a transformed photograph of which no separate interpretation overlay has been made. There are two essential preliminaries before working on screen.

First, ensure that the transformed image is of sufficiently high resolution for clear identification of the information to be interpreted.

Second, always do this work with the photographs – preferably a stereo pair – beside the computer where you can refer to them if you need to do so.

The transformed photograph will be imported, ideally geo-referenced, into graphics software or GIS where it can then be interpreted and overdrawn. The interpreter must be careful to keep zooming in and out within sensible limits, referring to the original photograph or photographs to resolve any questions. Image processing may be used to enhance indistinct features, but may also falsely 'create' others.

One possible advantage of working directly on-screen in a GIS is that any notes or queries about the reliability of some of the drawn information can be attached directly to a vector and saved as metadata.

This method has been successfully used for work in Austria where transformed photographs were finished using Erdas Imagine software (*Doneus 2001a*, *2001b*). There is also some use of on-screen interpretation by workers in England's National Mapping Programme. If you are not based in a photo library, or are not working with your own photographs, you first have to obtain digital copies of the required photographs which can be a long and costly process although some libraries now allow you to photograph or scan their photographs.

Creating written records

There is a wide range of written records that should accompany mapped information, and a range of ways in which they can be stored and accessed. The basic essentials for an aerial photograph and a map are similar – we need to know their location and the date that the information was recorded. These fix the geographical position of the site and provide a cut-off point after which later but possibly relevant information will not have been taken into account. In practice no one keeps such a simple record and a minimal accompaniment for any mapping project should list the following pieces of information.

- Co-ordinates. In the system used in that country at that date.
- Principal photographs. Mainly those used for transformation and final drawing.
- Comments. The photo interpreter's opinion of what the features represent and, where relevant, how they may be related to other components in that past landscape.
- Cross references. Identification numbers of any national or local records to which the site may relate or is related.
- Condition. Whether the mapped features were upstanding or levelled on the latest date of photography. This may assist management policies.
- Date of transformation or final drawing.
- Author.

In addition, it may be desirable to prepare basic written descriptions of the sites identified, in the format used by national, regional and local registers of archaeological information to which the interpretations are to be submitted. Records of these kinds may well be written direct to a computer as work progresses. Notes may be written in programs such as Microsoft Excel or Access and entries in both of these can be related to mapped data in a GIS. Integration within a GIS allows linked information to be displayed by clicking on any relevant features.

Final thoughts

The methods outlined in Chapters 7 and 8 help to bring the evidence of aerial survey and air photography together in forms that allow us to classify and analyse sites and **landscapes**. Aerial photographs – oblique or vertical – record fragments of past landscapes that become visible when lighting, soil or crops are in the right condition. This chapter has provided an introduction to the ways of combining (by mapping) those fragments to show archaeological and natural features both at ‘site’ and at ‘landscape’ scale. Without mapping there are limitations to what can be said about the photographed information – sites may be described and parts of ancient landscapes noted, but associations may remain unclear or unseen and past systems of land-use cannot meaningfully be studied.

The working documents of the photo interpreter were detailed in Chapter 7 – types of photograph, types of film and a range of maps. In this chapter we have examined conventional photo interpretation using paper prints (common at the time the original text was written) and more recent opportunities that the use of digital data now allows (in 2012). Interpreters are likely to use both methods. Digital approaches may be the preferred choice by interpreters working on their own (or their own organisation’s) photographs, but preparation of overlays may be necessary when working on material in distant collections or where photo interpretation has to be done in situ because time and money do not allow the purchase of copies.

Transformation of oblique aerial photographs is not the same as **photogrammetry** sensu stricto and makes no claims to be so. However, specialist software, as described above, has been written to enable accurate transformations to be made and so to facilitate the use of the oblique photographs that are such a rich source of archaeological data but which, because of their angle of view, cannot be corrected using conventional photogrammetry.

Transformed information is converted to become finished maps or plans of carefully prepared photo interpretations. Nowadays, most are likely to be completed in a GIS and to become one layer in a multi-faceted collection of inter-related data, thus becoming a more powerful tool than were the paper maps, photographs and written records of former years. In Chapter 9 we will turn to the meaning/interpretation of that information in broader archaeological terms.

9. TOWARDS ARCHAEOLOGICAL UNDERSTANDING

This chapter makes the assumption that aerial photography is the first stage in a logical sequence of processes of which each can add further information and understanding to **feature**s that have been photographed from the air (Fig 9.2). In this sequence, aerial reconnaissance and air photography constitute the primary data-collecting phase that is later enhanced by photo interpretation and **mapping**. From there archaeologists are able to sort and analyse the data, to integrate it with other evidence and possibly to supplement and question it with fieldwork and excavation. At any stage in this process an archaeological interpretation may be offered, but the more we can combine aerial evidence with other information the more powerful our interpretations will become – and the more questions will be asked in response. Importantly, this sequence of processes includes the feedback of information gained at any one stage to help our understanding of the others. Archaeologists working with **aerial evidence** find that mapping and analysis leads them in new directions and that they are asking new and different questions rather than following the established range of queries posed by excavators and others working in related fields.

There has been little doubt in Britain about the authenticity of information mapped from aerial photographs, especially when it is the work of an experienced photo interpreter, but the situation is different in parts of Europe where air photography and photo interpretation are seen as new techniques. The work described in this chapter would not have been possible without the acceptance that, in most cases, our airborne archaeologists and ground-based interpreters working on a range of photographs are able to identify and categorise archaeological features and there is no need for these to be verified on the ground. This chapter outlines some of the work in Britain that has been directed towards understanding the evidence mapped from air photographs and this may help strengthen the case for similar studies elsewhere. Most of the published results in Britain are from research in areas of levelled archaeological features – in landscapes where no trace is now visible on the ground. Interpretation in upland areas, where a considerable amount of archaeological evidence remains in upstanding form, is more easily integrated with analytical field survey (see below) and shows immediate potential for increasing our knowledge of the past. It should be noted that most of the projects referred to below are the work of photo interpreters employed in government-funded organisations in Britain that have no remit to undertake excavations, and which cannot themselves carry out the supplementary field investigations that may be desirable. This is a point to which we will return at the end of the chapter.

Data Sorting

A simple reason for classifying things is to enable the similar to be grouped together and distinguished from the dissimilar. In field archaeology, for example, this allows us to sort flint and pottery into two separate groups, to identify and separate long **enclosure**s from round ones, or to recognise Roman camps as a distinctive group. With specialist input it is often possible to sub-divide, or further classify, those groups. The groups and sub-groups begin to help our understanding of the past if their use can be extended beyond simple clustering of information. We may, for example, identify local or regional trends – perhaps a type of ditched feature is more commonly found in one area than in another – and so our classification of that type becomes more useful. Once we are able to attach a date range to our types their potential value increases tremendously. Within a **landscape**, for example, we may then be able to apply that knowledge and begin to add dates and perhaps suggested functions to our mapped information.

It is possible to isolate the act of classification from its application – but if a classification is not to be used, then why classify? So this section notes some of our attempts to classify **feature**s known mainly from aerial photographs and notes what conclusions have been drawn from these exercises. Applications of those classifications will be dealt with later in the chapter. The chapter has been written to reflect the sequence in which the work is carried out: we pose questions, we design a classification that seems appropriate to their solution, we classify, and finally we apply the results of those classifications to our landscapes. If we are lucky there may also be other evidence – from fieldwork, documentary sources, or excavation – that will link with, and strengthen, our analyses, or our work may itself instigate further investigation.

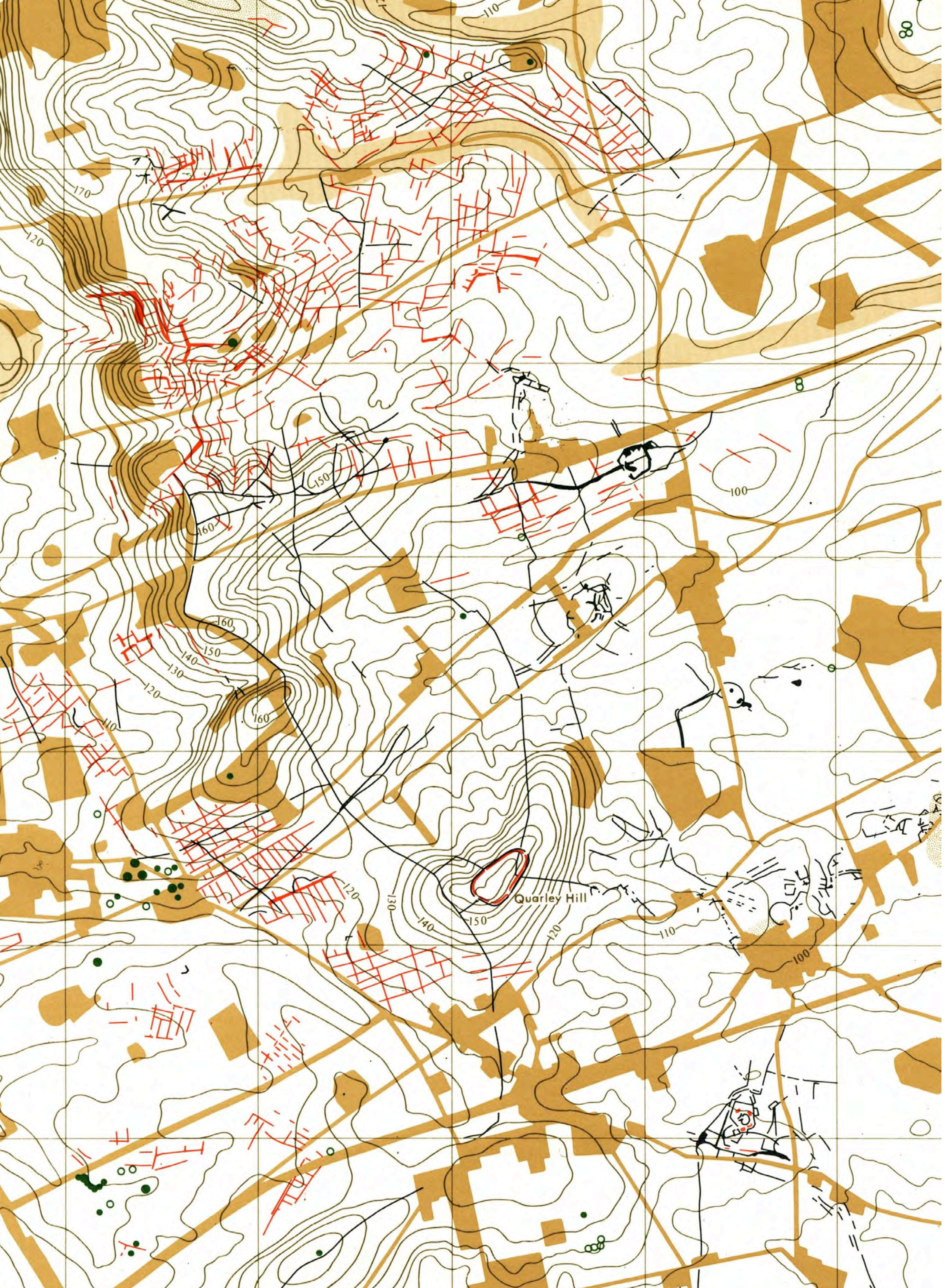


Fig 9. 1 A landscape on chalk downland

In southern England archaeological features survive as buried ditches (black) and upstanding banks (red), clearly showing more than one phase of past land-use. Field systems in this area are known to date from as early as the middle Bronze Age and may have continued in use to the end of the Roman period. Later in the Bronze Age a series of massive ditches divided the landscape and sometimes cut through earlier fields. In the map they appear to focus on Quarley Hill (bottom centre) on which a hillfort was later constructed. Ditched settlement systems lie scattered over the landscape, mostly on the higher ground. The original mapping was at 1:10,000 but is here shown as re-drawn at 1:25,000 for publication. The archaeological features are shown against a background of contours and ‘negative zones’, mainly due to modern villages, woods and roads. The grid interval is 1 km. For different topographical landscapes see Figs 6.1, 9.7, 9.8 and 9.13.

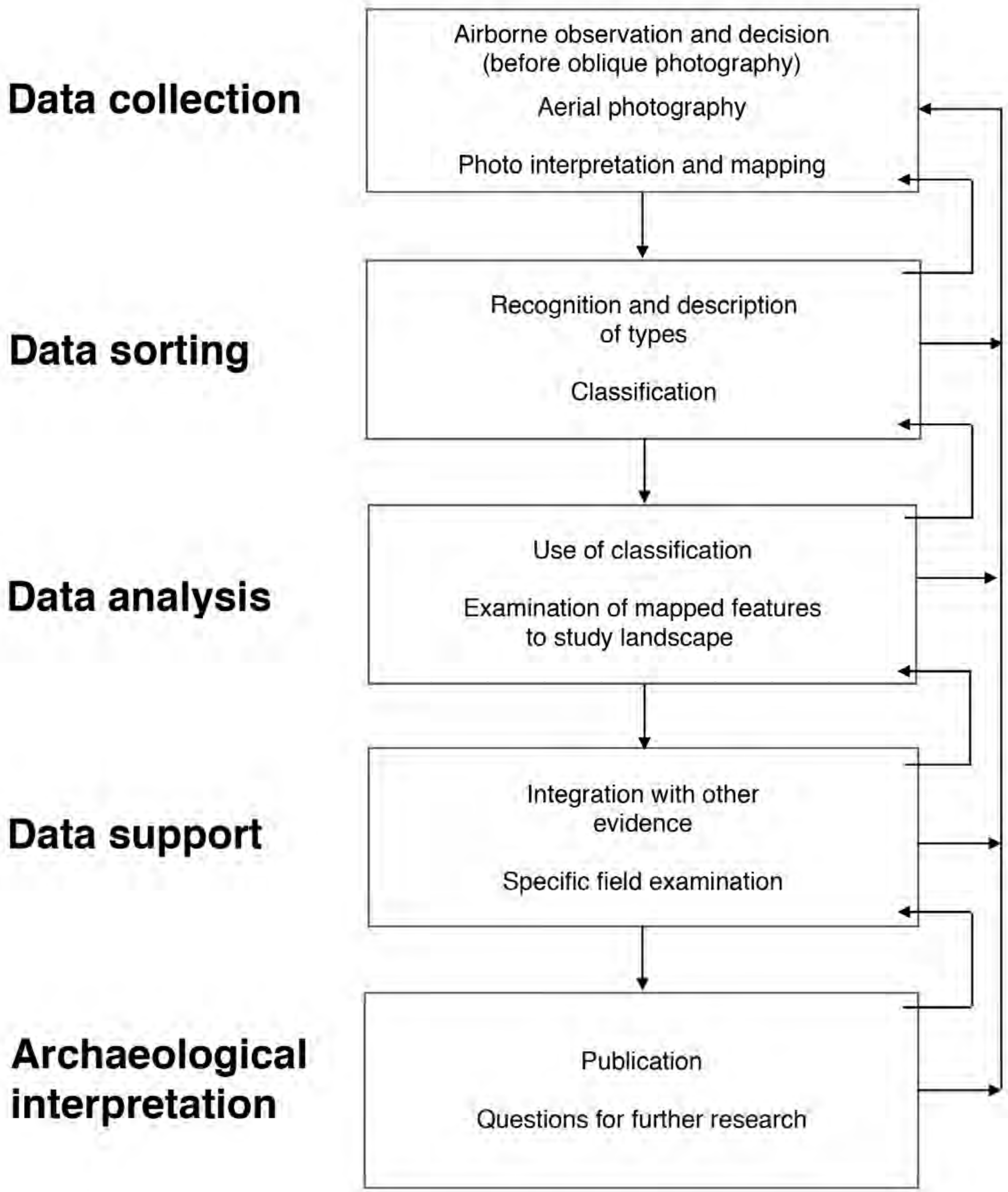


Fig 9. 2 From aerial photographs to archaeology

The diagram outlines stages and methods of progress from work in the air through analysis to archaeological interpretation. Note the constant feedback between all levels of activity and the increase in understanding as knowledge is added by each input. The diagram provides an outline of the propositions advanced in Chapter 9.

Beginning classification

A certain amount of elementary classification can be made by working directly from the photographs (it is sometimes even begun by the photographer, whose in-flight record may include a sketch or comment about each site photographed). There is often little problem in classifying a photographed **site** as, to take some examples from Italy, an alignment of Etruscan T-shaped tombs, a Neolithic **enclosure** on the Tavoliere or the **cropmarks** of a Roman villa and its surrounding vineyards etc (Fig 9.3). All these 'types' have definite visible characteristics that do not require **mapping** and measurement to establish their general classes. Such easily recognised site types tend to form sub-divisions in indexes of air photographs and this can make research into them, or publications of illustrated gazetteers, relatively easy. However, once a landscape has been mapped, or even if a random box of air photographs is examined, it becomes obvious that most of the recorded information does not fall into such easily assigned classes. Perhaps more important archaeologically is the realisation that these types do not exist in isolation. We need to ask whether they should be studied in isolation (as is the usual bias of excavation or analytical studies) or as part of their contemporary landscape.

Classification of **earthworks** has a long history in many countries and has advanced our understanding considerably even though many of the 'types' tend to be clustered loosely rather than truly 'classified'. The desire to classify sites mapped from aerial photographs perhaps draws its origin from the advances that archaeologists made through classification of portable artefacts, especially pottery and stone implements. Work on these followed a distinguished tradition and new finds, thoughts and theories have made classification of such objects a continually valid research topic.

However, there is a finite number of uses, even including the currently fashionable symbolic ones, to which (for example) a pot or a stone tool can reasonably be put. Pots are essentially made to contain while stone tools are specifically or generally designed to cut, scrape, strike or crush. Conversely an **enclosure**, especially a ditched one, could have had a vast range of uses – many of which we cannot now identify and most of which may have been associated with other dug features and with topography. Despite these problems, by the mid 1970s some pioneering work had been carried out on classification of stone-walled enclosures in Africa (*Mason 1968*; *Maggs 1976*; *Jones 1978*) while in Britain an early development of computer classification of stone-built sites in north-west Wales had just been published by (*Smith 1974*). These papers showed that it was possible to impose levels of classification on the enclosures studied.

Evidence from air photographs was being used in two different ways in the late 1950s and 1960s and resulted in two

Fig 9. 3 **Easily identified site types**

Site types such as these can be readily identified in the air or from photographs.

Top left. Etruscan tombs, seen as individual burial chambers, each with a narrow access passage.

Bottom left. A ditched Neolithic 'village' on the Tavoliere in southern Italy, with many smaller enclosures or 'compounds' in the interior.

Bottom right. A Roman villa (upper centre) with associated vineyards (top right) and field systems (lower left).

publications. The first, by the Royal Commission in England (*RCHME 1960*), was in a book which, as well as showing the wealth and density of levelled archaeological remains on river gravels, included lists of the more easily identified types of site. That volume, A Matter of Time, also included discussion about problems of classification and made attempts to link excavated information with that from aerial photographs. At a similar date and working in southern England, Brian Perry identified a category of site which he named 'banjo enclosures' (Fig 9.10). These were published as (presumably) sketched plans in a paper that also showed a few sites of 'other' types (*Perry 1970*). This work was perhaps the first in Britain to group together plans of a single type of site detected solely through aerial photography, but it may be questioned whether extracting one type of site equals classification. It did, however, show that there were identifiable and previously unrecognised components among the accumulating record on aerial photographs.

This writer's own 'games' with Neolithic causewayed enclosures in Britain (*Palmer 1976*) began with a mixture of earthwork sites that were accepted as definitely of that class, along with about twice that number of levelled sites that had been photographed and provisionally grouped as causewayed enclosures because of their interrupted ditches – the main characteristic of the type. A small range of analyses was attempted, mostly based on measurements of plans, which led to the conclusion that the two forms of site represented different survivals of a single type of Neolithic monument. This allowed regional groups to be suggested.

The development of morphological analysis

In Britain the ten years after 1976 saw most of the active thinking and advances in morphological analysis as applied to sites known only, or mostly, from air photographs. It was a time during which a small number of research projects began to lay foundations for the uses of aerial data. Since then there has been little new research input and our methods and theories remain, to a great extent, as they were 25 or more years ago although there has been some criticism of the validity of morphological analysis (*Young 1994*).

It is one thing to isolate and define a single type of site – a process that may be called 'pictorial classification'. It is another to devise and use a classification as one step towards answering a larger question, or series of questions, as was being attempted in the late 1970s. Some archaeological theory proposes that each classification ought to be designed for a purpose and that its application is likely to generate hypotheses (*Hill–Evans 1972*). It follows that no single classificatory scheme should be expected to be everlasting even if it is designed to meet a very basic requirement such as ‘let’s classify these data’. Our knowledge is constantly increasing and our questions tend to be guided by current interests and theory. A good and useful classification may thus be designed to meet specific, and possibly short-term, research requirements. It ought also to be subjected to field testing to verify conclusions. Most archaeological projects working primarily with air photo data, including this writer’s, have failed on this last point, and testing of results has never yet (in Britain at least) been written into a research proposal. So what has been achieved?

Once an area has been mapped, it is not a difficult task to extract sites of specific types. Most past landscapes in lowland England, for example, show a mixture of tracks, fields, settlements and blank spaces – all, or most, of which can be readily identified. Our increasing knowledge of European landscapes has shown that a similar **pattern** is repeated there, albeit with local variants. Within such landscapes a beginning may be to identify types of deliberately constructed features, as was done in the following research projects in Britain.

South Yorkshire-North Nottinghamshire (*Riley 1980*)

Derrick Riley had flown, photographed and mapped a large area of south Yorkshire and North Nottinghamshire, in north-central England, and shown that much of the ground was formerly managed in systems of very regular fields that he named ‘brickwork fields’ (Fig 9.4). Riley’s discovery and recording of these field systems was in itself a considerable achievement and resulted in the recognition of an archaeological landscape that would have remained quite invisible without the aid of aerial survey.

Wessex (*Palmer 1983*)

The situation regarding dating evidence was different on the Wessex chalk, in southern England, where this writer mapped fields and enclosures within a 4050 sq km area from vertical and oblique photographs at Cambridge University and the English Royal Commission (Fig 9.1). Also within the study area were 28 settlement sites that had been excavated, dated and provided with published or otherwise recoverable plans which could be incorporated in the analyses of the **aerial evidence**. The uses proposed for the resulting maps mapping exercise were fairly simple:

- Can sites recorded by air photography be ordered in any meaningful way?
- Can air photograph sites be related to excavated and dated sites and thus be fitted into a chronological sequence?
- Can any classes so formed be applied to discussion of the development of the landscape?

After mapping, the next stage was to gather a test sample of 437 of the most apparently complete sites. These were sorted into a range of 'simple' and 'complex' types that were further sub-divided by shape, size and/or complexity (Fig 9.5). Subsequent work on some of the Wessex material examined associations between enclosures and their entrance forms and other characteristics (*Palmer 1984*, pp. 59-64). Relating these to excavated sites was a contentious process, although it did appear to give some shape-by-date correlation that was used as a basis for discussion of how past uses of the landscape may have developed.

Welsh Marches (*Whimster 1989*)

A few years later, Rowan Whimster, of the English Royal Commission, published some thoughts on the methodology of classification and applied those methods to identify and define types of features mapped from air photographs in the mixed lowland and hill-country along the borderland between England and Wales. Here he was dealing with a landscape which had a mixture of upstanding and levelled sites. Whimster was able to identify some general site types on morphological grounds but the main impact of the study was to 'populate' the lower, heavily ploughed, ground with settlement enclosures at a density quite unimagined before analysis of the **aerial evidence** (2.16, 2.20, 9.7).

For valuable comments on some of the above publications, and other attempts to understand areas of past landscapes, see *Wilson 1987* and *1995*.

Yorkshire Wolds (*Stoertz 1997*)

More recently we have Cathy Stoertz's publication, again for the English Royal Commission, of aerial survey and analysis of a huge (1350 sq km) area of the Yorkshire Wolds, in northern England. Her work includes classification of enclosures by shape and measurement, and discussion of their relationships. The 'classification' section ends with a table suggesting date ranges for specific types of features as a means to impose a level of order upon a huge body of evidence. That table may suggest there to have been considerable continuity of types from the Bronze Age through the Iron Age and into the Romano-British period. With sites of similar plan occurring over a 1500-year time span it is obviously unwise to use that particular classification as a way of dating features.

Thoughts

There is a limit to what can be achieved with 'pure' classification unless we apply our classifications back to analysis of the landscape. We may be gaining a lot of possibly useful detail about 'sites' but cannot easily relate that to a context of their contemporary natural and cultural landscapes. Some research, notably that by Cathy Stoertz, has applied classifications to study an area and so has produced explanations for functions of parts

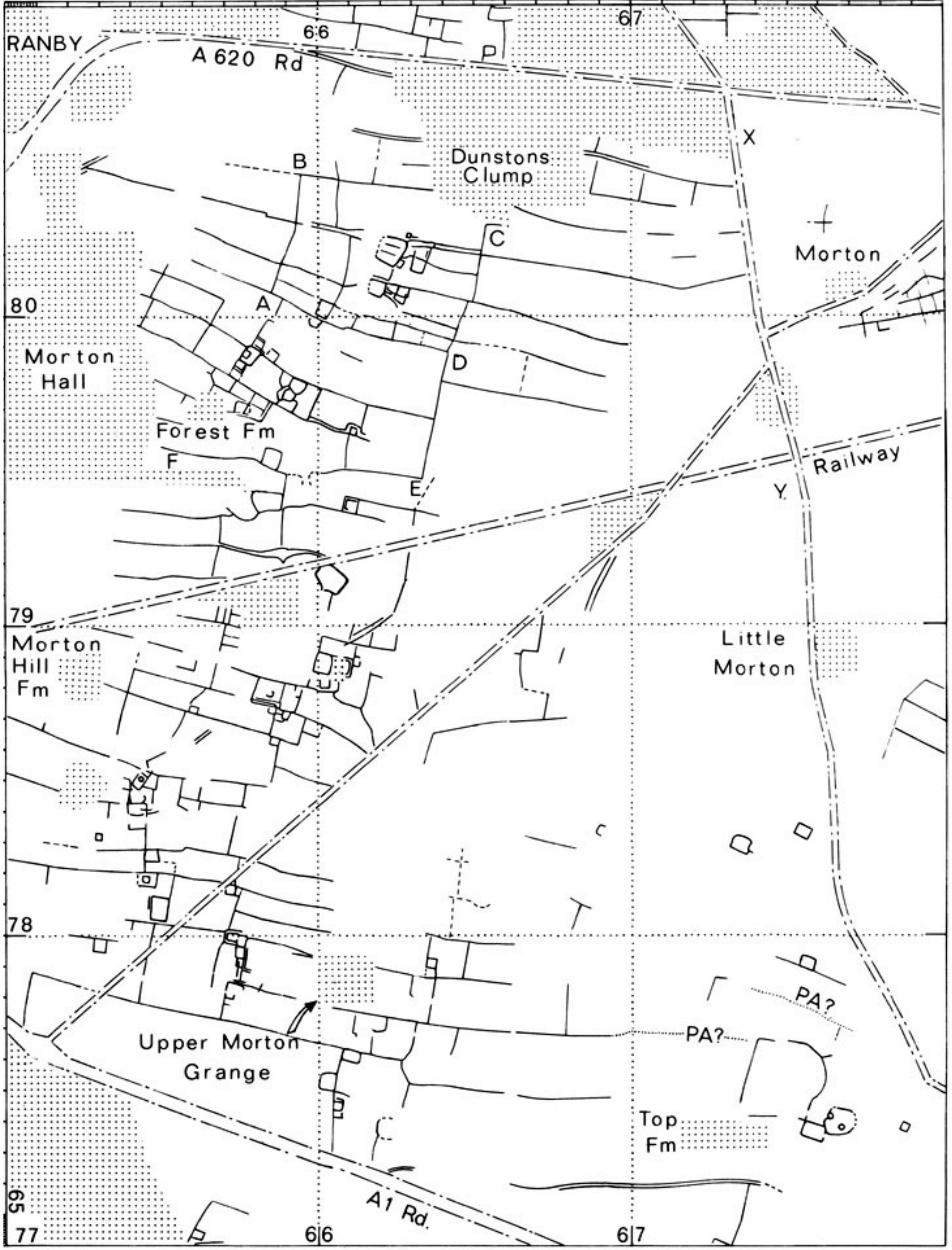


Fig 9. 4 'Brickwork' fields in Central England

These fields were so named because their plan resembles the joints in brick walling. The ditch-defined fields seem to have been made of long strips divided by cross boundaries.

Numerous small settlement enclosures can also be seen, in most cases forming integral parts of the farming system, sometimes with access via double-ditched tracks, as at C.

See also Fig 9.6.

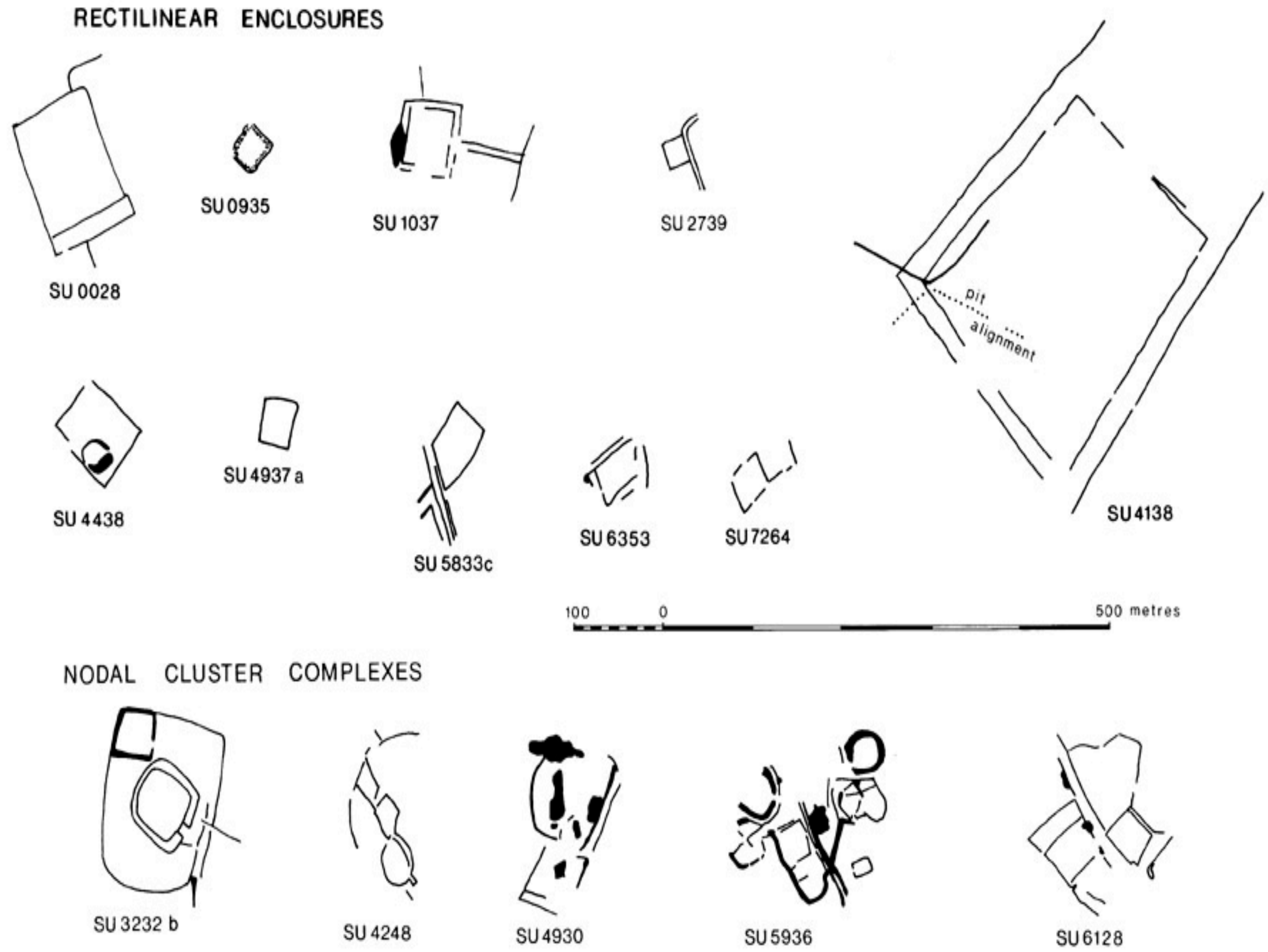


Fig 9. 5 A classification of enclosures in southern England

A sample of ditched enclosure types defined by their shape – for example straight-ditched four-sided enclosures with four sides becoming 'Rectilinear' – or by the plan form of multi-component structures – a 'Nodal Cluster Complex' being a group of features with or without a focal point. These could then be sorted by size, location, and association with other site-types. Some could also be related, hypothetically, to excavated and dated sites.

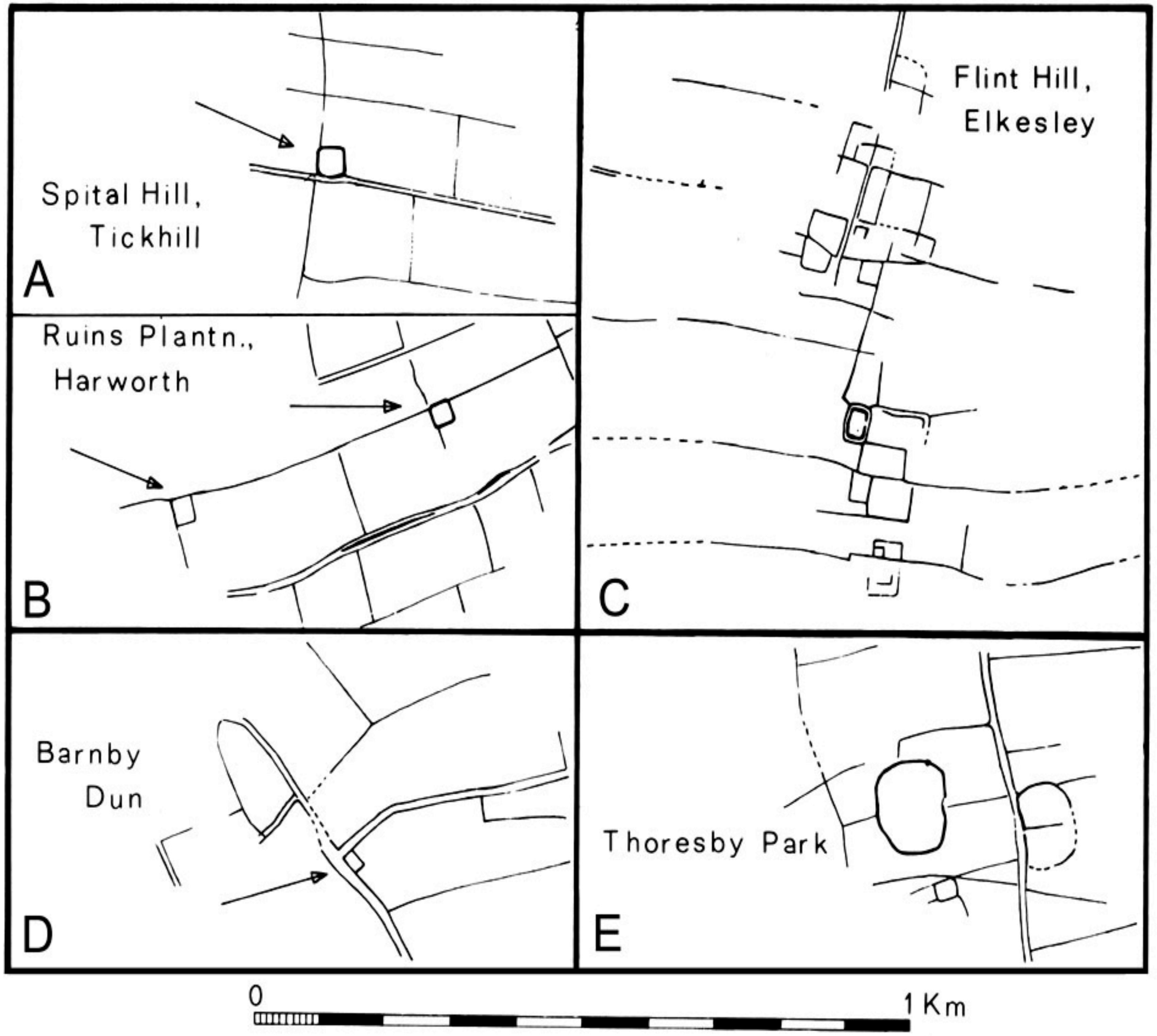


Fig 9. 6 Enclosure types and their association with fields

The enclosures at A, B and the southern part of C, from the English Midlands, appear to be 'fitted into' the field system and may therefore be contemporary with its use. D, E and possibly the northern part of C have clearly been 'superimposed' on pre-existing fields and so put them out of use. The communities from these later settlements may, however, have continued to use other fields from the earlier system.

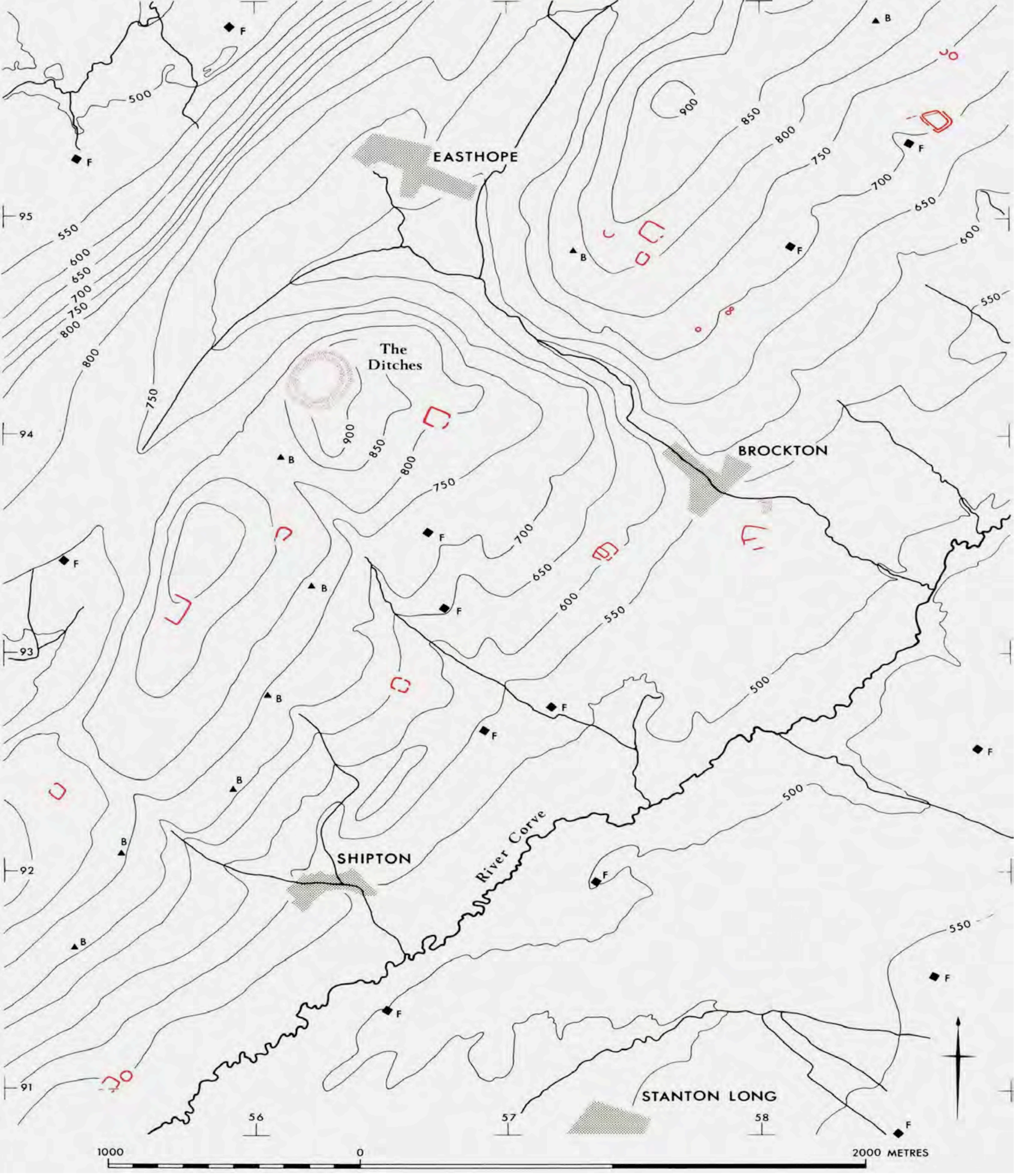


Fig 9. 7 A landscape in hilly country

In the hill-country of the Borderland between England and Wales the archaeological record comprises a number of isolated ditched enclosures, apparently with no form of land-division in between. The topography is not extreme and the fact that enclosures exist on low ground, on hill-slopes and also on the peaks of hills suggests there to have been past use of the complete landscape. Presumably this was carried out in ways that leave no trace from the air. It is possible that future changes in land-use, along with new aerial photography, will reveal more of the past landscape than has yet been seen in such areas.

For different topographical landscapes see Figs 6.1, 9.1, 9.8 and 9.14.

of those past landscapes. However, in the Yorkshire Wolds and elsewhere, there has been little questioning of any of the results, either by the aerial community or by others. This kind of discussion, and the field-based projects which might arise from it, is essential if we are to develop ways of dealing with landscape-sized areas of past occupation.

Computer-assisted classification

Research by Sam Redfern, of the National University of Ireland, explored the possibilities of using computers to automatically classify shapes (*Redfern 1997*; *1998*). In simple terms this is akin to Optical Character Recognition but needs the ability to work with a much larger number of shapes. Redfern developed an automated morphological-topographical classification that was tested on earthwork sites and worked directly from photographs. Once a computer has been trained to identify and extract simple shapes, it can automatically measure and classify these according to pre-defined parameters. Topographical information can be computer-generated from stereoscopic pairs of photographs and thus becomes part of the attributes of each site. Redfern worked with circular shapes because these are relatively easy to train a computer to recognise, and successfully applied the resulting classification in parts of Ireland.

There may be good potential for further development and use of automated classification. Redfern's work on photographic images has shown the advantages (such as objectivity) and disadvantages (hindrance due to lighting and shadows) of working from the source information. If interpreted plans were available for this type of computer classification they might provide a cleaner, if subjective, level of input on which to work.

However, this is not usually the case as one reason for attempting computer classification has been to make a first scan of a large area of land. The advantage proposed is that an archaeologist can then examine and decide on the validity of only those sites that the computer flagged as circular and thus save time that otherwise would be spent on visually searching all the images. Recent work in Norway has used high-resolution satellite images for this purpose and, although successful to a degree, has identified many problems associated with this process (*Trier* et alii *2009a; b*). Other problems with these methods of automatically detecting archaeological features – given that the majority of them are not simple circles – were nicely summarised in a conference presentation by Veronique de Laet who concluded that 'archaeological sites were not cooperative' (AARG conference, 2009). Despite that, work is continuing to refine such methods of helping us to identify aspects of the past. Progress reports are now common at meetings and in publications about computer applications and/or satellite data in archaeology.

Data Analysis

Uses of morphological and spatial analysis

The previous section outlined some classifications that have been developed for sorting archaeological features mapped or derived from aerial photographs. Next we look at how those classifications have been applied to study past landscapes. Here it becomes apparent that the most profitable archaeological work has been produced from those areas that, in the past, had continuous systems of features, either ditched or defined by walls. Without physical links between features, there is little that can be done at present beyond sorting them by location, shape, size and topographical situation, though even here there can be profitable returns, as indicated above for the Welsh Marches.

South Yorkshire-North Nottinghamshire

(Riley 1980)

Riley analysed his maps by first defining a field typology and then examining other features in relation to the fields. By mapping the field systems and so joining together fragments of information photographed in separate modern fields, Riley was able to demonstrate that many of the ancient fields, notably those he named ‘brickwork fields’, were the product of a carefully planned system. This began as a series of roughly parallel strips between which were cut cross boundaries so making smaller and near-rectangular fields (Fig 9.4). The long axes of the strips included a number of double-ditched boundaries (possibly with a central bank), while lanes, double ditches of slightly different character from the boundaries, usually cut across fields.

Riley’s classification of the enclosures (Fig 9.6) was done on mixed attributes – shape and character as well as association with types of field – and produced six main groups. Correlation between archaeological features and soils not only allowed comment on the past uses of the ditched systems and their relationship to local topography and water, but also provided some explanations for the real and apparent blanks in the mapped information.

After his 1980 publication, Riley continued aerial reconnaissance in the area. Field investigation was carried out by teams from Sheffield University and provided useful dating and environmental evidence. Some of this new evidence was summarised as broadly showing that early field systems developed at a time when unenclosed settlement was the norm (*Robbins 1997*). At a later date – during the first century BC or AD – it became more usual to enclose settlements and some were inserted within the fields which continued in use (see Figs 9.4 and 9.6). This is an example, albeit small-scale, of the follow-up studies that would ideally be part (or product) of any project of landscape analysis from **aerial evidence**.

Wessex (*Palmer 1983*)

After classification of the Wessex material, spatial analysis was attempted by measuring distances from the 437 sample enclosures to other enclosures, ancient fields and linear ditches. Distances were recorded in 100m intervals within a radius of 1000m from each enclosure. The resulting measurements showed three significant distance-to-feature associations. These suggested that a recurring spacing of settlement enclosures at 600m within which their associations with field systems implies either a certain amount of shared land among settlements or movement of settlement sites over time. The majority of sites were noted to be in close association to linear (?boundary) ditches (Fig 9.1). It was suggested that such analyses make a useful prelude to excavation and would allow questions to be formulated that might assist study of that landscape.

Yorkshire Wolds (*Stoertz 1997*)

Cathy Stoertz continued her analyses of the Wolds by initially separating ‘ceremonial’ from ‘non-ceremonial’ features and illustrating and describing the variations and consistencies of each type. Later in the volume she considered all sites together in a multi-faceted analysis of the landscape. Study of ceremonial features suggested that there were areas set aside for ritual and burial in the Neolithic which continued to serve as such, or were at least respected as such, by later prehistoric communities. Such foci tended to attract later burials although Bronze Age burial sites (recorded as ring ditches) also occurred elsewhere in the Wolds and cemeteries of Iron Age square barrows had a different, more localised, distribution.

Much of the Wolds was formerly divided into large parcels of land by ditched linear boundaries. These formed a network of land division that developed from late Bronze Age-early Iron Age origins and continued to exert a major influence on the pattern of land-use up to and through the Romano-British period (Fig 9.8). The location and form of some curvilinear sites, plus results from excavation, suggest that some were defended sites that occupied positions within the largest blocks of ditch-defined land. Excavation has shown these defended enclosures to be of similar date to the foundation of the land divisions and this usefully established a major series of events within a time span. However, these sites are but a small percentage of the total number of otherwise uninvestigated sites within this huge territory.

More informative are the localised series of linear trackways and complex, often linear (or ‘ladder’), groups of settlement enclosures that were constructed within, and often integral to, the major land boundaries. The best recorded of these allow a glimpse into past settlement organisation in its broadest sense. Large-scale plans show the different structures resulting from the grouping of enclosures. These include the creation of apparently ‘empty’ spaces within and adjacent to settlement areas which probably relate to stock management (Fig 9.9 B, C).

Having carefully described and classified the features, sometimes making links between types, Stoertz finally moves to interpretation of the landscape. Settlement sites of the Neolithic and Bronze Age are rare – or rarely identified – in Britain, and discussion of those periods, on the Wolds as elsewhere, revolves around ceremonial and funerary aspects. But from the late Bronze Age the area 'comes alive' and is divided by boundary **earthworks** and trackways which provide foundations for the distribution of subsequent settlement **pattern**s. As the density of settlement increases with time it is possible to identify some of the organised elements of the landscape. These are most apparent in the delineation of deliberate and often vast open spaces, in the location of the 'ladder' settlements and in the definition of areas reserved for burials.

The Wolds volume, with its small-scale (1:25,000) fold-out maps and many larger-scale analyses, marks a pinnacle in the publication of aerial surveys in Britain and shows not only the wealth of information that can be interpreted from aerial photographs but also the level of descriptive analysis that can be derived from such maps. Many questions arise from this study and from other work of this kind. Stoertz notes these in a general way, and adds occasional detailed points where, for example, specific excavation seems likely to provide answers to key questions of dating or association. In this way the study is looking forward to the contribution that could be made by a wide range of field-based studies in the future.

Thoughts

One aspect that has become clearer as a result of the above work is the importance of association. In the Wolds, for example, it is the association between features that created the large open areas which (along with other things) characterise later prehistoric land-use in the area. We are also shown the association of earlier 'ritual' features, both to one another and to foci in the natural landscape. On a more local scale we can see the association of enclosures to tracks and fields and can identify (or guess at) some of the access mechanisms – purpose-designed entrance ways or stock-herding features. Work in Wessex similarly realised the importance of association, rather than just enclosure shape, to assist our unravelling of functional landscapes. The range of entrance types in that part of the country appeared to fall into a number of different and identifiable types. These had previously been used as key elements in definitions of, for example, the 'banjo enclosures' already mentioned (Fig 9.10).

It remains to be seen whether and to what extent field archaeologists will take these surveys as starting points for research. This has been done in Wessex by Barry Cunliffe's 'Danebury Environs Project' (*Cunliffe 2000*; *Cunliffe–Poole 2000*) and by Richard Bradley and his co-workers' examination of prehistoric land divisions on Salisbury Plain, some 15 km north-west of Danebury (*Bradley* et alii *1994*). Further north, investigations continue to examine aspects of Riley's field systems and their associated settlements. It remains to be seen whether further work will be undertaken on the more 'disjointed' landscape of the Welsh Marches, where unfortunately small-scale excavation and surface collection have not been helped by the virtual absence of native pottery or other preserved artefacts from the pre-Roman period (*Silvester 2011*; and see *Murphy-Mytum* (forthcoming) for a similar landscape in south-west Wales, again known to a considerable extent from cropmark evidence).

This survey of analyses of **aerial evidence** has necessarily focused on research in Britain as similar studies have for the most part not yet been undertaken elsewhere in Europe to such an extent save perhaps for the Tavoliere and for centuriation systems elsewhere in Italy. However, the writers' knowledge of aerial photographs taken over countries such as Austria, Belgium, the Czech Republic, France, Germany, Hungary, Italy, Poland and Romania shows that identifiable/characteristic 'types' of enclosures and 'systems' of land allotment are among the features recorded there too. This opens the possibilities for classification of sites and analyses of landscapes as methods used to extend the archaeological potential of **aerial information** and hence to enrich our understanding of the landscapes of the past.

Data Support

Looking for answers

Aerial survey is the most effective and economical means of undertaking extensive surveys that allow us to see the broader landscape and, in optimum conditions, to extract the finer details. Results can be enhanced by evidence from a range of other sources and methods, of which most are non-invasive. Uses of these supporting/comparative data are at their most powerful when all sources are in a GIS and can be selectively combined, viewed and interrogated.

Documentary studies

Among the documentary evidence that may help us to understand mapped aerial evidence, is that shown in other maps – of soils, geology and topography, for instance. Other sources are those surviving from medieval and later periods for which there also may be substantial surviving field evidence. This is where the illustrative strengths of aerial photographs may prove valuable, often adding considerable evidence about aspects of daily life that were not well documented by contemporary sources, which often overlooked the lower classes of society. Village and settlement plans have been recorded from the air and information allowing us to better understand some industrial processes has been derived from examination of air photographs. This combination of air photographs and documents was excellently demonstrated by some of the

Fig 9. 8 Multi-period land-use in north-east England

This simplified map, with 5km grid, of part of the Yorkshire Wolds emphasises areas of enclosed settlement in contrast to open tracts defined by large and extensive linear earthworks. (Enlarge the screen to read the following key numbers.)

1. round barrows (burial mounds) of the Neolithic and Bronze Age.
2. square barrows (burial mounds) of the Iron Age.
3. ditched trackway.
4. enclosed block of land.
5. small rectilinear enclosures.
6. outlying enclosures.
7. further land blocks.
8. trackways.
9. paddock-like enclosures and larger, more regular fields.
10. zone without enclosure complexes.

11, 12: funnel-like features.

13. large area of land apparently enclosed by linear features
14. trackway.
15. land blocks without enclosures or complexes.

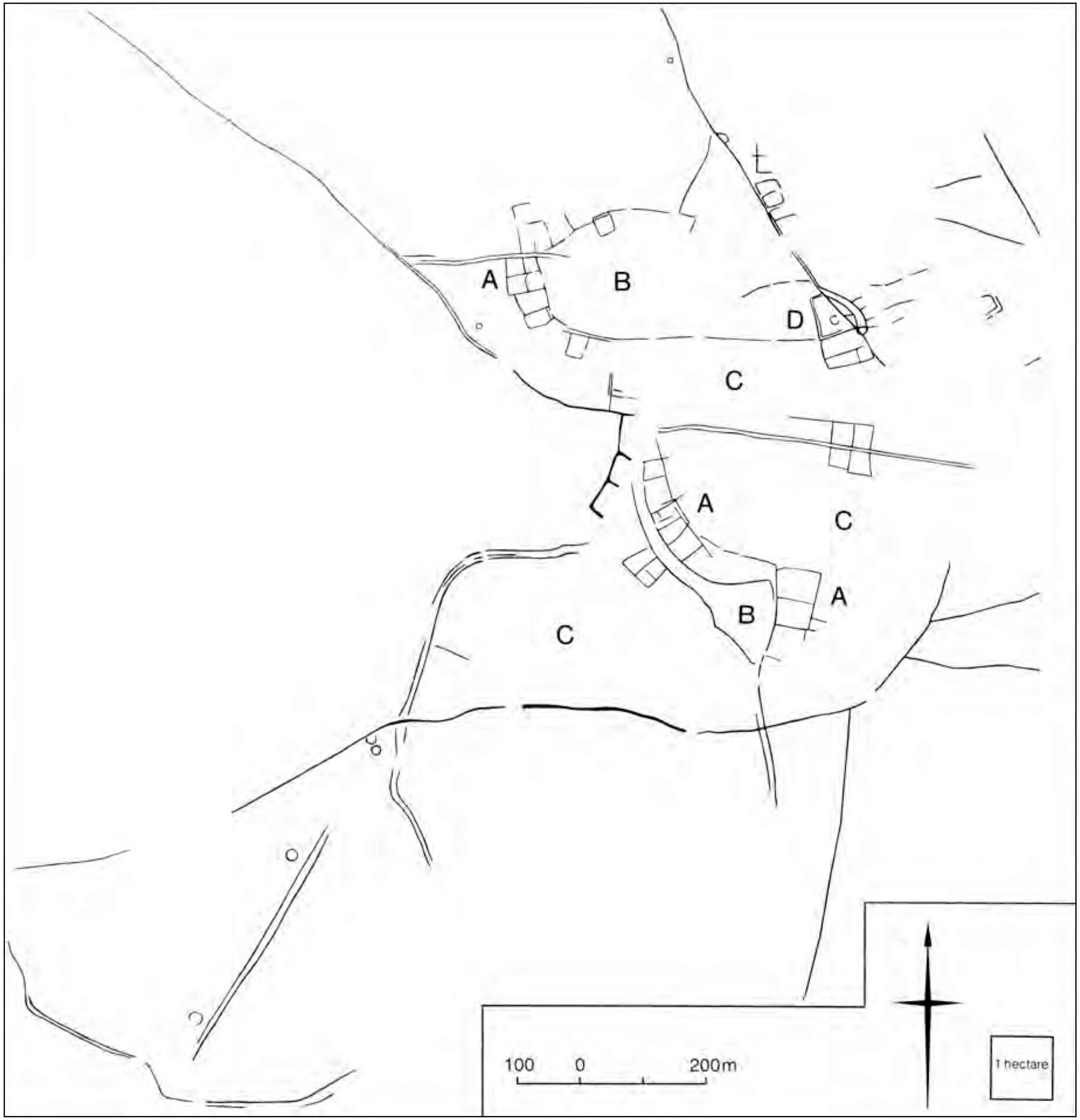


Fig 9. 9 Defining 'space' in NE England

Differences in ditch-defined enclosures on the on the Yorkshire Wolds.

A) Enclosed linear enclosure complexes (settlement areas?)

B) Spaces defined by enclosures.

C) Larger spaces defined by linear features.

D) Double-ditched enclosure.

Fig 9. 10 'Banjo' enclosure in S England

This type of enclosure, originally defined on the basis of air-photo evidence, is characterised by a long entrance passageway defined by flanking ditches.

Cambridge Aerial Survey publications, especially those dealing with medieval settlement (eg *Beresford–St Joseph 1979*).

Analytical field survey

As the majority of lowland sites recorded on aerial photographs are now levelled, detailed survey of the few that remain as upstanding earthworks is valuable to show us an intermediate stage in the decay of these former ditch-and-bank structures and to indicate some of the now-lost detail, such as hut platforms and eroded tracks. Analytical field survey of earthworks can be a powerful and informative tool at site and landscape level (*Bowden 1999*). Earthwork sites sometimes continue as levelled features in adjacent fields (Fig 9.11). Such sites enable direct comparisons to be made between the two forms of survival and so help us to visualise more easily how types of levelled features may have appeared in their original state. In upland areas where many sites remain upstanding aerial evidence can be particularly powerful as a guide to the field surveyor. Photo interpretation and mapping can provide information that can be rapidly checked on the ground, allowing changes and additions to be rapidly made without the need for detailed ground survey of the complete area. This has been successfully done in south-west Britain on 230 sq km of Bodmin Moor (*Johnson–Rose 1994*). In the Yorkshire Dales in northern England (Fig 9.12; *Horne–MacLeod 2001*) field investigation was later used to confirm some of the relative dating (and hence phasing of landscape change) that that was suggested during photo interpretation.

Geophysical survey

In Britain, Germany and other parts of Europe there is increasing use of geophysical surveys to examine levelled archaeological features. These may be undertaken prior to excavation or to gather more detailed information about sites discovered by other means. However, although geophysical prospection often adds detail to a site mapped from air photosgraph, it has become apparent that soils that give poor responses from the air are often equally unresponsive to ground-based prospecting methods. This is an aspect of data recovery that may benefit from further research so that we may become more aware of what we are not sensing and in which soil conditions this is so.

Recent work at such sites such as Carnuntum in Austria and West Heslerton in northern England has shown how the integration of geophysical and aerial survey with other data improves our interpretation of the results of each method and of the recorded archaeological features (Chapter 13 and *Doneus* et alii *2001*, *2012*; *Powlesland 2001*, *2006*, *2010*; *Powlesland* et alii *2011*). To be most effective, this requires high-precision survey of all types of data to ensure that they can be accurately matched in a GIS. Use of GIS broadens the prospects for visualisation of archaeological sites which can be illustrated, for example, by use of an air photograph or its interpretation draped over a terrain model, or by producing a ‘fly around’ of a specific area (*Forte 2001*; *2002*).

Fig 9. 11 Comparison of upstanding and levelled features

This site at Holbeach in the Fenlands of eastern England is one of the few Romano-British rural settlements which retains upstanding earthworks. The background field is now ploughed level but the crop-marked ditches in it can be seen as part of a larger system that includes the earthwork ditches in the foreground field. Photographs of such sites can help an interpreter to better define types of features that lie below the ground but which now show only as differences in soil colour or crop growth.

The photograph also shows the apparently ‘inverted’ relief that can be caused by lighting and direction of view – for some viewers the ditches in the foreground may appear to be ‘banks’.

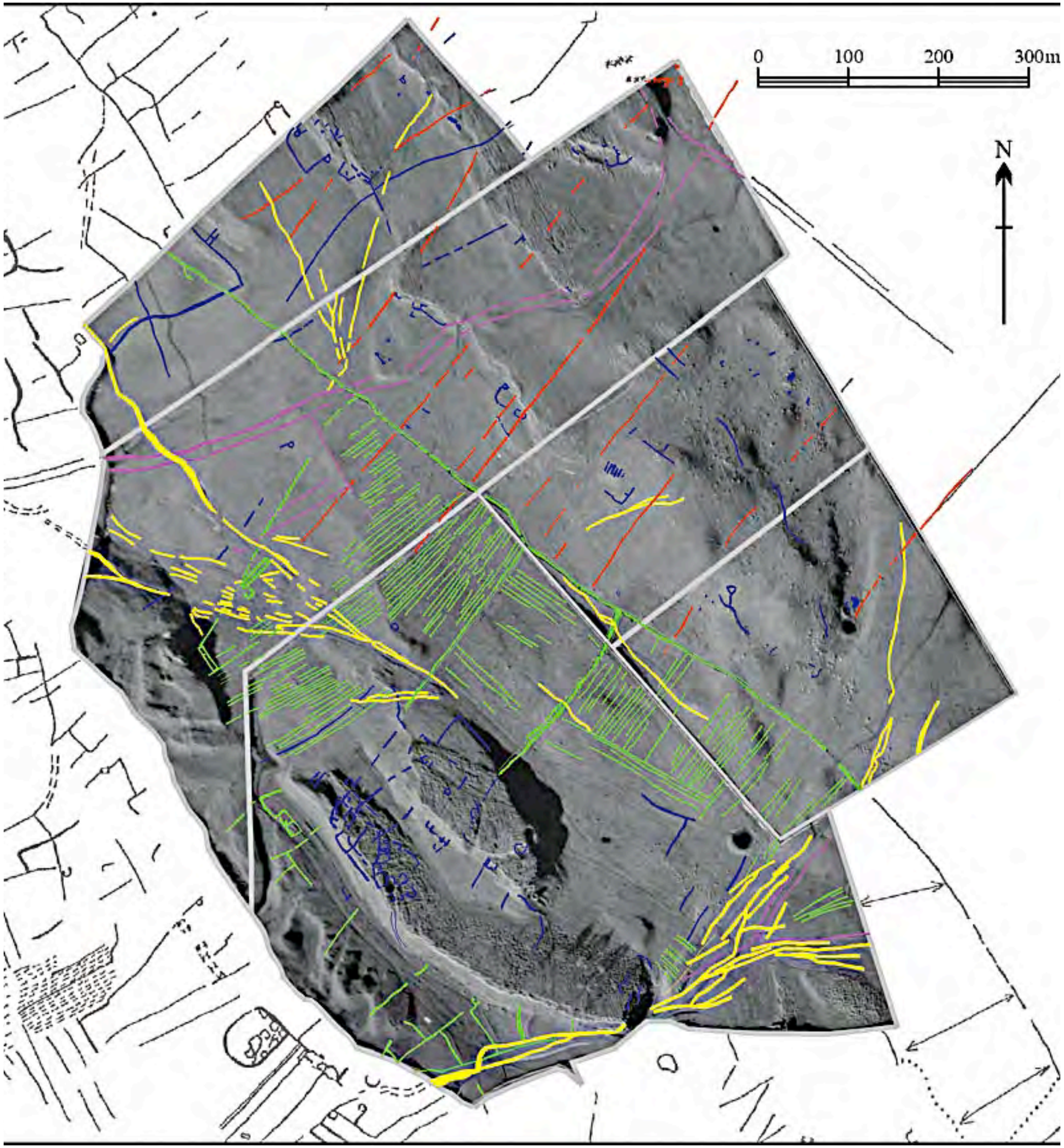


Fig 9. 12 Air photo evidence enhanced by field investigation

This example comes from a project that examined 80ha of the Yorkshire Dales in northern England as part of students' training in photo interpretation. The same area is shown in contrasting vertical and oblique photographs in Fig 2.1. Compare the single oblique air photo with a map showing information from all available photographs enhanced by field visits. The mapped information shows several phases of land-use: boundaries of coaxial fields, a driveway that cuts across the fields and utilises one of the boundaries, and the close-spaced parallel strips of later Medieval cultivation. In this landscape the archaeological features are upstanding remains in the form of mounds or walls. Modern dry-stone walls, showing as white lines, help to locate the photograph on the map.

Field walking/surface collection

Field walking is itself a useful method of obtaining information about past areas of occupation but it becomes considerably more powerful when combined with information mapped from aerial photographs. This can be illustrated through a large-scale survey of the lowland Fen region of eastern England undertaken over about 15 years from the mid 1970s (*Hall 1996*; *Palmer 1997*). In this study the field-walking programme used aerial photographs as a means of identifying the 'roddons' (silted-up rivers) which were a major influence on the distribution of settlement in the area. At a later date **air photo interpretation** was extended to map the evidence of levelled tracks, settlements and former fields recoverable from the extensive oblique and vertical coverage assembled over the previous three decades. The combination of the two forms of evidence allowed more informed discussion of Fenland settlement but also showed the shortcomings that arose because the two survey techniques were used successively rather than concurrently. Attention is drawn to these aspects in Fig 9.13. However, the project is also a powerful illustration of the fact that neither aerial survey nor surface collection on its own necessarily reveals a 'complete' view of ancient settlement. Wherever possible the two should be used in conjunction with one another, and with other methods of investigation discussed in this section. Planned and carefully integrated surveys, preferably with the air photo mapping carried out in advance of the fieldwork, would allow informative feedback between the two methods and help to overcome, or offset, biases in both (*Palmer 1996*; *Doneus et alii 2002*). An integrated survey operating over several years would allow cross-checking of information recorded by different methods. For example, sites identified on the ground but without aerial evidence could be noted for future aerial investigation, and vice versa. Such work would thus begin to build directly on acquired knowledge.

Excavation

Air photo mapping opens up whole new opportunities for the examination and 'calibration' of rediscovered landscapes through targeted small-scale excavation. Questions that are based on information mapped from aerial photos, or otherwise are derived from landscape study, tend to differ from those of the traditional site-centred excavation. A landscape approach is likely to pose a coarser range of questions, such as 'what for?' and 'when?'. Often study of detailed mapping is able to suggest specific places where small-scale excavation may help answer such questions. We know that competent photo interpretation and mapping can be sufficiently accurate to allow the excavator to place a small trench precisely to examine a chosen part of a site or a crucial stratigraphical relationship. The increased use of **air photo interpretation** and mapping thus gives opportunities for new approaches to the role of excavation in exploring some of the broader aspect of past settlement patterns and land-use. One of the most exciting challenges for archaeology today is to learn how to question this kind of landscape evidence and then to carry forward the answers into wider matters of interpretation and explanation.

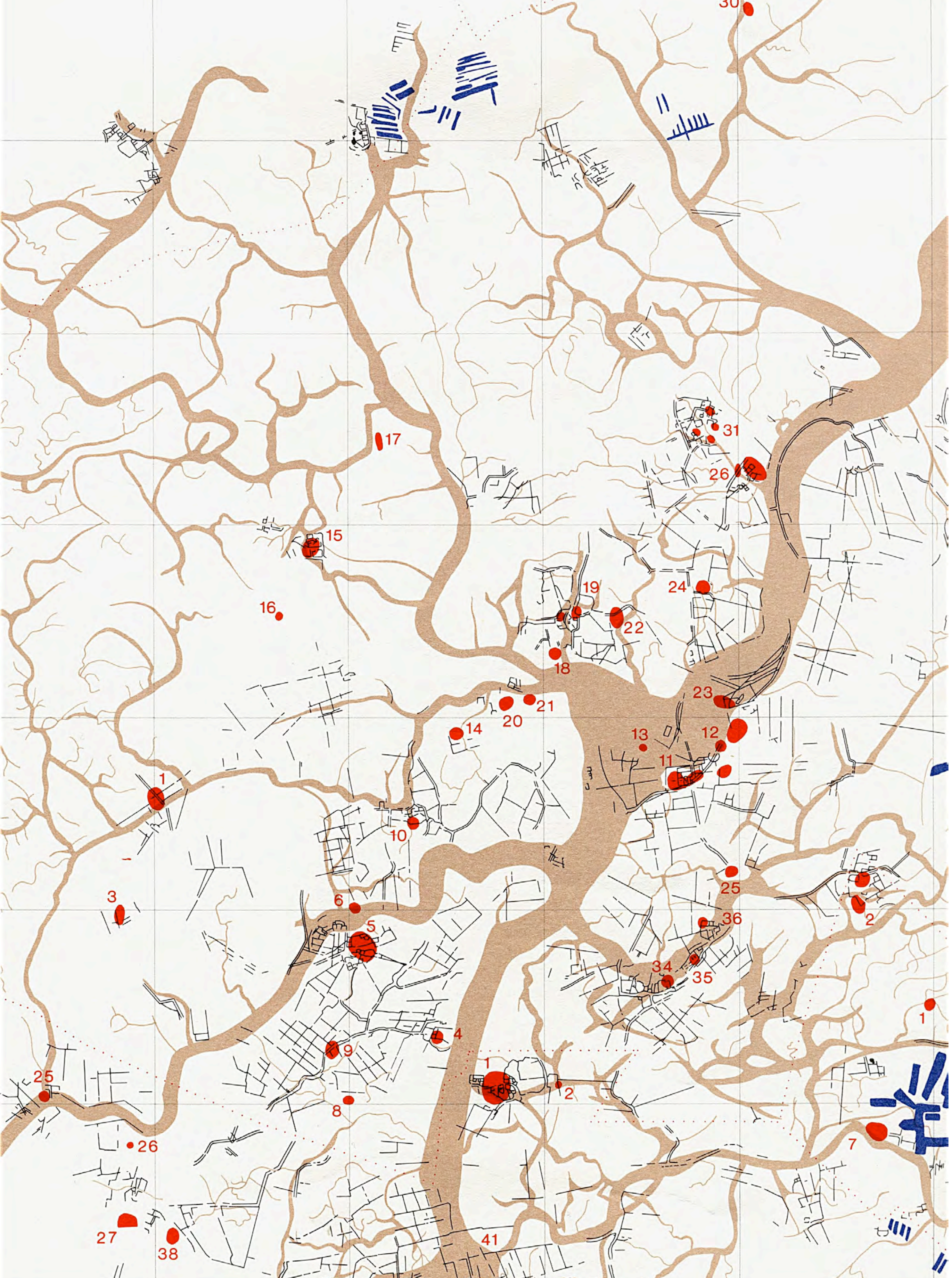


Fig 9. 13 Air photo evidence integrated with field-walked data

Romano-British settlement and land-use in the Cambridgeshire Fenlands in eastern England. The map combines field-walked evidence with that interpreted from vertical and oblique aerial photographs taken between the 1930s and the early 1990s. The natural background is essential to understanding Fenland archaeology. Here, brown shows the courses of rivers that were active in the Neolithic and Bronze Age. By the Roman period these had silted up and provided higher and drier ground than the surrounding marshy land. The old river courses are now called ‘roddons’. Settlements found by field-walking (red) cluster on and adjacent to the roddons, from which the local communities cut regular and extensive ditch-defined fields and access ways (black). Solid blue features show where peat was extracted to provide fuel for domestic fires and, at some sites, for the local salt-making industry in which tidal sea water was boiled to leave residues of salt.

Grid lines at 1 km intervals, Map: *Hall 1996*.

Rescue archaeology

While some people are devising these new strategies there is already in Britain a flow of almost random samples of the country from rescue projects undertaken in response to development proposals of one kind or another (developers in Britain are now required to finance such projects in advance of development). It could be considered that one of the most important results of this type of work is that it forces archaeologists to examine sites and places where they would not otherwise have chosen to do so. Assimilation of the results of rescue work in Britain may provide the start for a new understanding of the country's past that we would probably never have achieved through research-driven study. Rescue work usually takes place within a fairly short time-scale so that contact can be maintained between specialists. Thus, if large-scale mapping of aerial evidence is done in advance of rescue excavation there may be active feedback between the excavator and photo interpreter (Fig 2.21). This has, on occasions, given the opportunity to re-examine aerial photographs knowing what is actually on, or under, the ground (*Connor–Palmer 2000*). The value of such feedback in giving the interpreter confidence in his/her reading of the evidence cannot be over-emphasised.

Thoughts

Outside Austria there has been little planned integration of methods, be these of mixed surveys or of survey and excavation, and any investigation of mapped features has usually been done without the active collaboration of the photo interpreter. As noted above, independent small-scale excavation by members of Sheffield University has added dating, environmental and functional information to parts of Derrick Riley's brickwork fields and their associated settlements. Recent work reported by Bob Silvester and Britnell has added field-derived data to sites in the Welsh Marches mapped by Rowan Whimster (*Britnell 1989*; *Silvester 2011*). Cathy Stoertz produced a guide to 'topics' for further research, which may inspire field-based investigation (though this has not happened yet). Barry Cunlife's work on the Danebury Environs Project has provided a large amount of information on a small number of sites and has been planned, logically, from a Danebury-centred aspect (*Cunliffe 2001*; *Cunliffe–Poole 2001*). There are more than 100 other enclosures within the Danebury environs and it remains to be seen if any work will be undertaken on those to examine wider-ranging questions regarding past settlement in the area. There are no plans to expand or extend the Fenland survey although 41 of the 2500 sites discovered were partly excavated to assess their current condition and potential for preservation and future management (*Crowson* et alii *2000*). Other specific sites may become the subject of rescue excavation as they come under threat of damage or destruction.

Although these examples of mapped landscapes do not as yet seem to have inspired much ground-based research they have, in all cases, restored previously hidden ancient landscapes to the record. They have also provided a bench-mark for further aerial reconnaissance and allowed the planning of post-publication flights specifically to investigate 'blank' areas or questionable features. The Nottinghamshire part of Riley's fields has been remapped as part of England's National Mapping Programme, adding new information from Riley's own post-1980 photography and from other flying in the area since his death in 1993. Continued flying over the Danebury area, up to 1997 from Palmer's cut-off date of 1980, has added newly recorded settlement sites and has considerably increased the extent and detail of some of the field systems (*Bewley 2000*).It may be that the countries only now entering the aerial fraternity will have the greatest opportunity for pioneering integrated approaches from the outset, as in the Czech Republic (*Gojda 1997*; *2002*) or in the superficially unpromising terrain of Slovenia (*Grosman 2002*).

Archaeological Interpretation

It will be apparent from the descriptions above that various kinds of interpretation are involved throughout the processes summarised in Fig 9.2. Those processes allow us to collect information through aerial survey and photography and to make it available through an archive, possibly with a catalogue offering a first level of interpretation. By interpreting the photographs and presenting the resulting information on a map we are usually able to offer additional descriptions and interpretations, and by combining that mapping with other forms of data we are usally able to say even more. At each level of the process we may pose questions that need to be answered by further survey and research. The important point is that archaeological interpretation is a cyclical process that advances by adducing evidence, making hypotheses, testing these in the field and then formulating new interpretations and new hypotheses for further testing. What we are aiming for is not all-time answers, but ways of progressively asking, and answering, better questions about past settlement and land-use.

Final Thoughts

This brief overview of uses of mapped information in Britain indicates some of the research directions it has followed and some of the results and questions it has produced. British archaeologists have become aware that aerial reconnaissance for archaeological information needs to be a continuing process. In Britain many hundreds of 'new' sites are recorded each year, even after more than 60 years of intensive aerial survey. Mapping and analysis of the results will continue to develop as new evidence is added and assimilated. Photo interpretation and mapping constitute a slow and painstaking stage towards better understanding of the evidence. For extensive survey projects, this requires many years of aerial exploration and photography before a reasonable sample has been collected. In Italy (as in many other countries of Europe), even with a considerable amount of vertical cover, there may be many years to wait (save perhaps on the Tavoliere) before landscape projects on any substantial scale reach true fruition. Meanwhile photo interpretation skills can be honed through work on individual sites or on special areas where there are potentially quick returns from exploratory survey. Much useful knowledge will be obtained by making ground visits and (we may hope) by integrating aerial work with other methods of investigation. Work of this kind will increase the abilities of individual workers. Interaction with aerial specialists from other countries will help to develop techniques to assist in recording and understanding the ways in which past communities have made use of various parts of the European landscape over the passage of time.

Most important of all is the need to develop projects that follow through the taking of aerial photographs to the analytical ends noted above. Individuals, or members of a team, who can work on all stages from initial exploration and photography through interpretation and mapping to analysis and publication of the results, will take our understanding of aerial evidence to higher levels. Such work almost certainly needs to be managed within a university to maintain the required flexibility of approach, especially as regards follow-up studies and the opportunity to work within a GIS environment. In Italy and other countries this may well be the pattern that will develop. It will be interesting to see and encourage the developments of the coming years.

PART III

AERIAL SURVEY AT WORK

Chris Musson and Stefano Campana

10. HUNTING OUT THE ARCHAEOLOGY

Chris Musson and Stefano Campana

In British books on aerial archaeology the pictures are often arranged in chronological order, from deepest prehistory to relatively recent **feature**s that will become tomorrow's archaeology. This part of the book, instead, follows a sequence which reflects the themes of earlier chapters – how the **trace**s of the past reveal themselves and how the resulting photographs can be used – for discovery, recording, mapping, interpretation, conservation, illustration and of course research.

Our aim is to draw lessons from the pictures, not to suggest that everything we show is new or especially unusual. We have little doubt, however, that some at least of the cropmark (or even earthwork) **site**s illustrated here will be new to the archaeological record. Others may not yet be considered in some countries to be archaeology at all. But we know from experience that it is virtually impossible to fly over areas of good cropmark or **soilmark** development, or of even moderate earthwork preservation, without making new discoveries, especially if the mind and eye of the airborne archaeologist are kept open to everything seen below.

All of the pictures were take over various parts of Italy but the lessons that they hold will have relevance for many other parts of Europe. In the captions we explain (more or less as strangers) what we saw in each group of pictures, what might have caught our eye in the air, what questions we were asking then and might still be asking now. Our answers may not always be correct (or complete) but they are based on sound experience in other parts of Europe. They tell the reader why the photographs were taken and what processes might have been involved in their capture or interpretation.

The handing on of this accumulated experience and enquiring instinct is the ultimate purpose of this book.

Using light and shade light to emphasise earthworks

One of the most important aerial techniques is the use of light and shade to emphasise **pattern**s of earthworks that would be difficult to see or understand in dull or bland lighting like that often found in vertical photographs. Both highlights, on slopes facing the sun, and shadows, facing away from it, can be used to pick out **earthworks** only a few centimetres in height. The technique is equally effective in showing the form or detail of more substantial earthworks, as in the other pictures in this group.

The photographer deliberately uses light and shade to emphasise archaeological **pattern**s and to depict and ‘question’ them in the light of accumulated archaeological experience. Are the earthworks new to the record? Do they show new or unexpected detail about an already-known **site**? To make full use of the technique the archaeologist must arrange to fly early or late in the day, or when the winter sun is low in the sky. It is not always easy to do this but the archaeological rewards can be high.

Fig 10. 1 **Flying high to show the Roman aqueduct at Lucca in its landscape setting**

Fig 10. 2 Shadow photography in upland areas

In hill-country the effects of light and shade can be brought into play even when the sun is not particularly low in the sky. The larger picture uses the shaded hill slope on the right to 'explain' the location of the hillfort, while the closer view uses both highlight and shadow to 'describe' the form of the earthworks. Variations in plant-growth between the gentle or more steeply sloping parts of the site also contribute to the effectiveness of the second picture.

Fig 10. 3 A hillfort as seen in 1987

Many sites close to roads, as here, are at risk of damage from intensified agricultural activity. Low-light views such this, taken on one of the late Derrick Riley's aerial tours of Italy in the 1980s, can be particularly valuable in recording the nature of a site before it is affected by such work.

Fig 10. 4 Discovery through the use of light and shade

Earthworks and vegetation-changes that would be barely visible at ground level can often be clearly seen from the air. In these two pictures low light and slight changes in the density of the grass reveal a small ridge-top enclosure, its surrounding bank probably no more than a few centimetres high. It is always worth taking photographs, as here, from several different angles. Most such earthworks can also be seen at ground level once they have been detected from the air. But from this high viewpoint the patterns are clearer and the airborne archaeologist can move more quickly across the landscape than his ground-based colleagues.

Soilmarks, archaeological and otherwise

Changes in the colour, dampness or reflectance of the bare soil can reveal previously undetected sites, or give shape and dimensions to those previously known only from amorphous scatters of surface finds. Now that ploughing often takes place soon after harvest the opportunity to record soilmarks is spread across a large part of the year. But the marks are often less distinct than the same or similar sites recorded as cropmarks. Their presence is also more difficult to predict, since much depends on hour-to-hour and day-to-day changes in the dampness of the soil between the first heavy ploughing and the germination of the re-seeded crop. The search for soilmarks is therefore a fairly unpredictable affair, depending on luck as well as the archaeologist's accumulated experience. This gives a particular value to having a 'portfolio' of target types, of the kind described in Chapter 3, so that other subjects can be recorded if the hoped-for soilmarks fail to appear.

Fig 10. 5 Interpretation: certain or uncertain?

Top. This view shows how clear, and yet how indistinct, the soilmark traces of a known site can be. The dark soil of four filled-in ditches is clearly visible in the bare soil at centre left, along with a single circular 'compound' of the kind common in the huge Neolithic villages of southern Italy. The ditches appear less distinctly in other fields – at lower right two or perhaps three can be seen as darker lines beneath vines or fruit trees, weed-growth perhaps emphasising the marks here.

Bottom. There is often doubt about the archaeological or other origin of soilmarks. The colour variations in this picture are, for the most part, probably due to topography and drainage rather than archaeological factors. The 'rectangular-looking' greyish patch at the centre, however, caught the photographer's eye. Could this represent the remains of an otherwise vanished building? Only ground examination, or perhaps cropmark photography in later summers, could provide the answer.

Fig 10. 6 Interpretation: certain or uncertain?

Top. Only part of this enclosure is showing as a clear soilmark, though there is a hint of its continuation in the adjacent fields, too vague for confident interpretation if seen on its own. The alternating passage of the plough has 'dragged' successive lengths of the soilmark in opposite directions.

Centre. In Italy and many other parts of Europe the summer watering of the fields is now common. Here the rings created by the rotary spray have partially dried out but the adjacent reservoir and the alignment of the marks with the modern field boundaries make their origin obvious.

Bottom. It is unclear quite how modern watering might have caused the single light-coloured (dry?) circle in the centre of the photograph, with a dark (wet?) mark at its centre. The feature might alternatively be a robbed Etruscan tomb. It was photographed for this reason, and for discussion with tutors and students at the Siena training school in 2001.

Marks in ripening crops

Cropmarks change their appearance throughout the weeks of crop-ripening. They also respond in a wide variety of ways to subsoil conditions, most notably the dryness of the soil at critical stages in the growth of the crop. It is not always immediately obvious why some cropmarks appear as they do. The meaning of the marks, however, in terms of man-made disturbance of the subsoil is usually clear. The air photographer will usually be more interested in understanding what the marks mean than in speculating on the processes which led to their appearance. But a growing experience of the processes, wherever possible tested by observation in the field, will help both photographer and photo interpreter to understand and interpret the marks in cases where they take on an unusual appearance or where their interpretation is in doubt.

Fig 10. 7 **Green-on-green cropmarks**

Cropmarks often first show as 'green-on-green' – darker for ditches and pits, lighter for stone walls or other impervious surfaces. There may be no great colour distinction at this stage but there are usually differences in the height or density of the crop that can be emphasised by flying early or late in the day. Here, just right of centre in the photograph, the marks show a double-ditched circular enclosure, with the grid pattern of modern crop trial at to right.

Fig 10. 8 Cropmarks of varying appearance

In the dry climate of the Tavoliere plain, on the ‘heel’ of Italy, only days after the photograph in Fig 10.7 was taken in an upland context, these lowland cropmarks are already showing good but varying colour distinctions. The darker green areas represent deeper and perhaps damper soil. The ditch of the rectangular, probably medieval, enclosure in the foreground seems to change from a ‘positive’ to a ‘negative’ cropmark as it crosses one of these darker areas. In reality the colour stays exactly the same – it is the background colour which changes, as with some of the circular ‘compounds’ of an underlying Neolithic settlement. The narrow dark green mark running diagonally across the centre of the photograph is caused by an irrigation pipeline.

Fig 10. 9 Cropmarks of a Neolithic village in southern Italy

The former ditches of a complex Neolithic enclosure, with circular or annular ‘compounds’ in the interior, here show as dark green marks in a landscape displaying various hues of green and yellow-green. As the differing crops change colour over the following days different parts of the enclosure will come into sharper focus, before the whole site takes on the yellow-on-yellow or yellow-on-brown appearance shown in the next group of pictures.

Note in the upper part of the picture the broad dark-green stripe representing the deeper soil of a former stream or river course.

Cropmarks in fully ripened crops

In dry seasons which favour the development of cropmarks by placing the crops under stress at critical times in their growth the evidence of past settlement patterns may remain visible as yellow-on-yellow or yellow-on-brown marks long after the crop has become fully ripe.

In such cases there are often substantial height differences between the cropmarks and the surrounding parts of the field. In oblique photography these can be accentuated by flying in low light at the beginning or end of the day (as in Fig 2.9, bottom right). The next two photographs were taken in 1989 by the late Derrick Riley during one of his aerial tours of Italy together with Otto Braasch. Both pictures show the distinctive dark brown colour of ripened durum wheat in the days before reaping obliterates the **trace**s of the past for another year. The site shown in Fig 10.11 has been photographed every year from 2001 to 2006 but has only once during that time shown with such startling clarity.

Fig 10. 10 Enclosures, graves and inhumation cemeteries in southern Italy

In a field which shows geologically 'patterned ground', with a probably Neolithic enclosure in the background, the main focus is on two overlapping rectangular enclosures in the foreground, each with an entrance gap on its left-hand side. Just beyond the upper right corner of the smaller rectangular enclosure is a small group of graves.

The photograph in this and the next Figure date from 1989. Flights in more recent years have shown several other conjunctions between square or rectangular enclosures and aligned inhumation burials, presumably of early Medieval date. For another such site and adjacent cemetery see Fig 10.59.

Fig 10. 11 Roman villa In southern Italy

Here the crop has germinated unevenly across the field but is now thoroughly ripe. The multi-phase pattern of enclosures, access tracks and vine-trenches is focused on a many-roomed building just above the centre of the photograph, with
a pattern of aligned individual pits just below and to its right, perhaps for the storage of wine or olive oil in large jars (*dolie*).

The formerly green-on-yellow ('positive') cropmarks of the ditches and vine trenches now show as yellow-on-brown, as do some of the walls of the villa where the stone has been robbed away to leave only soil in the foundation trenches. The stunted crop of 'negative' cropmarks above some of the remaining stone walls now shows as dark brown on lighter brown or yellow.

Beaten-down crops and 'reversal'

Cropmarks can often show in different ways in adjacent fields, as in the picture in Fig 10.13, showing a typical multi-period cropmark **complex** on the Tavoliere plain near Foggia.

Sometimes ditches or other features seem to 'reverse' their expected appearance and show as light rather than dark marks above ditches in the ripening crop, as on the right. The causes of this phenomenon have been much debated amongst **aerial archaeologist**s.

In other cases the plants grow so strongly over ditches that they collapse under their own weight when subjected to high wind or heavy rain, the 'lodged' crop then appearing as beaten-down areas, contrasting with the still-standing crop in the rest of the field.

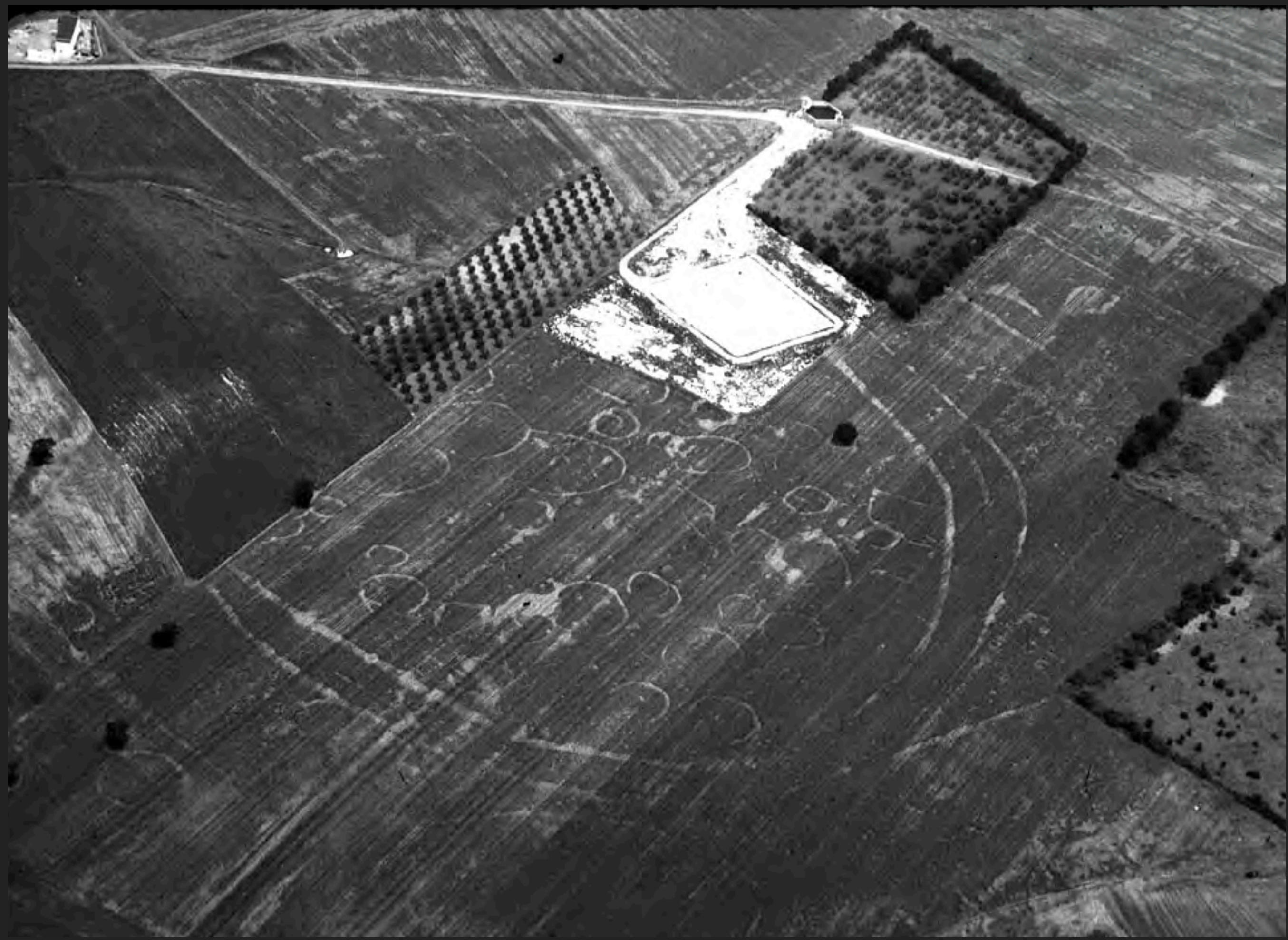


Fig 10. 12 **Neolithic features showing as 'reversed' cropmarks**

Sometimes ditches can – for reasons that are not always very clear – present themselves as lighter rather than darker marks in the ripening crop, as here at a double-ditched Neolithic enclosure on the Tavoliere, in southern Italy. Note the smaller C-shaped 'compounds' showing in the same way in the interior.

Fig 10. 13 'Green-on-green' cropmarks and 'lodged' cropmarks

Most of the cropmarks in this multi-period complex on the Tavoliere show as green-on-green marks. Those at upper right are caused by the collapse of the crop where the plants have grown particularly strongly over a pair of curving ditches, making them vulnerable to damage by high winds or heavy rain.

The bright green and 'fluffy' appearance of the far crop suggests that it might be alfalfa (*erba medica*), a now common crop in Italy which can produce excellent cropmarks.

In the near field, in addition to enclosure ditches and a ditch-lined trackway, there can just be made out a rectilinear pattern of individual pits, perhaps tree-holes for a former orchard – the spacing seems rather close for olives.

Vegetation marks: grassmarks and weedmarks

In the right conditions parched grass can produce remarkably clear cropmarks, as seen in the upper photograph in Fig 2.10 and 10.15. On hilltop pastures, especially where the soil is thin above the bedrock, surviving **earthworks** can be marked out by minor changes in the growth of grass and other plants, depending on small differences in the nourishment available and the varying exposure of the slopes to sun or wind. Weed growth, too, can give extra clarity to both earthworks and cropmarks when seen from the air.

On occasions the weeds themselves can create the cropmarks. Some of the drier parts of the countries around the Mediterranean could well see a second flush of cropmarks in the late summer, when returning rain brings new weed growth to the sun-parched pasture land or to the stubble of arable fields not yet ploughed for re-seeding. John Bradford remarked on this possibility on the basis of his own experience on the Tavoliere plain in southern Italy.

Fig 10. 14 A hilltop fort in upland pasture

Flights in recent years have shown many hilltop forts of this kind along the central spine of Italy. This one was photographed in 2003 on the return flight from the aerial archaeology school at Foggia in southern Italy. The marks here result partly from the play of light and shade, partly

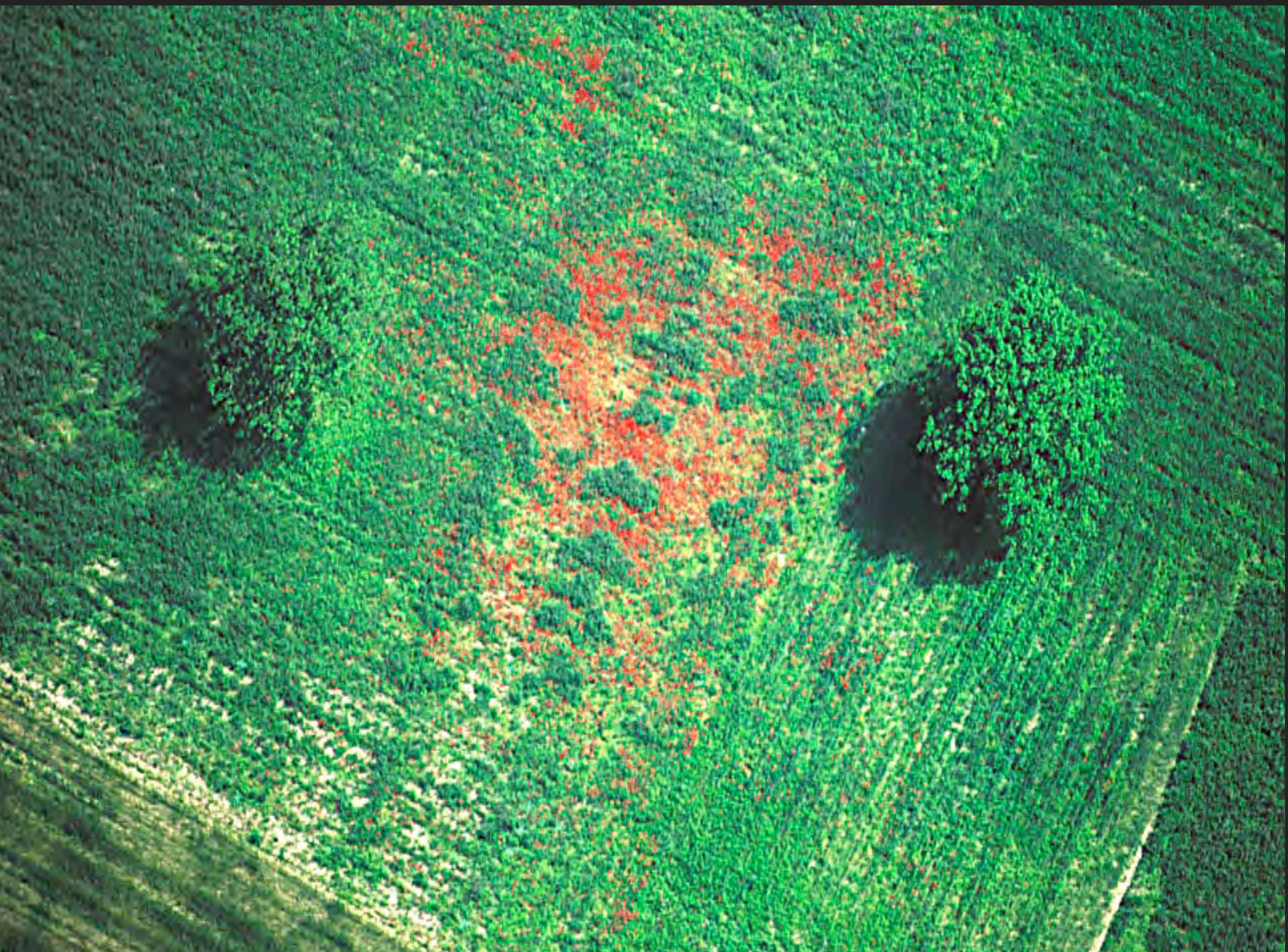


Fig 10. 15 Weed-marks

Here the green-on-green traces of parallel Roman vine-trenches are given greater clarity in places by a rash of bright red poppies.

Winter conditions

Light snowfall in winter can present special opportunities for recording both **landscape**s and archaeological sites, but heavy or wind-blown snow can conceal as much as it reveals. It may also be difficult to arrange flights at such times, or to cope with the cold of an open aircraft window when the outside temperature is several degrees below zero. If the cold becomes too severe for the crew, or for the heat-sensitive batteries of modern cameras, perfectly respectable photographs can be taken through the plastic so long as the photographer does not try to shoot directly into the sun.

Fig 10. 16 **Snow-clad landscape in Tuscany.**

Fig 10. 17 Earthworks beneath a thin covering of snow

The absence of distracting colour, along with the effect of shadows and highlights from the low winter sun, can reveal slight earthworks which would hardly be seen at other times of year, in this case an enclosure just to the left of the nearer farm building.

Under-water sites

The shallow waters of lakes or the coast are worth exploring in the right conditions, when the water is clear and there is little or no wind to disturb the surface and create sparkling highlights. The examples shown here and Figs 10.19 and 10.21 show that potentially interesting submerged **feature**s (of whatever date) can be effectively photographed from the air.

Fig 10. 18 Submerged harbour in Italy

The submerged features of the ancient harbour at Baratti, Populonia, on the western coast of Tuscany, can be appreciated in its entirety from the air. Only parts would be visible at any one time to an under-water diver or a ground-based observer on the shore.

Fig 10. 19 Underwater-features in Lake Trasimeno, central Italy

The U-shaped features on the left were recorded because they were a puzzle to the photographer. They do not align with adjacent property boundaries and in places there seem to be two lines, one perhaps more heavily covered by sediment (or weed-growth) than the other. If seen around the coast of Britain they might have been identified (tentatively) as tidal fish-traps. With some sort of sluice-gate or shutter at the open end. Might they perhaps have functioned as fish-traps even in the lacustrine context at Trasimeno?

Fig 10. 20 Under-water features in a lake in the central Apennines

The antiquity of these features in an artificial lake created in 1960s near L'Aquila in Abruzzo were unknown to the photographers at the time they were passing on a flight from Siena to L'Aquila. In fact they belong to two mills built in this location in the Middle Ages, their walls still well enough preserved to attract under-water enthusiasts to the cold but crystalline clarity of the lake's waters. Although features of this kind in relatively shallow water can be well enough depicted from the air their mapping might pose some interesting problems for AirPhoto or AERIAL, because of the effects of refraction at the junction between air and water. *(Information kindly supplied by Marina Nuovo.)*

Problems of interpretation and incomplete information

Aerial photographs do not of themselves give any evidence about the dating or function of sites. On occasions it is not even clear whether the features photographed are of archaeological rather than natural origin. The two views in Fig 10. 21 show the same site from different angle. Its interpretation was the source of much discussion at the Siena training school in 2001, without any firm conclusion being reached despite the experience of the people involved. Later site visits suggested that a geological explanation is the more likely.

Aerial information is often incomplete in other ways. Only some parts of the **landscape** will reveal useful information from aerial observation (see Fig 2.25). But this is true of almost any archaeological source, emphasising the value of each type of information in those cases where it is available. In the clay soils of Tuscany, for instance, only limited areas in river valleys or coastal lowland are likely to produce regular cropmark evidence, while the environs of many important historical sites, and the linking spaces between them, have been heavily obscured or totally obliterated by later terracing or mechanised agriculture (as in Fig 10.23, for instance).

Fig 10. 21 Possible enclosure or geology near Siena

Photographs from two different angles (or better still a stereo pair) can help the interpreter to understand the topography of a site. Here, the differing curves of the parallel fertiliser lines crossing the field show that the cropmarks occupy a slight knoll or promontory above lower ground. Close examination of the supposed ditches, however, left the interpretation uncertain. There is no visible entrance, though only part of the circuit can be seen. In places the cropmarks seem to lack the clarity which usually typifies man-made features, as distinct from the less precise marks produced by underlying rock strata.

Ground-based visits to such sites can often help to resolve the uncertainties. In this case site-examination suggested a geological rather than an archaeological origin for the cropmarks.

Fig 10. 22 **Cropmark enclosure, only partly visible**

In the centre of the picture on the left there are clear traces of a sub-rectangular enclosure, though at this stage of cropmark development its single ditch only shows where it has been cut into areas of deeper soil (the green patches in the otherwise uniform yellow of the rest of the field). Such an enclosure may never reveal its full circuit to the air photographer. There is no reason to doubt its existence as a man-made structure, however, though only ground-based work could give clues to its dating and function.

Fig 10. 23 **A castle in a sea of erosion**

Whatever the original context of this medieval castle, the evidence has now been totally lost, both from the air and on the ground, through the heavy terracing and cultivation of the surrounding slopes.

Photographing cropmarks from differing angles

It is always worth photographing cropmarks and earthworks from a variety of angles (soilmarks too). The contrast and colouration of archaeological cropmarks, and of the surrounding fields, may change as the aircraft makes its circuit, particularly when the cropmarks are poorly developed or are being photographed in dull light rather than clear sun. There is a real danger in these circumstances of flying past cropmark sites without realising that they are there. Overall flight patterns, as well as immediate manoeuvres, should therefore try to give the archaeologist differing views of the same piece of landscape. Even well developed cropmarks can show different features from different directions or height. Poorly developed marks, on the other hand, usually show best when viewed directly away from the sun rather than into it.

Fig 10. 24 Two views of a cropmark enclosure in Puglia, on the 'heel' of Italy

These two views of a remarkable 'baroque' enclosure were taken by Otto Braasch and the late Derrick Riley in 1989. The enclosure has not been seen again on more recent flights. The almost perfect circular shape is unusual but the distinctive bastions suggest that it belongs to the great flowering of occupation and site construction in this area in the Neolithic period. The photographs are interesting for a number of reasons. The enclosing ditch, for instance, appears as a dark mark round much of the circuit but (in the left-hand view only) as a pale mark in the more distant field. Both photographs also show the indistinct 'ghost' of a similar and presumably earlier enclosure, or perhaps a contemporary annexe, slightly offset from the more distinct cropmarks.

Fig 10. 25 A former building seen from different angels

This building, in the ancient town of Heba in Tuscany, was photographed several times in 2001 and later, usually from the direction shown on the left. On the right the opposite view has given greater clarity and extent to the central range.

Fig 10. 26 Photographing faint cropmarks

This group of poorly defined cropmarks on the Tavoliere was photographed directly ‘down-sun’, as shown by the aircraft shadow in the foreground. A faintly marked rectangular building lies just left of the shadow. Near the top of the picture a curvilinear enclosure or ring-ditch has a small group of inhumation burials on a lighter-coloured patch alongside it. It is doubtful if such faint marks would have been seen if photographed from any other direction.

Problems with pits

It is an axiom of **exploratory aerial survey** that one must return week after week and year after year to the same areas if one is to reap the full rewards of the technique. The occurrence and appearance of cropmarks varies from year to year as weather conditions and land-use change, and even in favourable areas like the Tavoliere plain in southern Italy or the arable fields of eastern England there will be new discoveries every year. Elsewhere, where the land use, agricultural practices or prevailing weather patterns are less favourable, decades of work may be needed before a representative proportion of the recoverable evidence has been recorded.

Fig 10. 27 Pits, tree holes, tombs or quarries?

Top. A rash of pits here lies mainly within an apparent cropmark enclosure. But their continuation beyond it to the left leaves doubt about their possible archaeological origin. The contrast of the image has in this case been enhanced so as to show the pits more clearly.

Bottom: Three or perhaps four rectangular pits, each about 3m long to judge by the comparison with the width of the farm track, lie between the foreground road and the first line of olive trees. They seem too large to have been dug as holes for the planting of now-vanished trees. Perhaps they are simple Etruscan tombs? Just above the road junction, however, a group of more irregular marks merge into one another. They might be hand-dug quarries rather than tombs. Ground-based observation might help to resolve the uncertainty in a case like this.

Fig 10. 28 **Pits, cemetery or tombs?**

Left-Top. This field, sandwiched between road and railway, shows the typical pits and surrounding circular marks of a now ploughed-out Etruscan cemetery.
Left-*Bottom*. The three large rectangular pits in this otherwise empty field were photographed as possible Etruscan tombs.

Fig 10. 29 **Tree holes?**

Right. The pits here are almost certainly tree holes, aligned as they are on the remaining parts of the olive grove.

Returning time and time again

The interpretation of pits can cause particular problems, both for the aerial photographer and the photo interpreter. Pit-like marks can be caused by a variety of underground features, from geological irregularities to bomb craters, hand dug quarries and recent or ancient tree holes. Often the only clue to their interpretation lies in their apparently purposeful relationship to one another or to a natural feature such as a stream or other ready source of water, or in their proximity to a more certainly identified archaeological site. Even then their interpretation is often a matter of conjecture rather than certainty, as demonstrated by the pictures in the following group of photographs.

Fig 10. 30 Motta della Regina, Puglia

This pair of linked medieval mottes has contemporary rectangular fields alongside and a multi-ditched Neolithic enclosure beneath. The top left photo is one of those used by John Bradford in his pioneering work on the Tavoliere in the 1940s. The picture at lower left, taken in the late 1980s, seems at first to show the same cropmarks but careful comparison shows that it is reveals the other half of the Neolithic enclosure. The whole complex can be seen in startling clarity in the large photo above, taken during one of Otto Braasch's recent visits to Puglia. Note how much the mottes have been eroded since the 1940s.

Fig 10. 31 A cropmark complex in two different years

The photograph on the left shows the marks in fully ripened grain in 2001, with the indistinct cropmarks of two enclosures and a small ring-ditch. In the lower view, from 2004, the whole pattern is revealed in startling clarity, with an extensive cemetery at centre and left, along with two differing-shaped ditched enclosures on the right. The dark stripe running from centre left to lower right, with boundary ditches along most of its length, is one of the droveways used to move stock in transhumance farming from pre-Roman times onwards. It would be a matter of luck if such perfect conditions were to be achieved in non-archaeological vertical survey.

Lighting and contrast in the recording of buildings

Aerial archaeologists usually prefer bright sunlight for their sorties but this can be a problem when recording buildings or townscapes. In these conditions traditional cameras and multi-layered films tend to produce results of too high contrast, with loss of detail in the shadows and an out-of-focus effect round the edges of highlighted areas, especially the tops of walls in ruined castes or other archaeological monuments (perhaps due to the scattering of light within the thickness of the film emulsion). Better results with traditional (or digital) cameras can be obtained in more subdued lighting, beneath thin cloud cover. But predicting such conditions is even more difficult than identifying days when bright sunlight and clear visibility will assist cropmark and earthwork recording.

Fig 10. 32 Castle at Staggia, Tuscany

The photo above, taken on traditional film in bright sunlight, displays exaggerated highlights and deep shadows, lacking detail. The view on the left, again taken in bright sunlight but this time using a digital camera, retains much better control of contrast, with an enhanced amount of detail in the shadows. On this occasion the subject was even more demanding since restoration work had now removed trees and undergrowth to expose all of the wall surfaces. Post-processing digital images in colour is far more straightforward than the complex darkroom work required in traditional print processing.

Fig 10. 33 Detail showing clearly when photographed in subdued lighting

Both traditional and digital cameras can retain good detail when working in relatively subdued lighting, though the absence of shadows can occasionally 'lose' some of the geometrical form of the building.

Fig 10. 34 Close and more distant views of the same subject

Two photograph of the same subject, the castle and Tuscan town of Montalcino, but concentrating on different aspects of the scene, the castle and monastery in the view in the right, the general townscape and its topographical context in the view above.

Fig 10. 35 Monastery of Lecetto, Tuscany

Two digital images showing the excellent contrast control which is possible with this technology. The left-hand view would satisfy many photographers but the upper shot, taken from a slightly different angle, gives the whole complex a better sense of form by including highlights on the right-hand faces of the walls and by achieving clearer rendering of the upper parts of the central tower.

Topography and geology

Archaeologists new to aerial survey tend to concentrate on individual sites or monuments, forgetting that publications and public presentations also need to show the general landscape or townscape setting. The character of any country's landscape also deserves recording in its own right, to illustrate its topography, geology and land use and to document the many changes which will take place – or have already taken place –over the lifetime of any seriously-intended air photo library. For the most part images of this kind take no extra time to record, just a little attention to the passing landscape and to the opportunities that general flight patterns present for its recording.

Fig 10. 36 Pictures of the present-day landscape

This magnificent digital image, taken from slightly higher than normal flying height, captures the character of the rolling hill-country of central Tuscany, with typical erosion of the clay subsoil in the foreground. Views of this kind are particularly valued by geologists, environmentalists and those involved in landscape protection and appreciation.

Fig 10. 37 Geology and geomorphology

These remarkable but entirely natural clay ‘eruptions’ were once widespread in Tuscany but the intensive agricultural activity of recent decades has now restricted them to relatively small areas, some of them protected as sites of national importance.

Fig 10. 38 Recently reclaimed coastal land in Tuscany

This kind land reclamation and partition can be compared with the radical changes that were wrought on the pre-existing landscape by the imposition of centuriation patterns in Roman times.

Fig 10. 39 Fossil river courses

This kind of view will be valued by geologists and landscape historians as much as by archaeologists. It always pays to take photographs that will be useful to other specialists. The location or survival of archaeological sites can be influenced by the contemporary pattern of water courses and by later changes in the pattern.

Landscapes in course of change

To the occasional aerial visitor to Italy one of the most striking aspects is the contrast between apparently ‘traditional’ land-use in some upland areas and the rapid degradation of such patterns elsewhere. Parts of the Murge Hills in the far south of Italy, for instance, show the widespread desertion of traditional farming patterns in favour of mechanical stone clearance and the heavy use of fertilisers. In Britain, aerial photography – both vertical and oblique – now plays a major role in recording landscape change and in characterising those areas that are considered to be worth protecting from sudden or damaging change. Aerial views can also have a significant impact in raising public and political awareness of the nature and value of such areas.

Fig 10. 40 A traditional landscape near L'Aquila in central Italy

This landscape of walled enclosures and small plots of managed pasture was photographed by Otto Braasch and Derrick Riley in 1987. At that time it appeared unaffected by modern farming practices. The contrast with the arable landscape of the valley floor in the foreground is intense. Do the two landscapes still exist side by side today? And if they do, for how long will this remain so?

Fig 10. 41 **Disused and disappearing *trulli* in southern Italy**

Puglia's traditional *trulli* (stone-built huts with corbelled roofs) will no doubt survive in tourist venues like Alborabello, but in the open countryside many are falling out of use and disappearing beneath piles of stone cleared from the surrounding fields (right). The same kind of stone removal can be seen below, along with the heavy use of fertilisers in some of the fields.

Viewing this and similar scenes from the air the visiting aerial archaeologists tried unsuccessfully to understand the relationship between the *trulli* and the surrounding landscape. Have such things been studied by Italian archaeologists? And if so, would photographs like this be helpful in their studies?

Monuments in the landscape

Oblique aerial photographs have a special capacity to show sites and monuments in their landscape setting and to record the relationship between their various elements. As simple perspective views, taken from a novel angle, they are particularly useful for communicating with the general public, or for use in books and guides illustrating areas of protected or nationally valued monuments or landscapes. Few such publications in Britain now lack their share of striking aerial images.

Fig 10. 42 Castel del Monte, Puglia, southern Italy

This grand hunting castle, built by Frederick II on a magnificent hilltop site in southern Puglia, is today a major tourist attraction. It is also a striking sight from the air, its gleaming stonework visible from far away in every direction. Close views of its octagonal tower and spiralling approach path can be very attractive but in this wider view the photographer has concentrated on showing the building in its broader landscape context, with stone-roofed *trulli* still in use in the fields beyond.

Fig 10. 43 Rocca di Calascio, Abruzzo, central Italy

The smaller of these two views focuses on the now largely deserted village rather than the castle and later church beyond. The larger image illustrates the dramatic ridge-top siting of this highest castle in Italy, along with its relationship to the octagonal church in the foreground. Both pictures have their value in recording the character of the site and its surroundings.

Problems of association

Local knowledge is essential in seeking the full benefit of aerial exploration and recording, especially in upland areas where a multiplicity of earthworks and agricultural traces may survive alongside one another. The aerial archaeologist is bound to wonder about such relationships and should take photographs to illustrate and record them. The physical and topographical relationship between the various elements in the pattern may be much harder to appreciate from the ground, where only parts of the pattern can be seen from any individual viewpoint. The right approach, of course, is to put the two kinds of observation together in the form of an archaeologist who both flies and studies the landscape on foot.

Fig 10. 44 Two hillforts and other upland walls

The mountainous spine of Italy has a plentiful supply of defended hilltop enclosures, many of them similar in form to those of western and northern Britain. In the United Kingdom the two hillforts in this photograph would probably be attributed to the pre-Roman Iron Age (though excavation has shown that them belong to later or earlier periods). Whether In Britain, Italy or elsewhere the aerial archaeologist would be looking carefully at the walls and terraces in between the two hilltop enclosures to see if the view from the air could give clues to the relative dating of the various structures present in this remarkably well preserved stretch of the central Italian landscape.

Fig 10. 45 Walled enclosure and hillslope terraces

This photograph was taken by the late Derrick Riley towards the end of the 1980s during one of his aerial visits to Italy along with Otto Braasch. The obvious intent was to question the relationship between the foreground enclosure, the building (or sheepfold?) beyond it and the (two kinds of?) terraces on the further slopes.

Both this view and the previous one were taken in colour. They are reproduced here in monochrome because of serious deterioration in the colour slides in the years since the 1980s.

Fig 10. 46 Earthworks in an upland landscape

The location of this upland complex was not recorded at the time of photography and the interpretation of the earthworks cannot therefore be checked with local archaeologists. The hilltop enclosure is presumably an Iron Age fort or a Medieval castle, more likely the latter in view of the apparent walling on the left-hand side and the rectangular foundations at the near end. The remains could of course belong to both periods, a medieval castle taking over an obviously advantageous location from an earlier fort.

Further questions arise, however. Does the curving bank on the left belong with the enclosure? And what are the seemingly rectangular earthworks in the foreground? Are they field terraces, or perhaps something entirely different? Do they 'belong' with the hilltop enclosure? Their interpretation would be easier if the photographer could return in low light, so that the slight changes of level could take on a clearer pattern through the use of stronger light and shade.

Loss and survival on the Tavoliere plain, southern Italy

The Tavoliere plain offers perhaps the best opportunity in Europe to study ‘complete’ landscapes from the past. Paradoxically, however, both the Neolithic and Roman phases, and those of later times, have been heavily damaged by the very cultivation which first brought them to light through cropmark and soilmark evidence. This paradox is matched by another: the best-preserved sites (or parts of sites) are likely to be those which show relatively poorly on aerial photographs, either because the plough has only just begun to bite into the buried features, or because they have been protected by a layer of alluvium before intensive ploughing of the plain’s former pastureland began in the earlier half of the last century. Even since the 1940s parts of the Tavoliere landscape have been radically changed, particularly in the south where many once-visible cropmark **complex**es have vanished from sight through the widespread planting of vines and fruit trees.

Fig 10. 47 Neolithic and Roman landscapes under threat

This striking cropmark complex at San Vincenzo, near Foggia, displays elements from the Neolithic, Roman and perhaps other periods. It was photographed for the first time during an aerial archaeology training school in 2003 and was much used at that time for discussion among the students. It shows various shapes and sizes of ditched enclosures, and a ditch-lined road or trackway, set against the steep slope down into a wide and shallow valley on the right. Parts of the pattern remain invisible in areas of deeper (darker) soil which have not yet produced cropmark evidence. At this stage it was thought that the only threat to the site came from the ploughing that had revealed it in the first place. But see the following pictures in Fig 10.48.

Fig 10. 48 Neolithic and Roman landscapes under threat

It was infinitely sad, only a year after the previous photo was taken, to see the same complex crossed by construction roads and massive foundation pits for one of the many wind-farms now being built in southern Italy. Fortunately a programme of geophysical survey and rescue excavation by staff and students of the Universities of Foggia and Bari, along with colleagues from Germany, allowed at least some information to be recovered from the now seriously damaged complex. Note the Roman-period grid of pits for olive trees in both photographs.

Fig 10. 49 Vanishing cropmarks on the southern fringes of the Tavoliere

Decades of ploughing have not (as some predicted) entirely obliterated the Neolithic ‘villages’ first revealed at the end of the World War II. But many villages, like this one on the southern fringes of the plain, will soon be hidden beneath unresponsive vineyards and fruit farms that are rapidly taking over this part of the plain (sometimes using plastic covers as here on the right).

The Etruscan and Roman city of Vulci, central Italy

The ancient city of Vulci, in the central Italian Province of Viterbo, has been studied by scholars both on the ground and from the air, as well as through excavation and field survey. In addition, the **mapping** of detailed evidence from vertical photographs has revealed the layout of streets and building within large parts of the town, along with numerous cemeteries and communication routes in the surrounding countryside. The site was also photographed from the air during the Siena training school in 2001, when the photograph on the next page was taken. Even better photographs of the same part of the town were taken during the later training school at Grosseto in 2005, though too late for the published version of the book. The original images and text have been retained here for consistency.

Fig 10. 50 Vulci: an Etruscan and Roman city in central Italy

The cropmarks of the ancient city were very difficult to see in 2001 and have remained so during examination of the resulting photographs, like that shown above in its original proportions. But the fugitive rectilinear pattern in this part of the city becomes clearer when the height of the photograph is digitally ‘stretched’ and increased in contrast (*left*). The pattern of apparent streets and buildings, is now more distinct, though perhaps not yet sufficiently so for detailed mapping. (For mapping of Vulci see *Pocobelli 2003*, *2004*, *2007*.)

Fig 10. 51 The ancient city of Vulci: the central area

Two of the original streets, on display after excavation, with the Domus del Criptoportico in the foreground and the Tempio Grande beyond.

Fig 10. 52 Vulci: Etruscan tombs

Left. The excavated Tomba della Cuccumella displays the typical outline of the ‘tomba al corridoio’, a rectangular underground burial chamber with a corridor approach. The faint T-shaped cropmarks of further tombs can be seen in the in the far field. *Above*. Another cemetery area. The image has been increased in contrast so as to enhance the clarity the tombs, arranged in groups or rows along or between now vanished ‘sacred streets’.

Roman roads and villas

Both in Britain, Italy and elsewhere across Europe **vertical air photographs** and **exploratory aerial survey** have been used to trace the lines of Roman roads and to locate the sites of towns and villas. There is rarely much doubt about villas or similar structures, though field examination during the Foggia training school in 2003 (as illustrated in Fig 4.6) showed that a cropmarked courtyard structure tentatively identified as a villa actually represented a demolished building of quite recent date. The examination of early maps could perhaps have provided this information but field visits are always instructive in showing what materials or ground conditions have produced the cropmarks seen and photographed from the air.

There are many marks in the landscape which superficially look like Roman roads but which are in fact of more recent origin. The most typical are pipelines for water, oil or liquid gas. These can easily be mistaken for ancient roads, both by the airborne photographer and the unwary or inexperienced photo interpreter, as was initially the case with the linear cropmark shown in Fig 10.53. The two examples in Fig 10.54 are more convincing, though in most circumstances such marks would need ground observation, wider-ranging exploratory aerial survey or the examination of appropriate vertical photographs to confirm their dating and interpretation.

Fig 10. 53 Not a Roman road

The straight line cutting across the picture from lower left to upper right was initially mistaken for a Roman road. But examination of the photograph reveals marker posts of the kind used to indicate the underground course of many modern pipelines. One of the posts is shown in the inset at top left

Fig 10. 54 Probable or certain Roman roads

The linear cropmarks in this pair of photographs are more convincing as Roman roads. That on the left continues in various forms across several fields and completely ignores (or is ignored by) two roads or irrigation ditches in the foreground. In the right-hand photograph the soilmark at the bottom of the frame and the faint cropmarks in the other two fields ignore the modern field divisions as the underlying road approaches the barely discernible traces of a building in front of the tree at the very top of the frame (the one shown in Fig 10.26).

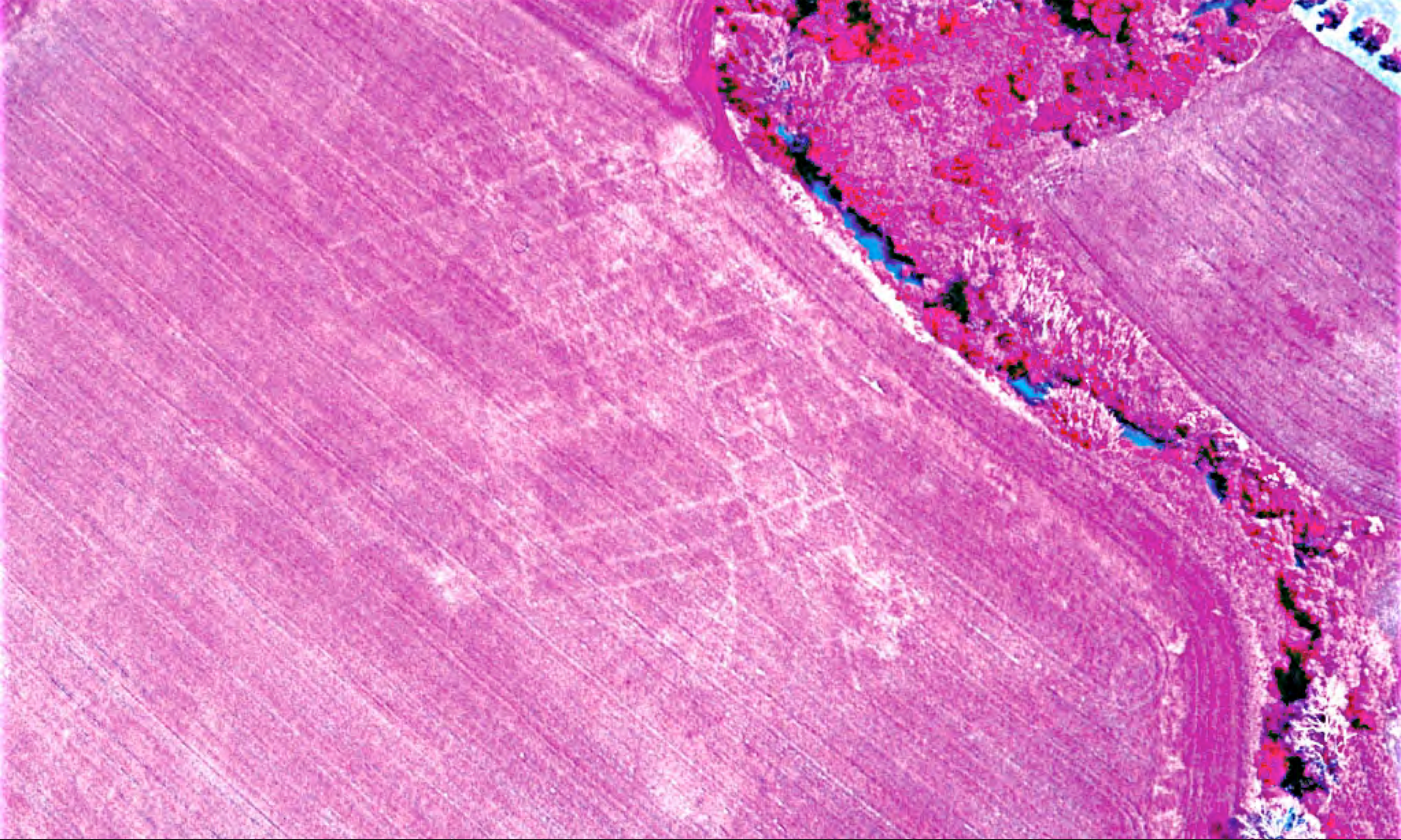


Fig 10. 55 Roman villa complex west of Foggia, southern Italy

This huge complex of buildings was one of a dozen or more villas of various forms and sizes recorded (in this case in false-colour infra-red) during the training school at Foggia in 2003. Of these less than half had previously been identified in vertical photographs taken for military or mapping purposes.

Exploring and interpreting ancient landscapes

Parts of the southern Italian Tavoliere show almost continuous Roman landscapes, as well as Neolithic **enclosure**s and cropmark traces of many other dates. In such a context the basic outline of the mapped archaeology will be best provided by the **mapping** of information from already existing vertical photographs. Even better, perhaps (were funds to allow it) would be the commissioning of new vertical coverage, taken in the middle or later part of May when the grain crops are passing through their critical yellowing phase. The role of exploratory aerial survey and oblique air photography would then be to add detail, to seek out areas not well represented on the vertical photographs and to search for aerial evidence where (for instance) Bronze Age finds have been recovered from surface collection but no other evidence is available. Exploratory survey at other times of year might concentrate on soilmark evidence, or seek out new information through the recording of weed-marks or grass-marks on the surrounding hillslopes or on the lower land of the Tavoliere itself.

Fig 10. 56 A multi-period ancient landscape in southern Italy

The cropmarks have here been framed to emphasise the scale and continuity of the Roman landscape, with its associated vineyards and other forms of planting. The Roman pattern marches majestically across two contrasting curvilinear enclosures, the more distant being a typical Neolithic 'village' with twin ditches and smaller penannular 'compounds' in the interior.

The dating of the circular enclosure the foreground is uncertain. It overlaps – or is overlapped by – a rectangular Roman farmstead, itself linked to an axial road of the centuriation pattern by a ditch-line approach track.

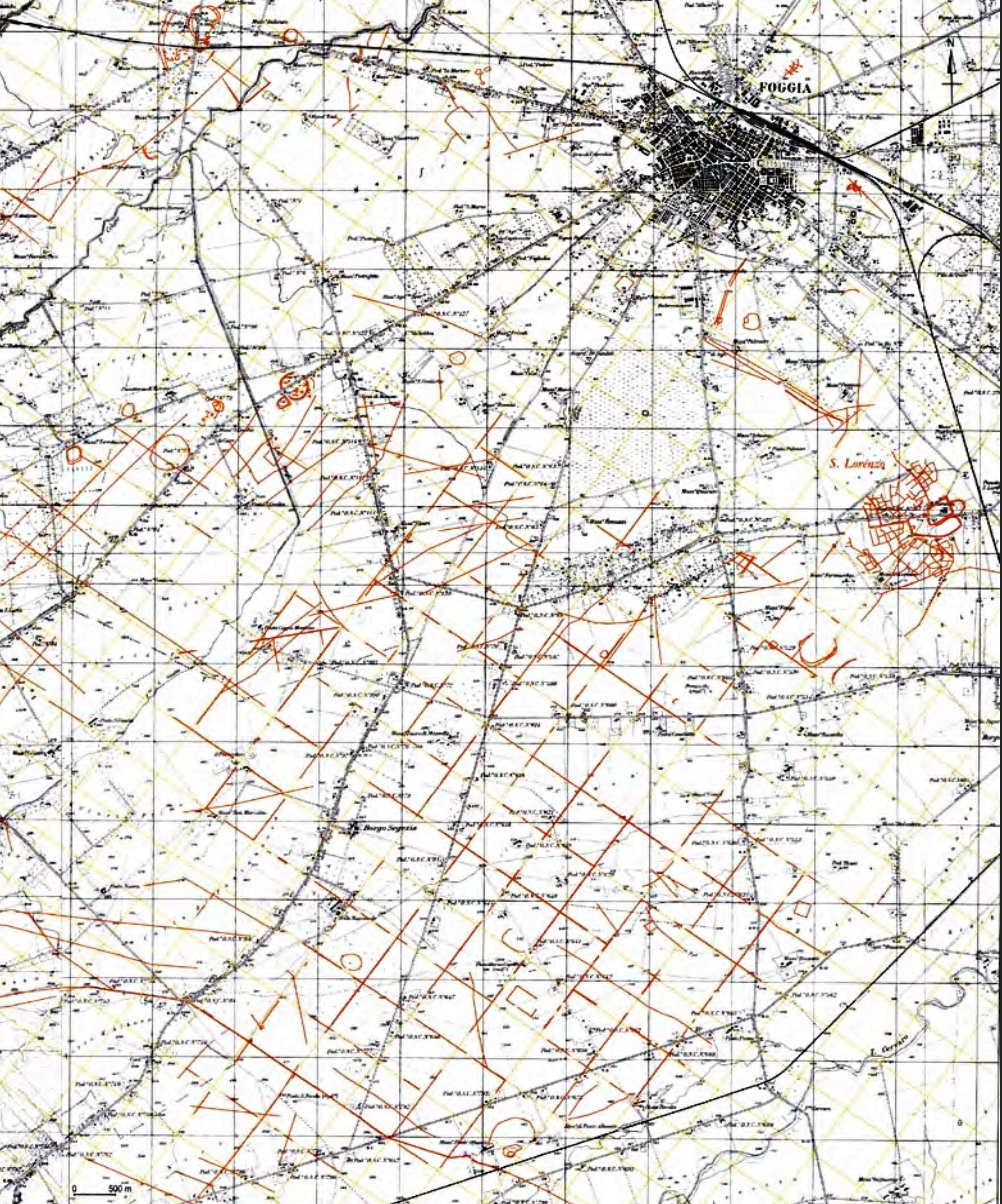


Fig 10. 57 Mapping the ancient landscape south and west of Foggia

A fine example of mapping from vertical photographs, created by Fabio Piccarreta and Giuseppe Ceraudo of the University of Lecce (now Salento).

The mapping in this case was done principally from 'historical' vertical photographs, using specialist photogrammetric plotting equipment that has provided the basis for the University's extensive air photo interpretation and mapping projects over the years.

Cemeteries and churches rediscovered

Among the cropmark sites recorded during the Italian training schools, and in other flights since legal restrictions there were lifted in December 2000, there have been significant numbers of churches and inhumation cemeteries. The churches, by and large, are reasonably easy to identify from their cruciform or apsidal shape. The cemeteries, however, especially where not lying within or alongside **enclosure**s, can be very difficult to spot from the air. The present writer (CM) found this so even when a more experienced surveyor in the pilot's seat (Otto Braasch) was already photographing the graves which he had spotted in the landscape below. It takes considerable experience to train the eye and brain to recognise small features of this kind, taking up only a tiny part of the area that lies within sight at any one time. As in life and excavation, the things that you have seen in the past, either directly or indirectly, will influence what you see and understand now and in the future. The aerial archaeologist, like other professionals, must accumulate experience and try at all times to be open to new kinds of aerial evidence.

Fig 10. 58 An inhumation cemetery in the Appenines

The student at the training school who (after only a few hours of aerial experience) spotted this group of graves was understandably pleased with his perspicacity. Faint marks hint at a continuation of the cemetery into the less responsive dark green area to the right. The alignment and proportions of the graves suggests a medieval (Langobard) origin.

Fig 10. 59 Two enclosures and an inhumation cemetery

In exploratory work over southern Italy in 2005 much of the survey work was focused on the Neolithic ‘villages’ but in a short flight south from Foggia attention was turned to square or rectangular enclosures, ten of which were recorded in about forty minutes of survey, including the two in this photograph. The better defined of the two has alongside it a double line of inhumation burials, perhaps originally aligned along a road or track.

Fig 10. 60 A cruciform church near Foggia

This clearly defined church, with a less obvious rectangular building and a large possible pit alongside it, lay directly under the take-off and landing path during the Foggia training school of 2003. Ground examination failed to show why the two buildings showed so differently. The church is one of several ‘lost’ churches known from documentary evidence to have once existed in the countryside around Foggia.

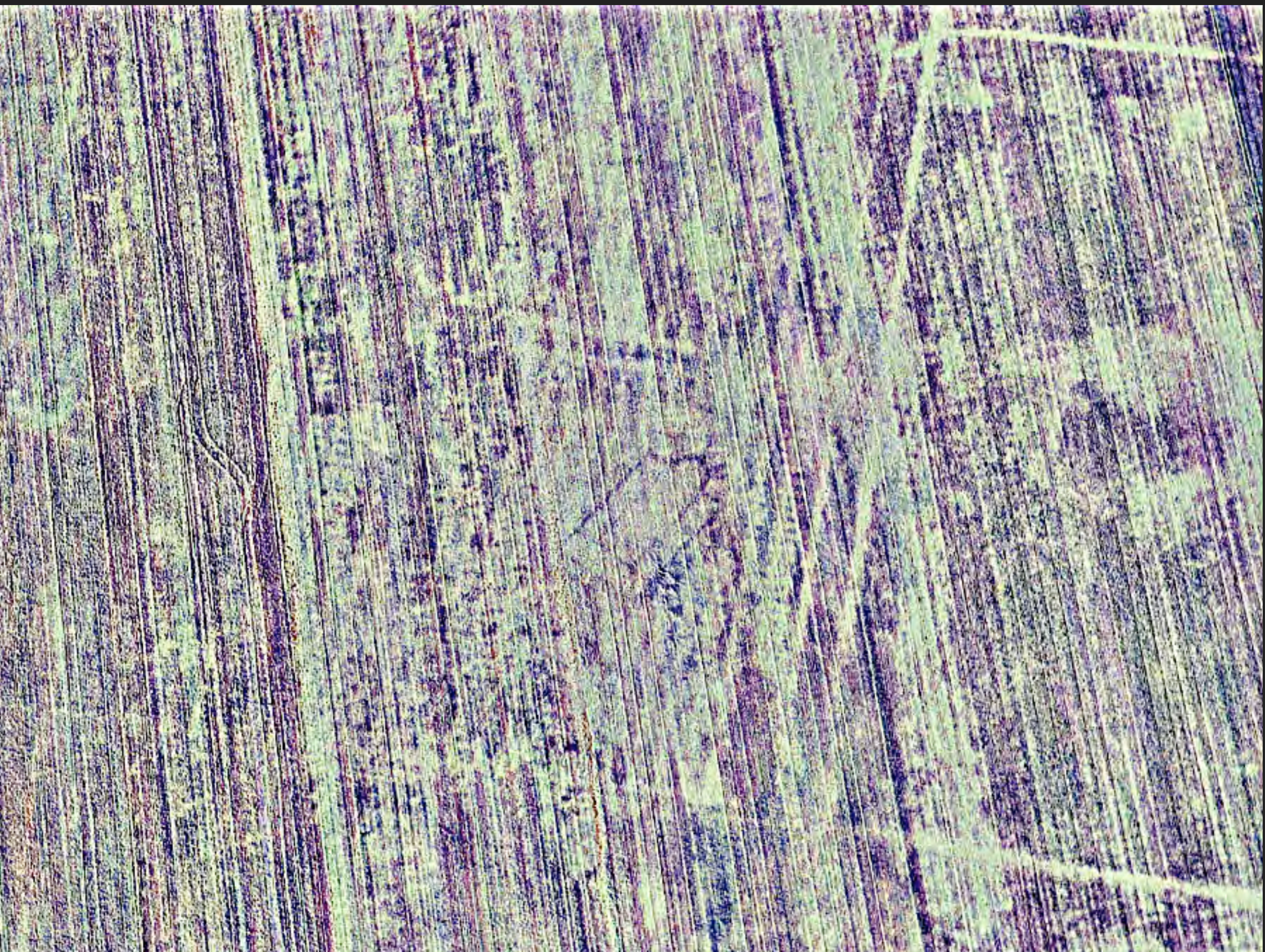


Fig 10. 61 An apsidal church and Roman landscape

The apsidal and aisled church at the centre of the frame has been accentuated by some basic image processing to give a dramatically changed colour rendering. Across the whole of the image beneath the parallel lines of the modern arable cultivation there can be seen the ghostly traces of the earlier Roman pattern.

A re-discovered Medieval settlement in southern Italy

During exploratory survey over the southern part of the Tavoliere in 2002 one of the most pleasing discoveries, visually and archaeologically, was an apsidal church picked out by negative cropmarks in a field of scarlet poppies (Fig 2.11, bottom and 10.62, left). There were hints of other cropmarks in nearby fields and these came dramatically during a further flight in 2004. The settlement to which the church belonged had now become visible as startlingly clear cropmarks, almost certainly those of the documented but previously 'lost' medieval settlement of Torre Alemanna, west of Cerignola.

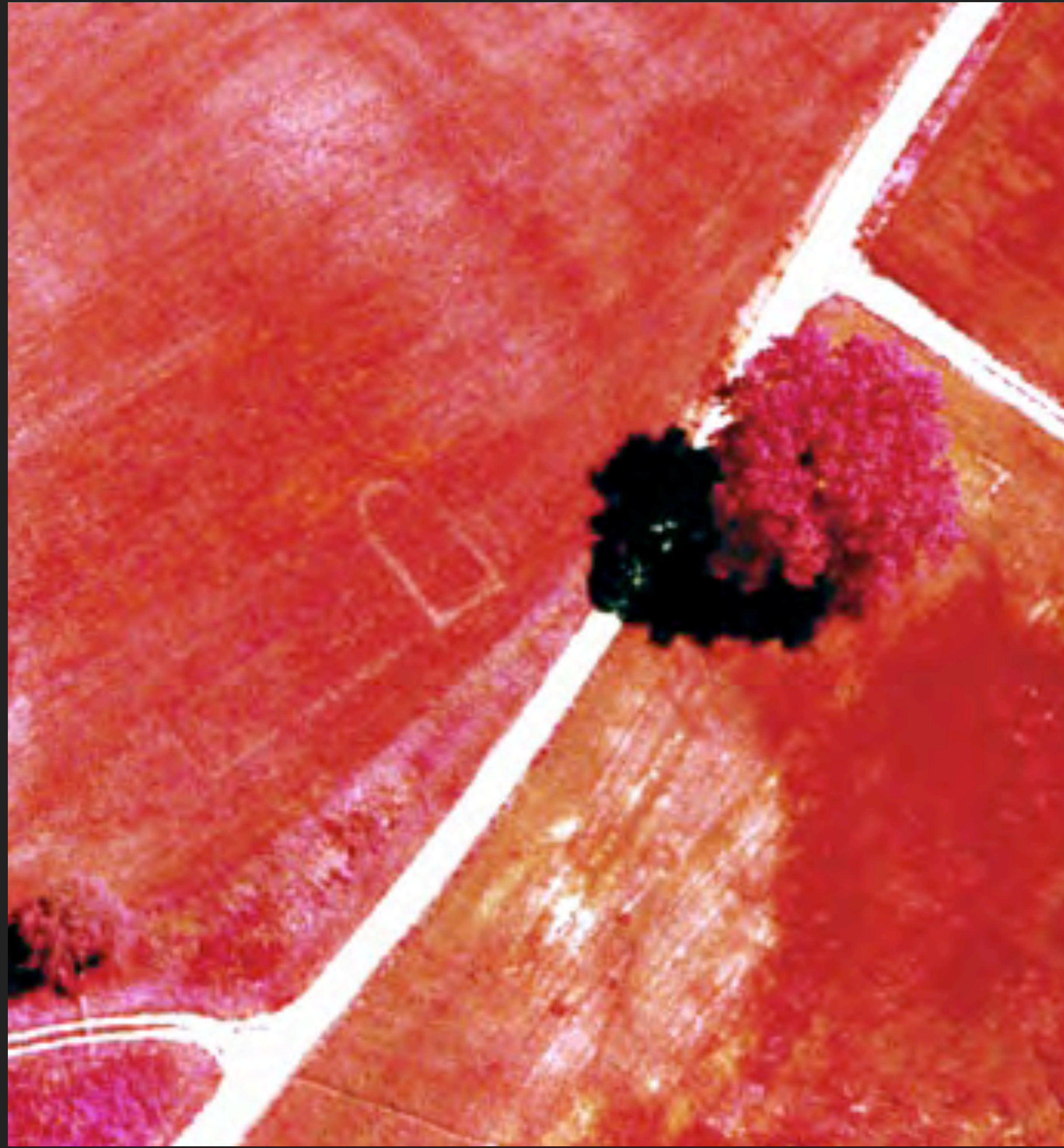


Fig 10. 62 Two churches and a 'lost' Medieval settlement

Above. The small apsidal church first seen in May 2002, here shown in false-colour infra-red.

Left. The same area two years later. A second church is now visible in the foreground. The 'lost' settlement of which these two churches form part is illustrated in Figs 10.63 and 10.64.

Fig 10. 63 The broader context of the churches shown in Fig 10.62

The extent of the previously lost settlement, within two widely spaced enclosure ditches, is shown in this broader view from 2004. The small church first seen two years earlier lies close to the single tree at top left. Much of the settlement's core must lie under the olive grove at top right. A pattern of fields, tracks and roads spread out into the surrounding countryside beyond the limits of this image.

Fig 10. 64 Structures within the settlement

The amount of detail in this view is remarkable. In addition to the main enclosure ditches there are numerous smaller ditched enclosures and apparent field boundaries, at least some of them passing beyond the outer enclosure ditch. The rash of pits and other marks in the core of the settlement leaves a ghostly network of internal tracks and roadways. At lower left a faint rectangular cropmark on a slightly darker area may indicate a third church within the settlement.

Castles from the air

Castles are obvious targets for aerial photography, allowing their general form and constituent parts to be captured in just a handful of striking perspective views. The following photographs concentrate on castles of stone but occasionally cropmark evidence can be recovered too, as at the site illustrated in Fig 10.68. Some would argue that this kind of photograph, much used already in Italy for calendars and postcards, could be equally well taken by a non-archaeological professional photographer. But this fails to recognise the archaeologist's extra ability to choose viewpoints or framing that illustrate the things which it is most important to show. The same applies to many other aspects of aerial survey, in which the archaeologist draws on his or her specialist knowledge to perceive – and understand – things that would mean little or nothing to the non-archaeological photographer.

Fig 10. 65 A patriotic castle

In the photo on the right of the 13th-14th century castle of San Pio delle Camere, in Abruzzo, a huge Italian flag has been laid out on the hillslope, perhaps as a target for pilots or hang-gliders.

Fig 10. 66 A castle submerged in woodland

At the castle of Monteverdi in Tuscany, where restoration work is in progress, the overall form of the castle can be made out despite the heavy coverage of trees.

Fig 10. 67 Castle and collapsed tower?

At the castle of Crevole in Tuscany the photographer suspected that the pile of stones at the top of the picture might be the remains of a collapsed tower. In fact it is stone from restoration work on the nearer part of the castle.

Fig 10. 68 Extra information from cropmark survey

A flight in 2002 over Torre Terteveri, near Lucera in Puglia, revealed buried traces of a curtain wall and an extra range of buildings respectively below and to the left of the surviving tower. There were also numerous pits, on the left, which may have belonged to the castle or which were alternatively of geological origin.

Fig 10. 69 A complex stone castle explained

At Castello di Montemassi, in Tuscany, two contrasting views show the castle in its urban context (*left*) and the relationship between the various building elements of the castle itself (*right*).

Fig 10. 70 A hilltown in its landscape context

Bagno Reggio, once almost inaccessible deep in the hills of central Italy, is now connected to the outside world by a high modern bridge.

Fig 10. 71 A town in context, and its Roman amphitheatre

At Assisi the archaeologist's eye was caught by the oval pattern of buildings in the foreground, reflecting the former footprint of the town's one-time Roman amphitheatre (see also Figs 2.14 and 10.85).

Fig 10. 72 The castle and town of Canosa in southern Italy

The castle stands above steep slopes on the left, with the curved outline of the medieval town to its right.

Townscapes in context

The aerial viewpoint allows towns and villages to be shown in their broader context, along with roads, rivers or other physical features which may have influenced – or been affected by – their form or siting. The permitted flying height over built-up areas is usually a minimum of 500m above ground level, making long-focus lenses necessary when recording just part of the urban pattern – a central square or a castle, for instance. On the other hand a wider aerial view can be particularly effective in showing the pattern of older street, buildings or defences embedded within the modern townscape.

Fig 10. 73 **The cathedral and baptistery at Florence**

An internationally known pair of buildings are seen here – for most people – in a new light. The photograph was taken, in passing, on transit back to the local airfield. The air photographer should be constantly looking out for such shots, even if there is no time to circle for other views. Over the years a valuable record can be built up from such lucky chances.

Fig 10. 74 The many-towered walls of Monteriggioni, Tuscany

Within its perfectly preserved town wall Monteriggioni now consists of a relatively modest group of fairly low-profile buildings, here photographed in relatively flat lighting beneath thin cloud cover to emphasise detail within the general form.

Fig 10. 75 Medieval towers in San Gimignano

In the medieval town of San Gimignano in Tuscany survivors of the much larger number of towers originally built within the settlement are here picked out by late evening lighting. High-contrast subjects of this kind are much easier to control in digital photography as compared with traditional film-based recording.

Urban monuments in Tuscany

There is little need to justify the merits of this and the following two photos, both for the general public and for specialists. Dramatic pictures of this kind can make complex townscapes or elaborate building patterns immediately intelligible as striking views from an unexpected and all-embracing viewpoint.

Fig 10. 76 Upland extraction of metal ore

At Monte di Maiella, in Abruzzo, a linear trench flanked by dumps of waste stone betrays an attempt to find and exploit a vein of metal ore (probably lead, zinc or silver). The relatively small scale of the dumps suggests that the work was soon abandoned, as in many unsuccessful mining ventures in the early days of the industrial age.

The archaeology of industry

The patterns of industry, from the present and recent past as well as from earlier centuries, can be explored and recorded from the air, particularly so for extractive industries such as quarrying, mining and the processing of metal ores. These activities often leave an extensive network of waste products, communication routes and cisterns or leats for the capture and channelling of water to drive machinery. But seemingly thriving modern industries, such as the English potteries shown in Fig 2.18, can rapidly fall into decay. Many will have been recorded in vertical surveys taken for national or regional mapping projects but selective oblique photographs, taken in the right light and from informative angles, can add significantly to the more all-embracing record presented by present-day or historical vertical photographs.

Fig 10. 77 **Marble quarry in southern Italy**

Right. This now-disused marble quarry was photographed in passing. Patterns of this kind deserve at least selective recording from the air, as for several former industries in Britain (coal-mining, slate-quarrying and the extraction of iron ore, for instance).

Fig 10. 78 **Heat transfer plant in Tuscany**

Left. The cooling towers and snaking overhead pipes of this plant are a relatively new features in the volcanic landscape of western Tuscany, drawing heat from the rocks below. Patterns of this kind can rapidly disappear, like the coal-mining industry in Britain during the 1980s/1990s.

Fig 10. 79 **Vanished industrial plant**

Right. The buildings of a once thriving plant have already been cleared, leaving little to be recorded from the air. Selective pre-destruction photography of such sites, often virtually undocumented while still in operation, will become invaluable to future historians and archaeologists studying the industrial and social realities of the present day.

Public presentation, remote sensing and excavation

Oblique aerial photographs can foster public appreciation of the country's archaeological heritage. In addition to showing the shape and scale of extensively excavated and restored sites like those at Paestum or Pompeii in Italy, or recent large-scale excavations in Britain and elsewhere, aerial photography is becoming increasingly used throughout Europe for recording excavations in progress and for demonstrating their results to the general public. Photographs from a high level, whether from a ladder, kite, balloon or light aircraft, will always have a greater immediacy and intelligibility for non-specialists than the detailed plans and section drawings that are the everyday currency of archaeological recording and communication. The methods and results of geophysical survey and related techniques can be similarly exciting to the general public.

In the 1990s Sweden started, but then unfortunately suspended, a project for the systematic aerial recording of all of the country's archaeological excavations. In Italy and elsewhere targeted aerial photography is often used to illustrate the character and topographical setting of both research-based and rescue-oriented excavations.

Detailed high-level photographs, taken from photographic towers, have for a long time been used as a standard technique for recording the excavations themselves. Balloons, kites – and more recently radio-controlled drones – can allow the acquisition of highly detailed vertical photographs that constitute an objective sequential record of the excavations in progress. GIS and image processing software can transform the photographs into accurate plans, resulting in a significant saving of time. Centimetric accuracy in excavation recording can also be achieved by applying the same principles to oblique aerial images, as illustrated in the following photographs.

Fig 10. 80 Excavations at Miranduolo, Tuscany

This photograph was taken in January 2005 using a digital camera and long-focus lens equivalent to 216mm on a traditional 35mm camera. Near-vertical photographs of this kind, in combination with carefully measured control points on the ground, can save time in the creation of accurate excavation plans.

Fig 10. 81 Excavations at San Genesio, Tuscany

Taken in January 2004 this photograph shows the high quality of detail that can be achieved from the air using a digital camera and long-focus lens (in this case a Canon 10D with 105mm lens, equivalent – because of the smaller size of the digital sensor – to 168mm on a traditional 35mm camera).

Fig 10. 82 Aerial recording and remote sensing

At Pieve di Pava, near Siena, the probable site of an early church was identified through documentary research and ground-based survey, followed by geophysical prospection by magnetometry (left, with pre-excavation interpretation) and by ground-penetrating radar. The building predicted by these remote sensing methods was remarkably well reflected in excavations in 2004 and later summers. The side-walls and apsidal east end of the church are seen above in an oblique view taken at the end of the first season of excavation. One of the red ground control points which allow accurate geo-location of the site can be seen at lower left.

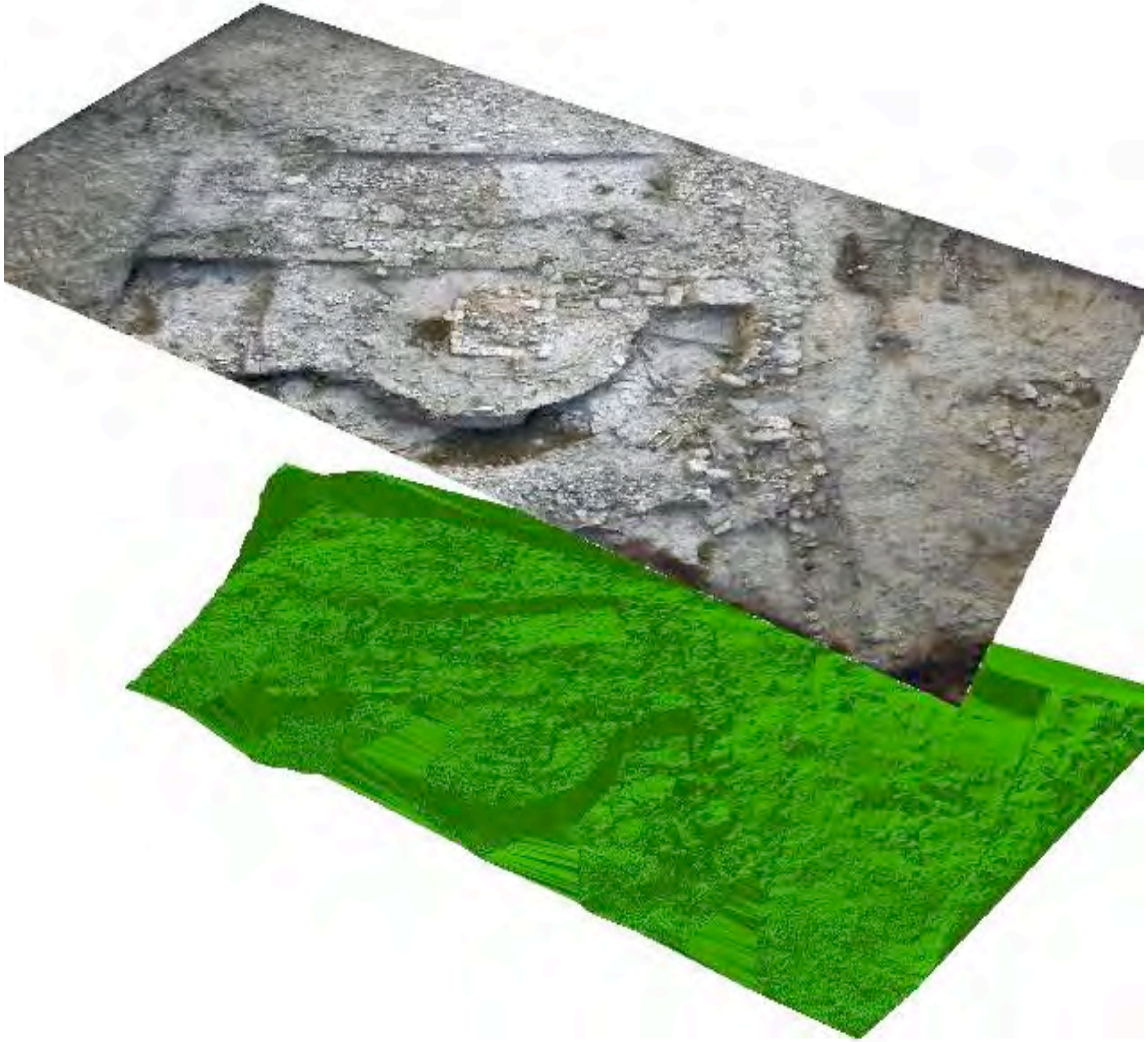


Fig 10. 83 Laser scanning at Pieve di Pava, San Giovanni d'Asso, Tuscany

There are other innovative techniques that can be used in recording archaeological excavations, including ground-based and airborne laser scanning. The airborne applications, known as 'lidar', are illustrated in Chapter 14. The centimetric accuracy achieved for the landscape at large can be matched by millimetric accuracy in the terrestrial recording of excavation evidence. Here, in green beneath a matching aerial photograph, is a laser scan of the excavations at Pava, made in 2004 by Mario Romano of Leica Geosystems.

The past in the present

Towns and buildings change their form and uses over time, in the past as well as today. Sometimes, however, the medieval or earlier patterns have survived, barely recognised within the streets and public spaces of the present day. Nobody who knows the Tuscan towns of Lucca (here) or Siena (in Fig 10.86) could fail to appreciate the value aerial views of the historic spaces that have created such a lasting impression on millions of tourists over the years.

Fig 10. 84 **Lucca**

Amid the streets of the Medieval and modern town the oval piazza preserves the shape and some of the walls of the one-time Roman amphitheatre.

Fig 10. 85 Siena

The Duomo and the Piazza del Campo, home to the twice yearly pageant and horse race, the Palio.

PART IV

FLIGHTS INTO THE FUTURE

11. Archaeological survey and mapping: questions of scale, technique and visibility
Stefano Campana

12. Aerial researches in Tuscany
Marcello Cosci

13. Multiple survey techniques at Roman Carnuntum, Austria
Michael Doneus, Wolfgang Neubauer

14. Digital airborne remote sensing: lidar
Colin Shell

15. Using de-classified satellite imagery
Anthony Beck, Graham Philip, Daniel Donoghue and Nikolaos Galiatsatos

16. Remote sensing and the archaeological landscape of Aksum
Maurizio Forte

INTRODUCTION

Stefano Campana

The contributions presented here are (apart from Chapter 11) a record of thoughts and experiences as they stood towards the end of 2004. In that sense they are mainly of 'historical' interest. But they will hopefully provide readers with some of the background to the debates of that and more recent times, as well as to the ever more rapid developments in the field of archaeological remote sensing that have taken place in the succeeding years.

The first part of the University of Siena's thirteenth Summer School on archaeology, in May and June 2001, was devoted to the theory and practice of aerial survey. In the subsequent few days an accompanying workshop took as its title From traditional air photography and its uses to new techniques using satellite data. The enthusiasm of the speakers and participants at the workshop reflected a period of great dynamism in the subject, with both students and practicing archaeologists wanting to learn about the most up to date methods of research.

The vibrant interest of the previous few years in the field of 'remote sensing' owed much to the progressive systematisation of its basic techniques and procedures, as well as to their compatibility with the growing use of GIS in archaeological work and the possibilities that they offered for application in a range of previously unexplored geographical contexts. The methods and instrumentation of this type of survey seemed to respond ever more frequently to the needs of research, opening up new vistas by bringing to light evidence – and related challenges – that were accessible through no other means. The progress made by the discipline, along with a constant stream of new and immediately applicable developments, had even then led some of the most traditional of archaeologists to make contact with experts in the field, and in a few cases even to initiate cooperative research projects.

In Part IV of the book we present a short selection of the contributions made at the workshop, slightly updated in some instances. The choice concentrates on subjects close to the central theme of the book, which provides a sort of manual on archaeological aerial survey aimed at the needs of students and research workers. For this reason we selected for the original publication a number of contributions that addressed some of the key themes under discussion around the turn of the century, in particular matters of strategy and methodology (with integration as a must) and the then relatively new technologies – for archaeological purposes – of satellite imagery and airborne laser scanning (lidar). The aim was – and still is – to provide the reader with a first introduction to some of the most innovative approaches to research, analysis and conservation in relation to archaeological sites and landscapes, as seen at the end of 2004. Chapter 11, however, looks at questions that have become progressively more prominent in the years since then.

Chapter 11, broadly based the author's contribution on pp. 5-26 of *Campana–Piro 2009*, is included as a correction to any idea that aerial survey on its own – or any other method of prospection for that matter – can produce a 'complete' representation of the archaeological landscape, or that any one scale is adequate for representing all potential aspects of the collected information. Individual techniques may have differing capacities to reveal particular types of information, especially when much of the evidence may have been reduced by erosion or other influences to near-invisibility. Unfavourable climate, weather patterns, soils, crops or land-use may also contribute to an apparent absence of 'aerial' evidence and a another conditioning factor may lie in the way the information – by whatever method it is collected – can be robbed of some of its significance by the use of inappropriate scales for its presentation in subsequent analytical studies and publications.

Chapter 12, by the late Marcello Cosci, focuses on innovative aspects of the author's work on vertical imagery within the traditional field of **air photo interpretation**, in particular to reveal the potential richness of information attainable through the analysis of historical air photographs (and in his final comments, of satellite imagery).

Next, in Chapter 13, Michael Doneus and Wolfgang Neubauer, research workers at the University of Vienna, describe pioneering work in the exploration of the extraordinary site of Carnuntum in Austria. The data acquired through the techniques of **photogrammetry**, repeated aerial survey, magnetometry, georadar and resistivity have been integrated and interpreted alongside one another to produce a highly detailed definition of the buried archaeological deposits of the Roman city.

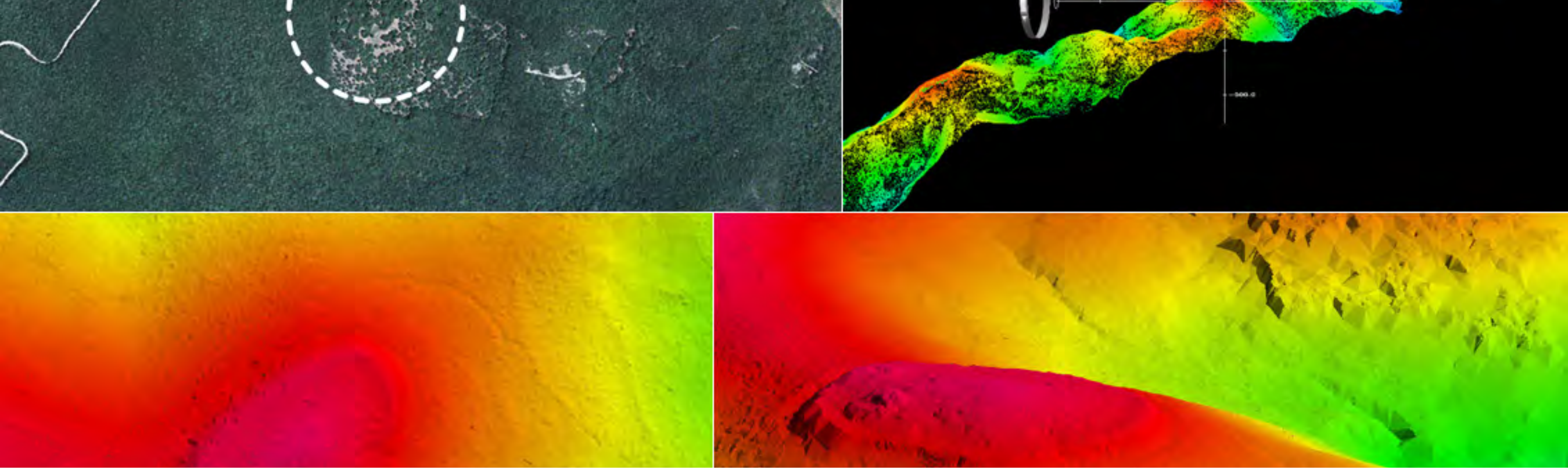
In Chapter 14 Colin Shell, from the University of Cambridge in the UK, presents a wide-ranging introduction to the use of lidar, a system that relies on a sophisticated airborne laser scanner to acquire extremely accurate models of the earth's surface. In 2004 the technique was considered in the scientific community to provide one of the most innovative and promising technologies of the previous few years, in archaeology as well as many other fields. In the period since then it has proved itself to be exactly that.

In the penultimate contribution, Chapter 15, Anthony Beck and Danny Donoghue, along with colleagues from the University of Durham, describe the results that they obtained from experiments with the analysis of high-resolution satellite data in Syria. The use of such techniques has proved of great importance in contexts where basic geographical and land-use information is absent or inadequate in intended research areas.

Finally, in Chapter 16, Maurizio Forte, then Head of Research at ITABC-CNR (Istituto per le Tecnologie Applicate ai Beni Culturali – Consiglio Nationale delle Ricerche) in Rome, presents a case study on the landscape of Aksum, in Ethiopia. There, the interpretation of satellite imagery, air photographs and digital models gained through GPS studies and the surface collection of artefacts were combined with the archaeological application of 'supervised classification', a system of semi-automatic recognition of the spectral signatures of surfaces features which made it possible to identify the likely presence of archaeological deposits (and to provide a first interpretation of their meaning).

In the past, perhaps, contributions such as these might have been considered interesting but limited in their potential application in wider aspects of cultural research or in different geographical contexts. The authors of this book, by contrast, feel that the sophistication of the contributions and the maturity of approach that they presented were directly relevant to the stimulating debate of the last decade or so about approaches to landscape archaeology and to archaeological diagnostics in general.

Stefano Campana, Siena, September 2013



11. ARCHAEOLOGICAL SURVEY AND MAPPING: QUESTIONS OF SCALE, TECHNIQUE AND VISIBILITY

Stefano Campana

As Part II of this book has amply demonstrated, cartography constitutes an indispensible instrument for the representation, management and communication of geographical data. Archaeological information is no exception. On the contrary, the complexity inherent in differentiating or bringing together the intricate and deeply stratified palimpsest of information about any particular area leaves no alternative to the use of maps within the creative framework of geographical information systems (GIS).

The kind of information that can be depicted in archaeological maps, just as in topographical maps, is in essence determined by the scale of representation. Various basic levels of scale have been recognised in archaeology. Clarke, for instance, identified three: ‘macro’, ‘semi-micro’ and ‘micro’ (*Clarke 1977*). Starting from the scale definition of Clarke it is possible to deduce that the ‘micro’ scale, aimed at intra-site analysis, works at the level of points in space, geographically circumscribed and definable by single identifiable cultural characteristics. The elements represented might include building structures, artifact scatters or remotely sensed **feature**s etc. The mapping scales might vary from lifesize to about 1:200. The ‘semi-micro’ level, still focusing on intra-site problems, represents the bringing together of various elements that constitute a multiple-activity area. The scales here might range from 1:200 to roughly 1:1000. The ‘macro’ scale deals with larger territories, from sub-regions and regions to national states, and aims at analysing relationships between sites, or perhaps one should say between ‘clusters of evidence’. The scales here might vary from approximately 1:1000 to 1:1,000,000 or more. Butzer (1982) proposed a more detailed graduation of scales, including ‘mid-scale’, used for within-structure aggregation areas (sites), leaving only ‘macroscale’ for inter-site patterning related to environmental features in or around a node defined also on a cultural basis. This formulation, however, can be criticized for producing three different within-site levels and only one addressed to inter-site **mapping** and analysis – a serious shortcoming when dealing with survey rather than excavation evidence. The essential truth, of course, is that no one scale is better than the others; the key point is that it is the purpose of the mapping that should determine its scale (*Raffestin 1987*; *Sydoriak Allen 2000*; *Lock, Molyneaux 2006*). For this reason, too, the transition from one scale to another during synthesis can have a very significant impact on the understanding of landscape **pattern**s (*Marquardt, Crumley 1987*).

The transition from the ‘micro’ to ‘macro’ level, for instance, does not consist of a simple mathematical and graphical process of reduction (simple enough to achieve in the age of GIS). Rather, it involves complex procedures of simplification, generalisation and blurring of distinctions which have significant effects on the quality and quantity of the information transmitted. The transition in the opposite direction, from the ‘macro’ to the ‘micro’ scale for instance, entails even more complex problems. In topographical mapping, for example, an increase in detail of this kind may involve the revision or supplementing of contour lines and spot heights. In this case the difference of scale does not significantly affect the strategy of work, nor the technical means or basic methodology for achieving it (through **photogrammetry**, for instance). The archaeologist who has to cope with the transition to a more detailed scale must, however, give thought to the availability or introduction of instruments that are barely applicable today at the smaller scale. Archaeological mapping at ‘macro’ scale depends for its support most of all on literary, bibliographical and documentary sources, on toponymy, iconography, epigraphy, historical cartography, aerial photography, satellite imagery and occasionally field survey (*Cambi 2003*). The ‘micro’ scale, on the other hand, is traditionally concerned with strategies for the recovery of material within a **site** and its subsequent examination and analysis (Haselgrove et alii 1985; Schofield 1991); in the past decade, however, it has also drawn heavily on the contribution of geophysics (*Gaffney–Gater 2003*).

The 'local' scale, a term used here to indicate the shadowy zone between mid- and macro-scale, represents in the writer's view the cognitive level which is most problematical. Up until now there has been a prevalent tendency for the simplistic superposition of the macro and micro scales. The results are almost invariably disappointing or illusory. Satisfactory results can only be achieved when there are contexts that are particularly favourable to the conservation and visibility of indications from the past. If we take, for example, a region such as Tuscany, in thirty years of active research about 18,000 archaeological sites have been identified. The representation of the evidence, through symbols, at the regional or provincial scale, from about 1:2,000,000 to 1:200,000, presents seemingly high or very high densities (Fig 11.1, *right*). The translation to the 'local' scale, for instance that of a moderately small river catchment area, at 1:50,000 or 1:25,000 scale, produces on the other hand an expanse of 'near-emptiness', in which it is easy to see the apparent scarcity of the available data (Fig 11.1, *left*).

Integration with the micro/semi-micro scale, often involving understanding of the intricate inter-relationship between individual sites or contexts, makes even more obvious the profound lacunae in our archaeological mapping at the inter-site level. The result at the 'local' scale is to present multi-period **archaeological landscapes** as a series of points (sites), usually lacking any kind of linking physical relationship (see Powlesland 2009). The result is totally inadequate either for the writing of history or for heritage conservation. This way of working does not in the great majority of cases allow us to perceive and understand the transformations through time of the missing 'connective tissue' which forms an indispensible element in the comprehension of **landscape**s made up not only of settlements and cemeteries but also of agricultural activity, communication systems and infrastructure element, ecofacts, morphology, hydrology, natural resources, economics and so on. The omission of this level of scale would mean in effect the abandonment of landscape archaeology, at least in terms of its original aim of integrating the rather differing cultural traditions related to field archaeology and to local history (*Fleming 2006*; *Aston–Rowley 1974*).

Another problem – directly related to the last and relatively common in archaeological mapping – concerns the relationship between the micro and the macro scales. In the absence of the missing 'local' scale, contexts which can be studied comprehensively at the micro or semi-micro scale have been generally discovered in mapping at the macro scale. The jump from macro to micro scale, without the benefit of intermediate variations, risks the loss of many significant pieces of information because these – depending on the nature of the individual context – become effectively invisible at the macro scale.

The prevalence of this kind of thing is particularly damaging because it generates a sort of short circuit, giving prominence only to those sorts of archaeological evidence that properly belong to the macro scale. Amongst the consequences of this approach to **landscape** archaeology there is the often undeclared tendency in the stages of synthesis to treat the recovered information and its distribution as if it represents the whole of the original reality – a totally unacceptable position undermined by recent studies which suggest that mapping at the macro scale (often without taking into account the kinds of evidence available from field walking-survey, aerial photography and large-scale geophysics, for instance) allows the recovery on the most optimistic estimates of no more than about 5% of the potentially surviving archaeological evidence (*Guaitoli 1997*, dealing specifically with Italy).

Archaeological visibility and non-visibility

Before turning to the various methods used in the search for the basic evidence it is necessary to consider briefly the concept of archaeological 'visibility'. In practice, and in contrast to the situation in topographical **mapping**, the great majority of the items recorded in archaeological mapping are not visible in their own right but appear as one kind of reflection or another of buried deposits. In the study of landscape archaeology the concept of visibility has usually been associated with questions of land-use and sedimentation (*Cambi–Terrenato 1994*). Discussion has also been focused, for the most part, on the impact of visibility and non-visibility on the results of surface-collection survey (*Terrenato 2000*). Moreover, the question of visibility has been addressed more often as a means of pointing out the limitations of archaeological documentation based on surface observation, rather than in an attempt to correct its shortcomings, perhaps by integrating surface observation with other methods of data collection (*Cambi 2000*). This kind of discussion took place mainly in the 1980s (*Schiffer 1987*) and the early 1990s (*Schofield 1991*; *Allen 1991*), only to be virtually forgotten in more recent years. The thoughts presented in the following paragraphs represent the fruit of the last decade in the study of Medieval archaeology in Tuscany at the University of Siena.

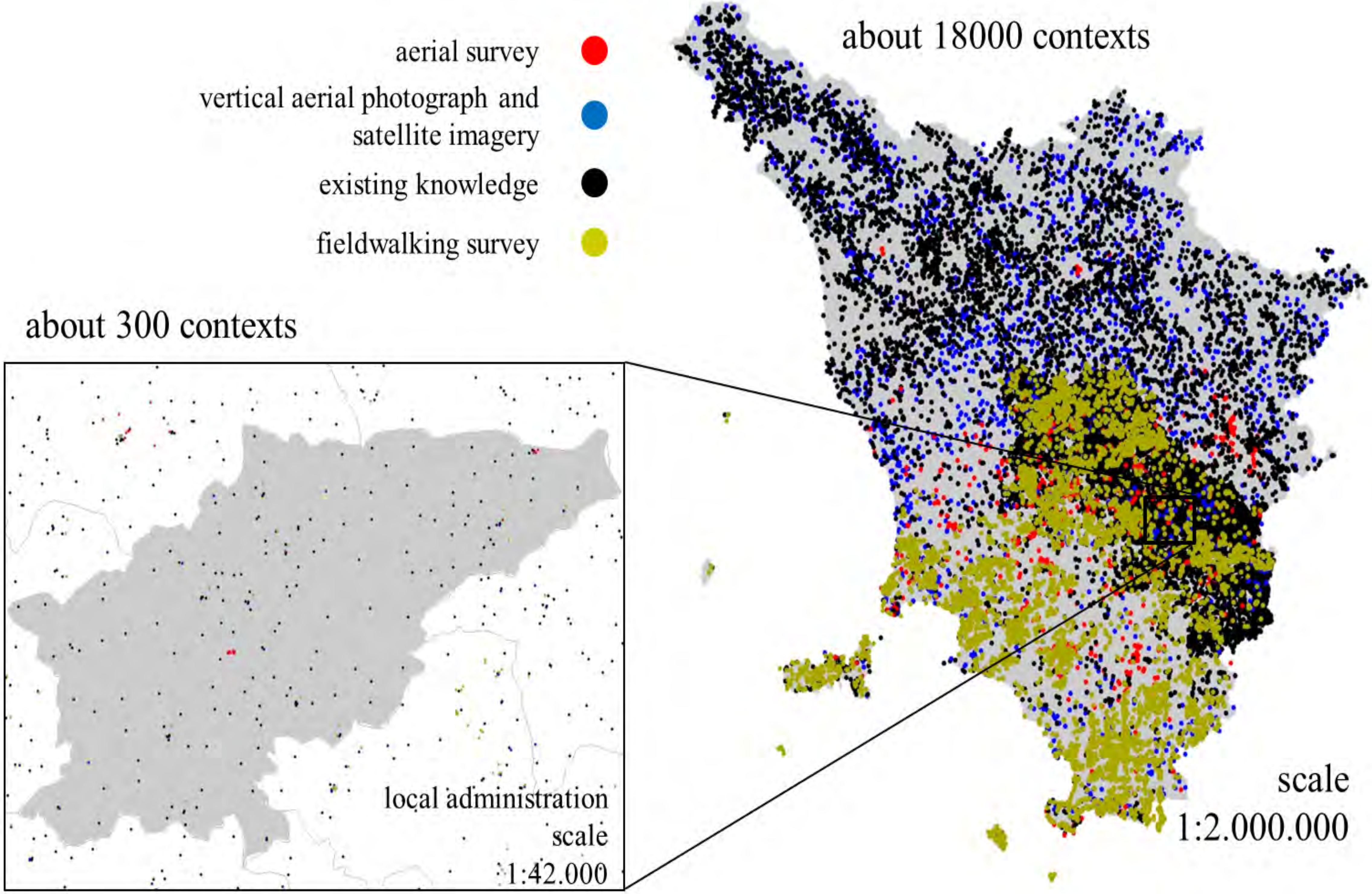


Fig 11. 1 Different scales of mapping, differing apparent densities and 'emptiness'

Right: representation at a scale of 1:2,000,000 of all known archaeological sites in Tuscany, from prehistory to the Middle Ages. Left: the same data at 1:42,000 for a single local administration studied in the archaeological mapping project of the University of Siena. With every increase in scale the apparent density of information becomes thinner and thinner.

Fig 11. 2 Changes over time in the character of the landscape in Tuscany

Panoramas from the same points in the landscape of Pienza in the Val d'Orcia, in 1930 and in 2000. The white 'eruptions' of the *biancane* (left) and the erosion scars of the *calanchi* (right) have now been totally erased by decades of mechanised arable cultivation.
From *Felici 2001*.

Fig 11. 3 Field-walking survey and surface collection

Difference in the surface scatter of artefacts at the site of a Roman villa (*above*) compared with the situation at that of a former Early Medieval village(*below*).

First and foremost the term 'visibility' – especially if used in the widest sense of the term – represents in archaeology a particularly ambiguous concept which can have a wide variety of different meanings or (perhaps more properly) which reflects a wide variety of different factors. Apart from problems connected with land-use and the local geology and soils, experience suggests a number of other factors that can sometimes have a significant impact on **archaeological visibility**.

The transformation of the rural and suburban landscape in the recent past can play a determining role in the observer's perception of a context, or of its complexity, as well as in the identification and conservation of archaeological deposits. A striking example is provided by the Val d'Orcia, a district covering about 500 km2 southern Tuscany, today characterised by an expanse of gently rolling hill-country dominated by cereal cultivation and (in the southern parts) by vineyards. This kind of monoculture, however, is the result of drastic and often radical transformations that began to take effect in the 1920s and 1930s, continuing in the post-war years and on to the present day (Fig 11.2). Val d'Orcia, in the past, was an area of summer drought and winter floods, its bleakness dominated by *biancane* (eruptions of clay from the underlying subsoil) and *calanchi* (deep erosion gullies in the clay substrata) (*Mangiavacchi 2004*). Its morphology and heavy clay soils (too intractable for widespread cultivation by traditional pre-mechanised methods) restricted agricultural activity and productivity.

A phenomenon not to be under-estimated is the contribution of agricultural activity, not so much in terms of land-use as in the differing impacts of intensive, biological or traditional farming on subsurface deposits and on archaeological material brought to the surface by the plough. As a generality it is worth noting the ever-increasing problem of the progressive degradation of surface deposits above archaeological features after up to half a century of mechanised cultivation. Also the present tendency under EU influence towards less deep ploughing, has resulted in less damage to the underlying deposits but at the same time to a reduced amount of archaeological material being brought to the surface.

Another key question concerns the extent to which the things that we are seeking are likely to be visible. Material culture changes over time, of course. The physical manifestation of settlements, communication systems and agricultural patterns can sometimes be monumental in character, at other times modest and ephemeral. The trappings of everyday life in one period may be highly durable, with well-made and hard-fired pottery, for instance, but such things may have been radically different in the preceding or following phases, with the use of poor-quality clay, inadequate firing or even the substitution of durable materials such as pottery by wood, leather or other perishable materials. Different material cultures may therefore present differing levels of **archaeological visibility** (Fig 11.3). The less intensive incidence of one culture in a particular area or location, and the less durable character of the materials used, can also give rise to fundamental difficulties in the archaeologist's recognition of crucial pieces of evidence (*Hamerow 2004*; *Liebeschuetz 2007*).

A question that is very familiar to Medieval archaeologists in particular is the relationship between visibility and continuity of settlement. In contexts where there is continuous occupation of the same location for a long period of time there are many difficulties in identifying the evidence from the earlier phases, not least from the air, because of the degradation and interruption of deposits and features by centuries of continuous settlement. This is so, for example, in the case of Tuscany where the researches have shown that after abandonment of the Late Roman settlement pattern **trace**s of early Medieval settlement can be traced beneath the many castles that dot the hills of Tuscany (*Francovich–Hodges 2003*).

These kinds of questions, revolving around archaeological visibility, have often been discussed in general terms but any proper examination of the concept would have to stress the arbitrary risks of research that does not take account of the problem. In this context it is hard to maintain the idea that samples recovered from surface-collection survey are in any real sense 'representative'. On the other hand it is important to recognise that problems of visibility are not necessarily incapable of solution, in that they vary according to the survey method used in any particular piece of research. It is therefore legitimate to speak, for example, of 'ground visibility' (*Schiffer 1987*; *Schofield 1991*; *Allen 1991*), 'aerial visibility' (*Mills–Palmer 2007*) or even 'cultural visibility' (*Francovich 2004*). Every method of research is selective in one way or another, in the sense that it aims to track down particular forms of evidence rather than others. Surface-collection survey, for example, cannot hope to reveal **trace**s of timber structures that aerial photography, by contrast, can in the right circumstance delineate with great precision, as for instance at Woodhenge, in southern England (*Cunnington 1927*) or for domestic timber structures in many parts of continental Europe.

Aerial photography, however, runs into significant problems when it tries to uncover archaeological evidence on heavy clay soils (*Mills–Palmer 2007*), while magnetometry and geo-electrical methods might produce excellent results in the same situation (*Campana–Francovich 2007*). And so on. In drawing this discussion of archaeological visibility (or non-visibility) to a close it should be emphasised that the intention is not in any sense to deny the credibility of landscape research, nor of any one or more of its methods in particular. The objective is to encourage a robustly critical approach to the inherent problems of this kind of research and to promote efforts to offset or moderate their distorting effects so as to attain a higher level of reliability and credibility in the study of **archaeological landscapes**.

Survey for mapping at the Macro-environmental scale: the region

There are many methods for the identification of archaeological evidence at the macro-environmental scale, ranging from the analysis of written sources, through iconography, archival and place-name studies to cultural anthropology, geomorphology (see for instance *Gamble 2007*; *Renfrew–Bahn 2008*). The following examples draw on the experience of the Department of Archaeology at the University of Siena in its research work in central Italy.

Tuscany covers a huge area (22,900 km^2), characterized by wide variability in its landscapes and hence a lack of homogeneity in the acquisition of archaeological data. Within the regional context the parameters which define the various grades of archaeological visibility, on the ground and in the air, interweave with one another, producing areas with extremely high levels of visibility and others with very low levels, interspersed with innumerable variations in between. For example, as concerns land-use, around half of Tuscany is given over to woodland, which clearly constitutes a serious obstacle to field survey and is equally inimical to the recovery of archaeological evidence from the air.

So, in the context of the present day (and the impact of lidar survey notwithstanding) at least half of Tuscany presents extremely low levels of visibility, both on the ground and from the air. In addition, large areas in central and northern Tuscany are particularly disadvantaged by the widespread presence of clay soils, in most circumstances producing relatively limited aerial visibility in the formation of cropmark and **soilmark** evidence. For reasons such as these the University's programme of research over the past ten years has been structured as far as possible to reduce the influence of such factors on the archaeological return, in pursuit of more homogeneous results. The strategy, inevitably, has to remain flexible and open, founded on the conviction that only the integrated use of a wide range of survey methods and technologies, applied at varying scales of detail, will make it possible to confront the innate complexity of studying settlement dynamics in the landscapes of the past (*Campana–Francovich 2007*).

Vertical air photography: historical and recent

Parts I and II of this book has emphasised the long and important contribution that aerial survey has made to the detection of archaeological features and their representation through cartography. In particular, 'historical' photographs from the 1930s, 1940s and 1950s show a landscape, in almost all parts of Europe, that is profoundly different from that of the present day. Building development, infrastructure projects, land-use change and mechanised agriculture have radically changed the landscape, completely destroying or partially concealing significant parts of the archaeological resource. Only through the detailed analysis of 'historical' air photo coverage from these decades will it be possible to recover, in part at least, the presence, siting and inter-relationship of settlements and other man-made features and natural phenomena (*Bradford 1957*).

Further reasons for such studies lie in the breadth of coverage represented in vertical air photograph present (but often largely un-exploited) in regional, national and military archives and in private collections (see, for instance *Guaitoli 2003* and *Going 2002*). In many countries more recent vertical images offer an up-to-date record of the landscape for comparison with the earlier coverage, thereby defining in detail the transformations that have taken place over recent decades in any chosen study area. In addition, 'new' vertical photography, if carefully timed to coincide with the best visibility of **cropmarks** or other traces of the past, can prove a highly effective research tool. In this context one might point to the research carried out in Italy at the University of Lecce (*Guaitoli 2003*), in Austria at the University of Vienna (*Doneus 2001b*) and in Great Britain by a variety of bodies, not least county authorities in the updating of their own 'mapped' information for their areas of responsibility. It has been demonstrated that vertical coverage which coincides with a window of high aerial visibility can document many hundreds of archaeological sites and features in a relatively short time (see for example *Coleman* in *Mills–Palmer 2007*). Any kind of cost-benefit comparison with other investigative techniques would see this as an extraordinarily favourable return.

Exploratory aerial survey and oblique air-photography

Amongst the methods available for territorial research aerial survey through oblique photography occupies a place of its own though working to its greatest potential when combined with other methods of remote sensing or ground-based survey. Aerial survey of this kind, while not providing the 'total' landscape coverage that characterises vertical air-photography, nevertheless permits the collection of data at the regional scale and in the process makes it possible to carry out more detailed analysis of particular locations or areas through repeated observation, with the capacity (within limits) to vary the degree of detail. The long history of this technique in the study of the landscape over very wide areas links it inevitably with the macro-territorial scale. In particular one might point to the National Mapping Programme for England, started in the late 1980s and still ongoing, with the aim of systematically mapping all no-longer-used features that can be seen on readily-available vertical and oblique aerial photography across the whole of England (see Fig 1.14; *Horne 2009*, *2011*; *Winton–Horne 2010*).

A key feature of the technique is its flexibility in the choice of time of year or day to carry out the photography (subject, of course, to regional or national variations in response to the local climate). This allows the photography to take place, at relatively economical cost, when the **cropmarks** or other traces of the past are at their most visible. Also important is the **aerial archaeologist**'s capacity to vary the point of view in flight, and thereby to capture the photographs in such a way as to obtain the best return from the local conditions of lighting and crop developments etc. In addition, oblique images, being perspective views of the landscape (albeit sometimes relatively distorted), present a picture that is closer to everyday reality and therefore for most observers easier to appreciate in comparison with vertical images. This makes oblique air-photography particularly useful both for the initial documentation of the evidence and for its subsequent communication to others. Moreover, the technique can provide effective documentation not only of **cropmarks** and similar anomalies but also of prehistoric and later structures and settlements in their rural or urban landscape settings. Real advantages accrue when the photographer is also the archaeologist who is himself studying the landscape, whether in the initial recognition of the evidence or in the stimulus that the aerial viewpoint gives to new ideas about its character or development.

Naturally, there are also limitations. Among these there is an inherent subjectivity and selectivity of the method, depending as it does on the personal abilities of the archaeologist-photographer (*Brophy–Cowley 2005*). Oblique aerial survey also suffers in comparison with vertical photography in lacking the latter's inherent stereoscopic properties and total coverage of the survey area. As a result there is difficulty in deriving precise and large-scale numerical comparisons for statistical or other analysis. These limitations, however, can be largely offset by combining oblique aerial survey with other techniques of remote sensing and/or with direct observation on the ground.

Within the strategic study of the landscape the capacity of **exploratory aerial survey** to reveal previously unrecorded sites or features, or to increase knowledge about known sites, varies according to the conditions of archaeological visibility from the air. The clay-dominated landscape of the Province of Siena, for instance, without doubt represents the least favourable zone in any part of Tuscany for recovering traces of the past in the form of cropmarks, **soilmark**s or micro-relief – the University of Siena has documented around 450 archaeological sites during more or less systematic aerial photography of the province's Medieval castles but in the process has recorded only two cropmark sites The role of exploratory aerial survey in this area is therefore likely to remain fairly marginal in terms of new discoveries, even allowing for the fact that the work was started less than ten years ago (the need for perseverance in aerial survey is emphasised repeatedly in earlier Chapters, as also in *Palmer 2007*).

In Tuscany the opposite end of the scale of aerial visibility applies in some parts of the Province of Grosseto. In the coastal zone of Maremma, for example, aerial survey has a more even balance between the documentation of already known structures and the discovery of previously unrecorded features. Since 2005, therefore, the University of Siena has concentrated its attention on this area, with encouraging results, in particular for the Etrusco-Roman and Medieval periods. Etrusco-Roman features are especially evident in some of the province's river valleys, particularly in relation to communication systems and domestic or semi-industrial structures such as villas and farms. More specifically, near the Etruscan and Roman hilltop town of Roselle there lies an area which so far represents the most favourable part of Tuscany for exploratory aerial survey. Immediately to the west of the town there are clearly visible traces of buildings of various dimensions, along with communication systems and agricultural land-divisions. It is becoming clear that this area offers conditions of visibility, conservation and archaeological richness sufficient for exploratory aerial survey, in partnership with other methods, to play a leading role in reconstructing the area's intricate multi-period landscapes (Fig 11.4/11.5).

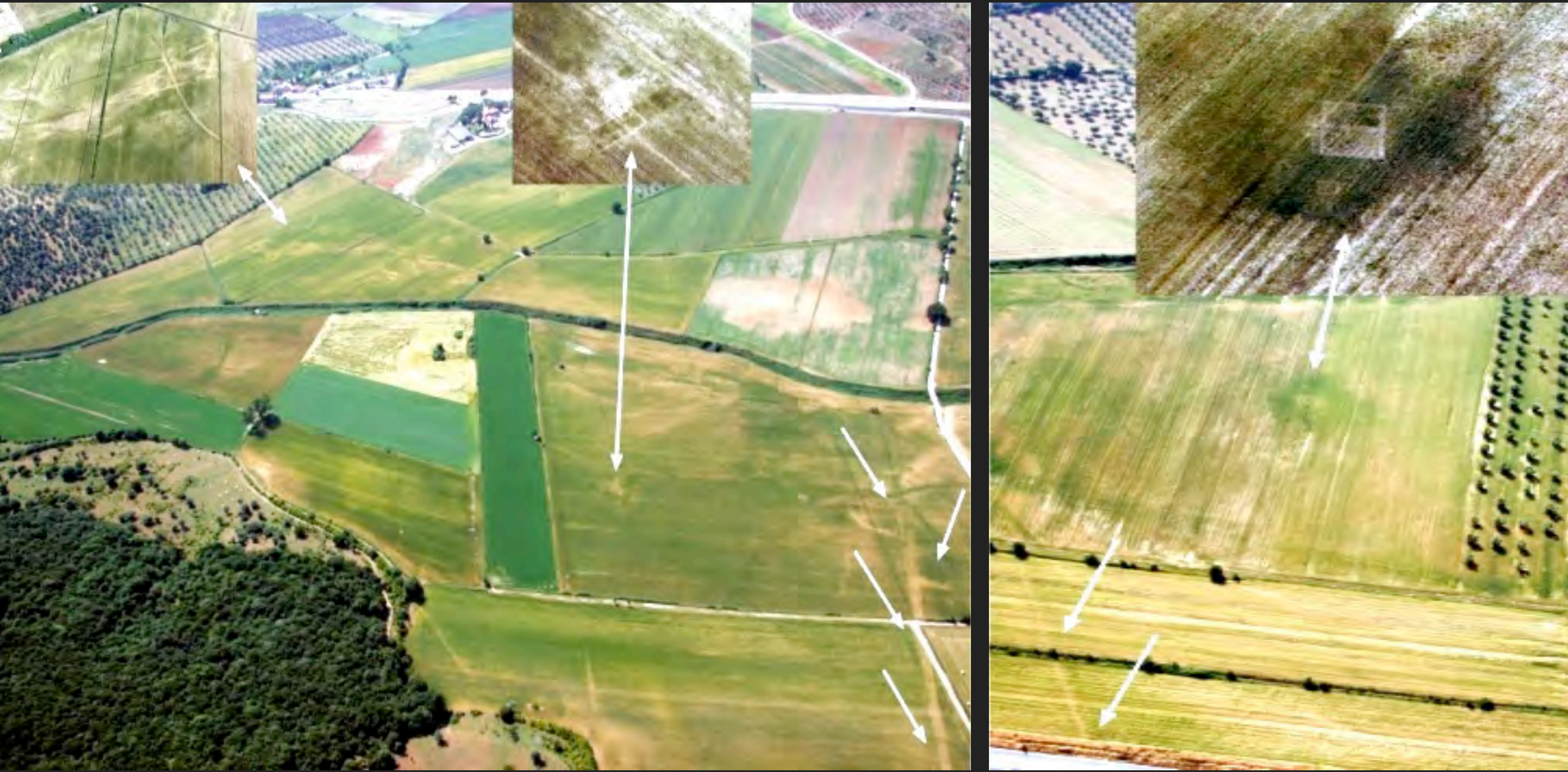


Fig 11. 4 Aerial photographs of landscapes in the valley west of Roselle, southern Tuscany

The insets at the top of the images show some of the more significant archaeological features in greater detail. *Top left*: the light-coloured parchmark of a former road or trackway. *Top centre*: a building complex with a light-coloured scatter of stone or building debris. *Top right*: the wall-foundations and surrounding darker area of a small farmstead.

Fig 11. 5 Air photograph of the valley west of Roselle, in southern Tuscany
The large field preserves darker lines of crop which mark out the divisions of a now-vanished field system, clearly differentiated from the rigid linear strips of the present-day cultivation pattern.

Satellite imagery

Subjectivity on the part of the surveyor has been noted above as one of the inherent limitations of exploratory aerial survey. Recognition (and therefore recording) of the evidence during flight is entirely dependent on the ability and experience of the archaeologist, since he documents only those things which he thinks archaeologically or historically significant, omitting all the rest. To overcome this problem it would in an ideal world be necessary to supplement oblique aerial survey with some form of 'total' recording at those times when archaeological visibility is at its best. It is theoretically possible to undertake vertical air photography to achieve this objective, though it is complex, costly and sometimes difficult to arrange quickly enough – or with sufficient repetition – to match the speed of change in the appearance and disappearance of the **aerial evidence**.

Similar considerations apply to the latest generation of satellite imagery. In appropriate circumstances images captured by high-resolution satellites are beginning to rival the results of medium-scale vertical photography. The level of detail in Ikonos-2, Quickbird-2 and Orbview-3 satellite images makes it possible to distinguish features with a minimum width of between 50cm and 1 m or of polygonal features with a surface area of around 500-1000m^2. In addition to being the important instrument for remote sensing in parts of the world where it is difficult to access traditional images such as vertical or oblique air photography, satellite imagery today constitutes a potentially valuable source for archaeological exploration in the western world (see *Chapters 15* and *16*; also *Wiseman–El-Baz 2007*).

Experience in Italy suggests that reasons for the increasing interest in high-resolution satellite imagery for exploratory survey and archaeological mapping lie in the GIS-ready and multispectral characteristics of the resulting data, the presence of the infra-red channel, the capacity for stereo-viewing and the possibility of planning (within certain limits) the moment of acquisition. Progress in appreciation of the multispectral and diagnostic features of the near-infrared channel will probably depend on the success of particular research initiatives but the possibility of timing data acquisition in response to specific archaeological needs will derive entirely from the way in which the aerospace industry works. In 2007, after a hiatus of around five years, during which little progress was made, we seem to be on the cusp of a revival in this sector, probably stimulated in part by new means of public access in the form of geographical browsers such as Google Earth. The very launch of the Geoeye-1 satellite has also brought the frontier of resolution down to 0.41m in the panchromatic spectrum and 1.64m in the multispectral spectrum (http://www.geoeye.com/).

Archaeological field survey: surface collection

In the Mediterranean area surface-collection survey is considered one of the most fruitful methods for the discovery and characterisation of archaeological sites and deposits

(*Francovich–Patterson 2000*). Archaeologists have always used the collection of surface material as a means of identifying the chronological and topographical characteristics of a site prior to excavation. For many decades, too, surface collection has gone beyond this simple pre-excavation function, serving also for the survey of wider areas defined by geographical or cultural boundaries or related to random or mathematically-based sampling strategies. Following definition of the search area and the choice between total or sample coverage, the fieldwork is placed in train (*Orton 2000*). Systematic survey requires the field-workers to walk at predetermined distances from one another across the bare-oil area. The archaeologist's task is to examine and document the area for the presence of smaller or larger concentrations of archaeological material brought to the surface by the plough (*Thomas 1975*; *Foley 1981*). Surface collection has assumed a significant role following the demonstration in regional studies of its capacity to identify, primarily, settlement areas (*Aston 1985*; *Brown 1987*).

That said, surface-collection survey, like any other field method, suffers from significant limitations, including its inefficacy in identifying ancient field patterns, communication systems and other aspects of the landscape's infrastructure. Moreover, there are often difficulties in presenting or discussing the method's results in quantitative terms while controversy also surrounds the representativeness of the results (*Banning 2002*). The relationship between the evidence present on the surface and that buried beneath the soil is undoubtedly complex, with a host of variations from site to site. The results are perhaps more trustworthy in the case of long-term projects which are structured to provide repeated survey of the same areas. In addition to variations in visibility from one year to another repetition allows the survey to be repeated with a different group of field-workers, thereby reducing or offsetting the possible of bias or differing ability in one group compared with another. In essence, however, the method still has its limitations, and it is always advisable to combine it with aerial survey and/or geophysical prospection of the whole or sample parts of the study area as a basis for test excavation to establish chronological or functional relationships more precisely.

Survey for mapping at the point-environmental scale: individual evidence

In the past the individual study of a single site has more often than not been focused on diagnostic work preparatory to excavation. Today, intra-site analysis is increasingly aimed at the recovery of information as a substitute for excavation when the latter is precluded for bureaucratic or (more often) financial problems. Modern excavation is time-consuming and expensive, and detailed intra-site analysis by other means can be faster and more economical. The results, of course, are very different. The kind of detail recovered through excavation cannot be reproduced by alternative methods but in spite of this the information recoverable through visual analysis and examination of various chemical and/or physical characteristics of the soil makes it possible to locate aspects of the evidence more precisely and on some occasions to formulate quite complex interpretations. In general archaeologists choose this kind of approach as a source for understanding broad-scale transformations across space, whether at the micro, local or macro scale.

Surface-collection survey

In the previous section it has been suggested that the quickest, most economical and effective means of gaining a preliminary understanding of a buried archaeological site is by direct survey on the ground. After the identification of a finds scatter the quantity and quality of the information that the archaeologist subsequently acquires depends on the objectives of the research and the method of collection and documentation adopted in response to this. A detailed analysis will first require the accurate topographical survey of the area, nowadays easily achieved directly through DGPS survey (*Campana–Francovich 2006*) or indirectly through air photography and **photogrammetry** (*Ceraudo–Piccarreta 2000*). The topographical information is essential, to allow the interpreted archaeological evidence to be placed within its local and broader landscape setting.

The next necessity is to decide how to carry out the survey and what material to collect. This is not in any sense a casual choice but one which will have a significant influence on the kind of analysis that can be undertaken subsequently. It is widely acknowledged by archaeologists that the distribution of surface material across a site does not always reflect the underlying stratification. Nevertheless, study of the surface distribution is a widely used research technique. Its effective conduct, however, requires the positional recording of every single find (*Ebert 1992*) or group of finds through collection within some kind of grid (*Campana 2005b*). Knowledge of the location of the material, albeit of objects in a state of continuous movement over the years through ploughing and other agricultural activities, allows the later stages of analysis to generate diachronic, synchronic and thematic distribution maps (of building materials, amphorae, table-ware or industrial by-products for instance).

Geophysics

The contribution of geophysics to the archaeological study of sub-surface strata has increased notably over the past ten years, both qualitatively and quantitatively. Today, geophysical techniques represent an indispensable and complementary method (or set of methods) alongside surface collection for the study of the archaeological relationships within (and in some cases outside) a site. To demonstrate, through a practical example, the special contribution of geophysical prospection in intra-site survey we can focus here on another area study, undertaken at Romitorio in central Tuscany by the University of

Siena's Laboratory for Landscape Archaeology and Remote Sensing (LAP&T).

The site at Romitorio, near Siena, lies within one of the sample areas in the project to create an Archaeological Map of the Province of Siena. In this area Late Medieval documents record '*uico nomini oracolo Santi Ampsani*' (714-715). The church referred to in the documents has generally been ascribed to the place-name Sant'Ansano, today attached to a farm close to Romitorio. Surface collection undertaken from 2001 onwards brought to light a wide range of archaeological material, interpreted as belonging to a village of the Late Republic-Early Imperial period (1st century BC-1st century AD). This had taken over an area used during at least the Archaic, Etruscan and Hellenistic periods (6th-2nd centuries BC), for domestic settlement in the latest period and perhaps as a sacred site in the earlier phases. This latter conjecture is based on the presence of a few fragments of painted black and red tiles, one of them bearing a horizontal red band parallel to the edge of the tile. Beneath this there can be made out two areas of probable geometric decoration, with alternating red and black chequers. A second fragment presents a less regular decoration, consisting solely of curvilinear red stripes. This type of decorated tile finds comparison with decoration on the roofs of temples in the Etruscan period. A fairly close parallel for the fabric as well as the red-and-black colouring and the repeating geometric motif can be found in the temple of Vigna Grande, in the Province of Orvieto, ascribed to the 5th century BC. The same area at Romitorio has also produced material from later phases of the settlement, during the Imperial period in the 4th and 5th centuries AD. There is no archaeological evidence for later phases of occupation.

The site was surveyed from the air at intervals between 2001 and 2007. Both recent and historical vertical photographs were also examined, though the analyses produced no firm evidence apart from traces of earlier agricultural field divisions. In all probability the lack of evidence from the air can be related to the effect of the clay subsoil, which is generally unfavorable to the development of cropmarks or soilmarks (but see *Mills–Palmer 2007*). Even a winter flight in 2004 after a light snowfall (which usually produces ideal conditions for the detection of eroded **earthworks**) failed to produce any positive observations. However, geophysical prospection over an area of about 10 hectares yielded more encouraging results – far better, indeed, than had been expected (Fig 11.6). In the field immediately east of the farmhouse regularly-arranged anomalies could be seen, some of them suggesting the outlines of buildings, with varying alignments which showed them to be of more than one chronological phase (Fig 11.6, nos.1-4). There were no clear anomalies that could be directly attributed to the religious building attested in the documents. One possible hint, however, lay in the presence to the north of a fairly well-defined rectangular **anomaly**, lacking any curvilinear element that might have belonged to an apse but with dimension of about 10 x 20m (Fig 11.6, no.1) and an east-northeast/west-southwest orientation, entirely appropriate for a church of this period.

In the fields to the south and east, however, there were further magnetic anomalies that posed new and unexpected problems of interpretation. In particular, two anomalies characterised by linear dipoles took the form of regular circles, each measuring 50 m in diameter (Fig 11.6, nos.5-6). Their morphology and topographical position (at the top of a hill dominating the surrounding countryside) can be paralleled in the Siena area, and more generally in Etruria, in funerary monuments. Tentatively, the evidence could be interpreted as belonging to two Etruscan tombs, completely flattened by long-term ploughing and now only showing as variations in the local magnetic field.

The picture became clearer, and the conjecture more secure, when account was taken of the painted tiles found during surface collection in the area. A key point, however, is that the geophysical prospection revealed archaeological features that had previously remained totally invisible to traditional archaeological research, including targeted aerial survey. Moreover, the integration – in this case – of magnetic and electrical survey produced even further evidence, as illustrated in Figure 6. Other less distinct and incomplete circular anomalies could be seen in the graphical representation of the site (Fig 11.6, nos.7-8), though the dimensions were variable and the interpretation uncertain. Further elements emerged from analysis of the magnetic data, including a variety of linear dipoles (Fig 11.6, nos.9-13). The dimensions and overall pattern of these anomalies suggested their possible attribution to agricultural boundaries, a curvilinear **enclosure** or to one or more trackways.

In summary, the gradiometer survey played a decisive role in the investigation, adding information about many phases of the settlement evidence originally revealed by field survey and surface collection. The use of geo-electrical survey (ARP©) also served to increase the range of evidence and to facilitate a more detailed interpretation. Overall, the new evidence supplemented and reinforced the suggested use of the site as a focus of ritual activity. The development of these ideas owed much to the integration of the different survey methods – without the evidence from documentary sources and field-walking survey the interpretation of the magnetometer/ARP© evidence might have seemed weak or illusory, and vice versa.

Fig 11. 6 Romitorio: geophysical map with anomalies reflecting archaeological features

1-4 Linear anomalies, perhaps representing buildings of more than one phase. 5-6 Two circles probably attributable to Etruscan tombs. 7-8 Less distinct circular anomalies. 9-13 Possible field boundaries.

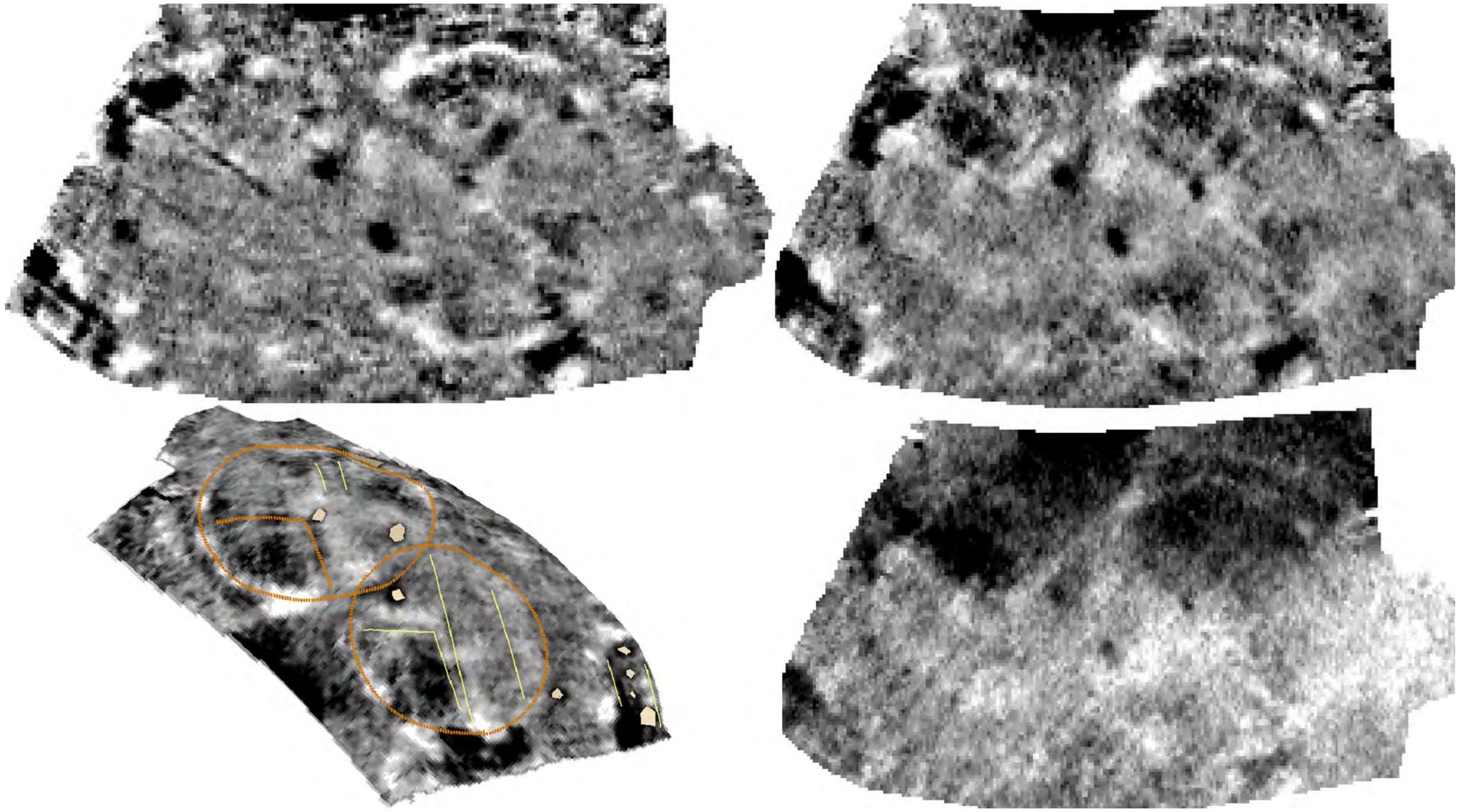


Fig 11. 7 Romitorio geophysical data *(above)*

Clockwise from top left: ARP© maps at 50cm, 1m and 1.7m depth, clearly showing two adjacent circular features, one more clearly marked than the other. Bottom left: 3-D visualisation formed by draping the magnetic map onto the DGPS digital terrain model, with overlaid archaeological interpretation in red.

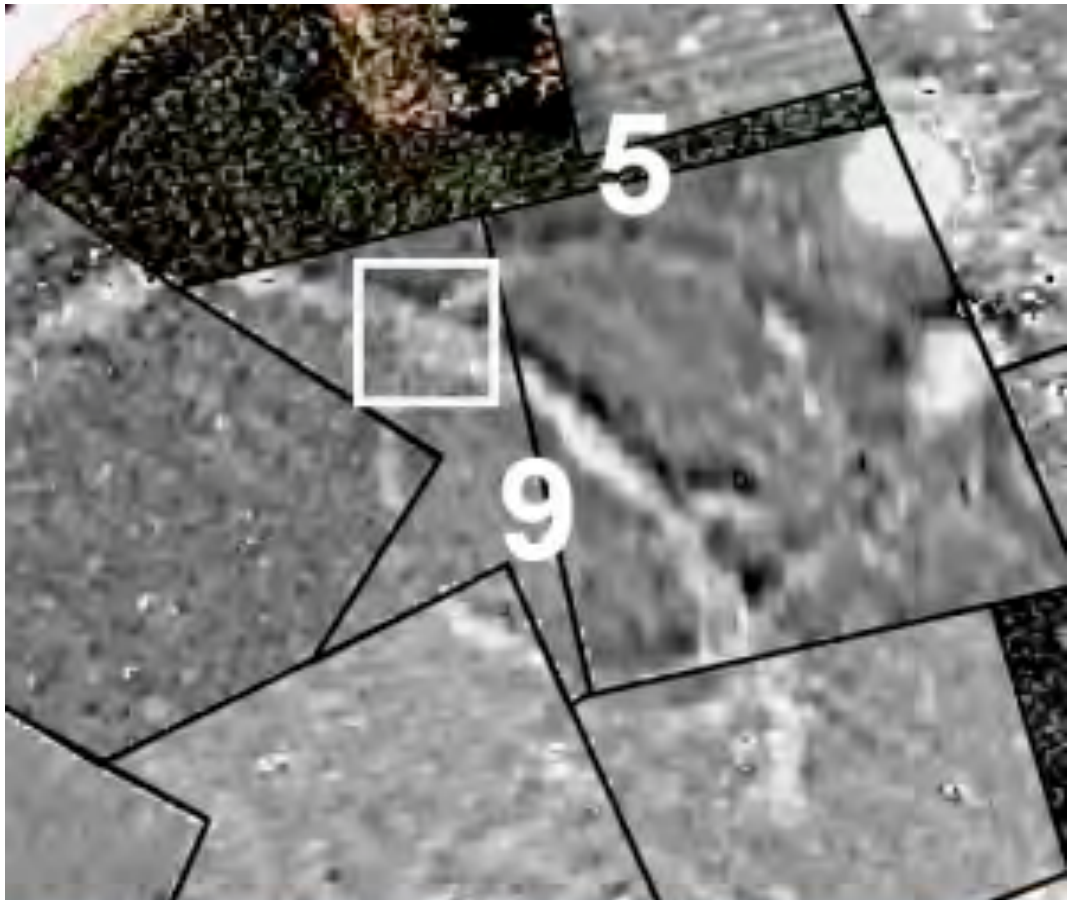


Fig 11. 8 Romitorio geophysical data *(right)*

Marked with the suggested areas of test excavation.

Test-excavation

Sondages or test excavations have generally been brought into play in contexts lacking good conditions of visibility. Various strategies have been adopted in the field, including random, mathematical or targeted sampling (McManamon 1984). The technique has also been used to enhance understanding of particularly significant contexts already surveyed through surface collection or geophysical prospection. Returning for a moment to the Romitorio case study it is clear that the combined use of several different survey methods has not resolved the full ity of the site, indeed the number of outstanding questions has been increased. For instance, the large linear **anomaly**, perhaps representing an agricultural boundary, a curvilinear **enclosure** or one or more trackways, appears to cut the southernmost of the two large circles (Fig 11.8). If the interpretation of the circles as Etruscan tombs is accepted, the linear anomalies should presumably be attributed to a later phase – in the Late Etruscan, Roman, Late Antiquity or Medieval periods. Clearly there is only one way to resolve these uncertainties – the application, in the zones most in doubt, of archaeological excavation. A trial section would probably suffice, at the intersection between the southern circle and the 'field boundary' (respectively nos.5 and 9 in Fig 11.8).

Local-environmental scale: landscapes

At the beginning of this chapter it was suggested that the 'local' level should be seen as the critical scale in 'landscape' research. If we try to translate data from the macro and micro scales and reproduce it at the 'local' scale the landscape appears to consist of widely separated sites (points) interspersed with large areas of 'empty' space (Fig 11.1, *left*). The problem has a direct impact on the type and objectives of historical reconstruction that it is intended to pursue. To explain more fully, mankind in the past, much like people of the present day, did not perceive the space around his settlements as being composed of 'emptiness'. In between any pair or group of settlements one finds the fields with their various crops, woodland, pasture, hunting areas, water sources, lagoons and ponds, quarries, mines, civil or religious administrative boundaries, streets and simple pathways etc. If the intention is to bring these elements into the historical interpretation it is essential to adopt a research strategy aimed at the recovery of the necessary information.

In attempting to do this the first problem revolves around the difficulty of identifying the indicators of such features through surface-collection survey. This returns the discussion, to some extent at least, to the question of archaeological visibility. It is no coincidence that the few archaeologists who have attempted detailed investigation of areas outside the confines of traditional settlements or other sites with clearly defined functions or boundaries have included pioneers of aerial archaeology such as O.G.S. Crawford and John Bradford (*Bowden 1999*). Their key research technique (aerial survey) and the favourable contexts in which they were working (the intricate and closely articulated landscape of Wessex in southern England and the cropmark-rich plain of the Tavoliere delle Puglie in southern Italy) played a determining role in the development of this approach. The majority of the features in the spaces between the settlement do not manifest themselves in the form of surface finds, and even when they do so the material is so difficult to interpret that it tends to be described as 'off-site' (*Banning 2002*). So, while at the micro and semi-micro scale the problem relates principally to the completeness of the sample and the complexity of articulation within a site, at the 'local' scale the debate is more concerned with the representativeness of the sample rather than its completeness. Amongst those who have tackled this problem in recent years the most significant results have been achieved by researchers who have made intensive use of remote sensing methods, in combination with geomorphological and palaeo-environmental analysis (for instance at West Heslerton in northern England; *Powlesland 2009*).

Airborne laser scanning: multispectral and lidar data

In the earlier section on exploration methods appropriate to the macro scale mention was made of the limitations which affect various forms of remote sensing. That discussion, however, did not address the various techniques of airborne laser scanning, though these are in every way compatible with that level of scale. The reason for omitting them at that stage was the rarity with which archaeologists have made use of ground-based laser-scanned data on a large enough scale for this kind of work. In general when archaeologists manage to obtain laser-scanned data this is related to relatively limited areas. Therefore, the sample is generally more appropriate for the 'local' scale of analysis. The most widely used airborne scanning systems in present-day archaeology are hyperspectral imaging and lidar. The former allows the acquisition of data across a substantial part of the enormous electromagnetic spectrum, from blue to thermal infrared, by registering the information in a wide range of individual bands (*Shell 2002*; *Donoghue 2001*; *Cavalli–Pignatti 2001*). It has been shown that these systems, if properly used, offer significant advantages compared with traditional aerial photography. Briefly, the advantages are as follows:

- Hyperspectral sensors, in combination with image processing (IP), are less dependent on the brief periods of time when the **aerial evidence** is clearly visible (to the naked eye and to traditional photography).
- Cropmarks become more easily detectable in the near-infrared spectral band (760-900 nm).
- Soilmarks are more readily detectable in the red part of the spectrum (630-690nm).

In the thermal infrared band (8000-12000 nm) it is possible to record information that is not recoverable using other 'passive' optical instruments (traditional cameras and films or digital camera).

In effect these systems, by registering chemical and physical properties that are different from those recorded through traditional air photography, can make a special and significant contribution to the study of **archaeological landscapes**, sometimes emphasising or revealing elements that appear only fleetingly (if at all) in traditional photography (*Powlesland 2006*). Their major limitations perhaps lie in their relatively poor geometric resolution (generally not less than 3 m/pixel) and in the relatively high cost of this kind of data.

Earlier in the chapter it was noted that the project to create an Archaeological Map of Tuscany suffers from a serious but relatively common weakness which compromises its capacity to document archaeological evidence evenly across the landscape. This lies in the near-impossibility of investigating areas of woodland, which cover about half the total area of the region. A new development of great potential in confronting this problem is provided by recent work in Great Britain, Germany, France and Austria, using airborne laser scanning or lidar (see *Chapter 14* and *Devereux et alii 2005*; *Doneus–Briese 2006*; *Sittler–Schellberg 2006*; *Crutchley–Crow 2009*).

The lidar system consists of an airborne laser scanner capable of recording the morphology of the underlying ground surface with great precision (for the principles of the system and the nature of first and last pulse see *Chapter 14* and *Doneus–Briese 2006*). After computer-processing of the data, using appropriate algorithms, it is possible to 'remove' the woodland vegetation and reveal in great detail the surface relief not of the tree canopy but of the underlying ground surface, along with any archaeological topography that might be present. A degree of caution is needed, of course, but the technique could prove absolutely revolutionary in its impact on the process of archaeological mapping by making it possible to record, without physical intervention, the previously hidden archaeological resource within woodland areas (where they may – paradoxically – be particularly well preserved because of the protection provided by the tress against the ravages of modern agricultural cultivation). In favorable circumstances it may even be possible to uncover whole 'fossil' landscapes (*Bewley 2005*). This could have a dramatic impact on opportunities for archaeological and landscape conservation, as well as for scientific investigation of settlement dynamics in various phases of our history.

It is worth emphasizing that interest in this technique is not limited to its potential for penetrating woodland areas but also for its contribution to the study of open contexts such as pastureland and arable areas. In these zones, as under woodland cover, the availability of extremely precise digital models of the ground surface will make it possible to highlight every tiny variation in level, by using computer simulations to change the direction or angle of the light and/or to exaggerate the value of the z coordinate (*Doneus–Briese 2006*). Moreover the method can fill a particularly obvious gap for work at the local scale by making

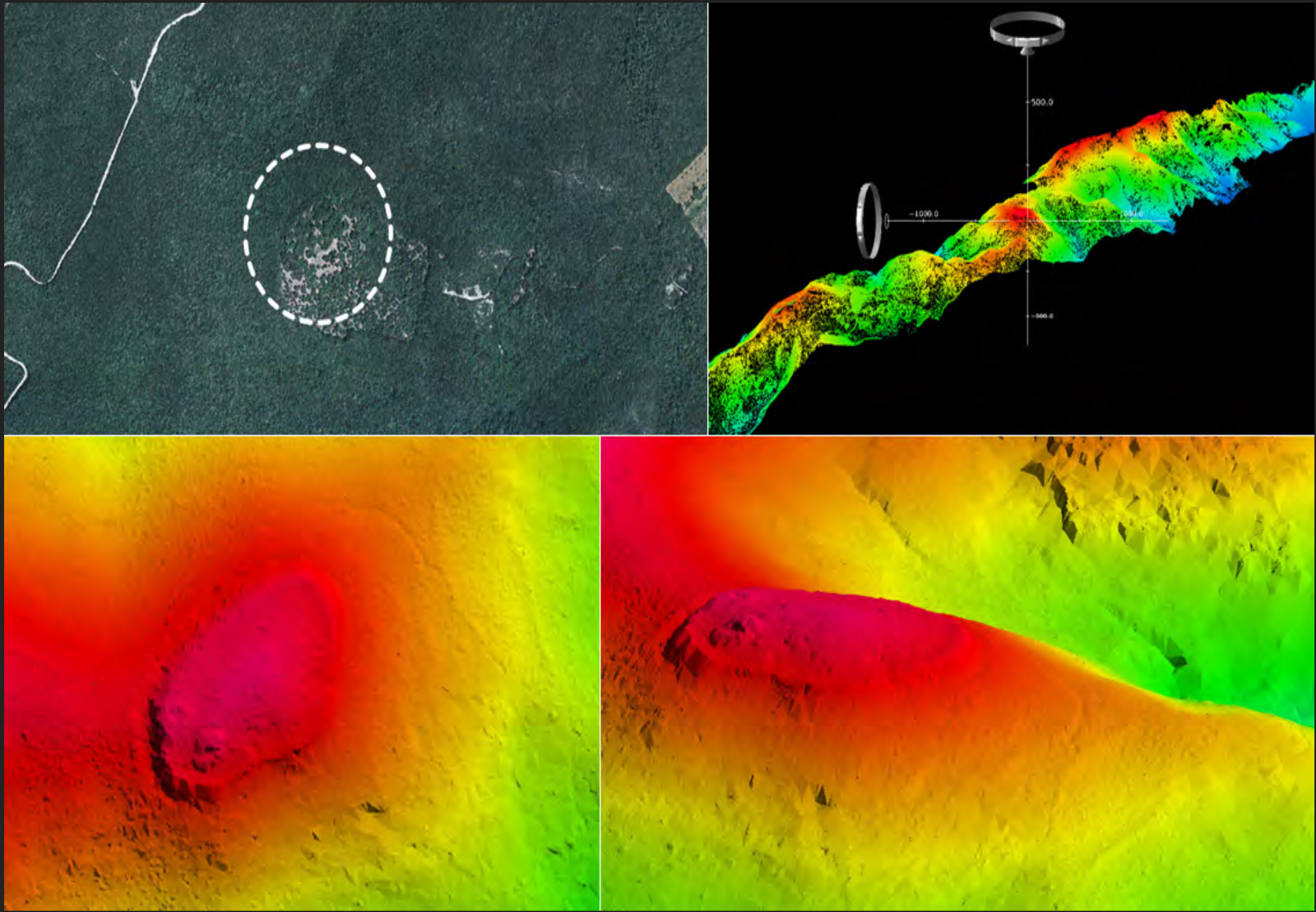


Fig 11. 9 **Sample area in Maremma, Tuscany, characterized by dense tree cover**

Top left: in the centre, under dense vegetation, are the well-known ruins of a medieval castle.

Top right: lidar point cloud collected by the UK Natural Environment Research Council and pre-processed by the Unit for Landscape Modelling at the University of Cambridge.

Bottom left and *right*: data processing and filtering by the Department of Geography at the University of Durham, UK, has allowed ‘removal’ of the dense vegetation to achieve a digital terrain model showing the previously hidden archaeological features.

Fig 11. 10 Large-scale geophysical survey instruments in use

From top to bottom: GSSI Terravision, Foerster Multicat, and ARP© Terranova.

available a numerical representation of the landscape's morphology, which through GIS can be readily integrated with data acquired through aerial photography and the other remote-sensing methods appropriate to this scale. We should seize on this as a very real opportunity to free the physical structure of the context from its former position as 'background information' and allow it to play a full part in the process of narrative interpretation.

In 2005, through a Culture 2000 project of the European Union, entitled European Landscapes: past, present and future, the University of Siena took its first steps in lidar data acquisition, processing and interpretation for four sample areas in the provinces of Siena and Grosseto. This was made possible through the good services of colleagues in England at the Natural Environment Research Council and the Unit for Landscape Modelling at the University of Cambridge. The results were processed in the Department of Geography at Durham University (UK) under the supervision of Prof Daniel Donoghue and Dr Nikolaos Galiatsatos. Success was achieved in one of the case studies, aimed at penetrating the tree canopy so as to record underlying archaeological features long protected from plough-erosion or other human activity by the woodland cover (Fig 11.9). We can see this as only the tip of the iceberg, however, with advances in the use of this technique in the coming years surely having a decisive impact on our understanding of ancient

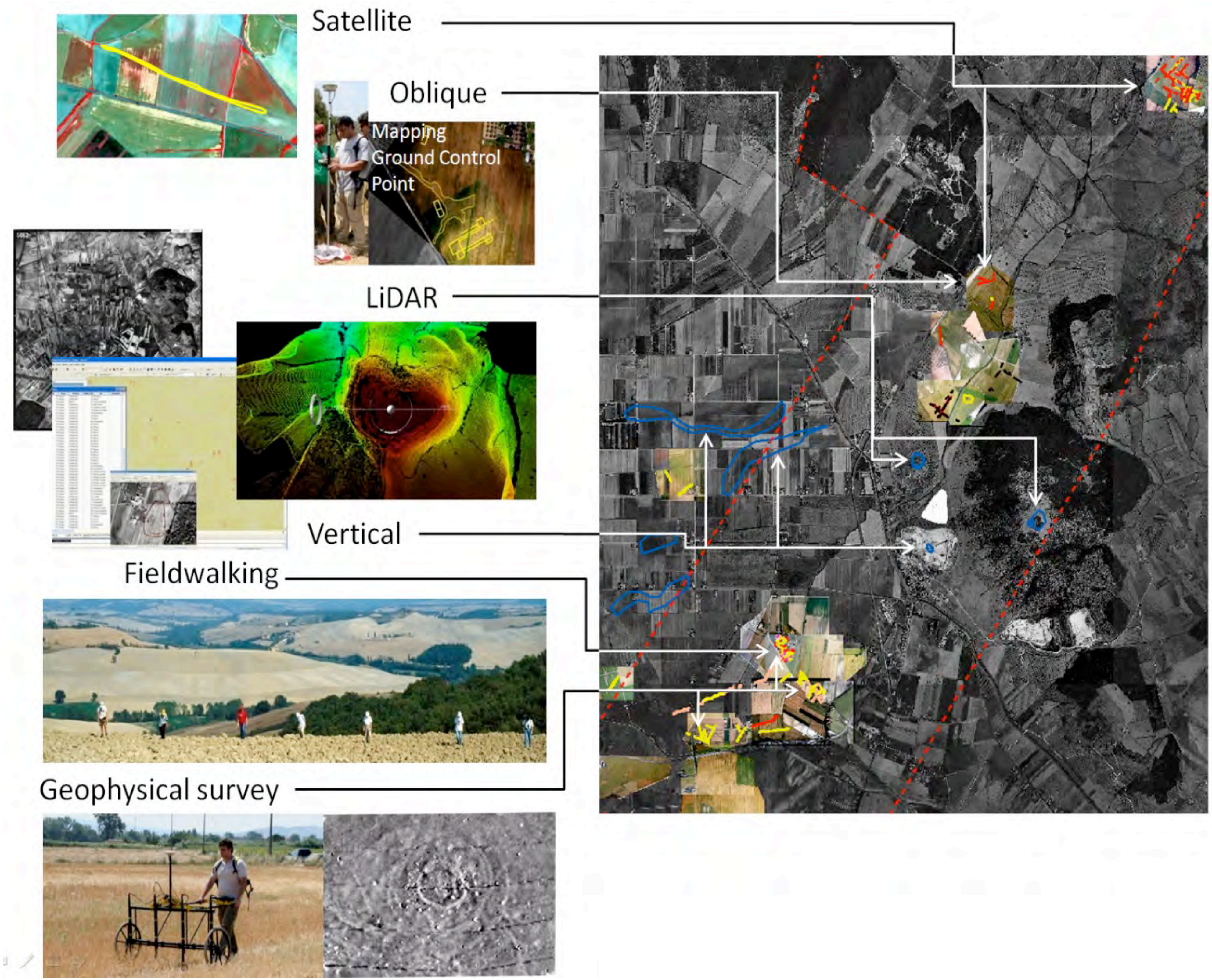


Fig 11. 11
Archaeological mapping: integration of differing detection methods

The integration of differing sets of survey data within a GIS environment makes it possible to create maps on which we can measure and position each piece of information while at the same time perceiving the overall picture, whether synchronically or diachronically.

landscapes across large parts of Europe.

Large-scale geophysical prospection

Recent years have seen an increasing availability of geophysical instruments technologically similar to those produced in the past but characterised by multi-sensor instrumentation (for an overview see *Gaffney–Gaffney 2006*). This change has reflected the needs of a large number of professionals, including archaeologists, for the rapid acqisition of geophysical data over ever-larger areas of ground. In archaeology this has led, for the most part, to the application of these new instruments on progressively larger individual sites and on the more or less systematic integration of the resulting data with information derived from field survey and surface collection (*Campana–Francovich 2005*; *Ciminale* et alii *2007*). Few archaeologists, however, have posed the following question: if geophysical methods enable us to gather such a significant mass of information for contexts initially identified through surface find scatters or aerial survey in times of good visibility, what would they be able to uncover in areas where other methods at present show only 'emptiness'? Even fewer archaeologists have been falling over themselves to seek an answer to this question (but see *Powlesland 2009*).

The University of Siena has been experimenting with several new systems in its chosen study areas and has recently launched a research initiative aimed at large-scale contiguous exploration. In particular, use has been made of the ground-penetrating radar system GSSI TerraVision, the Foerster gradiometer (in MULTICAT configuration and with a trolley pushed by an operator) and the ARP© system developed and managed by Terranova, a spin-off company from the University of Paris (Fig 11.10).

The Terravision system consists of 14 radar antennae set 12 cm apart at varying inclinations, mounted on a trolley (*Finzi et alii 2005*). Limited experience on only a single context has revealed practical limitations in the instrument's need for extremely homogeneous soil conditions (rarely encountered in agricultural situations) along with its lack of a fast and reliable georeferencing system for the collected data and of software dedicated to the processing and future management of the recorded measurements. This is undoubtedly an instrument of considerable potential but one which still needs further development.

The FEREX® fluxgate gradiometer system has 4 (or up to 8) sensors with a resolution of 0.1 nT mounted in parallel on a robust fibreglass trolley or on a hand-cart (*Campana 2006*). Depending on the configuration used the instrument is either pulled by a quad bike or pushed by an operator. These instruments, in addition to reducing the acquisition time through the use of a large number of sensors, are able to work without physical reference systems placed on the ground to control the positioning of the measurements. In practice, the need in some geophysical applications to lay out physical reference grids during the data-acquisition stage constitutes one of the most time-consuming and wasteful parts of the process. The new generation of instruments for the most part (though not the early versions of the Terravision system) are provided with in-built navigation systems based on DGPS technology and real-time visualisation on a computer or data logger of each completed traverse. The latest instruments permit data acquisition in the order of 3-4 hectares per working day, or about 60 to 80 hectares of high resolution data for each month of work.

There are also innovative solutions in the field of geoelectrics. A case in point is the ARP© (Automatic Resistivity Profiler) system developed by the group co-ordinated by Michel Dabas at the University of Paris (*Dabas 2009*) and experimented with by surveyors from the University of Siena in a variety of contexts.

Archaeological Mapping

A pre-requisite for the handling of this kind of territorial data is knowledge about each measurement's position in relation to a known system of geographical coordinates. Failure to satisfy this condition results in an inability to localise the acquired information. The entry of the data into an archaeological GIS is the basis for any attempt at integration of the information so as to facilitate a critical narration of the local history or conservation of the archaeological resource (Fig 11.11).

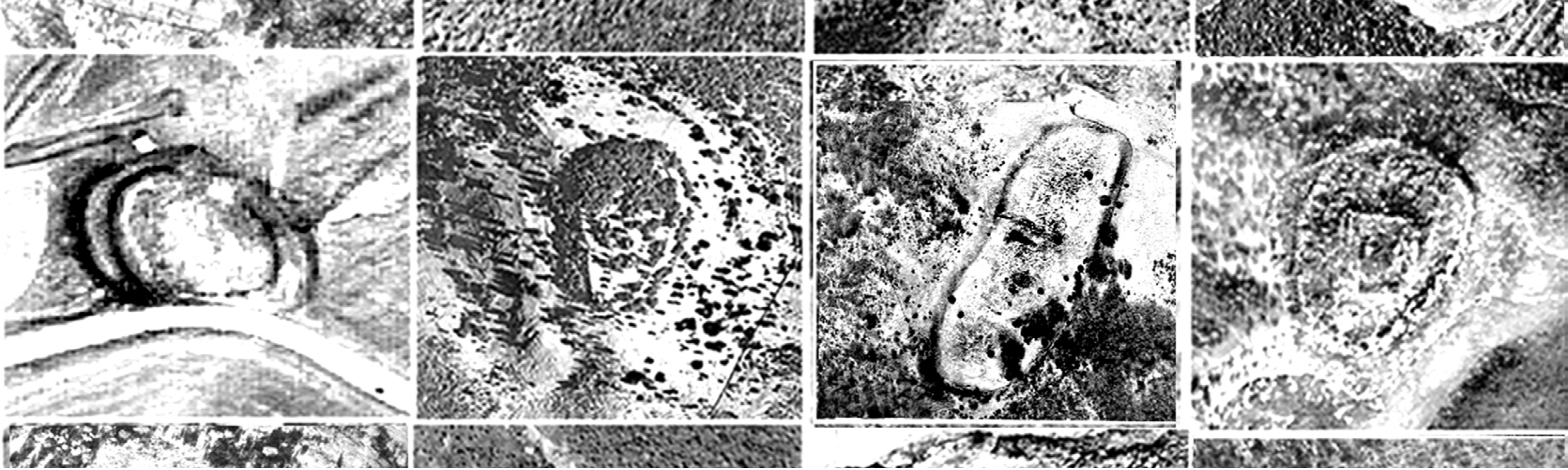
At scales such as 1:50,000 the mapped archaeological information is depicted by means of symbols so as to overcome the limitations of graphical representation. Typically, the site contours are also included as part of the background information. In the case of surface scatters one records the concentrations of material, preferably through a GPS unit working either in simple or in DGPS mode. Entry into the GIS of oblique aerial photographs, and hence of the information that they contain, is also essential. As explained in Chapter 1 aerial reconnaissance is a relatively recent development in Italy but research based on the photogrammetric analysis of vertical imagery has reached high levels of sophistication in recent decades, as illustrated in numerous published examples of photo-interpretation and cartographic representation (see for instance *Piccarreta–Ceraudo 2000*; *Guaitoli 2003*). Building on the experience and basic principles which allow the restitution of archaeological and topographical features through optical **photogrammetry**, software packages have been developed by American and British scholars which permit the geometric correction and georeferencing of **oblique aerial photographs** (*Scollar 2002*; *Haigh 1999*). Geophysical measurements are georeferenced in relation to the topographical relief through DGPS or total station survey of the selected measurement points or of the corners of the grids within which the measurements were acquired. In latest generation of instruments, by contrast, geolocation is achieved in real time through advanced systems of interfacing between the instrument itself and a topographical recording unit.

Georeferencing of the remotely-sensed data does not represent the end of the archaeological mapping process but only an intermediate stage. On their own, aerial photographs or magnetic and geoelectrical maps signify little. It is the responsibility of the archaeologist (often in collaboration with specialists such as geophysicists and soil scientists) to give sense to the photographs or to the measurements of chemical and physical parameters in the soil. In summary, the interpretation of the data is made real and communicable through cartographic representation of the elements perceived as anomalies. This is therefore the critical phase in landscape and archaeological research. In practice the process advances through the drawing, in a digital way as well as by hand, of the anomalies and other elements deemed to be of archaeological interest.

The georeferenced and graphical representation of the information contained in vertical or oblique aerial photographs, in high-resolution satellite imagery, in lidar data and in maps derived from geophysical measurements allow us to overlay on topographical maps the results of the various investigative methods, along with a mass of other data ‘stratified’ layer upon layer over the years. The result is a three-dimensional jigsaw puzzle, a complex representation in which we can measure and position each piece of information while at the same time perceiving the overall picture, whether single-phase or spread across time, along with the overlapping and stratified fragments of whole systems of ancient and Medieval landscapes. Through archaeological mapping and the use of GIS these become capable of study against other layers of archaeological and non-archaeological information in the writing of history, in heritage protection through the planning process, through conservation measures and designations or through monitoring of the shared cultural inheritance.

Acknowledgments

The author owes an enormous debt of gratitude to his mentor, the late Prof Riccardo Francovich (University of Siena), for his passion, support and criticism throughout all stages of the author’s research experience. Special thanks are also due to Chris Musson (for help with the English version of the text) and Dominic Powlesland (Landscape Research Centre, UK) for their valuable comments on the practice of archaeological research. Bob Bewley (formerly of English Heritage), Daniel Donoghue (University of Durham), Dean Goodman (Geophysical Archaeometry Laboratory, Los Angeles), Darja Grosman (University of Ljubljana) and Salvatore Piro (ITABC - CNR) have helped in a variety of ways. Helmut Becker (formerly of the Bavarian State Department of Historical Monuments) and Iacopo Nicolosi (National Institute of Geophysics and Vulcanology, Italy) contributed greatly in the field but also helped me to understand the best configuration for our magnetometer work. Salvatore Piro and Dean Goodman did great work during acquisition and processing of GPR data. Many researchers and students have collaborated, and are continuing to collaborate, in the Siena and Grosseto archaeological mapping projects. Special thanks are also due to the research team of the Laboratory of Landscape Archaeology and Remote Sensing at the University of Siena: Anna Caprasecca, Cristina Felici, Barbara Frezza, Mariaelena Ghisleni, Francesco Pericci and Emanuele Vaccaro.



12. AERIAL RESEARCH IN TUSCANY

Air photographs, computer enhancement and thermal imaging in studies of the ancient history of Tuscany

†Marcello Cosci

Introduction

Amongst the many research projects of the Laboratory of Archaeological Photointerpretation of the Department of Archaeology at the University of Siena particular attention has been paid over a period of years to a ground-breaking project which started from the idea of using the examination of vertical photographs to evaluate the archaeological potential of the Region of Tuscany. The initial aim was to investigate and make a database of the fortifications of the medieval period and, more generally, of hilltop settlements over a wider chronological range from the pre-Roman period to the post-classical.

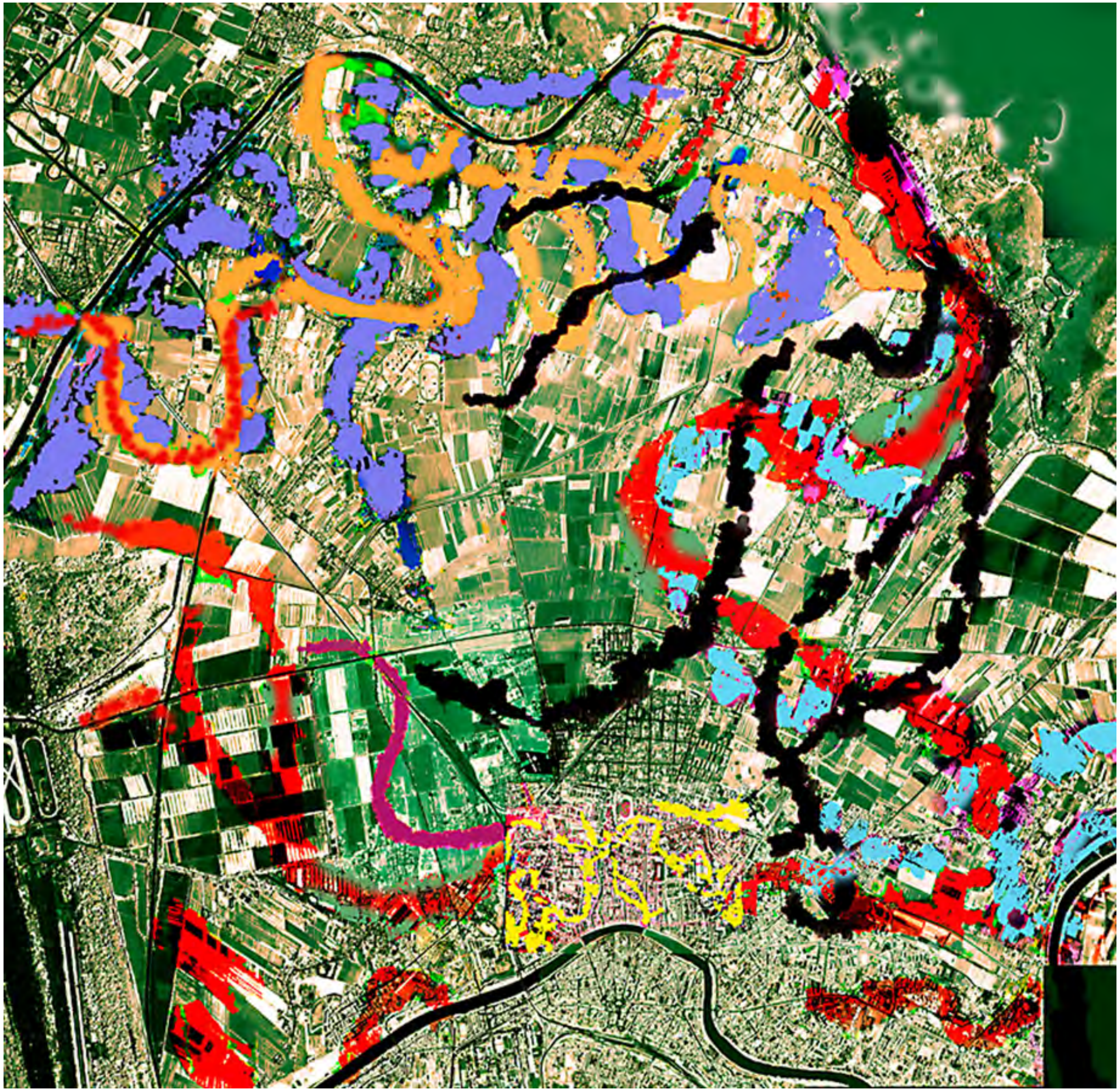


Fig 12. 1 The ancient course of the River Auser at Pisa

After reaching the city, in the times of Strabo and Namaziano, the Auser gradually moved north before stabilising in the course which it occupies today.

Marco Cosci was formerly Head of the Laboratory of Archaeological Photointerpretation within the Department of Archaeology at the University of Siena. He died after a long illness at the age of 80 in September 2009. He continued to work on 'aerial' ideas long after his retirement from the University of Siena. The text has been translated by Chris Musson from the original Italian, hopefully without too many errors.

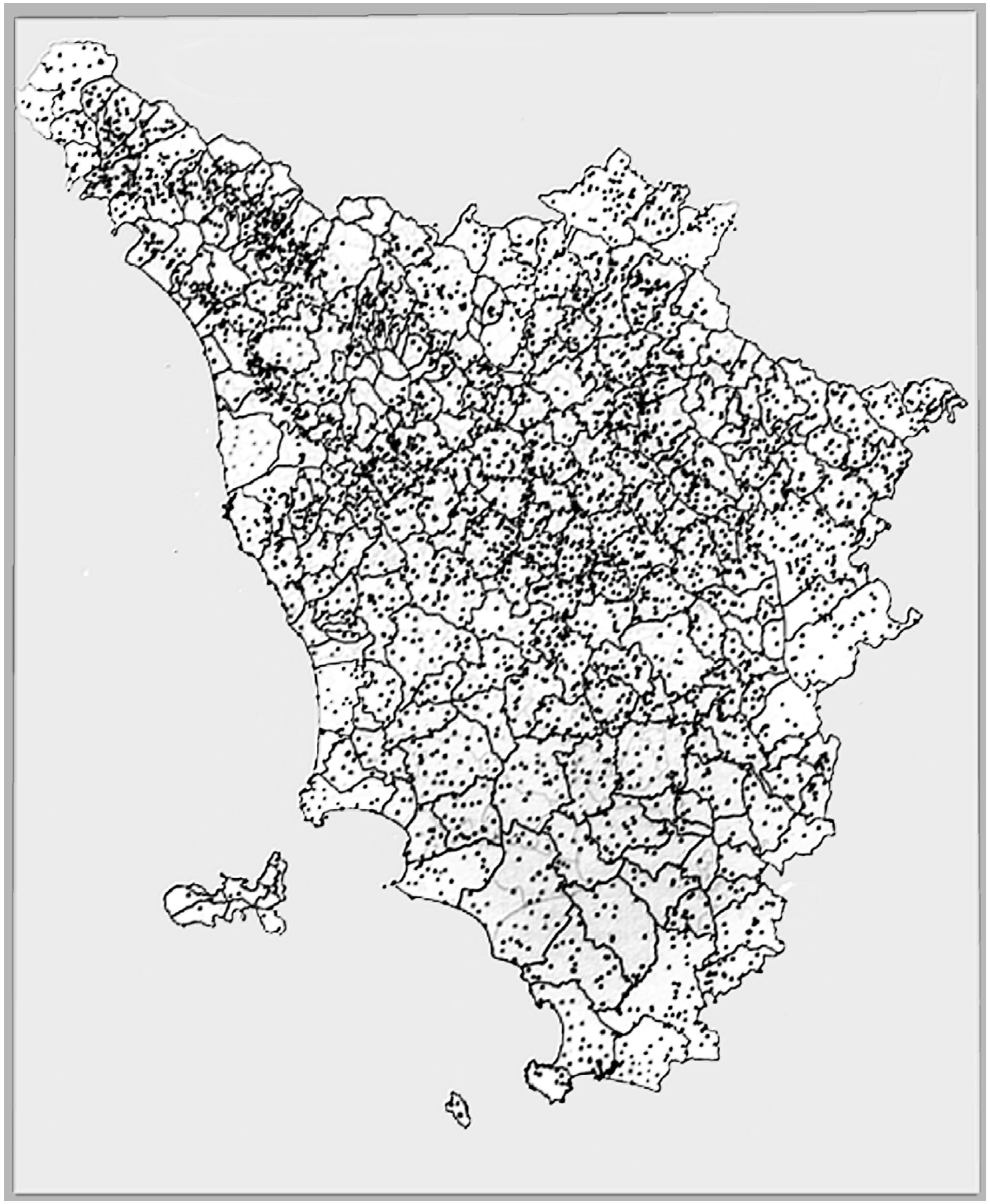


Fig 12. 2 The fortified sites of Tuscany: anomalies detected on aerial photographs

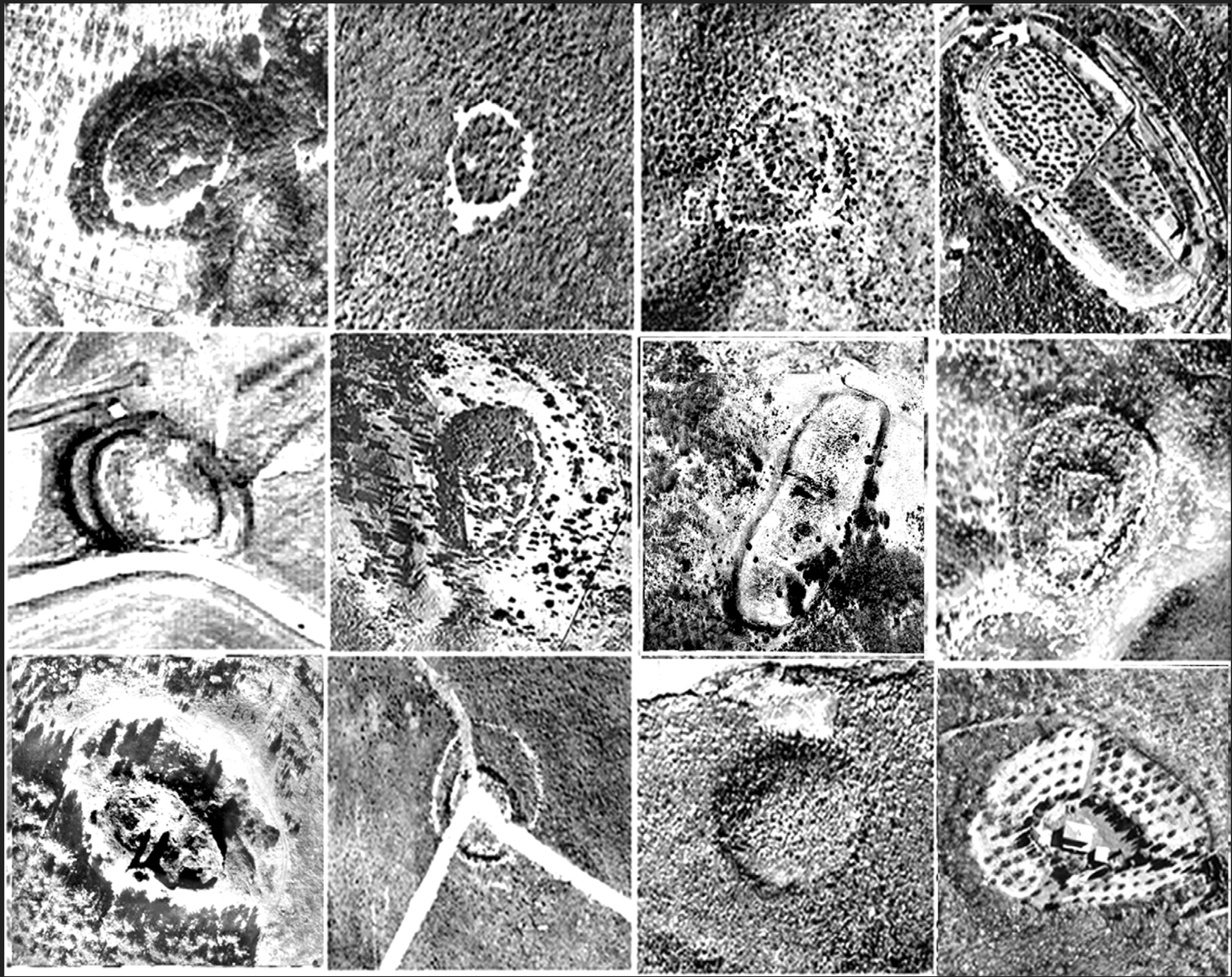


Fig 12. 3 **Examples of anomalies detected on aerial photographs of Tuscany**

The Project

The project was one of the first fruits of a collaboration with Riccardo Francovich through the founding in 1984/85 of a laboratory to undertake photo interpretation and related teaching. From the outset it was decided to base the work on the anomalies visible through painstaking stereoscopic examination of the photographs produced for **mapping** purposes for the Office of Cartography of the Department of Regional Planning of the Region of Tuscany, which made prints readily available for the research work. The project also made use of the EIRA photographs produced in 1975-76 on black-and-white panchromatic film at a scale of 1:13,000. This consisted of 165 aerophotogrammetric traverses comprising a total of 12,000 images covering the whole 2,300,000 hectares of the Region's land surface.

In this first phase of the work, in which priority was given to research on the so-called 'cavalry' hilltop settlements, there began to emerge a mapped body of evidence that indicated a substantial unrecognised resource. This now takes the form of a database containing an archive register of more than 4700 anomalies of possible archaeological origin (Fig 12.2).

Structures buried only a short distance beneath the surface often influence the overlying natural vegetation, which takes on a distribution which reproduces the outlines of the buried settlement. Alternatively the buried remains may inhibit plant growth above the structures. In other cases the moisture present in the defensive ditches reaches the surface through capillary action and faithfully reproduces the course of the **site**'s perimeter (Fig 12.3). However, many parts of the mountainous chain of the Apennines, especially in northern Tuscany, remain unexamined because of the umbrella-like mantle of tall plant growth that prevents analysis of the underlying ground surface. This results from the fact that the aerial photographs used in the project were 'commercial' in that they were produced exclusively for mapping purposes and therefore needed to be captured through flights undertaken in those parts of the year that offered the best conditions of lighting and weather conditions. In Italy this normally means no more than about twenty days a year which give a guaranteed opportunity for the best recovery of photogrammetric images. The flight traverses can be hundreds of kilometres long and the resulting photographs must be free of widespread or scattered cloud or of banks of mist that would make the images unusable for mapping purposes. These favourable days obviously occur in periods when plant growth is at is most vigorous.

Notwithstanding these difficulties in collecting and evaluating with clarity the signs of the past, it proved possible through stereoscopic examination of the photographs to make out **trace**s of micro-relief and geometric **pattern**s that indicated the presence of possible historical remains. With the help of generous support from the Office of Cartography an initiative was conceived and then put into operation during February 1989. This involved the Rossi Company of Florence overflying and photographing a small part of the Region around Arezzo which contained about fifty of the conjectured ancient sites. This winter flight, as expected, proved very effective in its recovery of archaeological information (Fig 12.4).

Finally, there remained to be investigated the low-lying areas of the Region where, by contrast, the hidden remains make their appearance in response to particular conditions that are more complex than those described above. On the higher land, if one excludes the zones with the tallest and most dense plant cover, **trace**s of one kind or another are evident on all of the photographic flights despite their being carried out at widely differing times of year. In the lowland zones, however, the formation of the telltale marks, in addition to being strongly affected by the agricultural cycle of ploughing and planting, make their appearance with greater or lesser regularity and duration depending on the amount of moisture present in the soil. Other influencing factors are the depth at which the remains are buried and their resulting capacity to influence the surface indicators in crops or bare soil, and most of all the presence at ground level of types of vegetation that inherently favour or inhibit the formation of the marks. The marks can therefore appear and disappear over a matter of days depending on the period of the season and the local geomorphological conditions. All in all, this means that we cannot always succeed in predicting when the marks will appear and how long they will last.

As a consequence the recognition of settlement evidence would make it necessary to programme and execute survey flights and oblique aerial photography repeatedly, in differing conditions of climate and season, at different times of the day, in varied lighting conditions and at varying heights using photographic emulsions with a wide spectral range. This kind of operation would admittedly be possible and practical for objectives of limited scope or geographical coverage but would be unthinkable over the huge territorial span involved in our particular research project. Even so, mature experience over many years in the reading of information contained in traditional vertical photographs has made it possible to demonstrate that these images too are capable of revealing, at least occasionally, information and details of great value, including, with considerably greater consistency, evanescent geometrical shapes that display orientations or dimensions that are recognisable and interpretable with varying levels of clarity and intelligibility as evidence of past activity.

The aerial evidence of course needs to be checked on the ground. Through repeated examination carried out in sample areas over the years by undergraduate students in medieval Archaeology at the University of Siena, a significant number of the sites – though relatively few in relation to the total number revealed by examination of the aerial photographs – have been verified in the field and tentatively dated. In a small but acceptable number of cases, however, the ground-based survey produced no result in terms of obvious signs of ancient activity. This demonstrates that the photo reading had accepted as valid some anomalies that were of purely natural origin. Others seen as man-made **features** of some antiquity may in fact have been the result of quite recent interventions. In the latter case the error perhaps arose through insufficient caution in allocating chronological attributions to the traces (air photographs, of course, cannot of themselves provide information about the dating of anomalies seen upon them). It is likewise possible that in some cases the accumulation of humus beneath the trees may have prevented recognition of the identified anomalies during the subsequent ground-based inspection.

Enlarging photographs for purposes of interpretation

It is commonly accepted that every photograph contains an amount of information and a capacity of geometric resolution at ground level that varies according to the type of film used in the photographic exposure. In the photograph at top left in Fig 12.5, captured in 1954 for cartographic purposes by IGM of Florence, the definition of the image is limited to 60 lines per millimetre, quite low in comparison with the high-resolution films of more recent times.

To make even the most fleeting of marks visible, therefore, it is necessary to obtain very high levels of enlargement. With the computer it is possible to enlarge a photograph at least 40-60 times without loss of necessary definition, taking it to a size that occupies a virtual space of about 100 m2. This can be done by scanning the entire photograph at a resolution of 800 dpi and then displaying it on a 21-inch monitor with a screen definition of 1280 x 1024 pixels.

This is illustrated in Fig 12.5 which represents at top left the whole of an original image, on which has been marked a half-centimetre square containing an apparent medieval motte. This square has then been progressively enlarged, with appropriate manipulations of contrast, until it occupies the whole height of the screen, revealing (at bottom right) what appear to be individual postholes along the inner margin of the surrounding defensive ditch. [*Editor's note: Care is needed, however, in the interpretation of such extreme manipulations. There is an ever-present danger that the manipulation will produce 'artefacts' which do not in fact represent real archaeological features.*]

With the maximum enlargement of the image obtainable electronically it is possible to recognise forms which would have escaped even the most attentive stereoscopic examination of the prints. For further stages of the project use was also made of the images produced during sorties by IGM in 1938, 1940 and 1954-55, the ENEL flights of 1973 and 1975, the EIRA flights of 1975-76, the Rossi Company's flights of 1975-76 and other

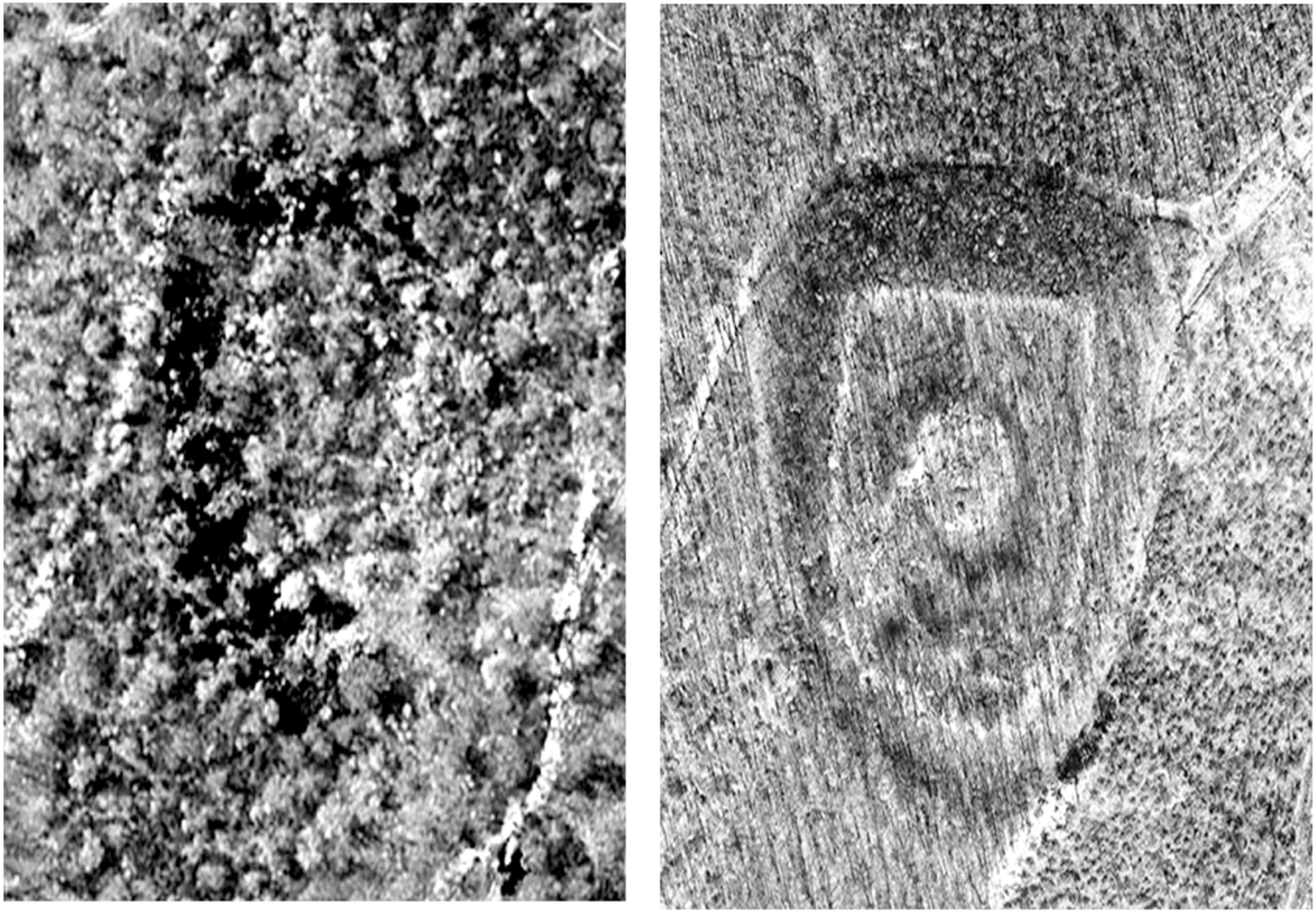


Fig 12. 4 The same site photographed at different times of year

On the left during a summer flight. On the right in wintertime.

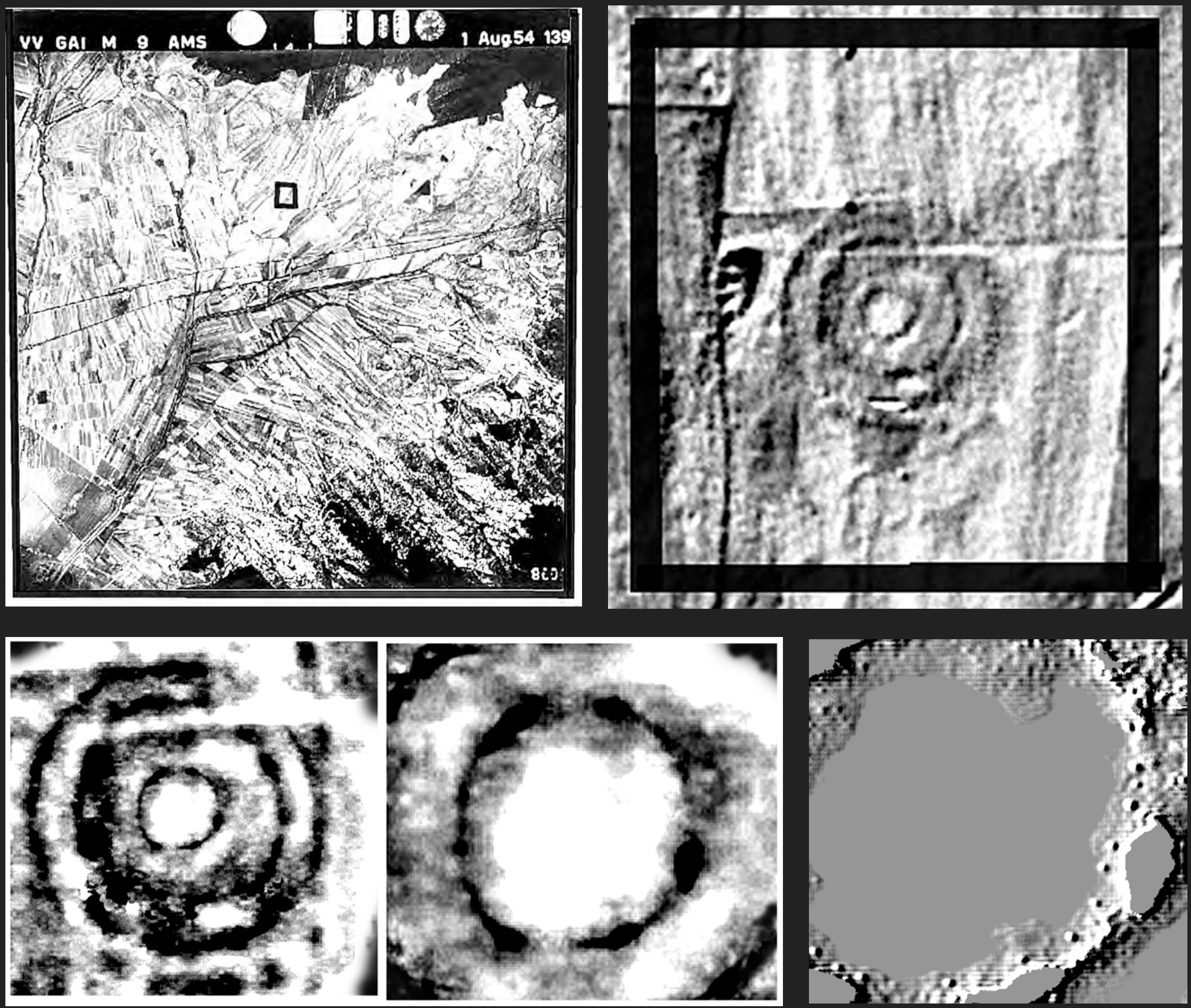


Fig 12. 5 Analysis of an IGM aerial photograph taken in 1954

The half-centimetre square on the original 23 x 23 cm photograph, at top left, has then been progressively enlarged on the computer screen to reveal elements of the medieval motte encompassed by the original square.

Between 1954 and 1956 IGM acquired the first aerophotogrammetric coverage for the whole of Italy. Commissioned by the USA Army Map Service, the flights, known by the name GAI (Gruppo Aerei Italiani, consisting of the companies EIRA, IRTA and SARA) were registered on black-and-white panchromatic film at a scale of 1:30,000. This survey constitutes an invaluable historical record. Being produced so soon after the war they record a landscape more or less unchanged from past centuries, barely touched as yet by the heavily mechanised agriculture and inexorable building activity of the succeeding years.

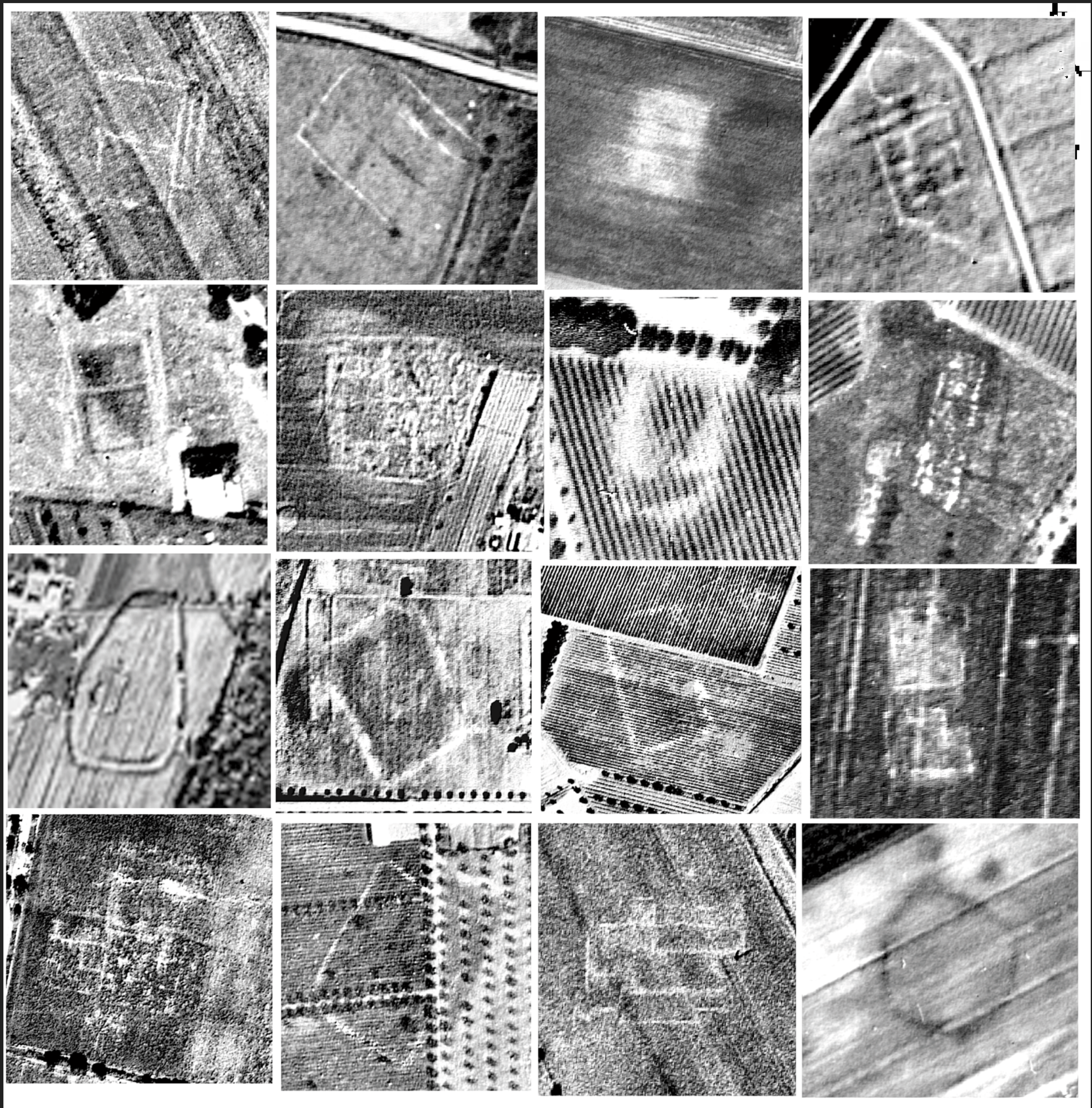
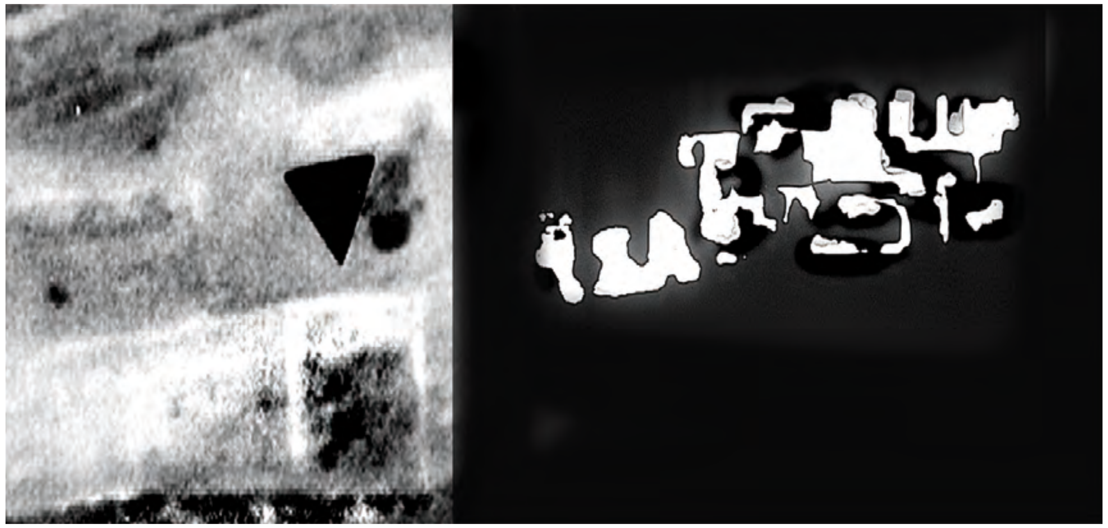


Fig 12. 6 **Examples of anomalies of possible historical significance**

flights consulted to one extent or another in the Office of Cartography. Very encouraging results have been achieved since the adoption of this innovative approach, which allows the minute examination of every single frame through gradual horizontal or vertical movements of the enlarged image.

Computerised enhancement of the images

In analysing a photograph the greatest difficulty arises from the fact that our human powers of visual perception are not capable of evaluating with mathematical precision all of the information which the photograph contains in the form of graduations of tone and colour. A black-and-white photograph of full tonal range, for instance, appears on the monitor as up to 256 graduated levels of grey, while a colour image can have several thousand tones of colour. Our reading capacity, however, reduces this to a number of levels which varies from 10 to 15 per cent of the original, depending on individual capacity. In reality the information contained in the original photograph is registered through innumerable levels of colour that vary from the purest white to the deepest black, themselves recorded on successive layers of sensitised emulsion no more that a few hundredths of a millimetre in total thickness. The deepest layers register the most luminous areas while the darkest are recorded in the layer closest to the surface. In the computerised enhancement of the image the use of the filters controlling contrast and luminosity make it possible to achieve the gradual elimination of all of the information contained in the scales of grey or, alternatively, of those with the highest luminosity. This operation makes it feasible to increase the reading capacity and evaluation of the information in the tones closest to pure black or pure white. An example of this is presented in Fig 12.7, which shows detail from an enlarged photograph of a coastal area close to Nicotera Marina in Calabria. The photograph depicts two stretches of sand-dune separated by a dark area of swampy land which was once a navigable waterway. Along the seaward face of the inland dune, at the points indicated by arrows, it is possible to recognise several harbour structures buried beneath the bright white of an overlying layer of wind-blown sand.



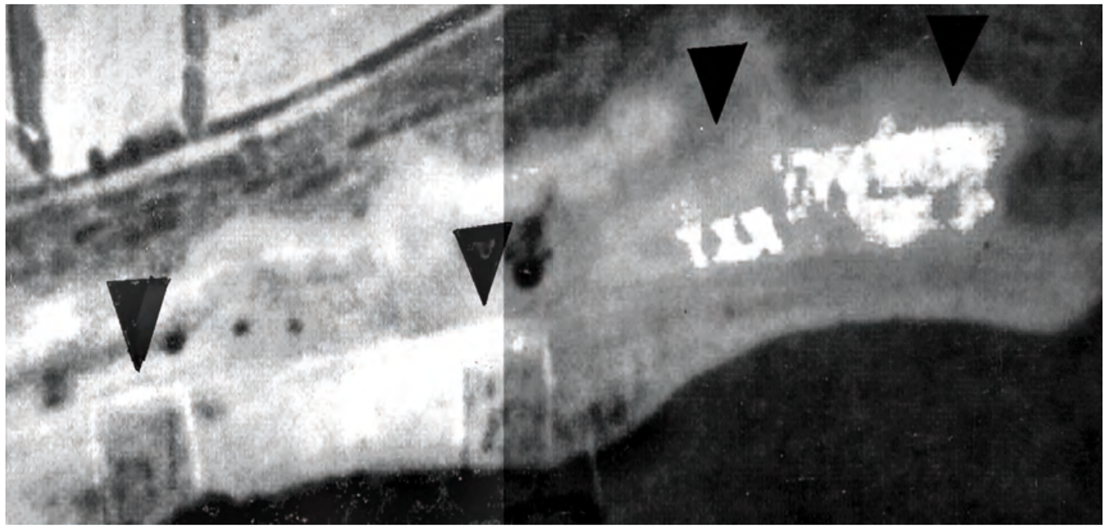


Fig 12. 7 Harbour structures in Calabria

The photograph at top left, of a former inlet (dark) near Nicotera Marina, flanked on both sides by sand dunes, has been progressively processed by manipulations of contrast and colour to reveal former harbour structures, indicated by arrows on the original image.

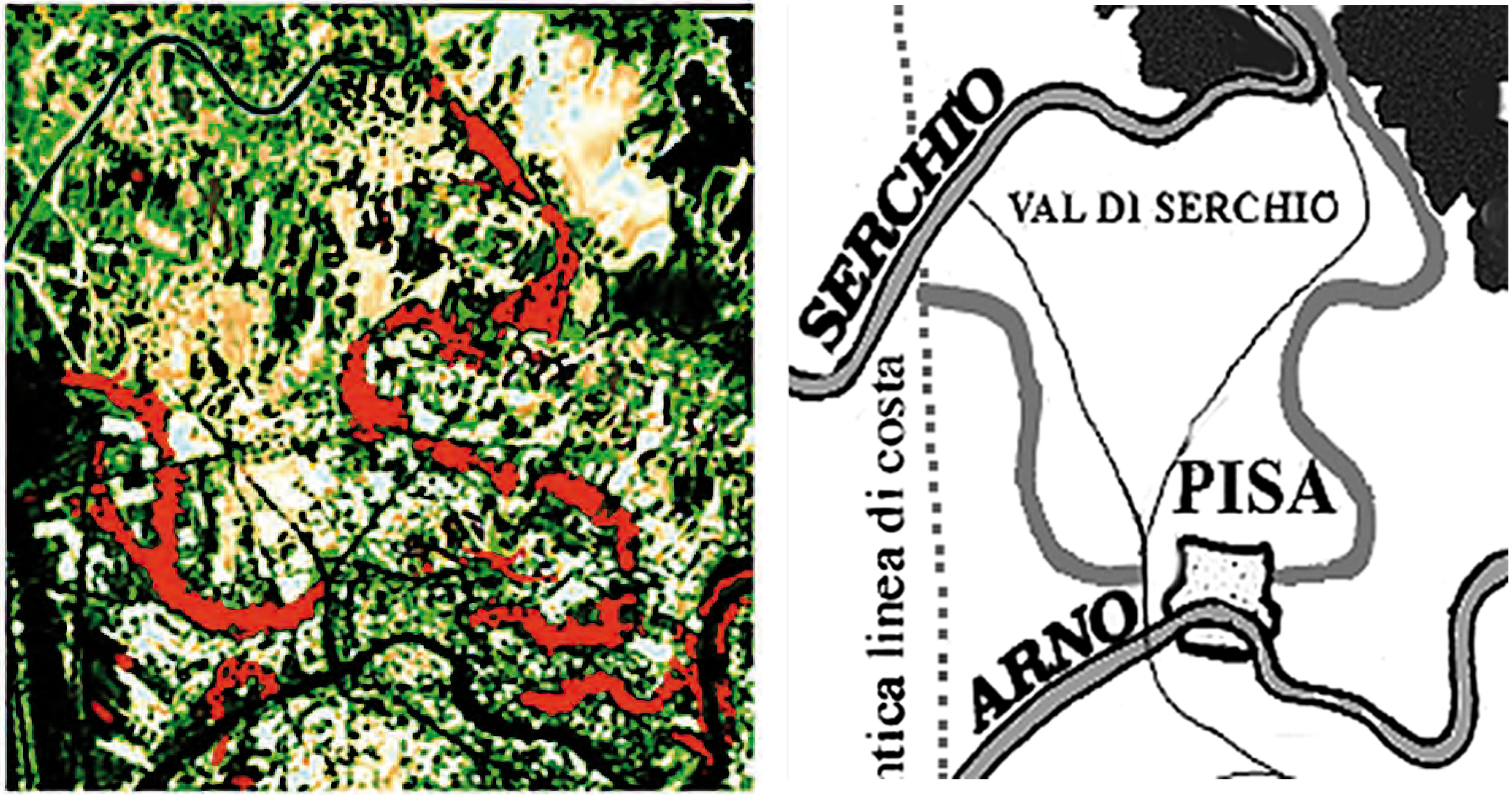


Fig 12. 8 The ancient and modern courses of the Arno and Serchio at Pisa

Pisa and the ancient course of the River Serchio (Auser)

As noted above, every image contains an amount of information that varies according to the season in which the exposure was made. This applies whether we are dealing with airborne platforms or with scanned images beamed back from space.

The presence of fossil traces of the River Serchio, called the Auser in antiquity, represents one of the most debated themes in the topography of ancient Pisa and the hydrography of the surrounding area. One of the documents that records the former presence of the River Auser at Pisa is that of the Greek geographer Strabo who in his Geografia V, 2, 5 says that 'Pisa is situated between two rivers, the Arno and the Auser'. This is confirmed by Claudio Rutilio Namaziano in his De Reditu Suo, I, 567-568, on the basis of a visit to the city in AD 416. There are numerous references throughout the medieval period that note the presence of the river's course at Pisa or in the adjacent plain. However, studies and research work undertaken by numerous scholars from the late 16th century onwards have nevertheless proved incapable of producing a really credible reconstruction of the environment within and around the ancient city.

In a piece of research on the general area of Pisa, undertaken with the objective of providing fuel for this debate, we made use of images captured by the Landsat, SPOT and Soyuz satellites. The images were treated with image processing software with the aim of defining and interpreting traces that were barely comprehensible without such manipulation. The evaluation of the spectral responses provided by multiple signals in the form of electromagnetic energy, as reflected in the chromatic variation of the vegetation and bare soil, made it possible to discern numerous traces of the ancient hydrographic **pattern**. These were characterised by differences in grain size and moisture content compared with the surrounding deposits. The ancient river channels favoured the collection and circulation of water and as a result showed up as marks that were relatively easy to see. The fluvial morphology was visible on the ground as tracts of varying length, revealed by the moisture that rose to the surface through capillary action from the lower parts of the river beds, and also by the lower reflective capacity of the finer material which accumulated in the river beds during their progressive stages of desertion.

The particular geomorphological characteristics of this part of the Pisa plain between the Rivers Arno and Serchio (Auser) became clear in the form of palaeochannels extending all the way from the Ripafratta Gorge to the city itself (Figs 12.1 and 12.8-10).

For the course of the Auser where it passed in antiquity beneath the present-day urban settlement, recourse was made to a night-time image captured shortly before dawn by an airborne platform with a dual-channel Daedalus 1230 thermal scanner operating within wave-band widths of between 9 and 35 microns at a resolution of 0.5 degrees centigrade (Fig 12.9).

The information registered on the night-time thermal image, processed on the computer through extreme enhancements of contrast, made it possible to reveal a series of paleaeochannels which show as continous very dark traces (Fig 12.10, *top*).

In the academic years 1996/97 and 1997/98 four undergraduate students on the Geological Sciences course of the Faculty of Mathematics, Physics and Natural Sciences at the University of Pisa were allocated as their thesis the task of confirming (or challenging), through detailed ground-level geophysical examination, the validity of the information furnished by the processed satellite images. The many detailed thermal images identified by the students at several location within each of the indicated palaeochannels (see Fig 12.1) recorded the relative widths of the channels (which varied from one river bed to another) as well as the thickness of the sands and gravels up to an almost constant depth of 6 m below the present land surface over the whole of the survey area. The relevance of this depth was confirmed by the fortuitous discovery in the outskirts of Pisa of an ancient urban river port of the Etrusco-Roman period, complete with many abandoned ships (*Bruni 2003*; *Camilli 2004a*, *2004b*).

These studies showed that despite their depth the lost river-channels, saturated with water after heavy autumn rain, presented a greater inertia and hence higher thermal capacity, with the result that they registered on the processed image as being more 'cold' and, within the surface morphology of the surveyed area, with a level of grey much darker than that of the surrounding soil (in conformity with the model adopted in the computer elaboration). The presence on the image of so obvious an anomaly owed its occurrence to the moisture in the body of the palaeochannels rising to the surface through capillary action and becoming frozen through intense evapotranspiration. This produced a negative thermal **anomaly** which, registered by the highly sensitive thermal scanning equipment, traced out on the surface of the ground the ghostly course of the vanished River Auser.

In order to render the information recorded in Fig 12.9 more comprehensible it was necessary to carry out, as illustrated in Fig 12.10 and 12.1, a series of enhancements which through gradual conversion from black-and-white to colour made it possible to obtain a final image that is clearly readable in every detail.

For further information on various aspects of these studies see Campana-Pranzini 2001; *Cosci 1998*, *2001*; *Della Rocca et alii 1987*; *Marchisio et alii 1998*, *1999a*, *1999b*.

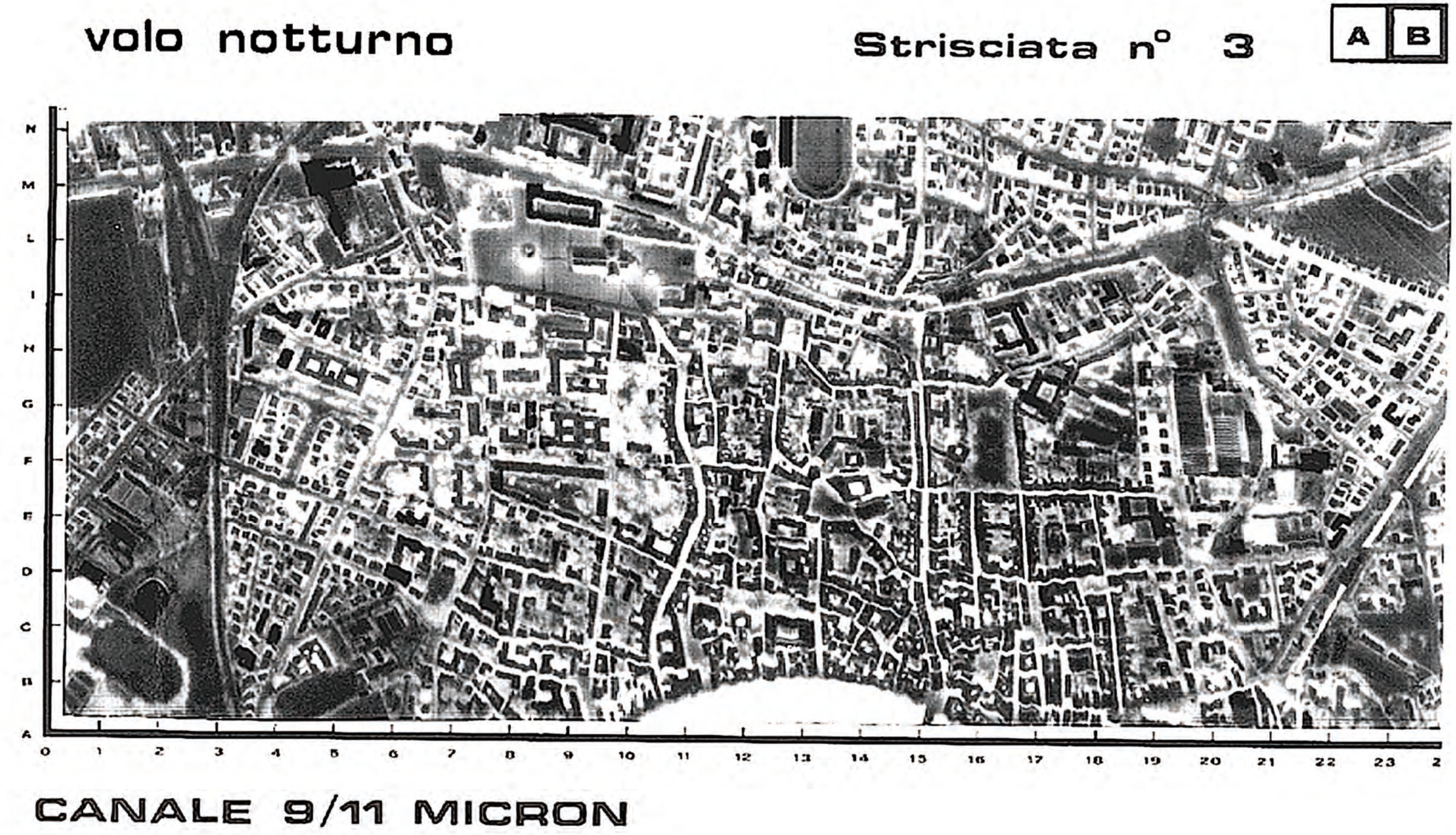


Fig 12. 9 Thermal image of Pisa

The image was acquired by airborne thermal scanning in December 1993, after heavy rain, by the Rossi Company of Florence. Unfortunately, the presence of no-fly zones within the survey area meant that the urban course of the Arno was not recorded, nor was the confluence with the Auser that was as described by Strabo and Namaziano.

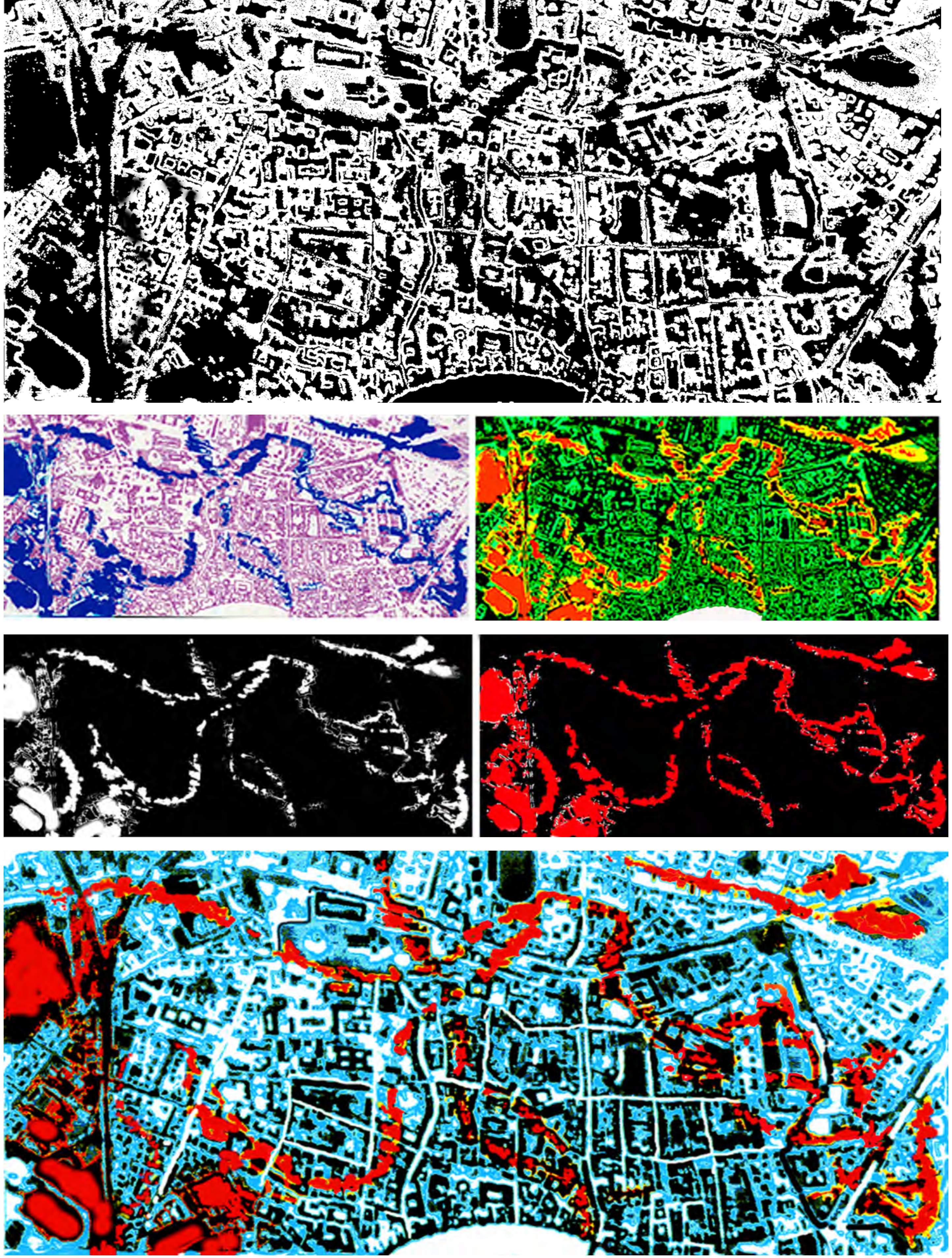


Fig 12. 10 Pisa: palaeochannels of the River Auser beneath the modern city

Successive manipulations of the thermal image shown in Fig 12.9 to emphasise and clarify the 'cold' imprint of the former river courses. See also Fig 12.1.

13. MULTIPLE SURVEY TECHNOLOGIES AT ROMAN CARNUNTUM, AUSTRIA

Integrated prospection of the largest archaeological landscape in Austria

Michael Doneus, Wolfgang Neubauer

This contribution is reproduced as written towards the end of 2004. For further and more recent information see Doneus 2004 and Doneus et alii 2012 in the main Bibliography. The authors are respectively Deputy Director and Director of the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Reality at the University of Vienna, Hohe Warte 38, A-1190 Vienna, Austria.

Introduction

The last decade has seen a considerable development in aerial archaeology and geophysical prospection. The main progress in aerial archaeology – apart from the political events and the associated start of active aerial survey in the countries of eastern Europe – has been in techniques for the rectification and **mapping** of air photographs. Today, digitised images can be rectified using sophisticated photogrammetrical techniques (*Doneus 2001*) or specialist programs (*Haigh 1998*; *Scollar 1998a*, *1998b*). They then become readily available for on-screen interpretation. Geophysical prospection has also undergone major developments through the introduction of ever more sensitive sensors and of special devices for rapid high-resolution measurement in the field. Computers have made it possible to handle the huge mass of data that can be gathered within a single hour of magnetic prospection or within mere minutes of scanning by ground penetrating radar (GPR).

However, it seems that the development of interpretation techniques has not kept pace with the speed with which data can now be collected. Consequently, geophysicists tend to present their data as prospection 'results' while **aerial archaeologist**s have a tendency to talk about '**cropmarks**' rather than archaeological **feature**s. Refinement in the interpretation of prospection data depends on the development of interpretation tools and on a high degree on archaeological feedback.

As one of the most important 'new' tools, GIS has found its way into archaeological prospection almost four decades after its first invention. GIS opens up the possibility of combining the various prospection data and results, which can then be re-evaluated and re-interpreted to give a more holistic view of a **site** or **landscape**. It also opens a vast array of new possibilities for interpretation, beyond the current practice of prospection archaeologists.

In Austria, archaeological prospection is concentrated at the University of Vienna. **Aerial archaeologist**s and geophysicists sit side by side in the Vienna Prospection Archive, enabling a close relationship between aerial archaeology and geophysical prospection. In recent years parts of our scientific investigations have been concentrated on the combination of different prospection techniques, this becoming a standard procedure in our daily working routine (*Doneus, Neubauer 1998*).

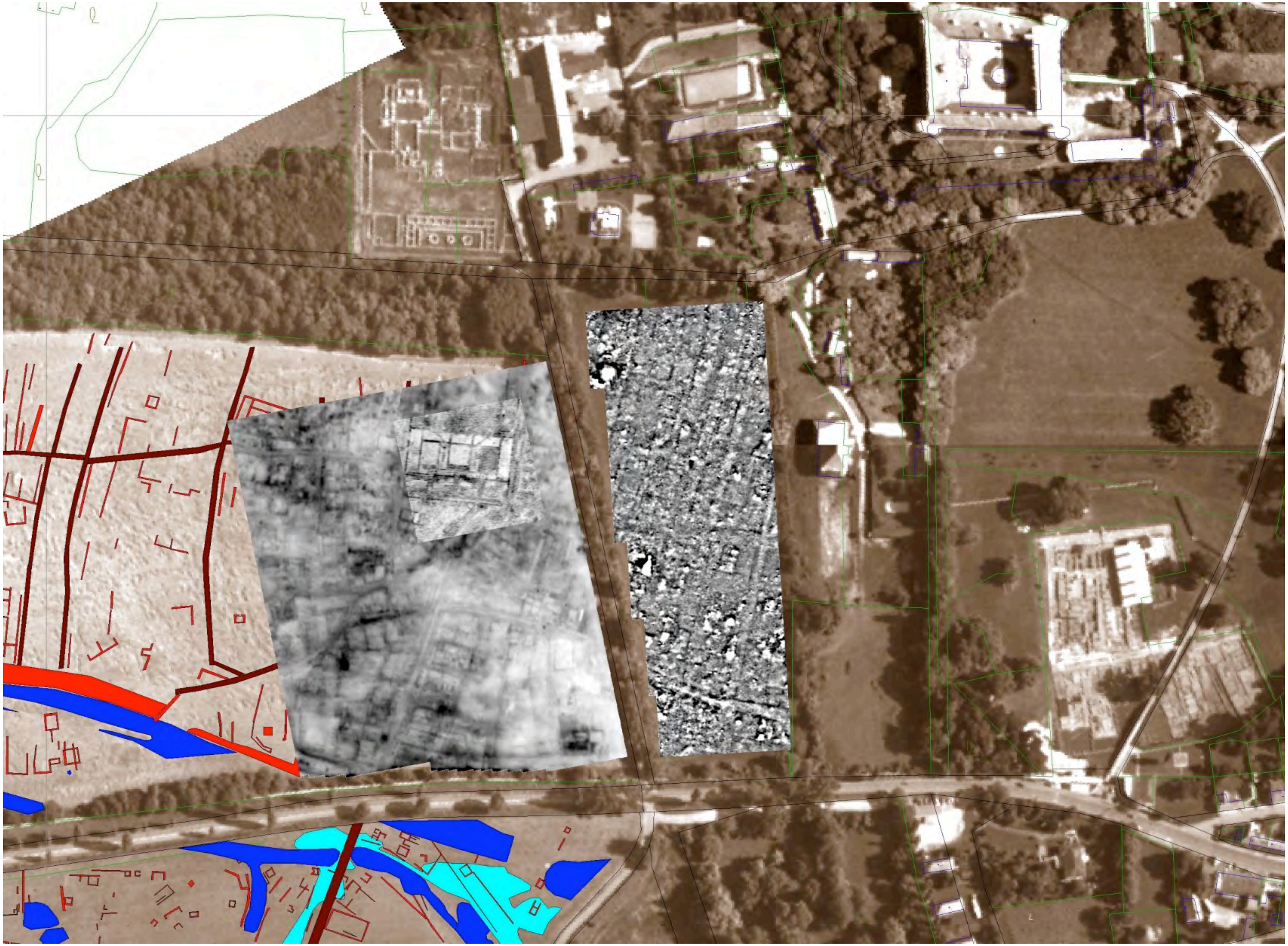


Fig 13. 1 Combined representation of part of the civil town

Based on an orthophotograph, along with excavation evidence for insulae and the monumental baths, plus magnetic survey, resistivity mapping, GPR imaging and aerial photo interpretation.

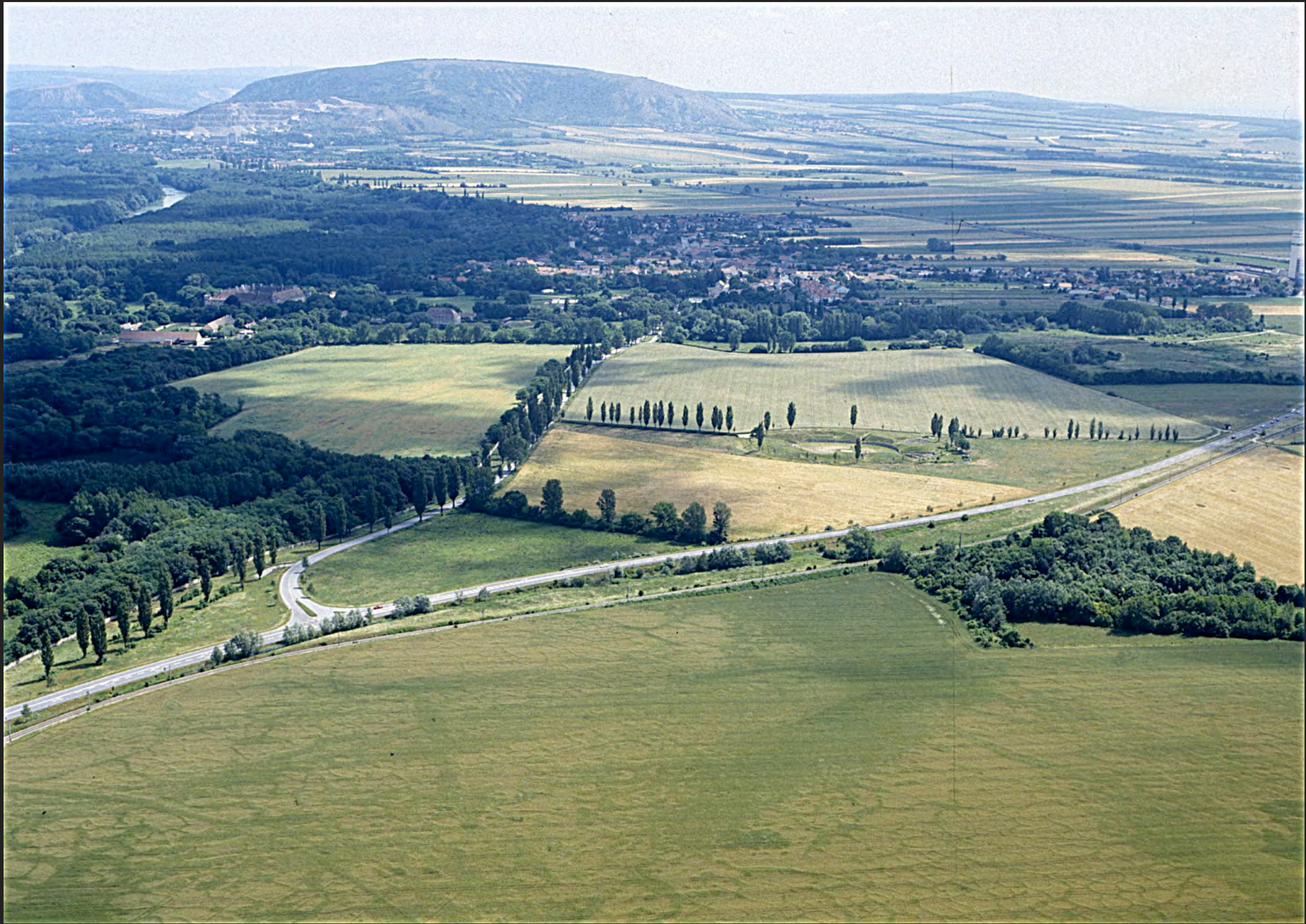


Fig 13. 2 Aerial photograph of the area of Carnuntum from the west

The civil town and civil amphitheatre II are in the foreground. Hundsheimer Berg and the stone quarry of Bad Deutsch Altenburg can be seen in the background.
Luftbildarchiv; Rel.No: 13088/37-1.4/01

The site of Carnuntum

The archaeological landscape of Carnuntum is located 45 km east of Vienna, close to the Slovakian border where the Danube cuts through the foothills of the Carpathian mountains in the east, its gravel terraces forming a flat to slightly hilly terrain. The subsoil is formed by river terraces covered by a chernozem. Carnuntum, the Roman capital of the province of Pannonia, was an important town during the first four centuries AD. The archaeological remains cover an area of approximately 1900 hectares within the modern communities of Bad Deutsch Altenburg and Petronell (Fig 13.2).

The site of Carnuntum (*Jobst 1983*) was divided in antiquity into two major parts: the military camp with the surrounding settlements (*canabae legionis*); and the so called 'civil town', raised to the status of a municipium by Hadrian (117-138 AD). In the military camp Septimius Severus was proclaimed Caesar on 9 April 193 AD. Thus the town received a new impetus and became Colonia Septimia Aurelia Antoniniana Karnuntum, capital of Pannonia. The heart of the town was fortified by a massive wall, 2 m thick. Together with the suburban settlements south and west of the town wall the total extent of the civil settlement may have reached as much as 300 hectares.

During the nineteenth century Carnuntum was known as the 'Pompeii at the doors of Vienna' because of the fine preservation of the Roman ruins. Since then, however, the situation has changed drastically. Both aerial photography and geophysical data show that the archaeological remains have suffered severe damage through agricultural use and organised looting in the past few decades. Many fields have been subjected to deep ploughing, often financed by looters and treasure hunters, and there has been large scale destruction of the ancient structures. A stone quarry has destroyed the mountain of the Pfaffenberg, along with the Roman sanctuary on its peak. The economic and housing development of the modern villages, located within the archaeological zone, poses another threat to the cultural heritage. At the same time agricultural erosion slices away centimetre after centimetre of the archaeological layers. This constant destruction cannot be fully prevented, so cultural resource management will have to concentrate on preserving the most important parts.

In order to support preservation an appropriate prospection strategy had to be established so that the archaeological remains can be recorded before they completely vanish. Therefore, in 1997 the decision was taken to create a map of the ancient city, based on aerial photographs, as a first step in a systematic prospection of the archaeological landscape of Carnuntum. Aerial photographs from the past fifty years are now being used to create a highly detailed map of the archaeological features. The preparation of this map is an ongoing internal joint project between the Institute for Prehistory of the University of Vienna and the Vienna Institute for Archaeological Science (VIAS).

In addition a case study funded by the Austrian Ministry of Science and Traffic was launched to develop a standardised combination of geophysical archaeological prospection methods (aerial archaeology, magnetics, resistivity **mapping** and GPR) so as to create a highly detailed interpretation model of particular archaeological monuments. As a study area for this part of the project a large building complex was selected in the civil town of Carnuntum. This had been detected some time before through resistivity **mapping** and could be interpreted as the town's forum, sought for over a hundred years (Fig 13.1, just left of centre). The ongoing conduct of the research project is funded by the Austrian Ministry of Science and the Department for Cultural Affairs of the County of Lower Austria. The project also encompasses the standardisation of GPR surveys for archaeological applications, with targeted surveys of the forum (Neubauer et alii 2002), parts of the civil town and the surroundings of the ceremonial arch known as the 'Heidentor'.

Aerial reconnaissance

The first aerial photographs taken over the area of Carnuntum date back to the 1930s when E. Swoboda, a former member of the flying corps during the World War I, used his contacts in the military to obtain aerial photographs of the area. Today the project's aerial archive contains several hundred photographs, both vertical and oblique, of the Carnuntum area (*Doneus 1996*). Vertical photographs have been taken by the Austrian Air Force, operating out of Langenlebarn. The collection includes vertical coverage of Carnuntum from various years and seasons, providing an excellent overview of the area's archaeology. The photographs include both black-and-white and infra-red false-colour material, taken with a Zeiss RMK. The scales range from 1:8000 to 1:15,000. Oblique air photographs are taken by ourselves, using high-wing aircraft (Cessna 150 or 172) and calibrated medium-format cameras (Hasselblad) with black-and-white as well as colour slide films.

A third category of data comes from an earlier project. Two decades ago, between 1978 and 1984, a project was set up to rectify aerial photographs from the area of Carnuntum. The idea was to create a city map at the scale of 1:2000. It was a joint project between the Austrian Archaeological Institute and the Institute for **Photogrammetry** and Remote Sensing of the Technical University of Vienna and can be seen as a predecessor of the present project. Unfortunately, this work was not continued, but the resulting orthophotographs, covering parts of the canabae and the military camp, are still available and will be incorporated into our own work.

In addition to the aerial photographs various kinds of maps are available. Most important are the cadastral maps of the modern villages of Petronell and Bad Deutsch Altenburg, at scales of 1:2000 and 1:1000, along with geological and pedological maps and plans from the last hundred years of archaeological excavation, the most useful being those of the Roman military camp, the two amphitheatres, the grand baths and parts of the civil town (*Jobst 1983*). Because of the differing data sources it was decided to use analytical and digital **photogrammetry** methods both to create a digital terrain model and to rectify the aerial photographs. The interpretation is carried out within a GIS, in which the orthophotographs can be combined with other data sources such as geophysical prospection results, excavation maps and older orthophotographs.

Rectification of the aerial photographs

The first step is to obtain a DTM for later use in the rectification of the aerial photographs. So as to allow rectification of oblique as well as **vertical air photographs** within an acceptable error tolerance the DTM has to be a fairly accurate representation of Carnuntum´s topography. From the former mapping project there was available a block of forty-six vertical photographs, covering the whole area. The block was created in 1976 at a scale of approximately 1:5000 by the Bundesamt für Eich- und Vermessungswesen, on behalf of the Institute for **Photogrammetry** and Remote Sensing of the Technical University of Vienna. The orientation work, by aerotriangulation, was also carried out by the Institute. The stereomodels were set up on the project's analytical plotter using the initial values of the aerotriangulation. The average model accuracy is approximately 0.30 m in plan and 0.25 m in height. Additionally, several other vertical stereopairs were oriented. In this case, ground control was obtained by field measurements using a tachymeter. A DTM was created from the vertical stereopairs, covering more than 2000 hectares through 127,000 measured points.

For digital rectification of the air photographs the images are scanned at a high resolution (12-15 m pixel-size). Control-point information is obtained either from field measurements using total station survey or from the oriented stereopairs. The orientation of the aerial photographs is either calculated using space resection (for single images) or a bundle adjustment. This is done digitally using Softplotter™ and ERDAS Imagine Orthobase. Depending on the camera used, the scale and the distribution and the quality of the ground **control points**, the resulting accuracy lies between 0.25 and 0.75 m. Each image is rectified using the outer orientation values and the digital terrain model. The resulting georeferenced orthophotographs usually have a pixel-size of 0.2 m and are ready to be used in any GIS.

Geophysical prospection in the civil town

The first geophysical surveys in Carnuntum were undertaken in 1990 in response to building activities and expansion of the modern settlements. All of the early surveys, done by Archeo Prospections, had to solve distinct problems on a small scale. During the late summer of 1996 a first large scale prospection campaign in the civil town was carried out during a two week long student training exercise on resistivity surveying, mapping an area of 5 hectares. The survey was located 280 m west of the excavated *insulae* and 80 m south of the grand baths in the

‘Tiergarten’ of Traun castle. These investigations, in a hitherto unexplored part of the town centre, resulted in the detection of the *forum*. This was the stimulus for specific research projects and further large-scale surveys in the area of the civil town, covering up to the time of writing about 100 hectares. The work was carried out by Archeo Prospections and the Central Institute for Meteorology and Geodynamics, in cooperation with the Vienna Institute for Archaeological Science (VIAS).

Magnetic, resistivity and GPR surveys are the most successful geophysical prospection techniques for archaeological purposes. Resistivity mapping using RM15 and GPR is far more time-consuming than large-scale high-resolution magnetic surveying using multisensor caesium gradiometers. These instruments are therefore normally applied only in detailed **target** areas. Magnetic prospection is the preferred method on extensive urban and suburban areas, complemented by targeted resistivity and/or GPR surveys to enhance the information, particularly in respect of features characterised by stony deposits. Magnetometry, carried out in a standard grid of 0.125 x 0.5 m, recovers such things as ditches, pits, ovens, brickwork and wooden palisades very clearly and is able to cover more than 3 hectares per day under good field conditions. But the stone walls of Roman buildings are usually only resolved in moderate detail, often being obscured by large anomalies, representing deposits of brick and tile inside and around the buildings. Additional survey by resistivity or GPR can highlight walls, floors or other stony features. For prospection of the inner structure of a Roman town large-scale resistivity or GPR surveying may be of primary use. But a combination with magnetics adds important information on such things as pits, ditches, wooden structures, robber-trenches and walls of bricks or tiles from the roofs.

In 1996 resistivity data combined with information gained from aerial photography gave an insight into an area of about 5 hectares of the Roman town. In the resistogram of the investigated building complex the symmetrical layout of the forum stands out clearly against the surrounding built-up district with its complicated street pattern. The resistivity measurements have been complemented by a magnetic survey. The combination of the two types of data and their archaeological interpretation resulted in a first interpretation model (*Neubauer, Eder-Hinterleitner 1997*), used as primary input for the present case study. The aim of the subsequent GPR survey was to gain higher spatial resolution and depth-related information to help in the creation of a three-dimensional interpretation model.

GPR is an advanced method of prospection, with high potential in archaeological applications. The adaptation of a commercially available PulseEKKO 1000 GPR device for archaeological applications and the determination of adequate measuring parameters were achieved through test measurements. The experience showed that the measuring distances used in previous studies are not appropriate for the examination of complex archaeological questions. Line spacing – as for other methods used in archaeological prospection – must not be greater than 0.5 m and conventional visualisations of single vertical sections are difficult to read and understand. Therefore only a small part of the information inherent in the measured data has been used so far for interpretation.

The archaeological interpretation of GPR data is thus made difficult or even impossible. The negative feedback from archaeologists, based mainly on the lack of relevant interpretation, has hindered the application of this potentially most informative and non-destructive method of prospection. In order to use GPR in archaeological interpretation processes a standardised method of data representation and visualisation had to be developed, following the established procedures of geomagnetic and resistivity mapping. Tests on commercial software showed no convincing results, so adequate software had to be developed, producing time- or depth- slices as digital images in horizontal plane or any vertical direction by computing a three-dimensional data block of the GPR amplitude distribution (Fig 13.3). Animation of such image sequences makes mental recognition of archaeological structures by the interpreter easier. Digital image sequences found via selection of relevant horizontal depth-slices are now georeferenced and integrated into the GIS for subsequent detailed, depth-correlated, archaeological interpretation.

Archaeological interpretation of the survey data

Archaeological interpretation is carried out using GIS. To allow the orthophotos, geophysical images and vectors to be overlain on one another they have to be set up in a uniform coordinate system, a prerequisite that is already fulfilled in the project's data. The interpretation drawings derived from GPR data, in combination with the available resistivity and magnetic data as well as information from aerial photography, lead to a detailed archaeological interpretation model. Two-dimensional interpretation maps and three-dimensional interpretation models can be derived from this basis.The orthophotos from aerial archaeology are enhanced using digital image processing techniques such as contrast enhancement, Wallis-filter and crispening to make the archaeological features more clearly visible. All of the georeferenced orthophotos and their filtered versions are then compiled in the GIS viewer.

The interpretation is done image by image on-screen in separate layers, using different colours and attributes for different kinds of features. Since every image shows the area in different conditions and consequently in different detail, the composite interpretation drawing acts as a summary of the information visible on all of the available photographs.

Aerial photographs showing archaeological features in an area of 270 hectares have been mapped. Although only about 10 percent of the available photos have been rectified and interpreted the composite map already shows a considerable degree of detail. In the *canabae* around the military camp it has proved possible to reconstruct the whole of the road network, parts of it displaying side-drains. Between the roads more than a hundred buildings can be identified. West of the camp parts of the *forum* are visible. The main road to the west is lined by graves and tombs (Fig 13.4). Further west the ditches of the auxiliary camp, where the cavalry was situated, have also been mapped. The camp has already been partly destroyed by the expanding village of Petronell. The second area, west of the village, shows a **complex** of buildings belonging to civil amphitheatre II, along with a large graveyard, the two partly intersecting one another and therefore clearly not contemporary. The civil town of Carnuntum, protected by its massive wall and two parallel ditches, is currently used for pasture and as a result archaeological features can only be seen from the air in very dry summers. In most of the photographs only the road network is visible (Fig 13.5).

Greater detail can be seen in the results of the geophysical prospection. A large building **complex** was explored in this case study (Fig 13.6). It has a symmetrical layout covering an area of over 3000 m^2, with a wall thickness of up to 1.5 m. It forms the southern end of the *forum* of Carnunutum. The northern part of the building complex could be reached from the lower open square of the forum by a monumental set of steps. The complex includes three large halls, each with a floor area of about 150 m^2 and one of them with an *apsis*. The corresponding room to the east is equipped with a hypocaust, showing that it was heated and probably served as the *curia*, the meeting hall of the city council. The central hall shows a pedestal or platform in front of the rear wall. In the southern part small rooms, some constructed with cellars, are flanked by corridors. These were reached by two sets of steps and a *porticus* from a triangular open space to the south. The halls lining the *forum*, each with a *porticus*, presumably housed shops, with cellars below. Beneath the floor level of the building two channels or drains were traced, leading to the river Danube. Information was also documented on the depth of the foundations, the filling layers and the plastering, as well as the height of the remaining walls, the positions of wall-debris and the depth reached by the modern plough.

A full description of the mapped features would be inappropriate here (but see *NEUBAUER, EDER-HINTERLEITNER 1997A* and *NEUBAUER ET ALII 1998*). The authors hope, however, that this brief summary gives an impression of the great variety of structures detected and the high degree of detail possible through the application of these combined techniques of prospection, mapping and interpretation.

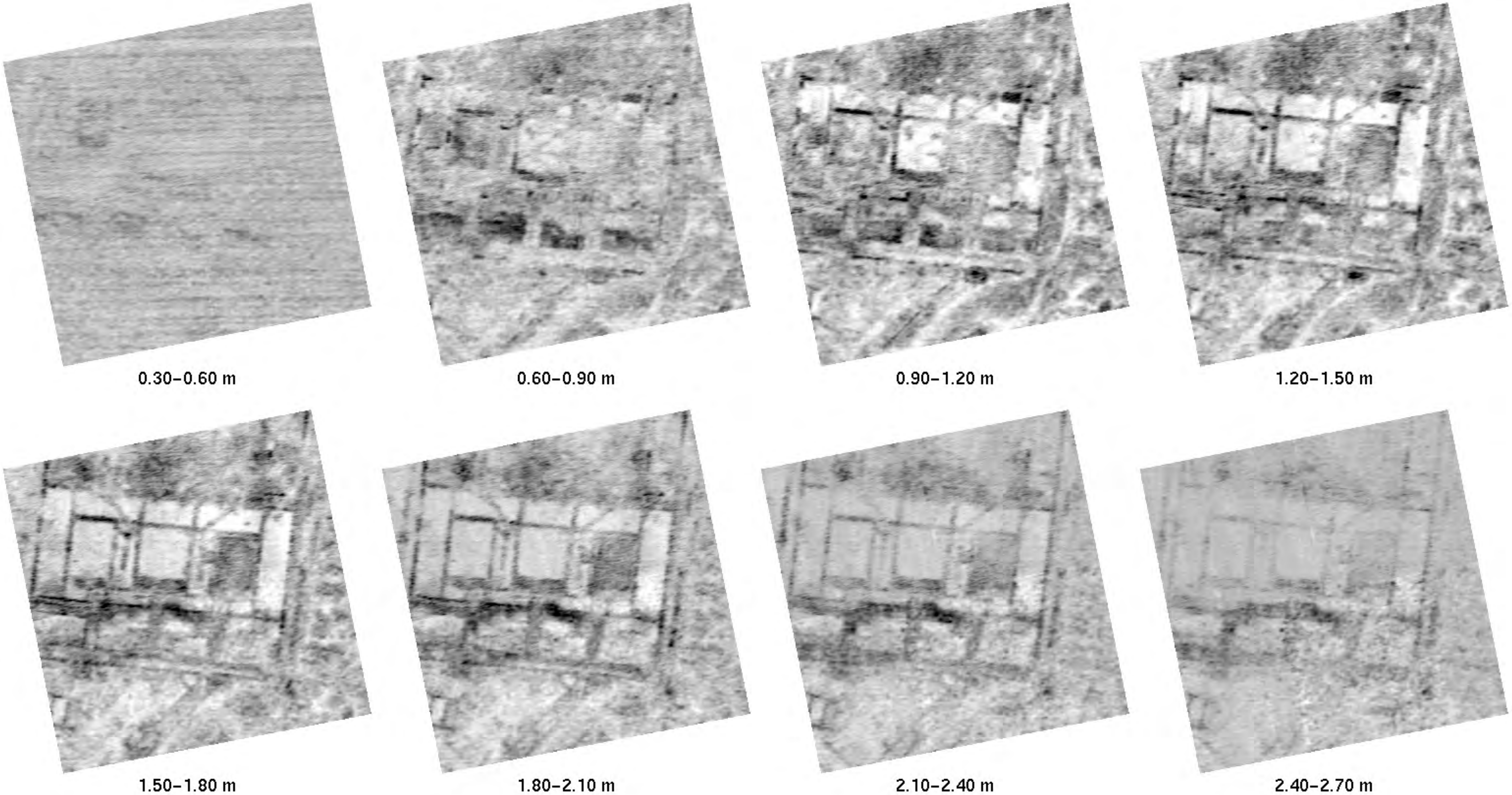


Fig 13. 3 GPR depth-slices through the southern part of the forum

Fig 13. 4 Aerial archaeological interpretation

The area around the legionary camp.

Fig 13. 5 Aerial archaeological interpretation

The area of the civil town of Carnuntum.

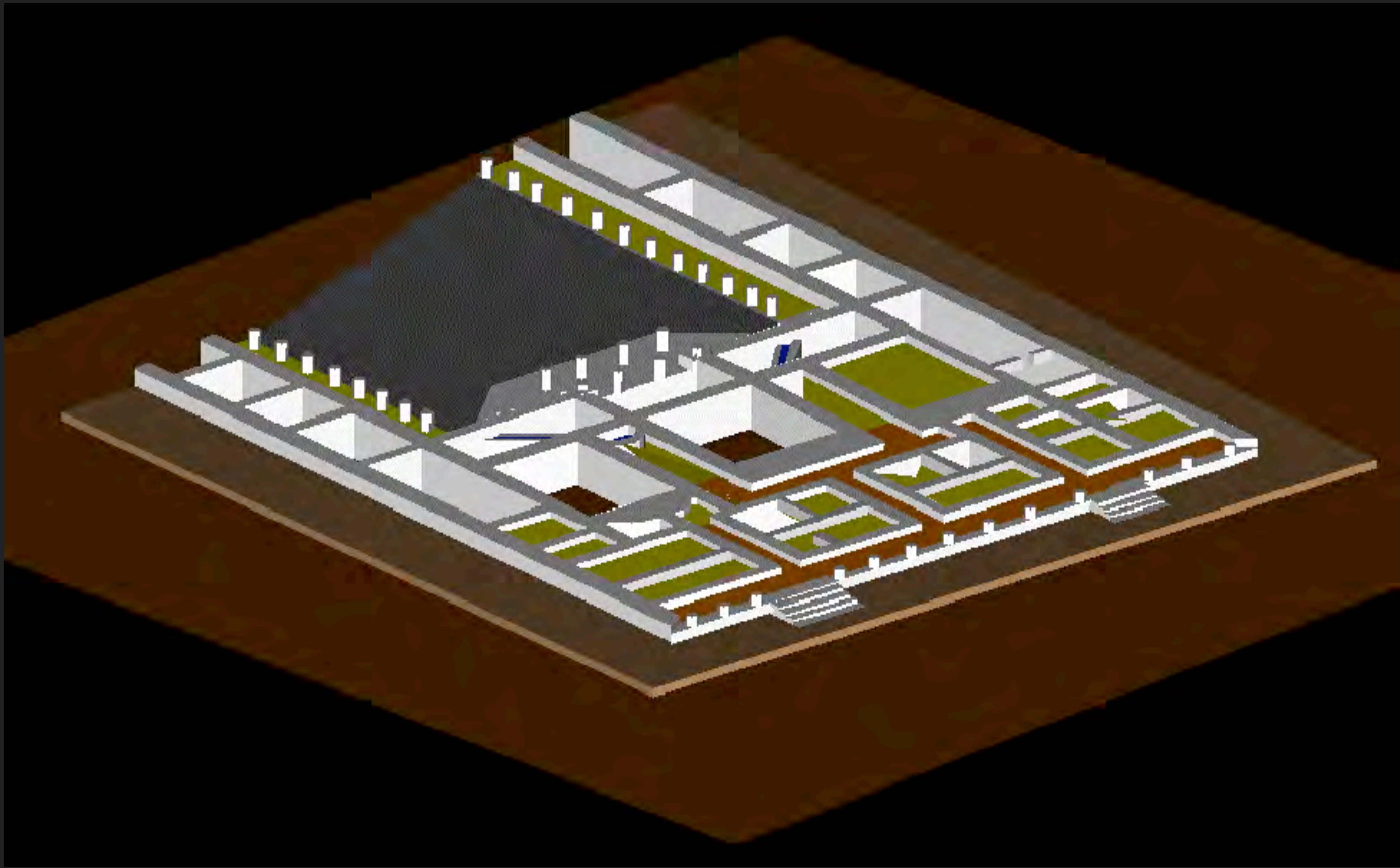


Fig 13. 6 **Three-dimensional interpretation of the GPR data for the forum**

Conclusions and future prospects

This case study can be regarded as a prime example of combined archaeological-geophysical prospection. The available aerial photographs are complemented by extensive non-destructive magnetic, electric and electromagnetic measurements. The resulting images can be combined with supplementary information. Thus quick and economical insights can be gained into the archaeological monuments by digital image combination. Combined interpretation of data with a reading distance of 0.5 m or less, along with digital orthophotos at a similar resolution, provide an accurate basis for conservation and development planning and represent an economical means of documenting the archaeological monuments. The choice of specially adapted measuring devices and measuring parameters can make this information even more precise through the addition of GPR data, providing depth-information. The developed interpretation techniques allow the incorporation of GPR data into the standardised GIS-based interpretation process used for other types of archaeological prospection data. Based on GPR and other available geophysical data a detailed three-dimensional interpretation model of individual archaeological monuments can be derived.

Experience from methods of evaluation and interpretation developed during this case study gives the opportunity to plan a specific strategy for the wide-scale prospection of Carnuntum. There is clearly an urgent need for this from the scientific point of view, and for development planning. Such prospection could make an enormous contribution to the formulation of cost-effective conservation strategies through combined and focused action for this largest of archaeological zones in Austria. Further work will concentrate on integration of the remaining aerial photographs and combination of the results with geophysical prospection. It is planned to apply geophysical prospection methods to the survey of 550 hectares of the urban and suburban central area of Carnuntum. Flying and air photography will continue over this most magnificent of Austria's **archaeological landscapes**. Even after fifty years of aerial survey new features are still to be found, both in the centre and in the surrounding area, each adding a new piece to the puzzle. After more than a hundred years of archaeological investigation involving a patchwork of excavations, we can now hope to summarise all the available information so as to produce the first comprehensive map of the ancient city of Carnuntum.

14. DIGITAL AIRBORNE REMOTE SENSING: LIDAR

Colin Shell

Introduction

This contribution is reproduced exactly as written towards the end of 2004. It provides a good general introduction to the use of lidar imagery in archaeological and landscape studies. For more recent contributions among the rapidly growing literature on the subject see CRUTCHLEY–CROW 2009, DONEUS–BRIESE 2011 *and* SHAW–CORNS 2011.

Aerial photography has revealed, and over widening national horizons continues to reveal, the wealth of archaeological evidence that is the fundamental resource for our understanding of cultural landscapes through time. **Site**s ranging from small indeterminate groups of **feature**s to large settlements with associated field systems are not only being discovered but are also being placed in their landscape context; and their spatial inter-relationships can also be explored. The methodology of aerial photography is well established and the underlying reasons for the appearance of sites through cropmark and **soilmark** evidence is well understood (*Wilson 1982*, *2000*; *Scollar et alii 1990*).

Aerial archaeology is but one application of Earth Observation science. An ever-increasing range of instrumentation is being deployed to observe the geo-environment from platforms that range from low altitude small unmanned aerial vehicles to orbiting satellites. Some of the instruments are capable of providing data of distinct archaeological value. The devices may passively record reflected visible and non-visible solar radiation in specific spectral bands able to show vegetational stress, soil moisture variation etc through which archaeological sites can be identified. Alternatively, instruments may actively investigate the Earth's surface through techniques such as microwave radar, which is sensitive to moisture levels in both plants and the soil. Radar's ability at longer wavelengths (23.5 cm L band of the Shuttle Imaging Radar) to penetrate dry sand cover to reveal the underlying late quaternary landscape of desert regions is a well known and dramatic example of the discoveries that can be made (*Lillesand–Kiefer 2000*, fig 8.27).

Throughout the remote sensing industry there is an ongoing drive to improve sensing devices in both their sensitivity and image resolution. The standard text-books on remote sensing, such as that by Lillesand and Kiefer (2000), appear in new editions with increasing regularity. Some of the new sensing techniques are now employed for archaeology, and for aerial photography itself digital technology is beginning to replace film recording. The papers presented at the NATO research workshop on Aerial Archaeology at Leszno in Poland in 2002 placed some of these developments in their context at that time (*Holden et alii 2002*; *Shell 2002*; *Bewley–Rączcowski 2002*). The principal purpose of this paper, which builds on a presentation given at the Aerial Archaeology Workshop at Siena in June 2001, is to show how these techniques, then in their initial stages of archaeological use, are by the time of this book's publication in 2005 becoming established tools, and particularly to examine the application of airborne laser scanning instrumentation (lidar – light detection and ranging) as a tool for both detecting archaeological sites and digitally exploring their location in the landscape.

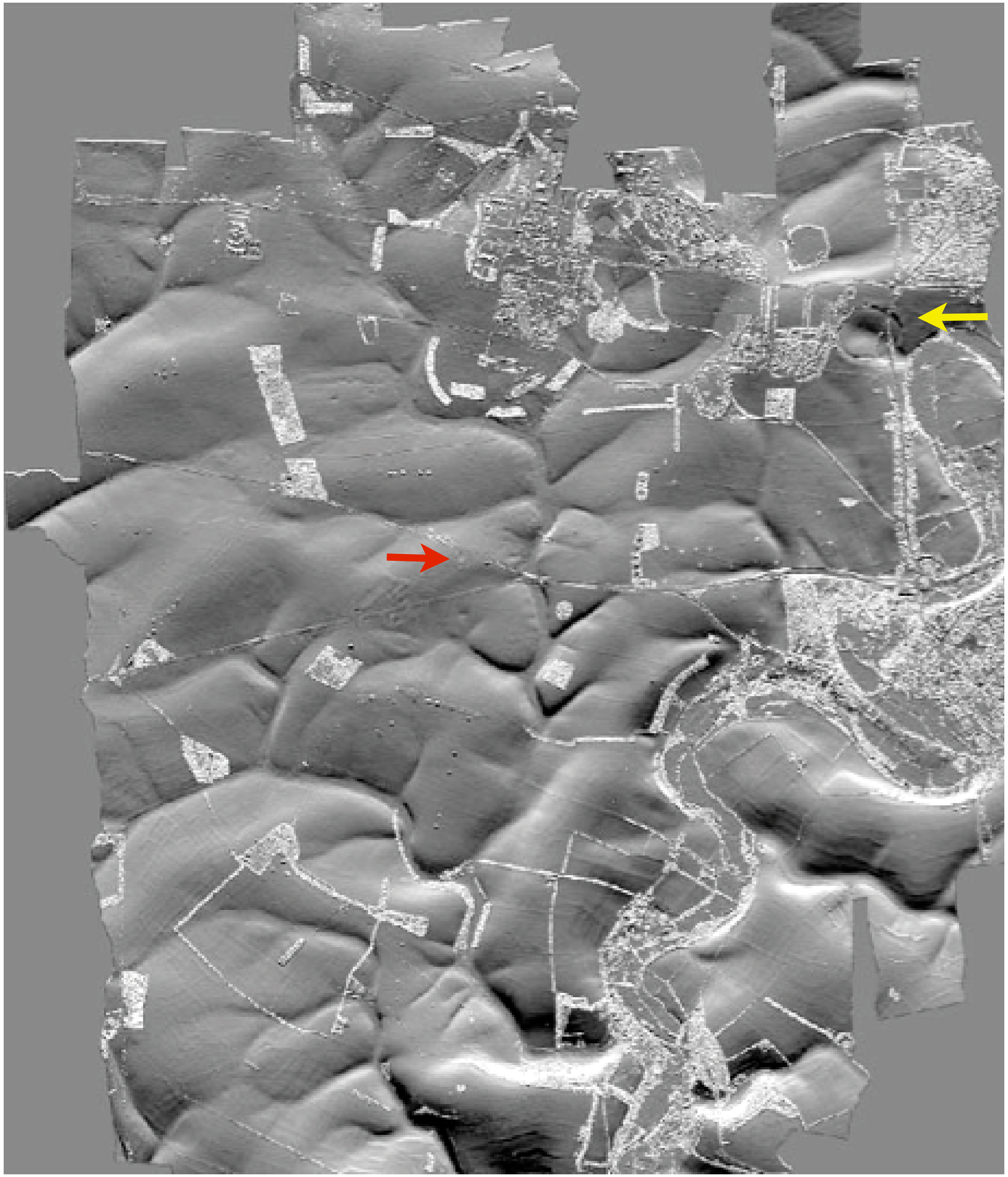


Fig 14. 1 Lidar survey of the Stonehenge World Heritage Site, UK

The lidar survey (digital surface model, including trees and buildings) is here relief-shaded from the north. Stonehenge itself lies near the centre of the frame (red arrow). Durrington Walls, the other great Neolithic enclosure referred to in the text, is at top right (yellow arrow). The Figure covers an area approximately 6.8 km x 7.7 km.

Digital imagery

Digital imaging is replacing film-based recording in the public photographic market, and is also now an alternative to film-based photography for aerial mapping with large-format survey cameras. The images from the new digital survey cameras can be readily used with photogrammetric software to construct high-resolution digital surface models for combination with a continuous image mosaic that is exactly georeferenced to the relevant national survey coordinate system. The High Resolution Stereo Camera (HRSC) originally designed by the German Aerospace Centre (Deutsches Zentrum für Luft- und Raumfahrt, or DLR) for the survey of Mars showed its potential for earth survey in its initial airborne trials (Jaumann–Neukum 1996), and confirmed it in the collection by the airborne version (HRSC-AX) of 3D data to estimate the severity of the Oder river flood of August 1997. The camera is of the push-broom type with four spectral bands, red, green, blue and near infra-red, and panchromatic vertical and stereo recording. The image is built up from successive across-track records of the ground on linear CCD arrays as the aircraft flies its survey path. The instantaneous look direction of the camera is calculated from the record made by an inertial measurement unit (IMU) of the camera's attitude and the high-accuracy GPS positioning of the aircraft itself. The HRSC-AX is now employed for commercial survey by ISTAR in France, and Leica Geosystems has developed its ADS40 digital survey camera with the DLR from the HRSC design principles.

The alternative approach to digital imaging by employing rectangular-area pixel arrays in large-format survey cameras is limited by the size of arrays currently available. Z/I Imaging and Vexcel have developed respectively their Digital Mapping Camera and the UltraCam by using multiple lens-array combinations. The images from these are merged electronically to create a large-format single image of centimetric ground resolution. The recording CCDs in all these cameras have high dynamic range and their manufacturers suggest that part of their high cost is offset by avoiding the need to process and scan traditional film output. Technical details and image specifications for these digital survey cameras and other devices referred to in this paper can be found at the manufacturers' websites, which are readily accessible through internet search engines.

Much early space imagery, such as that from the Landsat series of satellites, achieved a ground pixel sizes of the order of 30 m or greater. The Landsat 4 and 5 Thematic Mapper (TM) sensor had a multispectral capability at 30 m ground resolution including spectral bands in the near and mid infra-red (*Lillesand–Kiefer 2000*, p. 379). This level of resolution is capable of detecting large archaeological features and sites, but is equally of value for defining the large-area setting of sites. Declassified 1960s United States CORONA intelligence satellite photography, and the more recent Russian KVR-1000 photographic satellite (Fowler–Curtis 1995), with its approximately 1.5 m ground resolution, approached the resolution of aerial photography. The deployment of the very high resolution IKONOS and Quickbird satellites with a ground pixel sizes respectively of 0.6 m and 0.8-2.0 m in panchromatic mode, and four times greater multispectral ground sampling distance (GSD), has further closed the gap between digital space imaging and aerial survey photography. Whilst the coverage from these satellites is not extensive, and is discontinuous, the extensive moderate-resolution (5 m GSD) coverage of the Indian Remote Sensing IRS-1C/1D satellite is being used by EuroMap GmbH to create country-wide natural colour ortho-mosaic photomaps – so far for Germany, Switzerland and Austria, and, at the time of writing, in preparation for Italy. Similar national coverage is available for Britain from aerial photographic campaigns by Getmapping and UK Perspectives at 1 m or better GSD. Although flown to provide a national photomap this, like other commercial aerial photography, may record by chance archaeological sites visible as **soilmarks** and **cropmarks**.

Digital Terrain Models

All imagery can be better employed for studying the landscape context of sites if combined with a digital terrain model (DTM) of comparable resolution. This may have been derived from traditional aerial **photogrammetry**, as in a recent project to examine the location of the megalithic monuments in the Carnac, Morbihan, landscape in France (*Roughley–Shell 2004*; *Roughley 2004*). Digital terrain models can also be generated by **photogrammetry** from suitable satellite imagery, such as the downward- and backward-looking sensors of the Japanese ASTER instrument on the NASA Terra satellite. This can provide a digital elevation model with height accuracy of 13 m RMSE from its 15 m GSD stereo imagery (*Cuartero et alii 2004*). Alternatively, interferometric synthetic aperture radar (InSAR or IFSAR) measurements (*Lillesand–Kiefer 2002*, pp. 687-91) can be used to directly measure the Earth's topography from the phase difference of a returning radar signal detected at two or more receiving aerials. The Shuttle Radar Topography Mission (SRTM) of February 2000 measured with C-band InSAR the height of most of the Earth's land surface every 30 m between ± 60º latitude, with a vertical accuracy at best in the region of 16m, and relative accuracy in the region of 6m (*Rabus et alii 2003*). Three arc second (~ 90 m) interval SRTM data is freely available from the USGS EROS Data Center for the world; 1 arc second (30 m) data is available for the United States and its dependencies. This is an enormous resource for studying the distribution of sites in their large-scale landscape context.

By deploying InSAR in an aircraft, the increased proximity to the ground, just as for digital imaging devices, improves the ground sampling distance and accuracy by up to an order of magnitude. As an example, the InSAR mapping of England and Wales in Intermap Technologies' NextMap project, has measured at 5 m GSD the ground height with a 0.5-1.0 m accuracy. The close interval of the readings allows surface features such as buildings and trees to be recognised and filtered from the data, converting a Digital Surface Model (DSM) to a Digital Terrain Model (DTM) defining the ground surface itself. Primarily commissioned for flood modelling, the NextMap continuous terrain model of England and Wales is a major resource for visualising the topographic location of archaeological sites. The NextMap data has been merged with Getmapping 2 m colour aerial photography to create 3D Photoscape, a product which provides, on a county by county basis, the ability to interactively fly across the digital landscape and explore landscape settings. Although for commercial reasons limited in its functionality to displaying just the aerial photographic cover over the terrain model, the software is an inexpensive pointer to the future way in which the general public as well as archaeologists will be able to access and explore these types of datasets.

High-resolution airborne digital sensors: imagery and terrain modelling

In addition to the gradual development of very high resolution airborne sensors for imaging at centimetric GSD, airborne laser scanning (commonly referred to as 'lidar') has rapidly established itself as a powerful alternative to **photogrammetry** for terrain modelling, with its capability of measuring routinely the height of the earth's surface at sampling intervals from 0.5 m to 2.0 m to an absolute positional accuracy in x,y, and z of 0.15 m, with the data exactly georeferenced to the universal GPS satellite (WGS84/ETRS89) or the relevant national coordinate system. High-resolution airborne imaging, including in the non-visible range, is capable of not only discovering sites, but also defining detail within them (*Shell 2002*). Similarly, at 1.0m or smaller GSD, lidar detects the fine changes in relief that are the vestigial surface expression of an archaeological site, even after extensive degradation from the plough.

The UK Environment Agency (*Holden et alii 2002*) is able to simultaneously measure and image the ground by flying its Optech ALTM 3033 lidar in combination with a multispectral Compact Airborne Spectrographic Imager (CASI 3). The University of Cambridge Unit for Landscape Modelling can fly its Optech ALTM 3033 lidar with either a Zeiss LMK15 aerial survey camera or two Thales Optronic 8010 wide-band sensors in a filtered spectral mode for image acquisition. Whilst it is of value to have combined image and topographic data, the optimum conditions for archaeological survey may differ. Lidar is able best to penetrate deciduous tree cover in a leafless state, and similarly measure ground height when there is minimal vegetation cover. Winter is an appropriate time for detecting soilmarks in arable fields, but airborne imaging sensors more readily detect sites during the periods of cropmark formation.

High-resolution airborne sensing

Apart from a direct, visible, colour difference due to the material from the buried site being brought to the surface by the plough, soilmarks may be visible through differential drying or temperature variation that reflects local soil-moisture variation and the associated difference in thermal capacity (Scollar et alii 1990; Shell 2002). The soil moisture and thermal capacity combination can also affect the first appearance of cropmarks in a winter-sown cereal, with the higher soil moisture and temperature assisting germination and initial growth. In the later stages of growth the plant's response to stress, as measured in its varying spectral reflectance of sunlight (Figs 14.2, 14.3), is due either to a direct relationship with the leaf moisture content or its effect on the leaf's physiology. The reflectance in the short-wave (mid) infra-red range (1.3-2.5 µm) is largely governed by the leaf moisture content itself (Ripple 1986), whereas its affect is indirect in the visible (0.4-0.7 µm) and near infra red (0.7-1.3 µm). The red light reflectance is increased by a reduction of chlorophyll levels as the moisture stress increases, and the increased near-infra-red reflectance results from stress-induced changes in the leaf's cellular structure. Fig 14.4 shows the contribution of the enhanced near-infra-red reflectivity of a winter wheat crop in defining the narrow ditch structure of a Neolithic long barrow (burial mound). There was no visible cropmark in the field at the time. The image was obtained with a Thales Optronics 8010 wide-band push-broom electron-optical sensor in panchromatic mode, with a GDS in the region of 3 cm.

A plant's ability to respond to the heating effect of sunlight is also directly related to its access to water, which it uses to control its temperature by evapotranspiration. With increased drying of the soil, a plant will eventually show signs of wilting and an accompanying colour change. Thermal sensors can directly measure plant temperature differences associated with varying water content (Soil Moisture Deficit, SMD) of soils across an archaeological site. Fig 14.5, in an image synchronous with Fig 14.4, shows the lower temperature (darker grey) of the winter wheat growing over the deeper humic soil of the ditch enclosing the Swaffham Prior long barrow; it also shows details of a nearby linear pit-alignment. The Thales Vigil thermal linescan has a temperature sensitivity of better than 0.16 ºC equivalent temperature, and 20cm GSD when flying at 300m altitude (*Shell 2002*).

In thermal imaging, the plant is effectively sampling the moisture regime to the depth to which its roots have grown. The rooting system of a cereal such as wheat can penetrate to depths greater than a metre, depending on the soil moisture availability at the time it is developing. In contrast, grass in grazed pasture may have root systems that are confined to 30 cm of topsoil. The left-hand part of Fig 14.6 shows a thermal linescan image of a pair of curved hollow ways (sunken trackways) in permanent pasture at the Wandlebury **hillfort**, south of Cambridge, in eastern England. The corresponding geophysical survey (Fig 14.6, right), undertaken with a fluxgate gradiometer (*Gaffney–Gater 2003*), similarly defines the hollow ways but additionally shows the higher magnetic response of several deep Iron Age pits. These pits are not apparent in the thermal image, probably because of the limited sampling depth of the grass. A calculation based on the local early summer rainfall record shows that the thermal detection of the hollow ways is occurring at an SMD that

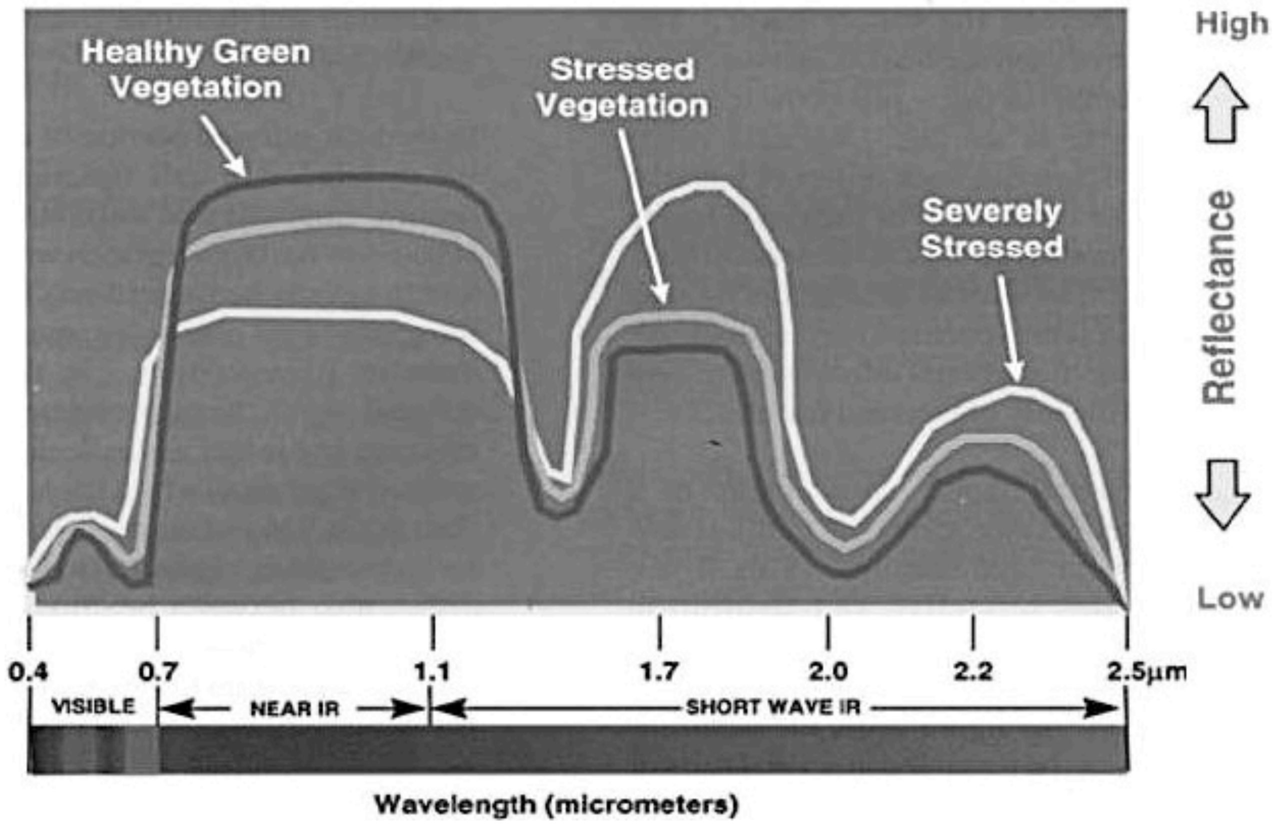


Fig 14. 2 Typical spectral response characteristics of green vegetation

(after Hoffer)

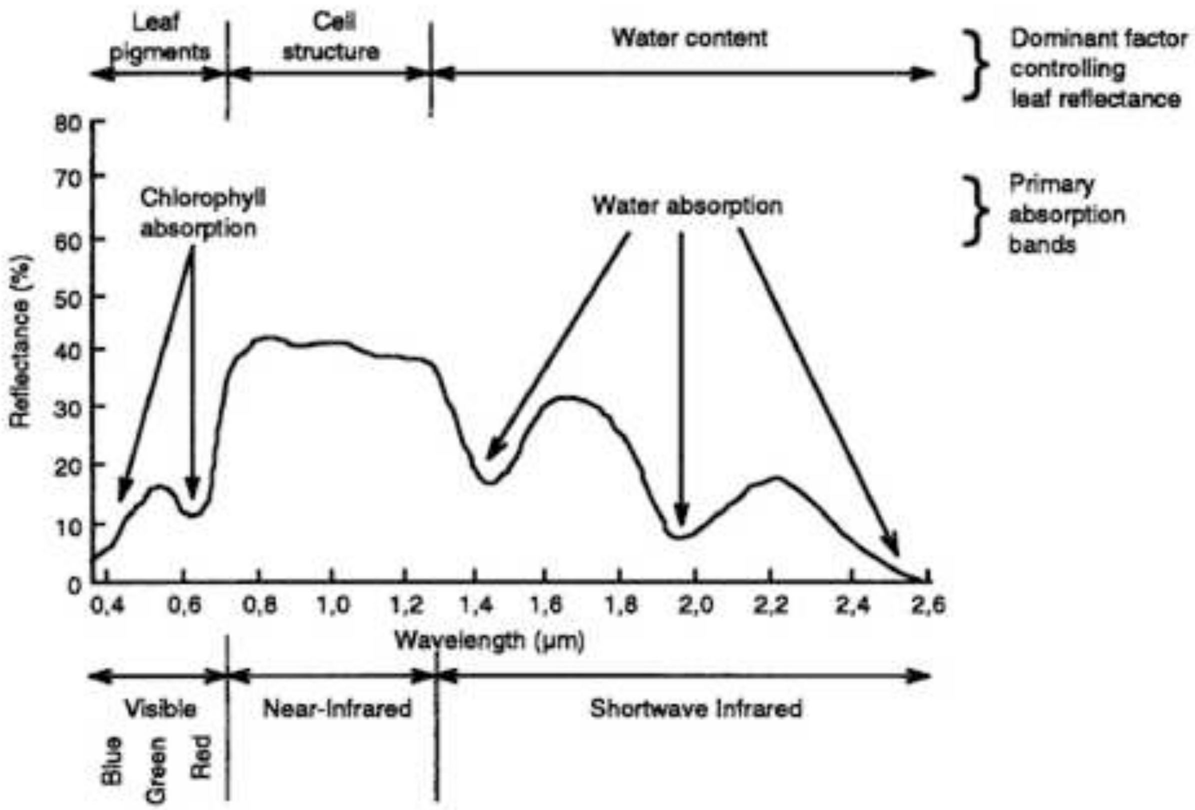


Fig 14. 3 Change in plant spectral reflectance caused by increasing stress

(after NOAA)

Fig 14. 4 Digital image of Neolithic long barrow, Swaffham Prior, Cambridgeshire, UK

From Thales Optronic 8010 sensor in wide-band (0.4–1.2 µm) panchromatic mode (after Shell 2002).

Fig 14. 5 Digital thermal image of Neolithic long barrow, Swaffham Prior, Cambridgeshire, UK

Image obtained with a Thales Optronic Vigil thermal infrared linescan (after Shell 2002). Note the linear pit-alignment to the left.

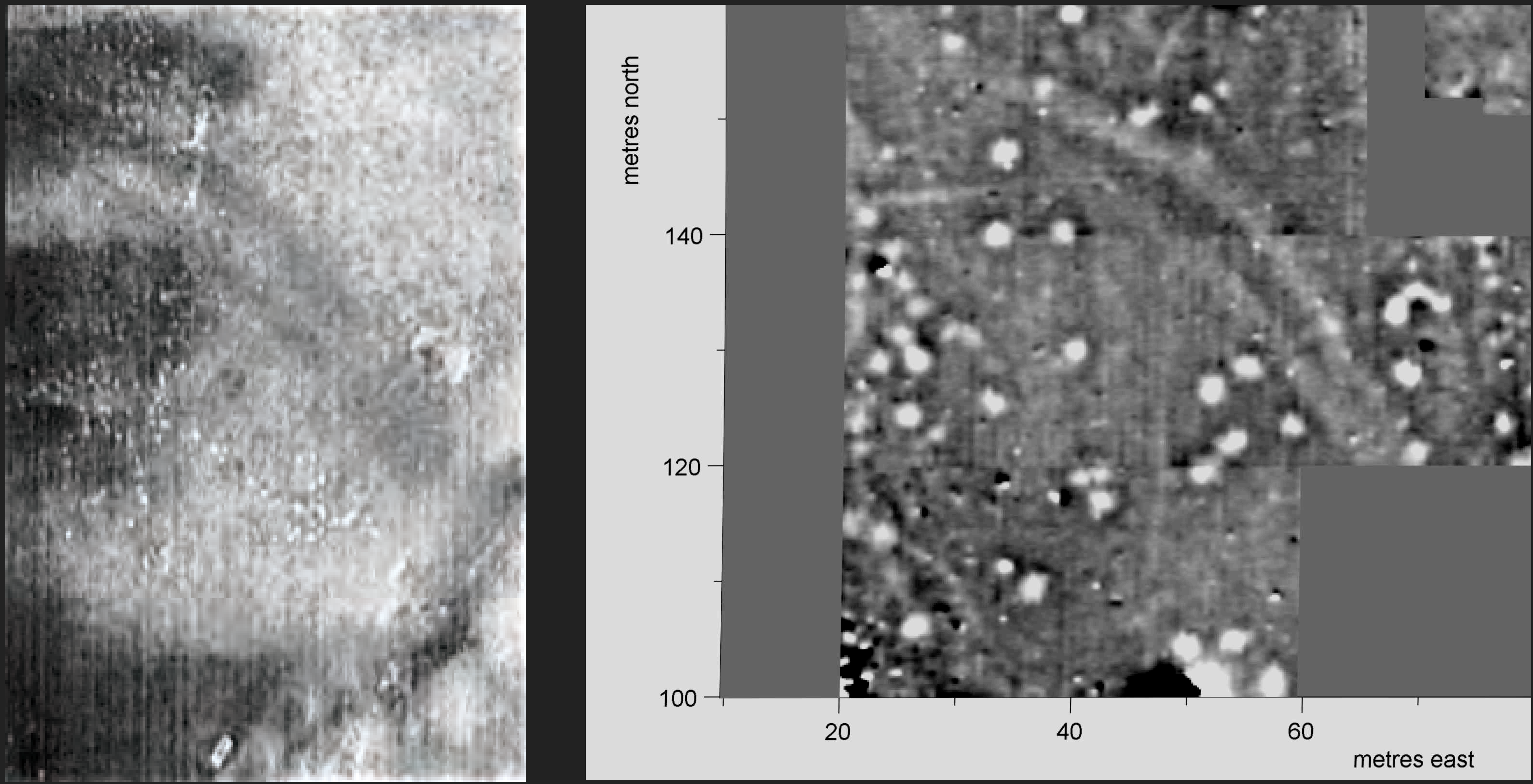


Fig 14. 6 Contrasting images of hollow way, Wandlebury hillfort, Cambridgeshire, UK

Left. Thermal image from infrared linescan sensor (Crown Copyright).
Right. Fluxgate gradiometer survey of the corresponding area.

is at least 20% lower than that required for visible parching of the grass (*Evans–Jones 1977*). From this we can see that thermal imaging may be much more successful in detecting sites in regions where the SMD rarely reaches the level necessary for grass parch marks to form.

The CASI 3 multispectral scanner can image the ground in up to 288 wavelength bands, subdividing the visible and near infra-red regions of the spectrum between 0.43 µm and 0.90 µm. In practice 15-20 bands are used, and these can be selected to monitor the wavelengths most sensitive to plant-growth conditions. The best attainable GSD is in the region of 1m, with a swath width of 500 m. In this it corresponds closely to airborne lidar's ground sampling interval. A GSD of 1 m is not adequate for defining the finer features of sites, but may readily show the strong contrast between bare soil and vegetation that is useful in monitoring erosion and animal damage.

High-resolution airborne terrain modelling with lidar

Airborne lidar is one of the most important innovations in airborne sensing in recent years and its value for archaeology can be immediately recognised. The technique is a development of the optical distance measurement that has been in common use in ground survey with total-station instruments for over twenty years. The distance to an object is calculated from a very accurate measurement of the time taken for a pulse of laser light to reach the target and be reflected back. In airborne lidar the laser beam is scanned from side to side as the aircraft flies a pre-planned pattern over the survey area, measuring between 20,000 and 100,000 points per second. The scan angle is restricted to 10 to 15 degrees to minimise obscuration of the ground by closely-spaced buildings and trees. Typically, with the aircraft flying at 1000 m altitude and 120 knots (62 m/sec) ground speed, a scan angle of 12 degrees with 40 scans per second and 33.333 measurements per second will measure the distance to the ground every 0.8 to 1.0 m, with a positional accuracy in x, y and z in the region of 15 cm.

The laser beam is about 25 cm in diameter and may encounter buildings, or a branch or leaves of a tree as well as the ground below it (Fig 14.7). The lidar records the first and last pulse measurements and the intensity of the reflected beam. This builds up a very accurate, very high-resolution digital surface model of the ground and the features upon it. The surveyed swath is about 450 m wide, and is flown with a 20-25% side overlap to avoid loss of data from the continuous changes in the aircraft's attitude in flight. A small number of cross-swaths is flown to assist in the matching of adjacent swaths in the post-processing.

The aircraft's position in the air and the changes in its attitude must be known with the highest possible accuracy in order to calculate the position of each laser-measured point. For this, the lidar system has a very accurate dual-frequency global positioning system (GPS) recording the aircraft's position every second and an inertial measurement unit (IMU) recording the aircraft's roll, pitch, yaw and heading up to 200 times per second (Fig 14.8). The position of the aircraft is determined by reference to a GPS ground station located for best accuracy within 20 km of the survey, recording the same GPS satellite constellation as the aircraft. The position of the ground station must be known to a high accuracy; ideally it is located on a pre-surveyed GPS reference point of the national survey grid. Otherwise the reference position must be determined with a high-precision static GPS survey (Holden et alii 2002). It is only in these best circumstances that the absolute accuracy of the measured points is in the region of 15 cm. The relative accuracy of adjacent readings is higher. The first and last pulses coincide when the ground surface is measured, but may be separated where trees are encountered (Fig 14.9).

The lidar data can be retained as the original point measurements, from which can be created a triangular irregular network (TIN) surface model, often used with 3D visualisation software. Alternatively the data can be converted to a regular grid of a specific spacing with interpolation of missing data where it may occur. In grid form the digital surface model is more readily integrated with other vector data and raster imagery in GIS and Remote Sensing software. The UK Environment Agency supplies its data in 2 x 2 km Ordnance Survey National Grid squares. There is no standardised procedure for gridding lidar data, and it must be remembered that height errors of up to 1m may be introduced by some types of gridding procedure (*Smith et alii 2004*). Many existing lidar datasets have been recorded at a 2 m average GSD, which is sufficient resolution for flood hazard modelling, but does not reveal details of archaeological features as clearly as 1m interval data, which should be preferred. Higher-resolution, 0.5 m, GSD data is capable of revealing further fine detail, such as relict cultivation marks in modern pasture (*Shell–Roughley 2004*).

The most direct way of viewing the lidar data is to represent the height by either colour coding, or by use of a continuous grey scale. Fig 14.10 is a height-shaded lidar DSM of the Stonehenge World Heritage Site (WHS) from a survey undertaken to investigate lidar as a tool for augmenting existing aerial techniques (*Bewley et alii 2005*). The height-shading of the 1 m GSD data clearly shows the Avon river valley and the related dry-valley system of the surrounding landscape, with higher ground to the north. Areas of woodland and the cuttings and embankment of the A303 road to the east of Stonehenge are visible but lack detail.

It is self-evident from aerial photography that details of low **earthworks** are greatly enhanced by low oblique sunlight. The advantage with lidar data is that the digital surface model can be relief-shaded with a digital sun from any direction (azimuth) and elevation, including from the north, and the image contrast can be adjusted as required. Relief-shading reveals the depth of fine detail of the topography recorded by the lidar (Fig 14.1). The major monuments are made visible, including Durrington Walls Neolithic henge monument (ceremonial **enclosure**), as well as the Early Bronze Age barrow cemeteries and extensive field systems in the modern arable fields in the west of the survey area. Lidar detects the slight surviving surface evidence of features, even where they are greatly reduced by the plough. Fig 14.11 illustrates this, where a complete field system to the west of the Lake barrow cemetery is seen to survive as broad slight **earthworks** that measure only 30-40 cm in height.

The lidar survey of the Stonehenge WHS has identified several new features in a landscape already extensively surveyed, including through a detailed transcription of the aerial photographic record as part of the English Heritage Programme (*Bewley 2003*; *Bewley et alii 2005*). As well as detecting surviving field systems in arable fields, lidar is equally able to reveal relict field boundaries in pasture, even where the land has been improved. From a study of the Loughcrew landscape, Co Meath, Ireland, (*Shell–Roughley 2004*), Fig 14.12 shows **enclosure**s and ancient field boundaries in pasture improved by stone-removal and ploughing. A length of over 150 km of field boundaries has been transcribed from the 5 x 6 km lidar survey area.

Modern features such as field boundaries, buildings and woodland are included in the lidar digital surface model. These may be removed from the data to create a digital terrain model, a model of the ground surface itself, which may more readily represent the landscape in which the monuments were originally constructed, and facilitate the study of the potential visual inter-relationships between the sites. Much of the woodland in the Stonehenge WHS has been planted in the last 200 years, in some cases to screen new buildings so that they cannot be seen from Stonehenge. The woodland itself may contain surviving archaeological earthworks. Where there are sufficient lidar last-pulse measurements reaching the ground surface, a reasonable digital terrain model can be generated by filtering from the data the higher elevations that are the reflections from the trees. This has revealed, for example, field boundary banks and the line of a former military railway in Fargo Plantation, in the Stonehenge WHS (Fig 14.13). The boundaries form part of a field system now known to incorporate part of the western end of the long Neolithic monument known as the Stonehenge Cursus (*Bewley et alii 2005*).

Lidar and landscape research

Software for GIS and Remote Sensing has a number of capabilities that can enhance our exploration of lidar data. An example of this is the calculation of a ‘viewshed’ from a particular point in the digital landscape that shows which areas are visible from that point, and which are not. A viewshed calculated from the centre of Stonehenge using the digital terrain model with trees and buildings removed (as well as the stones of the monument), shows us the extent of the landscape from which the monument can be seen when unhindered by trees (Fig 14.14). From this it is apparent that the view from Stonehenge along the ritual Avenue in the direction of mid-summer sunrise reaches 2.75 km to a point on Durrington Down that is just 500 m from the western entrance to the great enclosure at Durrington Walls. Without the intervening trees and buildings, at midsummer any observer from here would see Stonehenge being lit up by the sun rising at their backs. Similarly, the topographic positioning of monuments such as Neolithic long barrows (elongated burial mounds) can be investigated by plotting their location on the relief-shaded lidar image (Fig 14.15). The locational information has been augmented by 1m interval raster contours generated from the lidar DTM and with it we can see how the seven Neolithic long barrows grouped together in the western part of the WHS occupy very specific locations on the forward slopes of ridges around the western arm of the dry-valley system.

Computer visualisation of the digital landscape can be used interactively to study monument locations and their spatial inter-relationships, especially if the lidar terrain model is draped with informative imagery such as that from CASI or aerial photography, or vector information from the local Sites and Monuments Record. Fig 14.16 shows a section of the Loughcrew Project's O.5 m GSD lidar model, draped with the orthorectified mosaic of 0.20 m GSD vertical aerial photography that has been georeferenced to the Irish national survey grid. The view shows the landscape southward to the Slieve na Calliagh hills, upon which are located the Neolithic passage-tombs at Loughcrew (*Shell–Roughley 2004*). Whilst visualisation has an important research role, it also can present the immediacy of the landscape to the general public, both for education and as a tool in the processes of planning and landscape management.

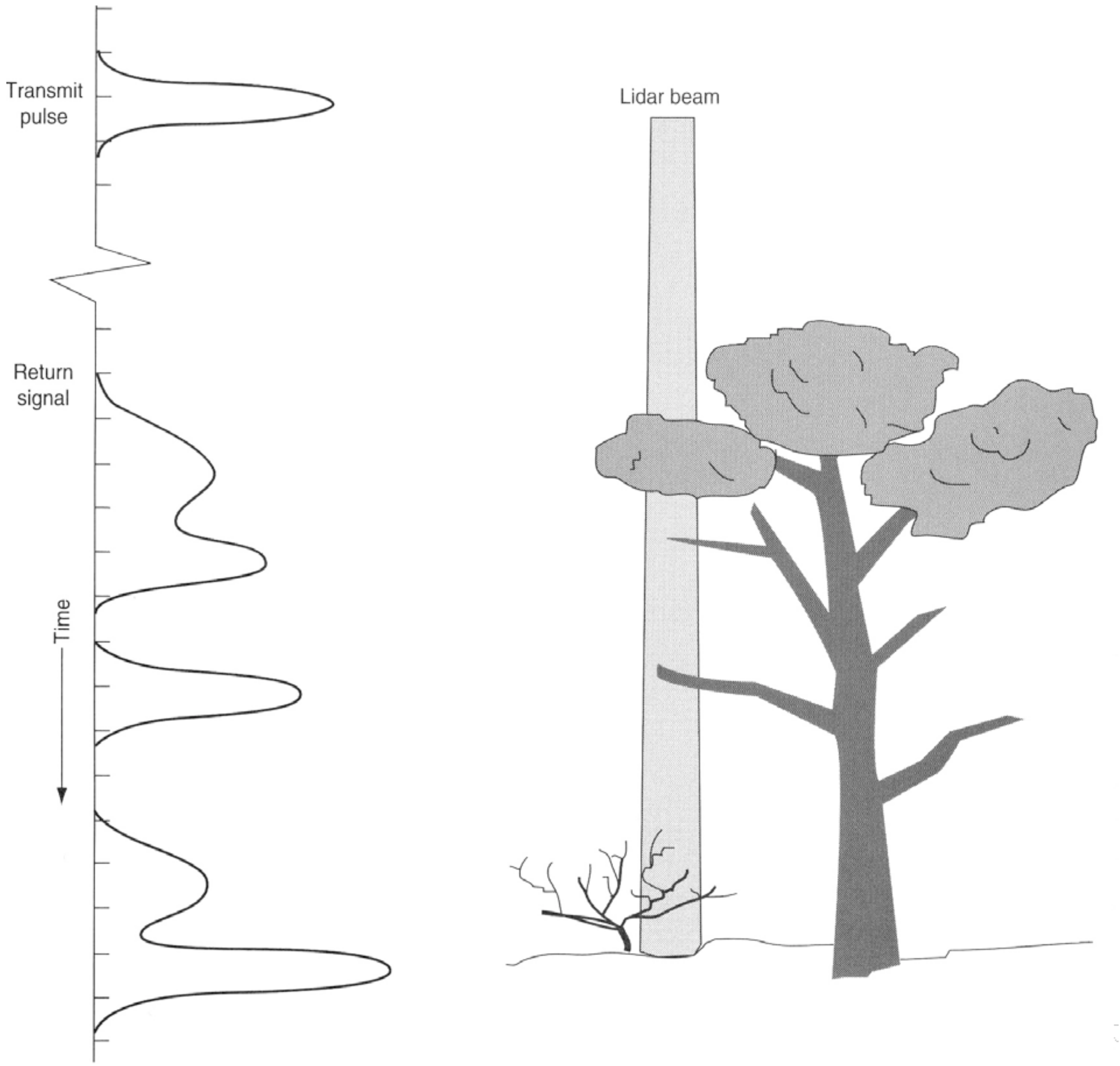


Fig 14. 7 Diagram of lidar first and last return pulse generation

The first return will produce a digital surface model (DSM) including the tops of buildings and woodland. The last return can be height-filtered to create a digital terrain model (DTM) from points that correspond to the actual ground surface.

Both diagrams after Lillesand and Kiefer.

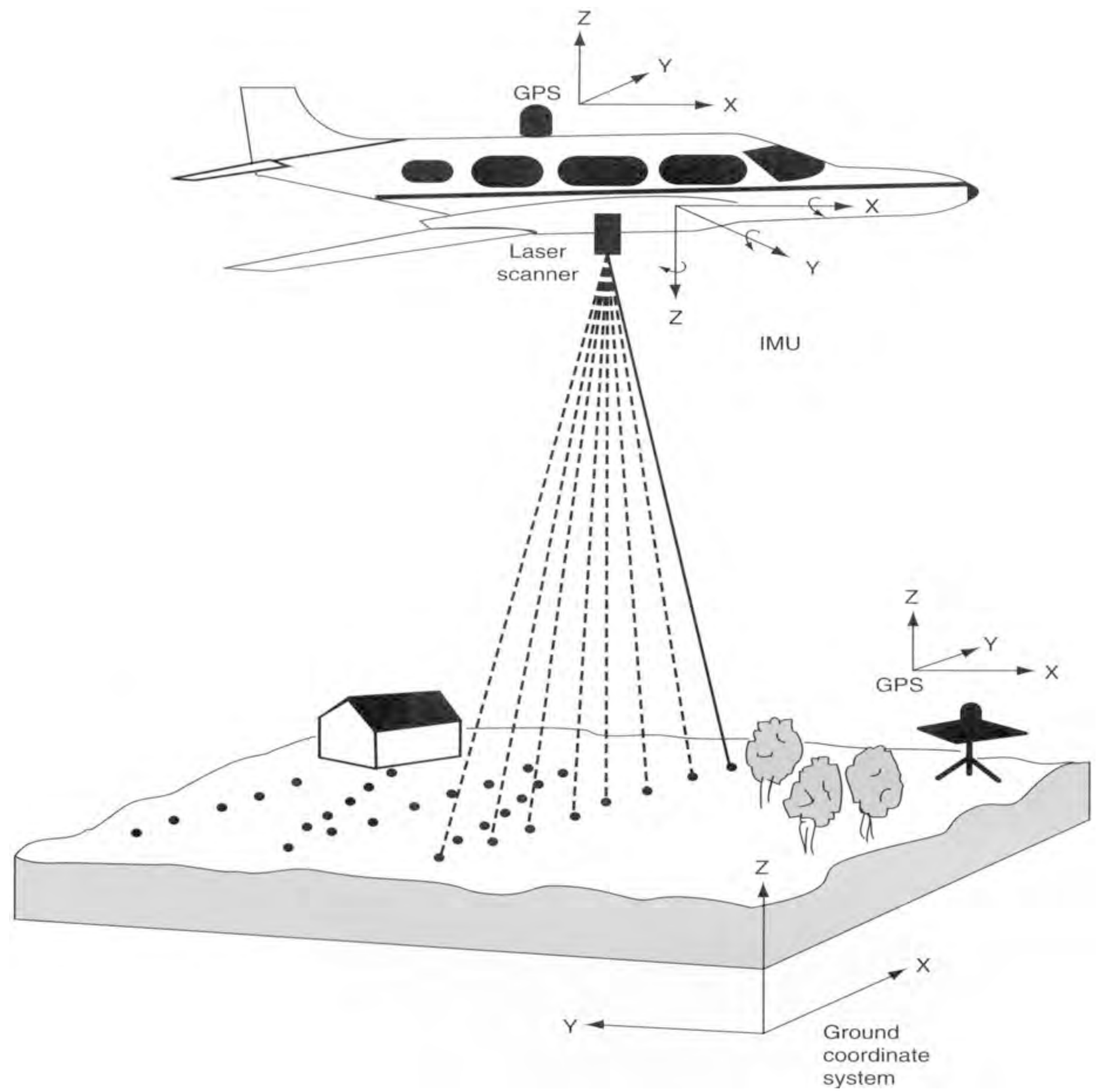


Fig 14. 8 Survey framework for determining the position of measured lidar points

The critical instruments are the aircraft's GPS, the ground-based GPS reference station recording the same array of satellites, and the inertial measurement unit (IMU), which records continuously the orientation of the laser scanner as the aircraft changes attitude in flight.

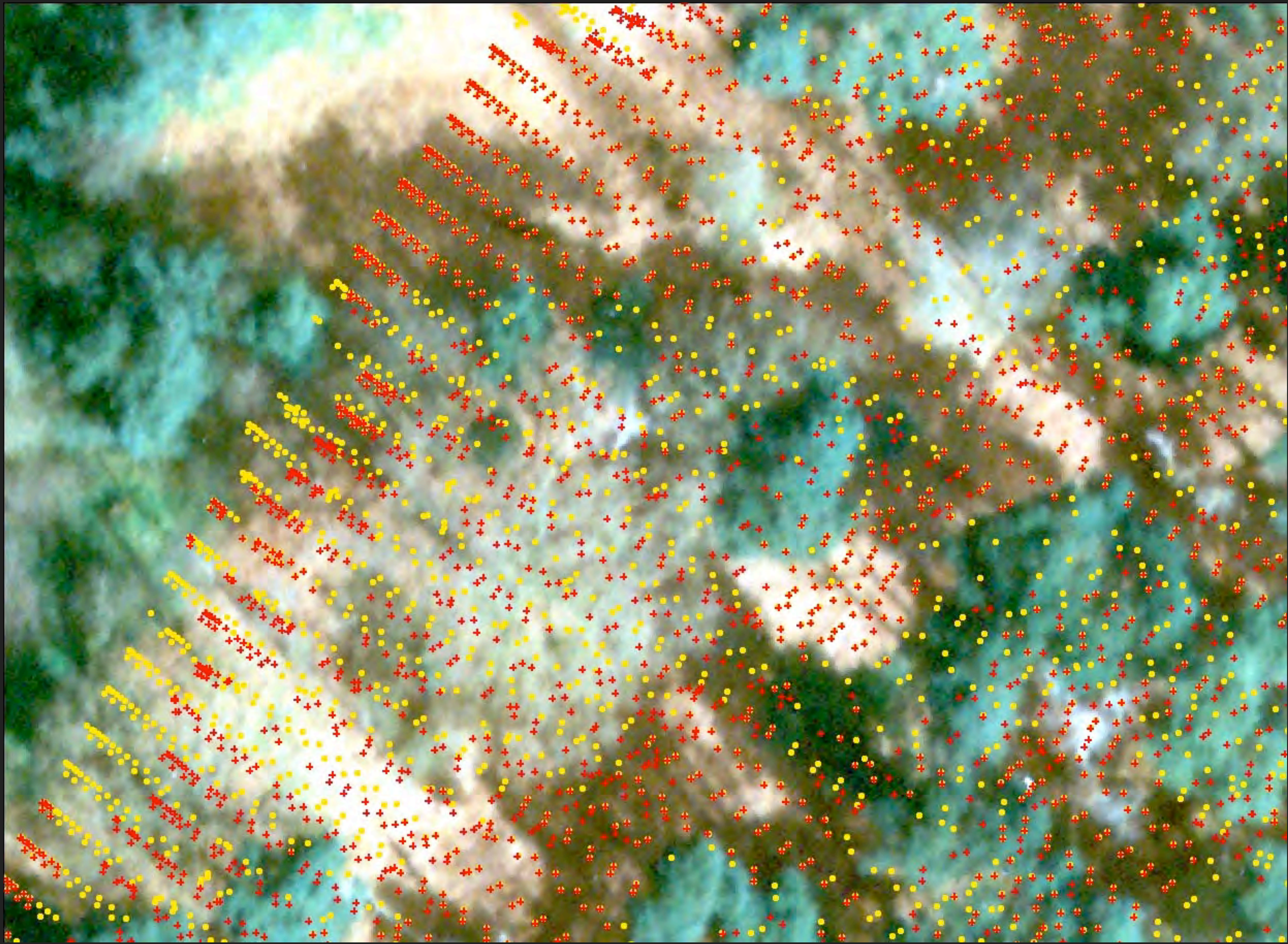


Fig 14. 9 Lidar imagery over woodland

Plot of the first (red cross) and last (yellow dot) return positions in a lidar survey over woodland. Note the curved edge of the survey area at top left, caused by the changing attitude of the aircraft. The background is the georeferenced image

Fig 14. 10 Height-shaded lidar survey of the Stonehenge World Heritage Site, UK

See also Fig 14.1.

Fig 14. 11 Ancient field system, Stonehenge World Heritage Site, UK

Relief-shaded lidar survey. The small rectangular fields, at upper left, are currently under arable cultivation. They lie to the west of the mounds of the Lake barrow cemetery, clearly visible in and adjacent to the wooded area at top right.

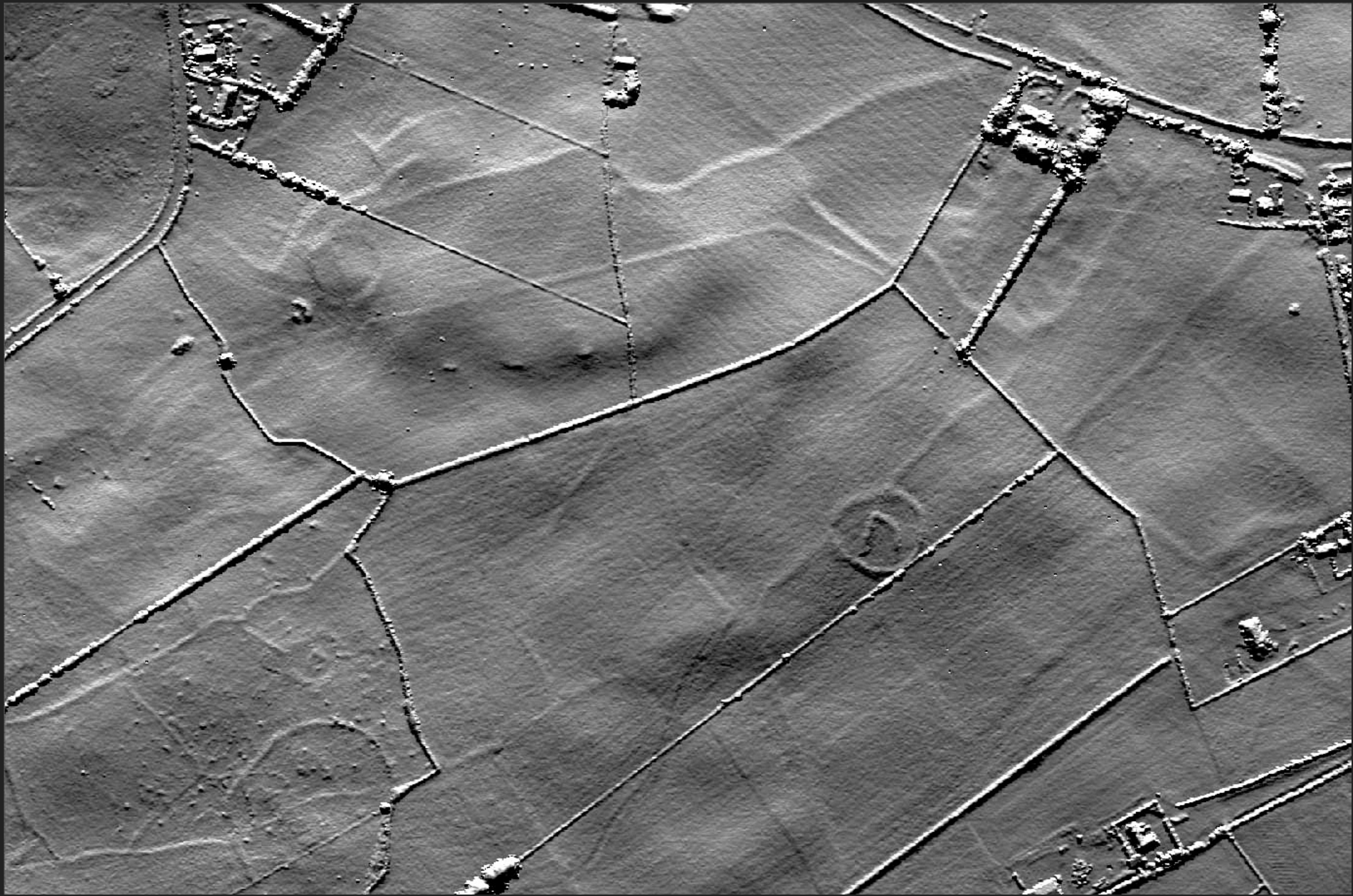


Fig 14. 12 Landscape below the Loughcrew passage tombs, County Meath, Ireland

Relief-shaded lidar image of enclosures and field boundaries in ‘improved’ pasture (grassland subject to stone removal and periodic ploughing). Note the better preservation of the earthworks in the legally-protected un-ploughed area at lower left.

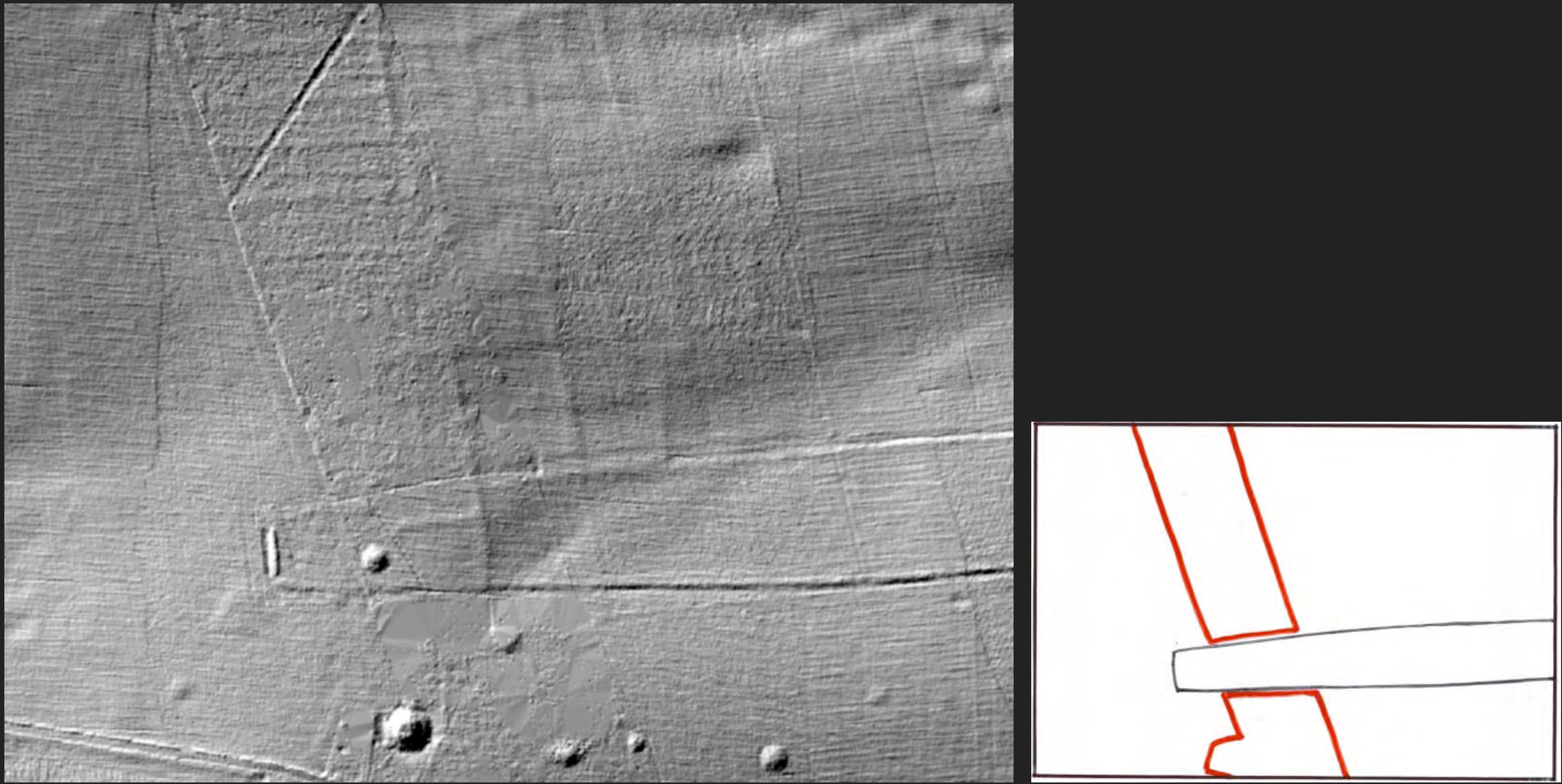


Fig 14. 13 Relief-shaded digital terrain model, Stonehenge World Heritage Site, UK

Shaded from the northwest, showing ancient field banks and the course of a recent military railway (top left) in Fargo Plantation, as seen when trees (inset diagram, red) are removed from the lidar dataset. Across the lower part of the image can be seen the earthworks of the Stonehenge cursus monument and Early Bronze Age burial mounds. The vertical line near the left of the frame and the fine horizontal banding in the image are artefacts of the lidar data and are not archaeological features.

Lidar survey and remote sensing in planning and management

Both the relief-shaded lidar image of the Loughcrew landscape and the Stonehenge WHS digital visualisation are able to convey immediately to the viewer the presence and distribution of surviving archaeological remains. Through this the potential impact of a proposed development or change in agricultural regime can be better understood. Realistic models of proposed developments can be incorporated into such visualisations so that the public can assess and comment on their impact. Similarly, forestry managers can evaluate the impact of future woodland planting proposals.

Agriculture has been identified as the single greatest threat to the survival of England's most valuable sites (*Trow 2003*). Under new conservation-oriented agricultural support schemes farmers may be rewarded for preserving archaeological sites and taking out of cultivation such areas as the early field system in the Stonehenge World Heritage Site, where field boundaries can be seen from the lidar data to survive despite years of ploughing (Fig 14.11). Investigations have also been carried out in the use of combined CASI imagery and lidar for managing the archaeological monuments in the Salisbury Plain military training area immediately to the north of the Stonehenge WHS (*Barnes 2003*). The training area requires the monitoring of both the historic and natural environment in its integrated management plan, seeking evidence of changes in bare ground, excessive grazing and disturbance by both military and animal digging.

The United Kingdom Highways Agency's currently proposed road-improvement scheme for the Stonehenge area includes placing the A303 road in a tunnel south of Stonehenge and in a long cutting to the west, inside the boundary of the World Heritage Site. The new tunnel and cuttings were modelled within the Stonehenge lidar DSM (Fig 14.17) to study the impact of the scheme on the setting of the monuments in the western part of the World Heritage Site. At the Public Inquiry into the scheme it was possible to demonstrate that a supposed beneficial effect of the scheme on the setting of the Early Bronze Age burial mound known as the Bush Barrow, in the Normanton Down cemetery, was predicated on the long-term maintenance of woodland that blocks the view between Bush Barrow and the cemetery at the Winterborne Stoke Crossroads to the west. Removal of this woodland would not only re-establish the visual relationship between the two cemeteries, but would also bring into sight a significant section of the proposed western road-cutting if built as planned (Fig 14.18).

Fig 14. 14 Viewshed plot within the Stonehenge World Heritage Site, UK

Plot of the viewshed calculated from a height of 1.5m above the centre of Stonehenge (yellow circle, bottom left). Trees, buildings and stones of the monument itself have been removed. The viewshed marks in green the areas that are not visible from Stonehenge. Displayed over the relief-shaded digital surface model and overlain with the vector data from the Wiltshire County Sites and Monuments Record (yellow). The huge Neolithic enclosure of Durrington Walls lies at top right.

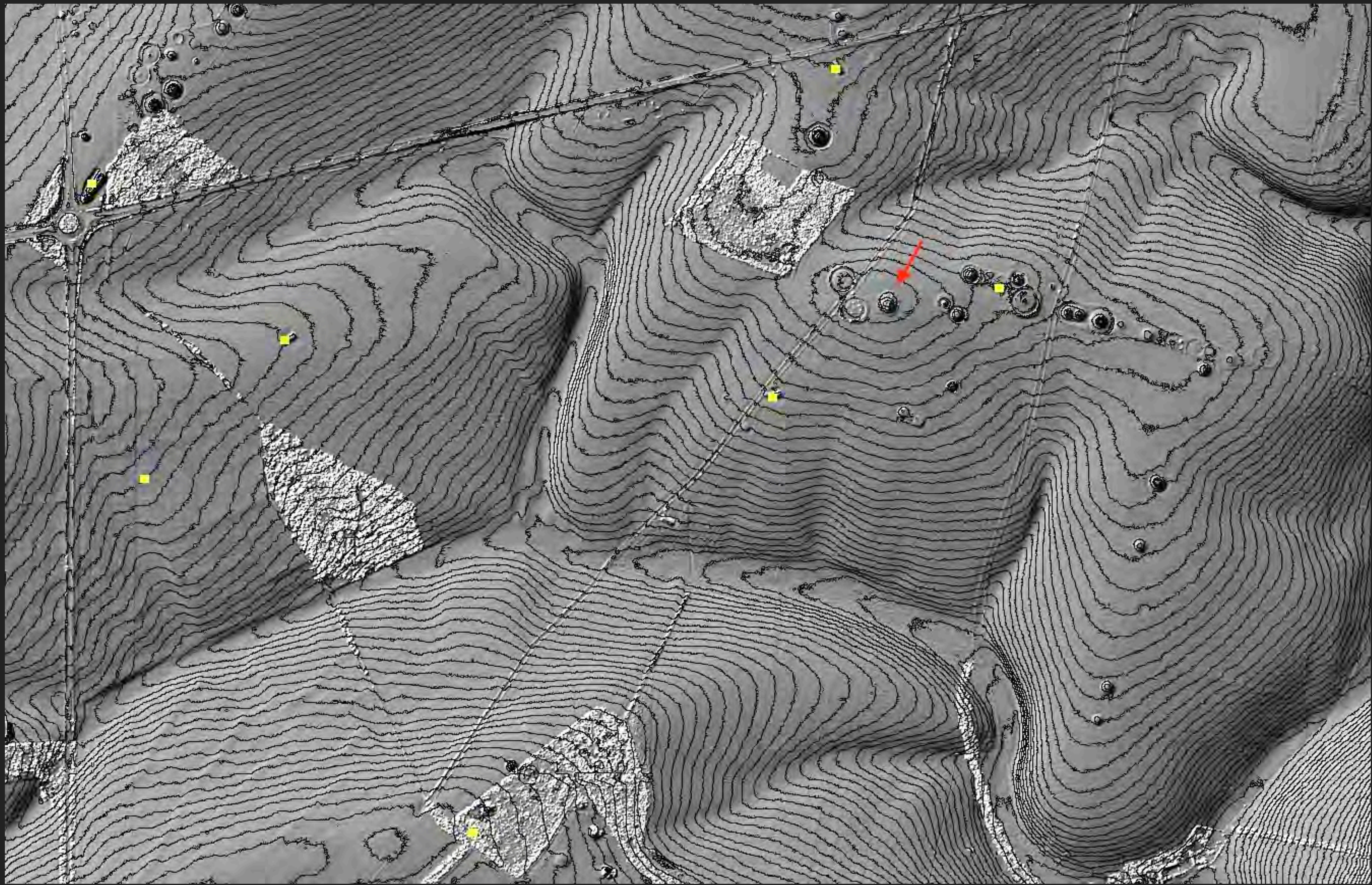


Fig 14. 15 Relief-shaded digital surface model, Stonehenge World Heritage Site

Relief-shaded DSM image with DTM raster contours at 1 m intervals, showing the topographic location of the Neolithic long barrows (yellow squares) around the dry-valley system in the western part of the Stonehenge World Heritage Site. The location of the Bush Barrow is shown by a red arrow. From *Bewley* et alii *2005*.

Fig 14. 16 Ancient landscape at Loughcrew, County Meath, Ireland

Visualisation created from the lidar 0.5 m GSD digital surface model, draped with the geo-referenced 20cm GSD vertical photographic mosaic. View looking southwards, across the earthworks in the unimproved pasture shown at bottom left in Fig 14.12, towards the Loughcrew passage tombs on the Slieve na Calliagh hills, with Cairn T (yellow) on the eastern summit. From Roughley–Shell 2004.

Fig 14. 17 Digital terrain model of part of the Stonehenge World Heritage Site, UK

Lidar digital terrain model with proposed A303 Stonehenge Road Improvement Scheme included. The road would be placed in a tunnel by Stonehenge and the area around it restored to grassland. Copyright: United Kingdom Environment Agency.

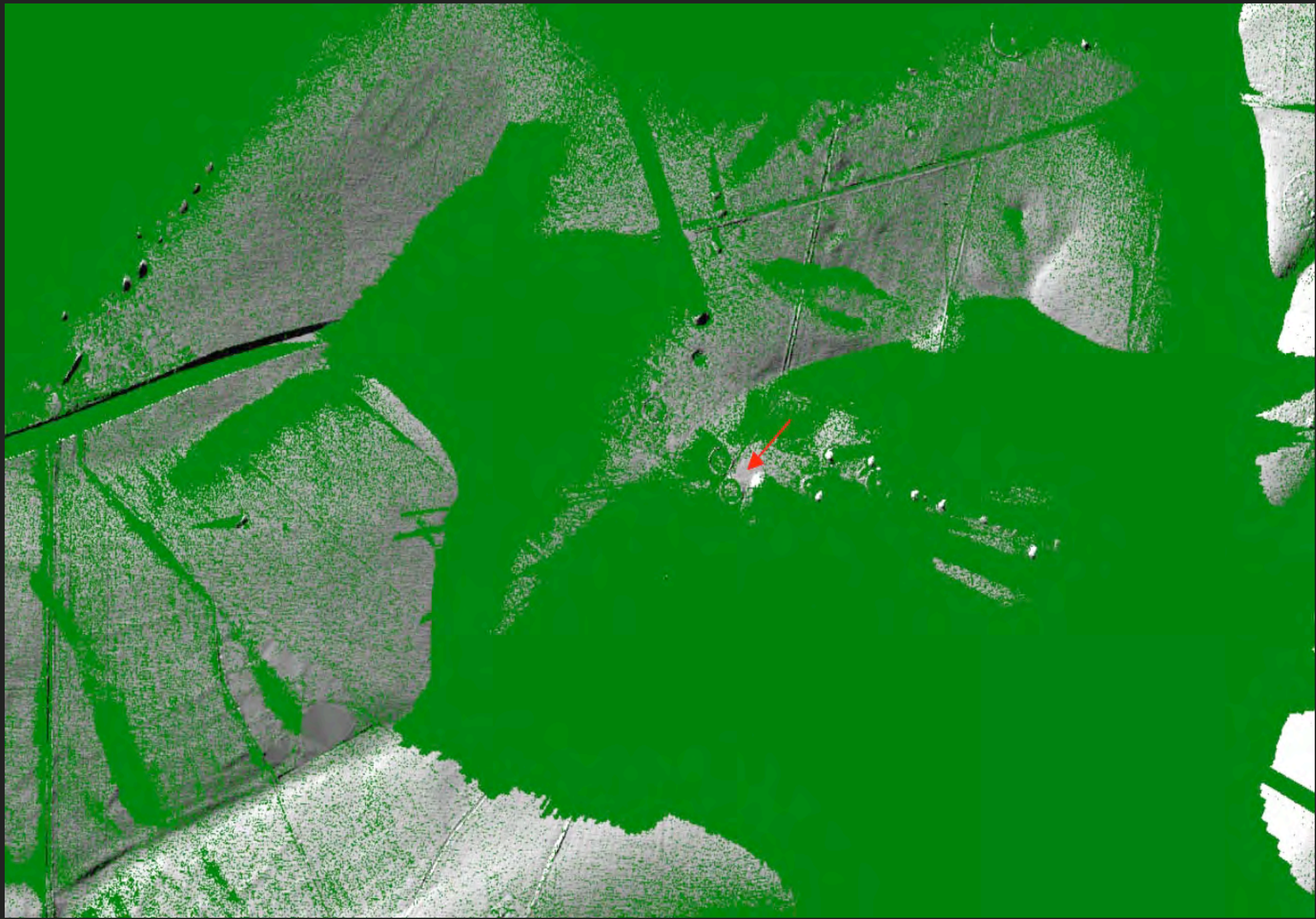


Fig 14. 18 Viewshed from Bush Barrow, Stonehenge World Heritage Site, UK

Viewshed from by the Early Bronze Age burial mound, Bush Barrow (red arrow), in the Normanton barrow group (mounds to right of arrow), calculated using the lidar digital terrain model. This shows that, with the intervening trees removed, the aligned mounds of the Winterborne Stoke Crossroads barrow cemetery are visible on the western skyline at extreme left, and also the extent to which the western cutting of the A303 Stonehenge Road Improvement Scheme would be seen if constructed.

Conclusion

The contribution of digital remote sensing to archaeology is in the spheres both of research and conservation. Whilst there have been significant advances in digital sensors, including the development of digital large-format survey cameras, the principal new development has been the introduction of airborne lidar. As well as its use for archaeological site prospection and site location analysis, using established software tools such as the calculation of viewsheds and the study of monument inter-relationships by landscape visualisation, airborne lidar has equal value for resource management and landscape planning. The use of lidar data in reconstructing past environments must always be undertaken with caution, but equally lidar terrain modelling has an assured position in future understanding of past landscape change.

Acknowledgments

The author's research in archaeological remote sensing has involved the collaboration of many colleagues including Ralph Brownie of Thales Optronics, Bob Bewley and Simon Crutchley of English Heritage, Nick Holden and Alastair Duncan of the Environment Agency, Gill Swanton of Kynet Consultancy, Roy Canham of Wiltshire County Council, and (closer to the office) Tim Cockerell, Gabriel Amable and Corinne Roughley of the University of Cambridge. The Loughcrew lidar survey was funded by the Heritage Council of Ireland under its Archaeology Grant Scheme 2003.

15. USING DE-CLASSIFIED SATELLITE IMAGERY IN SYRIA

Geo-locating CORONA imagery for archaeological surveys and cultural resource management: a case study

Anthony R. Beck, Graham Philip,
Daniel N. M. Donoghue and Nikolaos Galiatsatos

This contribution is reproduced virtually as written towards the end of 2004. The examples of prices are of course out of date in 2012 but the general message still remains valid.

Introduction

The last decade has seen the declassification of high resolution (sub 2-3 m) panchromatic military imagery such as the American CORONA (http://edcwww.cr.usgs.gov/) and Russian KVR (http://www.spin-2.com/) missions. The data is relatively cheap, readily available and has a significant historical component which is of particular benefit to archaeology. Several reports have already indicated the value of de-classified imagery for the identification of archaeological **features** (*Comfort et alii 2000*; *Fowler 1996; Kennedy 1998*).

A recent account (*Philip et alii 2002*) has demonstrated how geo-corrected CORONA imagery can be employed for the identification and accurate ground location of archaeological features. It can provide valuable input to **landscape** studies, particularly in areas where the archaeological resource is poorly understood and/or documented, such as parts of the developing world, where there may be no systematic databases of archaeological remains, and where access to detailed topographic mapping and aerial photography can be problematic (*Donoghue et alii 2002*).

In the present case-study, CORONA imagery was employed within a regional *Survey project, Settlement and Landscape Development in the Homs Region, Syria* (SRH). In addition to archaeological research questions, the project has as one of its aims the creation and maintenance of a GIS-based Cultural Resource Management tool. Using CORONA data as a prospection tool the project has identified approximately 550 **sites** of archaeological significance within an application area of some 630 km2. A considerable proportion of these were previously unknown, and only a few were recorded. In some instances historical satellite imagery provides the only archaeological record. This is particularly the case for parts of the study area that have undergone extensive landscape modification in recent decades (Fig 15.1).

As Fig 15.1 illustrates, there is a wealth of archaeological information contained within CORONA imagery. Although this information can be usefully analysed in isolation, the incorporation of the imagery within a GIS environment will ‘add value’ to any analysis by allowing the incorporation of other spatially referenced datasets. Unlike modern satellite data CORONA is purchased as either film (positive or negative) or print and thus needs to be digitised and geo-located before it can be overlaid with the other spatially referenced datasets. To complicate matters the CORONA missions were conducted for military reconnaissance and not for **mapping** purposes. Hence, the non-metric nature of the camera system makes the imagery difficult to geo-locate in order to determine metric measurements. Errors are not standard across the negative.

This study considers the specific question of how CORONA imagery can be geo-referenced accurately and cost-effectively.

Fig 15. 1 **Detection and destruction in Syria**

Palimpsest of field systems seen on the CORONA imagery (background) and their present-day destruction (inset).

Accuracy in this context means accurate enough to find a site on the ground with a handheld GPS, although the more accurate the rectification the better. Although many archaeologists may be content with a Root Mean Square Error (RMSE: 'the square root of the arithmetic mean of the squares of the deviation of observed values from their arithmetic mean': www.harcourt.com/dictionary) of many decametres. But some projects now integrate multiple satellite data sources in their analyses, for instance for time-change analysis or to exploit the different spectral properties of different imagery. For these analyses to work the user must be confident that each overlying pixel from the different sources refers to the same or nearly the same point on the ground. Modern, high spatial resolution IKONOS satellite imagery (http://www.spaceimaging.com/) and GPS are compared as registration tools.

It seems likely that other military reconnaissance missions with different spatial, spectral or geometric characteristics will be declassified in the future, although the experience of CORONA suggests that image data may be released without full declassification of the technical characteristics of the data-collection system. Therefore, the geo-location of CORONA can be seen as a vital preparatory step for the effective use for archaeological purposes of such declassified military datasets that researchers might find useful in the years ahead.

Rectification Techniques

Rectification is the process of correcting systematic and random errors in imagery. Rectification procedures can either be spatial or non-spatial. Non-spatial rectification is commonly used to correct camera lens and scanning aberrations (or other errors in a collection device). Spatial rectification is used to locate imagery somewhere in space (normally to a specified projection) and will also account for collection distortions.

Spatial rectification relies on the ability to recognise areas within the imagery with known locations or the use of ephemeris data (satellite sensor and orbit characteristics, not discussed here as this information is not available for CORONA). Concurrent known points in both the referenced and un-referenced media are referred to as Ground **Control Points** (GCPs). Hard-detail (points that are unlikely to move over time and are normally man-made) tend to be used as ground **control points**. Corners of fields, walls or buildings and road intersections are common examples. Once these control points are established, the image is stretched so that the points align as closely as possible, normally using a polynomial algorithm.

However, rectification does not always result in perfectly matched control points. By adjusting the Polynomial Degree of the correction algorithm the accuracy of the transformed points can be increased. However, reducing the error can create a higher degree of warping in the image as it is transformed to match the control points. Therefore, the lowest possible polynomial degree that still gives an acceptable result should be used (AutoCAD 2000). Most rectification packages show the RMSE of every ground control point for each polynomial degree. These error values detail how far a transformed (rectified) control point is from its true value. Thus outlier ground control points can be evaluated and removed from the rectification process. Outliers occur because either the control point locations are inaccurate (the **feature** perhaps having changed) or the un-registered medium is distorted. As a general rule increasing the number of ground control points and spreading them evenly across the image increases accuracy in the final rectification. It is important to understand that, whatever rectification technique is used, it will only work if ground control points in the declassified imagery are still extant in the **landscape**.

Projection

Prior to any rectification or data-collection procedure a projection system needs to be determined. In most areas that have institutionalised cultural resource management bodies the regional or national projection system is easily accessible. It is advisable (and in some instances mandatory) that this projection mechanism is used. This will ensure that any results will integrate seamlessly with the national cultural resource management data and other datasets, enabling subsequent data re-use and integration (*Bewley et alii 1999*). Where such a system does not exist then it is advisable to use one of the standard worldwide referencing systems such as Universal Transverse Mercator projection (UTM) or Lat/Long and an appropriate datum (if in doubt use World Geodetic System, WGS 84).

Furthermore, all systems must support the projection used: i.e. the cultural resource management institution, the primary registration medium (IKONOS or its equivalent) and the GPS system. Pre-registered satellite imagery will normally come in a worldwide referencing system. If the registration imagery needs re-projection, by one of the many available algorithms, then some data loss is inevitable. It should also be ascertained if the GPS supports the regional system as an internal or user-defined system.

In the case under discussion it was decided to use UTM as this projection is more instinctive for in-field work than Lat/Long (working in metres rather than seconds of arc), is widely supported (for example by Landsat, IKONOS and most GPS systems) and is already in use in cultural resource management databases elsewhere in the region (Palumbo 1992).

Geo-correction using other datasets

The available **mapping** for our application area is at 1:50,000, of unknown quality and date and is located in the Syrian Grid. For security purposes the precise parameters of the Syrian Grid are not publicised. With GPS data collected from the 2000 season we were able to rectify the mapping to UTM, although the accuracy was deemed too poor to correct the satellite imagery. Therefore, we needed to find some other mechanism with which to locate our spatial data. We had acquired a 6 x 7 km portion of the IKONOS Geo product. The IKONOS imagery comes pre-registered in UTM with 1 m ground resolution and a stated RMSE accuracy of 25 m.

During the interim fieldwork season, conducted between April and May 2001, raw co-ordinates from the Garmin GPS12XL were overlaid with the IKONOS data to determine the spatial compatibility of the two media (Fig 15.2). The removal of selective availability theoretically allows the collection of co-ordinates to ±5 m with a handheld GPS.

The correlation between the two datasets was good. This encouraged additional research to compare the effectiveness in terms of cost, practicability and accuracy of the two spatial referencing techniques as means for geo-correcting CORONA imagery.

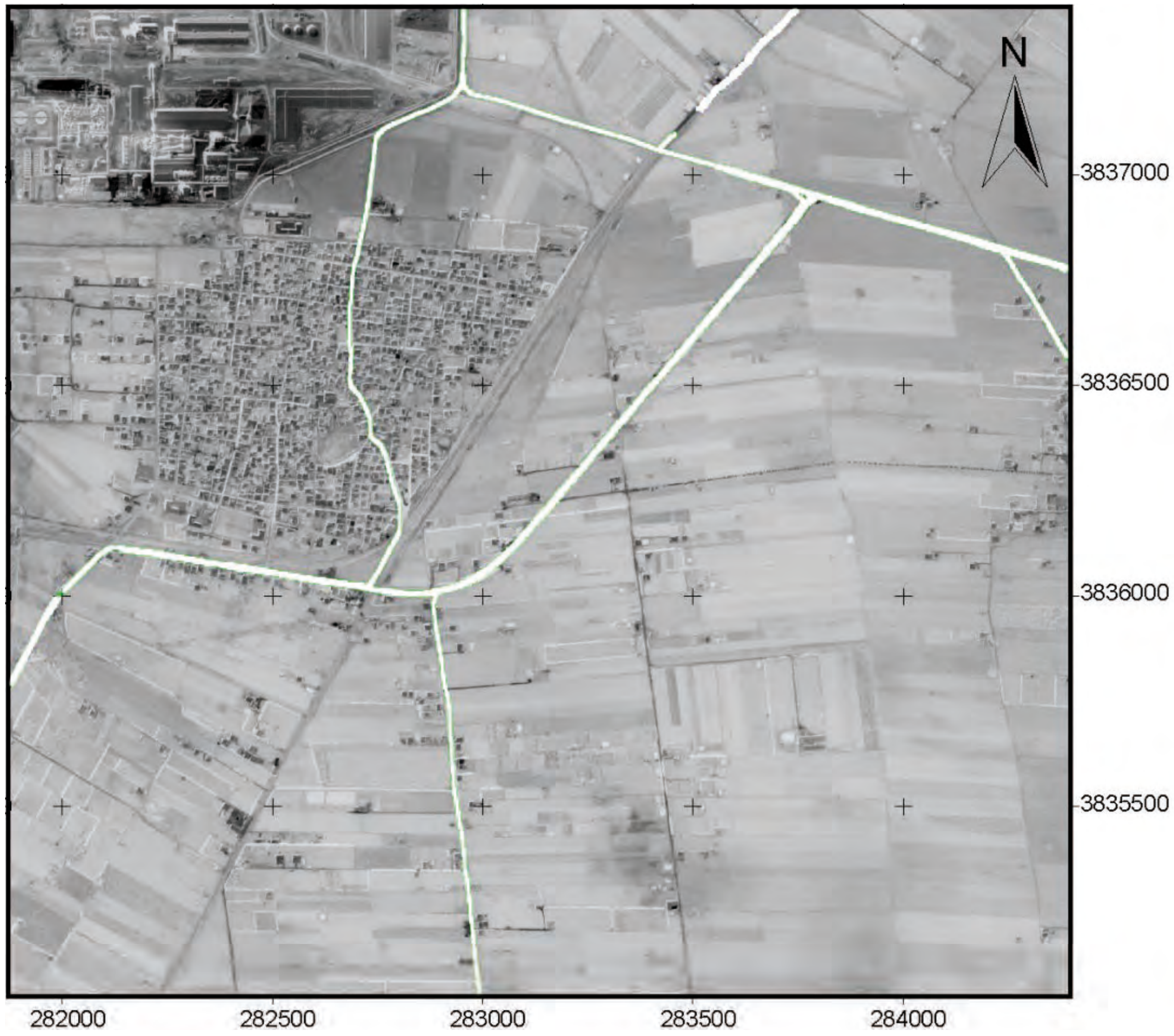
Methodology

The methodology described here outlines the procedure to rectify spatially un-referenced raster satellite imagery to such a degree of accuracy that GPS measurements can accurately overlie the imagery, or accurate measurements can be taken directly from the geo-located imagery. GPS measurements and IKONOS imagery are used to collect ground control points. Rectification and evaluation occurred in AutoCAD Overlay 2000, ArcInfo and ArcView GIS.

By GPS

A Garmin 12XL GPS was used to collect ground control points in both the northern and southern application areas. Sample lines of roads, tracks and their intersections were collected as polylines using the GPS. More time was spent at junctions to improve accuracy. This data was downloaded using the Mapsource software supplied by Garmin and exported as a text file. This text file was imported into ArcView by using AV Garmin, an extension written by the California Department of Fish and Game to create point, polyline or polygon files (available from *fttp://maphost.dfg.ca.gov/outgoing*). This file was also imported into AutoCAD.

The most important factor to bear in mind when conducting this type of survey, in tracking mode, is to set an appropriate time interval for recording. When travelling on tarmac roads with speeds ranging between 30-60 km per hour one reading every 5 seconds gave adequate results, but when defining a site extent by foot one reading every 10-15 seconds was more appropriate. However, these are only rules of thumb and each individual survey will have unique requirements.



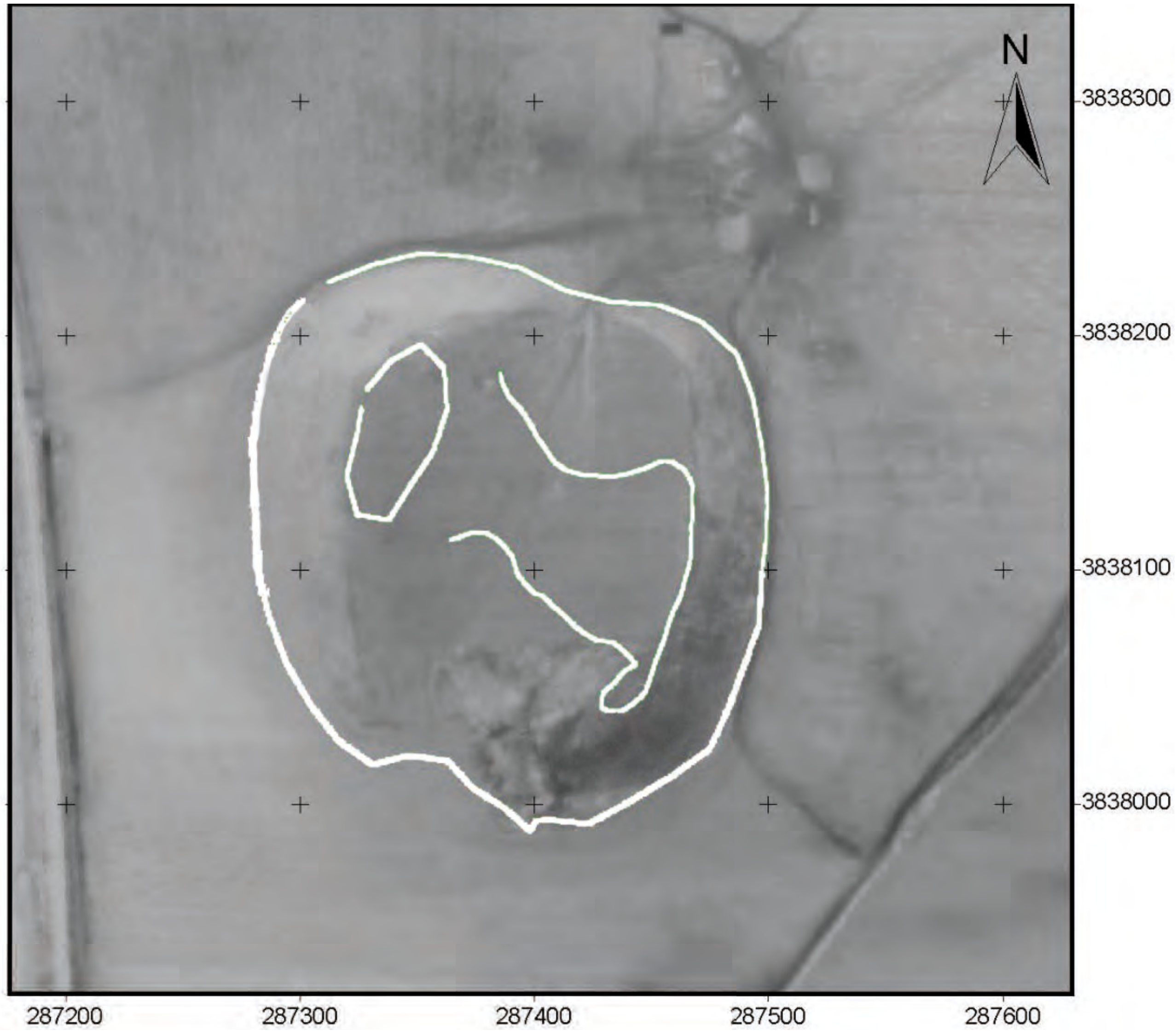


Fig 15. 2 **Comparison of GPS tracks (in white) on hard and soft detail, overlaid onto Ikonos imagery**

In some cases the accuracy of the vehicle-based control point measurements was a cause for concern. At certain locations the variability between successive ground control point readings could be as large as 70 m. These areas were re-recorded. This problem could probably be reduced by the use of an aerial mounted on the vehicle. Nine intersections were identified and used to provide control points for the rectification. Due to a lack of contextual information in the GPS road map it was necessary to rectify coarsely a copy of the imagery in order to resolve road intersections that were difficult to determine. A second-order polynomial gave the best result, with an average RMS error of seven pixel units (the image has a pixel resolution of 2.38 m). The resulting image was generally a good fit. However, the inadequacy of the road map did not facilitate an even distribution of ground control points. It is important to understand that apparently mundane, essentially practical, issues of this sort may have an important influence on the cost and effort involved in the GPS-based geo-correction of CORONA imagery.

By IKONOS

When IKONOS imagery was used as a substitute for a base map it allowed rectification to occur in a traditional manner. If anything, there was so much information provided in the CORONA and IKONOS imagery that some effort on the part of the analyst was required to select the most appropriate points. Seventeen ground control points were identified that were spread relatively evenly around the image. A second-order polynomial gave the best result with an average RMS error of 5 pixel units.

Results

Fig 15.3 demonstrates the effectiveness of the rectification procedures. Rectification using IKONOS as a basemap gave the better results, with near-perfect rectification at site 191. However, the GPS rectification is still more than acceptable with a 10 m offset to the NE. The coarse rectification had an offset of approximately 100 m. At such accuracy more time would need to be spent on the ground-location of small features observed in the imagery. If the survey programme includes the purchase of IKONOS data (or a future equivalent) for the entire application area this will provide by far the most accurate mechanism for the rectification of CORONA. Furthermore, the errors associated with the GPS can be a cause for concern. While differential GPS may allow more accurate geo-correction, this is unlikely to be a realistic option, in the foreseeable future, for archaeologists working in the more sensitive parts of the world.

Discussion

Because of the problematic characteristics of CORONA imagery, described above, the number of ground control points required will, in part, depend upon the relative location of a specific application area within a negative. Furthermore, in the three decades that have passed since the collection of CORONA imagery, there has been extensive modification, at least in the

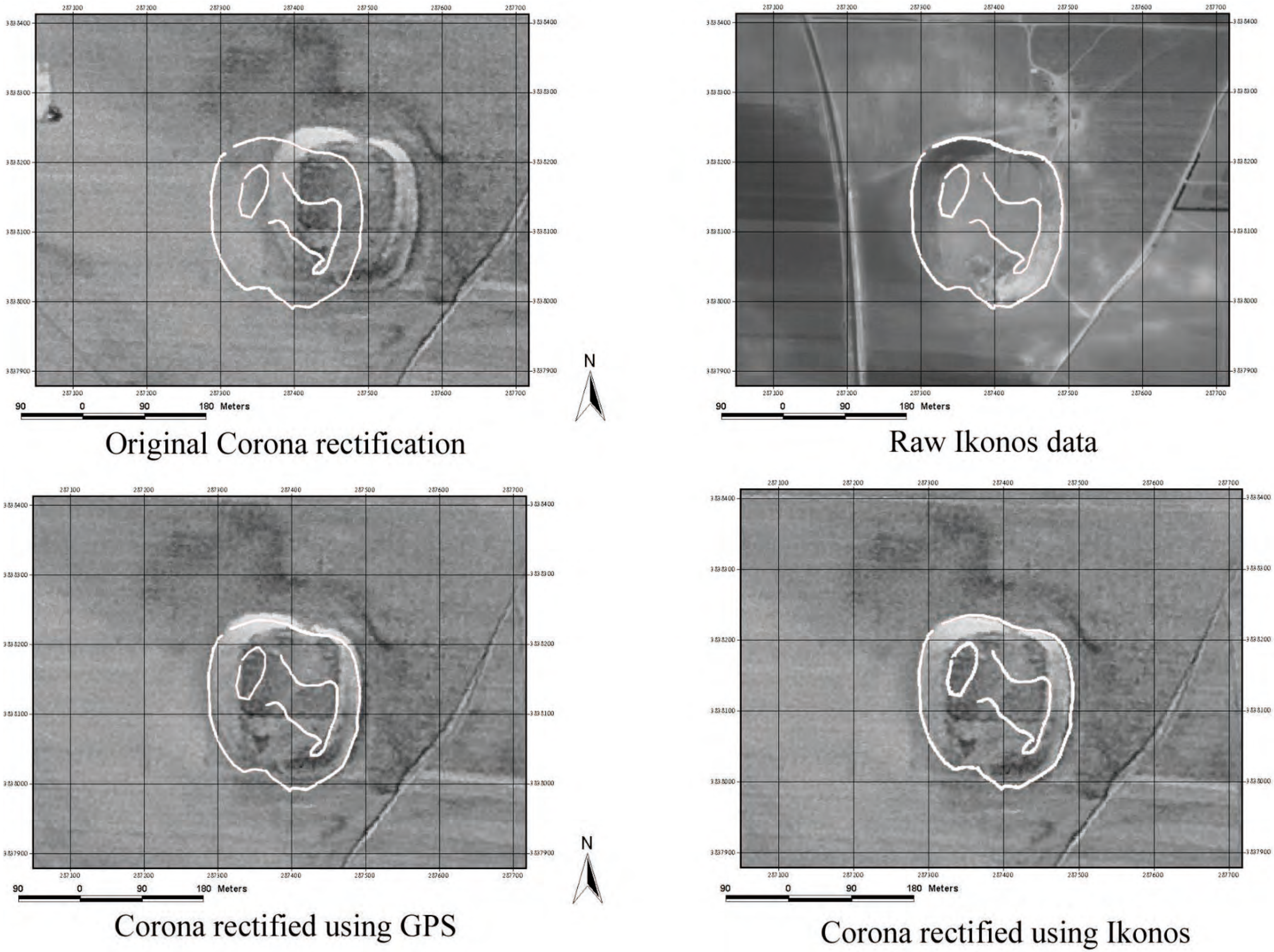


Fig 15. 3 **Comparison of the rectification techniques**

study areas considered here, of the landscape and road networks. This can make it difficult to correlate an individual feature as it appears in CORONA with its appearance on other data sources. Major roads and road junctions may have been added, widened, or moved since the late 1960s, while other prominent landmarks may also have changed in the last thirty years.

It is in this aspect of geo-correction that IKONOS imagery has a major advantage over GPS collection. Although the GPS and IKONOS may have approximately the same degree of accuracy as regards their ability to position surface features in terms of a specific co-ordinate system, IKONOS imagery provides a range of additional background detail that can significantly increase confidence in the identification of ground control points. This allows greater flexibility in the rectification process when compared to the constraints imposed by control point collection. However, IKONOS data can be purchased at different levels of geometric and orthographic rectification, and increased rectification results in a more expensive product. Fortuitously, the application area has relatively little topography and so the IKONOS Geo product is quite accurate. In areas of uneven terrain a higher-accuracy product would be more appropriate to compensate for errors introduced by the terrain. This could substantially increase the cost of using IKONOS. However, as competitors such as QuickBird (*http://www.digitalglobe.com*) enter the high-resolution marketplace the price of such imagery is expected to fall.

Cost of Data Collection

As ever in archaeology, cost is an overarching consideration, with the cost of data collection normally constituting the single most expensive component of a project. Although the cost of collecting ground control point data may appear low when compared to that of purchasing high-resolution satellite imagery, the ‘hidden’ costs of field data collection can be substantial. In the case of the work in Syria, a team of at least two was required to conform to UK Health and Safety legislation, and it cost approximately $600 (at 2001 prices) for a return flight from the UK to Syria. Furthermore, one must include the cost of GPS equipment, vehicle hire, accommodation and subsistence expenses, and salaries. There was also a significant input of staff resources by the Syrian Directorate General of Antiquities and Museums. On the other hand, the IKONOS imagery was relatively expensive. It was at the time of this study (in 2001) priced at $29 per km2 or $18 per km2 for archived imagery (late-2004 equivalents $27.50 and $21). At 2001 prices this equated to $18,270 to cover the whole application area (still less than the annual cost of many archaeological field seasons). However, it would not be essential to have the IKONOS imagery covering the entire application area in order to geo-correct the much cheaper CORONA data. If the initial CORONA imagery could be coarsely rectified, then appropriately distributed sub-sets of IKONOS imagery, amounting to some 5% or 10% of the total application area, could be identified and purchased, giving the potential to substantially reduce the cost of imagery (an approach successfully tested in subsequent studies using both systematic and random selection criteria.).

Processing costs should not be forgotten. For the purposes of this study rectification was undertaken using AutoCAD Overlay 2000. A dedicated image processing system, such as PCI or ENVI can be brought into use for future rectification. However these systems tend to be expensive, and the costs (purchase, maintenance and training) of such dedicated systems are likely to discourage most archaeological organisation from using them in the short to medium term. However, there are some processing packages that can be purchased with significant educational discount (AutoCAD or Idris) or which are available free (GRASS). Although they may not be as effective as the more 'professional' packages (and still do not overcome the maintenance and training costs) they are affordable packages for archaeologists.

Conclusions

Both IKONOS and GPS collection techniques have demonstrated their effectiveness for providing locational information to rectify a small sample area of CORONA imagery to a high degree of accuracy. Subsequent studies have suggested that this technique will work over the whole application area of 630 km2 providing an effective mechanism to co-register the IKONOS, CORONA and Landsat imagery. Once co-registered it becomes possible to exploit the different spatial, spectral and temporal characteristics of the imagery so as to improve landscape identification and analysis.

´Furthermore, the integration of IKONOS in this way could produce a major change in the way in which survey projects are conducted. It is appropriate that the preliminary phase of an archaeological survey project should now include a significant Desk Based Assessment (DBA) of the available satellite resources, linked to an initial 'reconnaissance' phase of fieldwork. This assessment should provide the basis of a GIS in the appropriate projection for the region. Potential sites can be identified from the imagery, and landscape themes (soil type, crop cover etc) can be extrapolated from multi-spectral imagery. The provision of this type of data will produce a higher level of contextual information. This, in turn, will encourage field teams to focus and reflect on the academic, theoretical and methodological aims during the all-important early stages of the project.

Acknowledgements

The authors acknowledge generous support from the Council for British Research in the Levant, the Natural Environment Research Council and the Hellenic State Scholarship Foundation.

16. REMOTE SENSING AND THE ARCHAEOLOGICAL LANDSCAPE OF AKSUM, ETHIOPIA

Maurizio Forte

Aksum, in Tigray Province of north-eastern Ethiopia (Fig 16.1, Fig. 16.2), was the capital of a kingdom which dominated the southern reaches of the Red Sea in the 1st millennium AD. It was also an important trading partner of the Roman and Byzantine empires. The city itself is situated about 22 km west of Adwa at an a height of approximately 2200 m above sea level; the hills of Bieta Giyorgis and Mai Qoho dominate the present-day city from the north-east and east. These and other hills, rising to between 2289 and 2406 m, delimit a roughly circular plain about 10km in diameter, with Aksum at its centre and four seasonal rivers flowing out of it at the north, west, south and south-east. Archaeologically, the area can be divided into three principal zones based on the density of ancient **sites**: the Core Zone, which comprises the city of Aksum, the hills of Bieta Giyorgis and Mai Qoho and the plain of Abba Liqanos; the peripheral zone, which covers the plain to the north and south of Aksum; and the marginal zone, consisting of the hills which surround the plain.

Leaving aside research and excavation work at Aksum in the early 1900s (*Littman et alii 1913*), systematic ground-based exploration and excavation only commenced in 1997 within the research programme of the Joint Archaeological Expedition of the Istituto Universitario Orientale (UIO) of Naples, Italy, and Boston University (BU) in the USA (*Bard et alii 1997*, *2000*; *Fattovich 1997*; *Fattovich–Bard 1993*; *Fattovich et alii 2000*; *Forte et alii 2001*; *Forte–Williams 2003*; *Littman et alii 1913*; *Phillipson 1998*). The IUO/BU project had already been under way since 1993 under the direction of Rodolfo Fattovich (IUO) and Kathryn Bard (BU). It encompassed multidisciplinary research in the fields of archaeology, palaeobotany, archaeozoology, ethnoarchaeology, history, geology, geomorphology and palinology. The project's initial aim was to test the hypothesis, based on traditional sources in Ethiopia, that Bieta Giyorgis had been the seat of the first settled development of Aksum (Forte et al 2001). As shown on the following pages the project was later strongly influence by the contribution of the Istituto per le Techniche Applicate ai Beni Culturali of the Consiglio Nazionale delle Richerche (ITABC-CNR) at Rome in the direction of digital applications in the field of satellite-based remote sensing and virtual reality representation of the archaeological landscape.

This contribution will describe the remote sensing applications which have provided the fundamental basis both for the comprehension and predictive modelling of the geo-archaeological landscape and for the virtual reconstruction of the archaeological landscape. The pioneering relevance of this international project (assisted by a number of other universities in America, as well as by NASA) lies above all in the methodological advances that it introduced through the use of digital applications. This is in fact the first archaeological case study in which the processes of digital data entry using spatial analysis, GIS, remote sensing and field investigation have been integrated with one another in order to reconstruct the **landscape** through the techniques of virtual reality using purpose-designed software.

At the time of writing the author was on the staff of ITABC-CNR, Roma (Istituto per le technologie Applicate ai Beni Culturali – Consiglio Nazionale delle Richerche, Rome). He is now (in 2012) Professor of World Archaeology at School of Social Sciences, Humanities and Arts, University of California, Merced, USA. The text has been translated by Chris Musson from the original Italian, hopefully without too many errors.

Fig 16. 1 **Ethiopia and the location of Aksum**

Fig 16. 2 **Location and landscape setting of the area of Aksum**

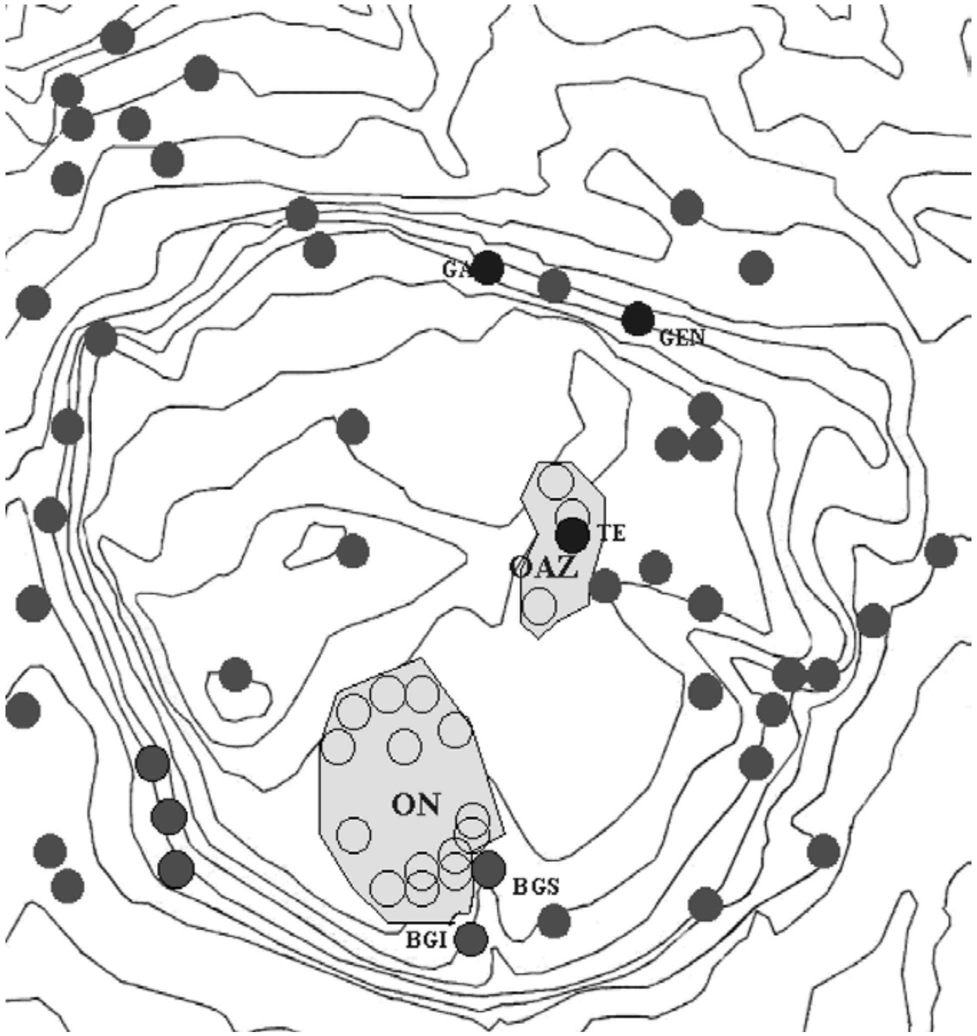


Fig 16. 3 **Principal sites and archaeological areas**

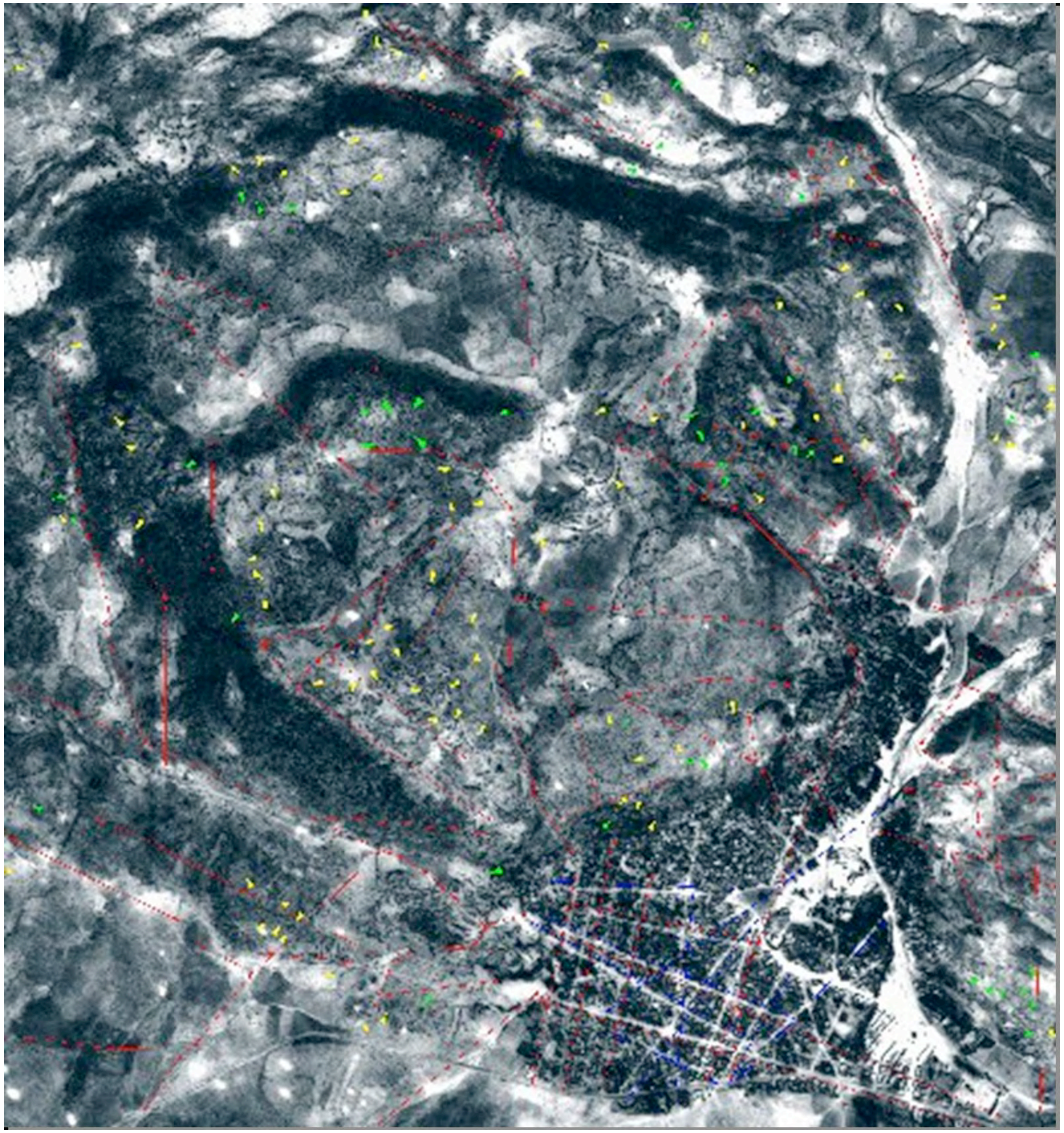


Fig 16. 4 **Rectified mosaic from the 1964 air photos**

Overlain on the mosaic are the locations of man-made 'features'.

The cultural context

The cultural evolution of Aksum has conventionally been subdivided into four phases or periods: pre-Aksumite (ca. 700-400BC), proto-Aksumite (ca. 400-150BC), Aksumite (ca. 150BC-AD 700) and post-Aksumite (AD700 onwards). The archaeological sites of pre-Aksumite period, which mostly relate to ceremonial areas, have been detected in the zones marked as OAZ, ON and GN in Fig 16.3. From the proto-Aksumite period they are found mainly in OAZ and ON, in association with stone platforms, rough-hewn stele and shaft-burials (in OAZ) and monumental structures (in ON). Most of the sites belonging to the Aksumite period are to be found in areas OAZ and ON, together with two churches (BGS and BGI), a quarry for stele and a stone platform. Lastly, the post-Aksumite phase is documented in OAZ and ON as well as at BGS, BGI and GA.

The remote sensing project and digital representation of the landscape

International projects like ‘Aksum’ could well be characterised as ‘extreme archaeology’ in the sense that operating conditions in the field are extremely difficult, if not prohibitive, both from the point of view of environmental conditions (in our case the conflict between Ethiopia and Eritrea) and as regards logistics – every piece of the expedition’s equipment and supplies had to be carried on foot or by camel for many kilometres. We make this point solely to emphasise the way in which the application of GIS, spatial analysis and remote sensing provided an essential underpinning not only for advanced digital elaborations but also for depicting the local topography and for facilitating cartography, ground-observation and classification within the study area. For the area of Aksum generally our only ‘outside’ sources of information were aerial photographs from 1964 at a scale of 1:60,000 (Fig 16.4), general mapping at 1:50,000 and theodolite-based archaeological maps and cartography. That being so it was clear that the contribution of satellite imagery would constitute a fundamental starting point for the acquisition of suitably detailed and up-to-date cartographic and topographical support. The remote sensing applications were aimed at the following objectives:

- ‘supervised’ and ‘unsupervised’ multispectral classification of soils, vegetation and the relationships between sites and the local terrain; Align second line left here and throughout
- data-fusion of panchromatic (air photo) and multispectral (satellite) imagery;
- georeferencing and rectification of the 1964 air photographs;
- survey by differential GPS (DGPS) of sample areas to identify soils for classification;
- high-resolution DGPS survey of micro-relief on the north-western flanks of Bieta Giyorgis for the creation of a centimetrically accurate DTM for the area;

- texture mapping onto the DTM of the air photo data and of all of the satellite-derived raster data (before and/or after the multispectral classification);
- integration of all the spatial data within a GIS platform, (using ArcView 3.2);
- virtual representation of the archaeological landscape using OpenGL graphics software (Terra-Vista and Vtree programmed in C++, see Forte–Kay 2002).

The sequence of work put in train in 2000-2002 foresaw the creation on the basis of the remote sensing data of preliminary models of selected interest-zones so as to study the local terrain before making specific plans for the fieldwork, which was then carried out in May and June 2001. In such projects this initial phase of digital exploration is extremely important since the use of digital data and virtual reality allows the project team to familiarise themselves with the terrain within the research area before committing themselves to work in the field. It also makes it possible to formulate methodological proposals for testing, within work-programmes that have been optimised beforehand as terms of the time and resources required. This (in our view) already well-established methodology, envisages the following phases of elaboration:

- analog (identification of '**features**' on the aerial photographs, checking the available cartography and study of the micro-relief);
- digital-analog (as above, using rectified versions of the aerial photographs);
- digital-spectral ('unsupervised' and 'supervised' classification of the satellite data);
- digital-virtual (3D representation of the study-area's terrain through digital modelling and detailed relief mapping);
- analog (field-based survey and research);
- digital-DGPS (acquisition of topographical data in real time using DGPS);
- virtual (after completing the field-acquisition and on the basis of the remotely sensed and cultural data one can proceed to the representation in virtual reality of the archaeological landscape and to the comparison in real time of the various forms of data).
- In the same sequence, the methods adopted for the respective stage of scientific research are as follows:
- basic visual examination;
- interactive visualisation on-screen using GIS software;
- image processing with remote-sensing software;
- navigation (fly-through etc) in real time 3D using the remote sensing models (software for remote sensing and scientific visualisation);

- ground-based exploration and topographical survey, with geo-archaeological sampling of soils and anthropological classification within the study area;
- processing of the GPS data, using differential correction software, for subsequent transfer to a GIS platform, followed by real-time processing of the data using PDA/handheld computers (ArcPad, PocketPC etc);
- transformation of the vector and raster data into 3D models, including the creation of purpose-designed graphics software.

We are convinced that the formulation of this kind of methodological protocol can open up new prospects for the treatment of remote sensing data and for the integrated use of spatial data in other software and hardware contexts. The 'virtualisation' of the primary data, during and after the field-based stages, leads us to imagine in the near future ever more rapid transmission of the data, almost in real time, from the field to the laboratory. Moreover, the application of a methodological protocol in the digital application of remote sensing in archaeology provides the best foundation for a multidisciplinary investigation of this kind.

The 1964 aerial photographs proved to be particularly useful for the diachronic interpretation of the territorial setting and its background archaeology. It also facilitated the creation of a good resolution of raster data (3 m) upon which these and other data could be overlaid.

The area chosen for detailed examination comprised the summit of Bieta Giyorgis, the hill which dominates the north-eastern part of Aksum over a surface area of about 4 km2 (Fig 16.3). The presence of a number archaeological sites on the hill had already been established by Italian and German expeditions in 1906 and 1974 (*Phillipson 1998*): a necropolis with stele in the central part (Ona Enda Aboi Zegwè, OAZ), a quarry and two Aksumite churches (BGS and BGI) on the southern flank, and petroglyphs north-east of Ona Nagast (ON) and on the south-eastern side.

Ona Nagast is a site of more than 12 hectares identified during field survey about 700m south-west of OAZ. Part of the ancient settlement is covered by a modern village. At its western end there is a substantial rock-cut cistern of unknown but certainly ancient date. According to local tradition this was the residence of the first Aksumite kings. Ona Enda Aboi Zegwè (OAZ) occupies an area of about 10 hectares near the centre of the summit plateau. It too is partially concealed beneath a modern village; there are visible on the surface over a hundred stele, up to more than 10m high. During the campaign of 2000 excavations were carried out at four new sites: Baati Asba (BA), a rock shelter on the north-western part of the hill, Gunda Nebri (GEN), an open site to the north-east, Tukul Emeni (TE), in the central area and Guadguad Agazien (GA), on the northern flank of the hill (Fig 16.3).

Differential GPS (DGPS) for archaeology

The link between GIS and GPS is obvious: terrestrial survey can be cartographic (with data typically acquired from aerial photographs or satellite imagery) or alternatively derived from the recording points in relation to the world's orbiting satellite array (GPS). The principal methods of acquisition for GPS data are 'static', 'rapid static', 'cinematic' and 'stop & go'. The optimum operating space for cinematic DGPS is about 10 km across. This type of survey is particularly useful for GIS-type applications since the definition of specified areas (polygons) can be done continuously, as can arcs and points in the stop & go method. The use of GPS in archaeology can be carried out in two phases or methods: applications using GPS units of metrical precision (typically with locational accuracies of between 30 and 100 m); or alternatively through the use of equipment with sub-metre, centimetric or even sub-centimetric precision (typically differentiated as single frequency or dual frequency types). The three operating contexts for use of these systems of differential survey, notwithstanding some mutual interaction, can be distinguished as follows,:

- cartographic or 'point' survey;
- remote sensing;
- DTM (digital terrain modelling).

In multispectral remote sensing applications using centimetric GPS can be aimed at the identification of so-called 'training areas', that is areas which need to be sampled at ground level to classify matching regions in the satellite imagery that can then be identified as having specific spectral characteristics or 'signatures'. The precision of the instrument allows the extremely precise identification of sample areas both on the ground and in the satellite data and therefore a better spectral classification (typified as 'supervised' in the sense of being based on ground-level observation within these closely-defined training areas). The required information is recorded through the means of geographical coordinates and in the cinematic method, for example, it is possible to acquire polygons that can be automatically recognised as vector data by remote sensing software. The centimetric definition of the sample areas can then be used to correct potential errors in the spectral classification caused by the inclusion during the classification process of pixels which cross the boundaries of the chosen sample areas. 'Ambiguous' pixels of this kind can introduce redundancy into the spectral classification by drawing on areas that include more than one type of soil or vegetation. This in turn inhibits a correct distinction between colour-classes in the classification.

In DTM-generation the use of DGPS in cinematic mode within any chosen survey area allows the acquisition in the field, in a relatively short time, of tens or even hundreds of thousands of precisely located altitude points (depending of course on the accuracy of the altimetric measurement at sea level). The subsequent interpolation of the data produces a DTM of the surveyed area, or of a single site, that is extremely detailed and which is therefore of immediate relevance for archaeological interpretation.

The case study of Bieta Giyorgis

The centimetric DGPS survey carried out at Aksum, using the dual-antenna single-frequency Leica 510, encompassed use of the static method, the cinematic-rapid mode (at time-intervals of 2 and 15 seconds) as well as the stop & go system for the collection in real time of around 90,000 3D points (Fig 16.5). The specific objectives of the DGPS work within the project were as follows:

- use of the static method to collect new points for correction of those previously acquired through non-differential GPS and for the creation of a new cartographic base for the GIS;
- use of the cinematic method for the creation of a microtopographic DTM of the upper part of Bieta Giyorgis;
- use of the stop & go method for locational definition of the training areas selected for spectral classification of the SPOT XS and Landsat TM satellite imagery.

The successful attainment of these three objectives made a substantial positive contribution to the prospects for the in situ archaeological research.

The new measurements with centimetric GPS of the previously recorded sites and archaeological areas permitted correction of the earlier survey results, which had suffered from an average displacement of between 100 and 200 m in a southerly direction. This, and the subsequent integration of the centimetric DGPS data with a new total station topographic survey of sub-centimetric accuracy, made it possible to completely revise the archaeological cartography.

Within the summit area of Bieta Giyorgis the DGPS acquisition in cinematic mode of data for the creation of a micro DTM produced results that were extremely interesting: the survey not only filled in notable gaps in the micro-relief as represented in the 1:25,000 cartography (in which the summit of the hill appeared almost flat) but also showed the remaining morphology of the area very well, including artificial terracing and other features of the palaeoenvironment.

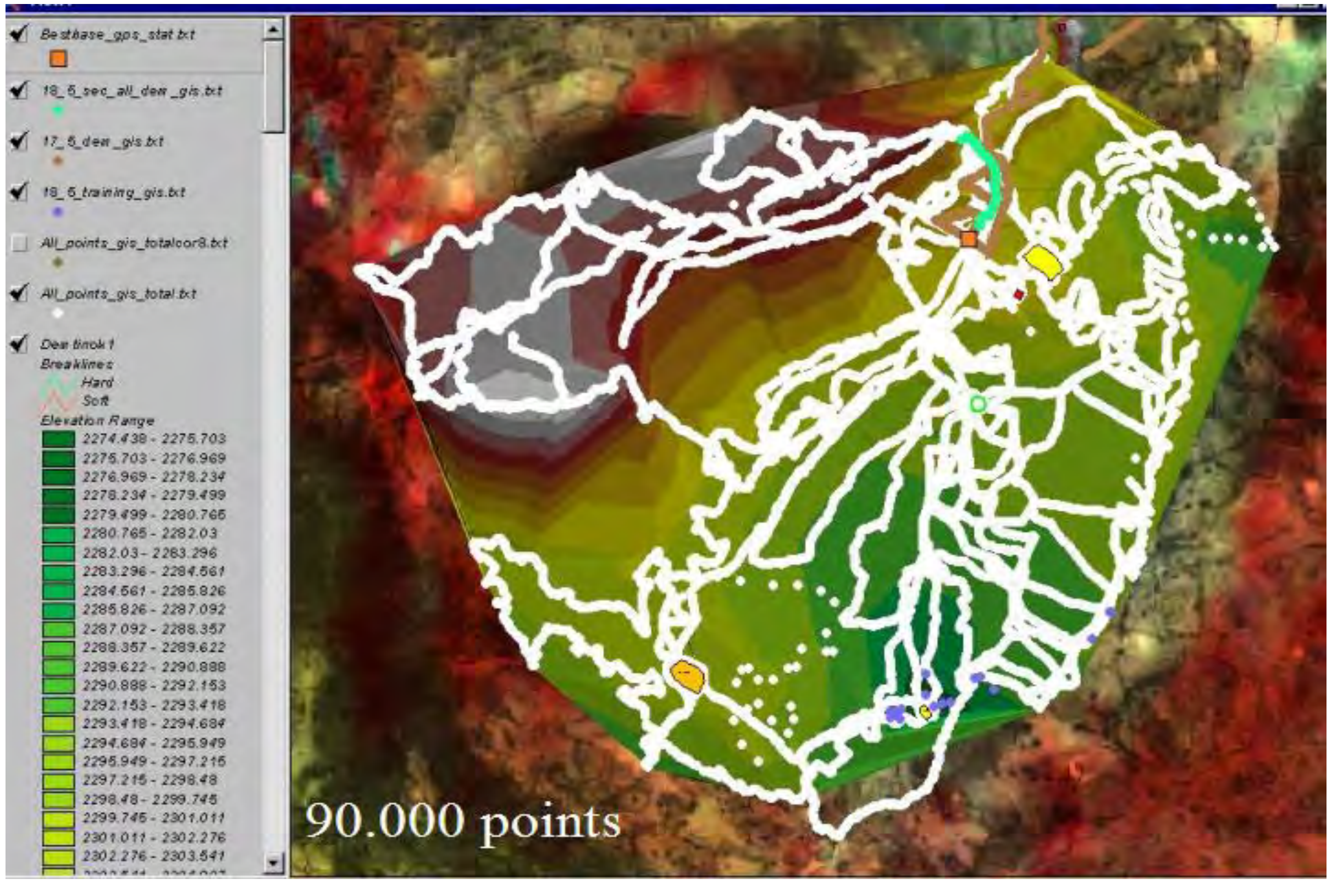
Centimetric precision in the localisation of the training areas helped in the creation of a very accurate supervised spectral classification. For example, in the case of geological surfaces composed of limestone and clay the classification appeared extremely detailed: the pixels which had matching spectral characteristics were colour-coded individually (1 pixel = 20 m), on the basis of the sampling at micro scale, and therefore represented very effectively only the regions of interest selected at ground level. Acquisition of the outlines of the training areas by differential GPS, as compared with the traditional method of ground survey or the selection of sample areas of the digital image solely on their characteristics of colour and reflectance, allowed a much better ‘supervised’ classification of the regions of interest outlined on the ground. As a result, by applying the results obtained in the sample areas (in our case on the summit of Bieta Giyorgis) to the whole of the surrounding area, one obtained a wide-ranging multispectral classification, giving a realistic possibility of creating trustworthy predictive models for reconstruction of the archaeological landscape.

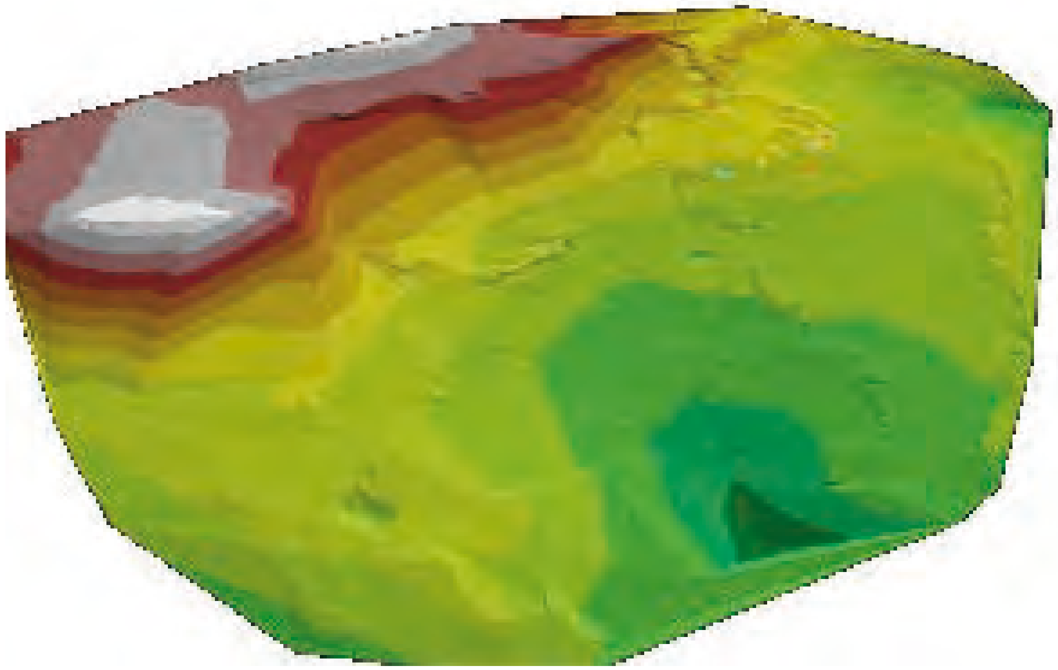
The analysis of associations between archaeological sites and other characteristics or topographical forms, using instruments such as GPS and spectral remote sensing, can make a contribution of great importance if the intention is to proceed to predictive modelling. The question posed to GPS and other remote sensing techniques is always the same: what types of relationships link the various diachronic models and the characteristics of the territorial background? What physical factors have conditioned the ancient settlement patterns? (For socio-political factors, of course, one has to turn to other forms of analysis.) (*Forte et alii 2001*)

In the case of Aksum the significant influences on the relationship between archaeological sites and other elements in the landscape might involve a range of physical factors – soil types and land use, the forces of erosion, terracing, altitude, surface geomorphology, proximity to water courses and the catchment area for natural resources.

In the construction of the DTM through DGPS a striking feature is the speed with which an impressive amount of topographical data can be collected in a relatively short time – at Aksum, for instance, about 107 hectares of coverage was collected in 9 days of work over a height-range of 2266-2345 m above sea level. In our case the interpolation of the height data using either the grid method or TIN contributed important details of the agricultural terraces, many of which seem likely to have originated in antiquity. In Fig 16.5 it is possible to compare a representation of the terrain based on the traditional cartography at 1:25,000 scale (top right), compared with the much more detailed DTM made possible by the subsequent DGPS survey (bottom right). The contrast illustrates the extent to which the DGPS data contributed to the addition of elements that were missing from the traditional cartography.

The use of DGPS over a large part of the hill significantly improved the prospects for the renewed topographical survey by correcting the earlier survey results while integration of the DGPS survey data with the laser-based total station measurements allowed the cartographic survey to be completed and presented in very fine detail.





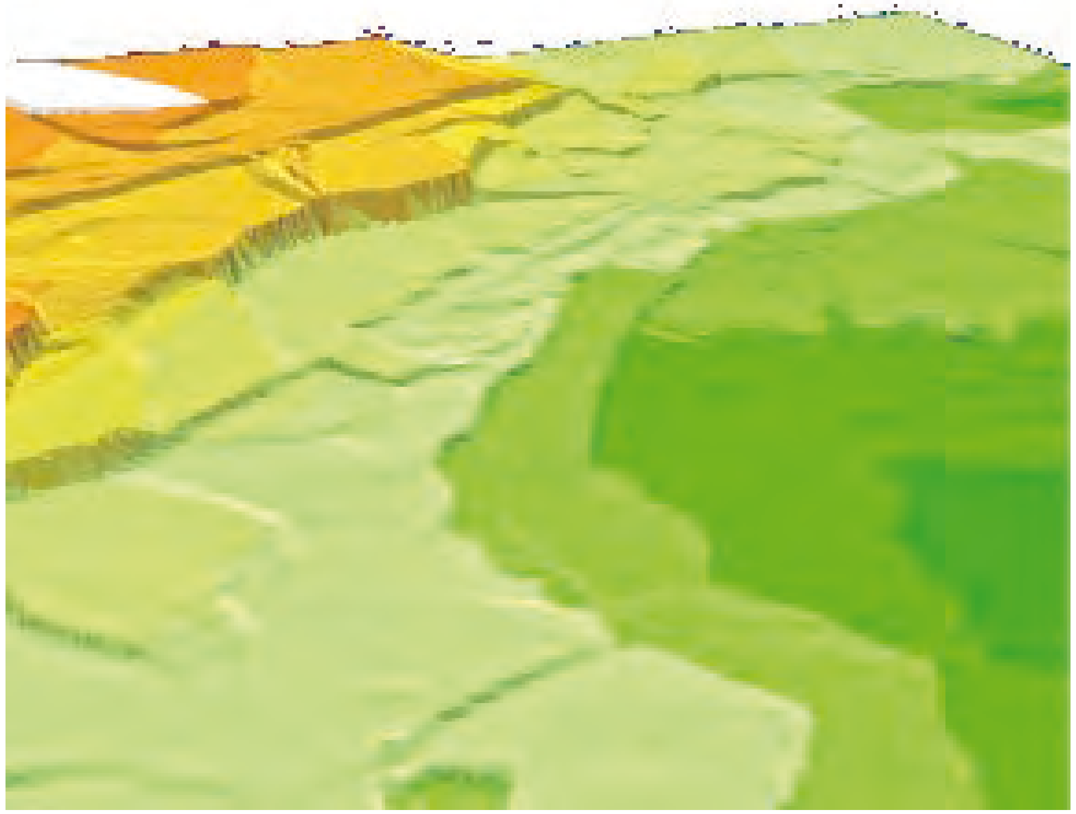


Fig 16. 5 DGPS relief of the Bieta Giyorgis plateau

White lines and spots (*above*) show the locations of 90,000 points acquired in real time during the field survey work.
On the right are comparative representations of the terrain provided by the 1:25,000 scale cartography (top) and the much more detailed view made possible by DGPS survey.

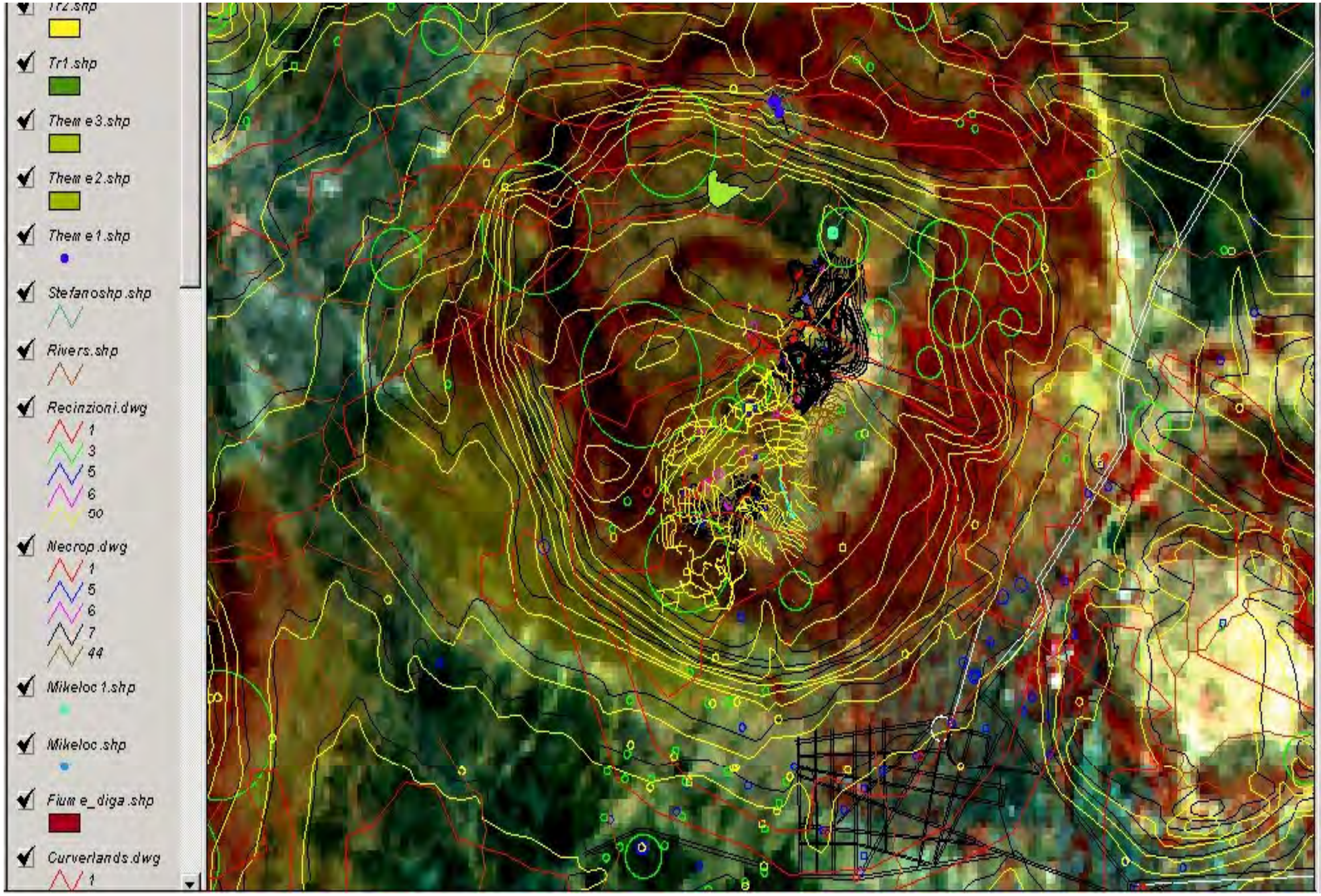


Fig 16. 6 GIS visualisation of the SPOT XS image

Band sequences 3, 2 and 1 overlaid with contour lines, areas of terracing and locations of the principal archaeological areas.

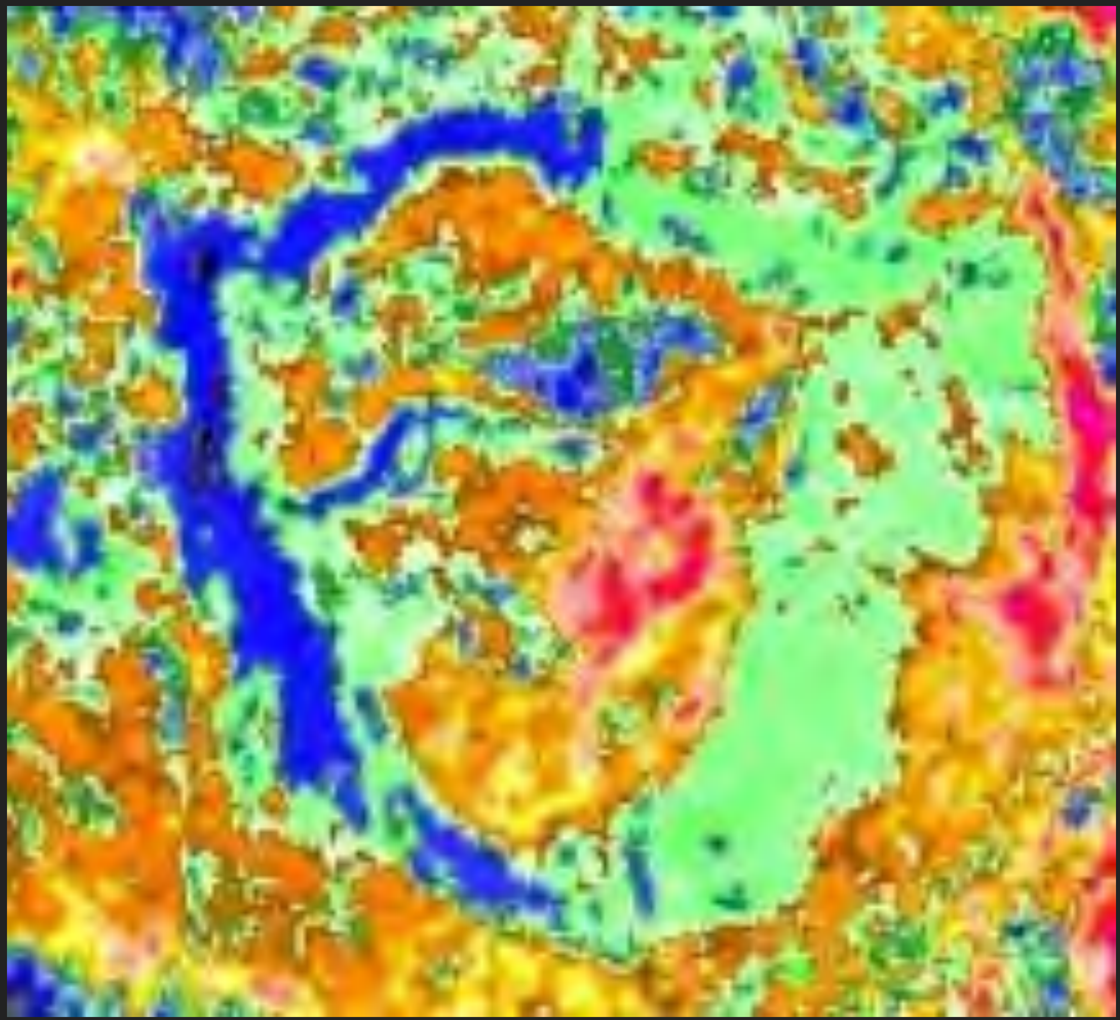


Fig 16. 7 **SPOT XS: unsupervised multispectral classification of the Bieta Giyorgis plateau**

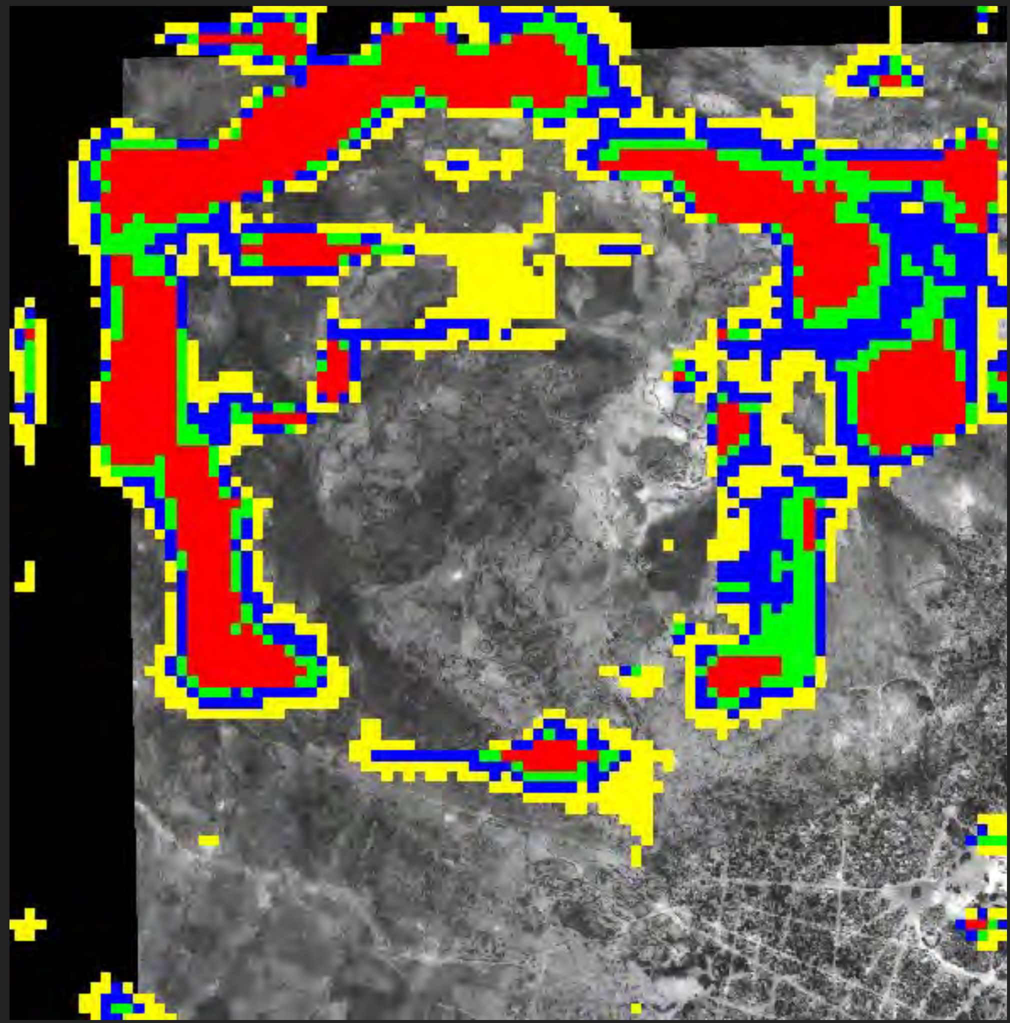


Fig 16. 8 **The 1964 air photo data overprinted in false colour with the vegetation indexes derived from the 1993 SPOT imagery**

Multispectral classification and remote sensing by satellite

The absence of adequately detailed cartography for the project's archaeological objectives turned the team's attention strongly towards the use of remote sensing data for georeferencing and for spectral classification. For Aksum we had available two satellite images: one from Landsat Thematic Mapper dated 22/11/1984 and the other from SPOT XS dated 23/2/1993. The first digital elaboration involved the creation of a raster photomosaic which combined the Landsat and SPOT images with the aerial photographs of 1964 (Fig 16.6). This not only made it possible to create a multispectral and multi-resolution base map but also facilitated examination of some of the landscape changes that had taken place in relatively recent times.

A first classification of the Landsat imagery was attempted by the America geologists Magaly Koch and Thomas Schmid, who selected and sampled 15 types of soil at 30 m resolution. For this part of the elaboration several different types of classification were tested – Mahalanobis Distance, Minimum Distance, Maximum Likelihood and Paralellopiped. In this elaboration the central part of the Bieta Giyorgis study area produced a concentration of high reflectance values with spectral signatures close to those of the pyroclastic materials found in the nearby hills, for example at Mau Qoho. Other preliminary classifications concerned the igneous rocks (plutonite) on hills not affected by the forces of erosion.

The use of the multispectral SPOT XS imagery at 20 m resolution, by contrast, produced even better results. In the sequence of RGB bands 1, 2 and 3 (Fig 16.6) the pixels in red give a good representation of the extent to which eucalyptus forest now occupies a large part of the plateau. The unsupervised classification in false-colour (20 classes, Fig 16.7) was particularly useful for making a preliminary identification of the principal classes of soil, rock and vegetation on the summit plateau of Bieta Giyorgis. Moreover, it is possible to see in dark blue the shadow on the western side of the hill (corresponding therefore to a region that could not be classifiable in terms of its spectral characteristics). The eucalyptus forest appears in light green while orange, light blue and fuchsia denote other classes of soil, rock or vegetation. Detailed classification of the vegetation cover involved the calculation of values for 'vegetation index'. Fig 16.8 shows the vegetation index results (0.1-0.4) calculated from the 1993 SPOT imagery overlaid on the aerial photo data from 1964. It is clear that the eucalyptus trees (first planted about ten years before the SPOT imagery was collected) now hide from investigation a large part of the archaeological landscape which was clearly visible on the aerial photographs from the 1960s.

To overcome the ambiguity in the classification of spectral signatures, as explained above, use has to be made of a supervised classification based on selected training regions. For this purpose, in 2001, the principal training areas were surveyed with differential GPS, creating a measurable perimeter on the ground for each area of interest so as to obtain a vector that could then be exported for use with the remote sensing software. At the same time every sampled area was photographed and a surface sample collected for pedological analysis. On the basis of these training areas a supervised classification was devised, using as classifiers the *Maximum Likelihood Enhanced* and the *Maximum Likelihood Standard* protocols. For every colour identified in the supervised classification a matching class of site/structure was associated with the soils, in the following sequence:

- green: NB_SB1-3, TR1, TR7, TR4, BA, GA, OAZ3, TR3, TR6
- yellow: TR3, GN, TR1, TR5, TR4, TR7, OAZ X-XII
- blue: OAZ9, OAZVT2, OAZ2
- red: OAZVT2, OAZ1, OAZ2
- dark red: OAZ7, TR10, TR7, TR8, TR9, ON
- light blue: TR3
- orange: TR3, TE

As can be clearly seen from Figs 16.9 and 16.11 the results were very positive in terms of the detail with which sample areas with the same reflectance can be recognised. In particular the supervised classification allowed the detection of possible relationships between sites and soils, thereby distinguishing six areas of soils and five clusters of archaeological sites. In Fig 16.9 the supervised classification identifies with green pixels a more or less homogeneous area on the north-eastern part of the hill; yellow pixels predominate in the north-western quadrant while light blue pixels mark out another area in the north-central part of the plateau. Another class indicated by orange is statistically little relevant but is scattered across virtually the whole of the summit plateau.

These classifications must be treated as preliminary pending the results of the pedological analyses. However, one can already advance the hypothesis of an association between sites and the four types of soil classified by the American geologists, known in the local Ethiopian dialect as *bacahel*, *macaeo*, *ognunma* and *walka* (Fig 16.10). On the basis of this classification, along with the spectral signatures, we have marked by circles in Fig 16.11 four principal settlement areas, three at the north and one in the central-south region. The supervised classification shows very well that the differing spectral signatures (corresponding to the training areas measured on the ground by DGPS) correspond to specific characteristics of geomorphology and soil composition (this needs further checking, however, by ground-based analysis). As a consequence, for every principal class of soil we have a particular and well-defined concentration of sites, structures and settlements.

Finally, other results that are useful for archaeological interpretation have been obtained by integrating the remote sensing elaborations with evidence from archaeological survey work on the ground: an ancient trackway (presumed to already be in use in the pre-Aksumite period) crosses the hill from the east and is visible on the SPOT image. This trackway almost makes contact with an un-inscribed monolithic limestone stele situated near the centre of the plateau (Fig 16.9). The particularity of this stele is that it is not associated with any tomb, as is the case in the classical Aksumite typology, but instead appears isolated in the landscape. For this reason it might well be seen as serving the function of a border stele, a territorial *landmark*. It is interesting to note that more than one trackway crosses the area of Tukul Emeni, precisely where another border stele was erected in the late Aksumite period. Moreover, again with the likely function as landmarks, there have been discovered several petroglyphs at the foot of the southern slopes of Bieta Giyorgis.

Comparing these ground-based archaeological observations with the results from the remote sensing elaborations, we can hypothesise two principal areas of settlement in the pre-Aksumite and Aksumite era, separated by the trackway and boundary marker stele: Area 1 to the north and Area 2 on the south (Fig 16.11). On the basis of the early and more recent excavations and the revised topographical survey, we can as a preliminary hypothesis identify in Area 1 a landscape given over to sacred and symbolic functions and in Area 2 a landscape dedicated to industry and domestic settlement. In addition, an open site of the late pre-Aksumite or early proto-Aksumite period

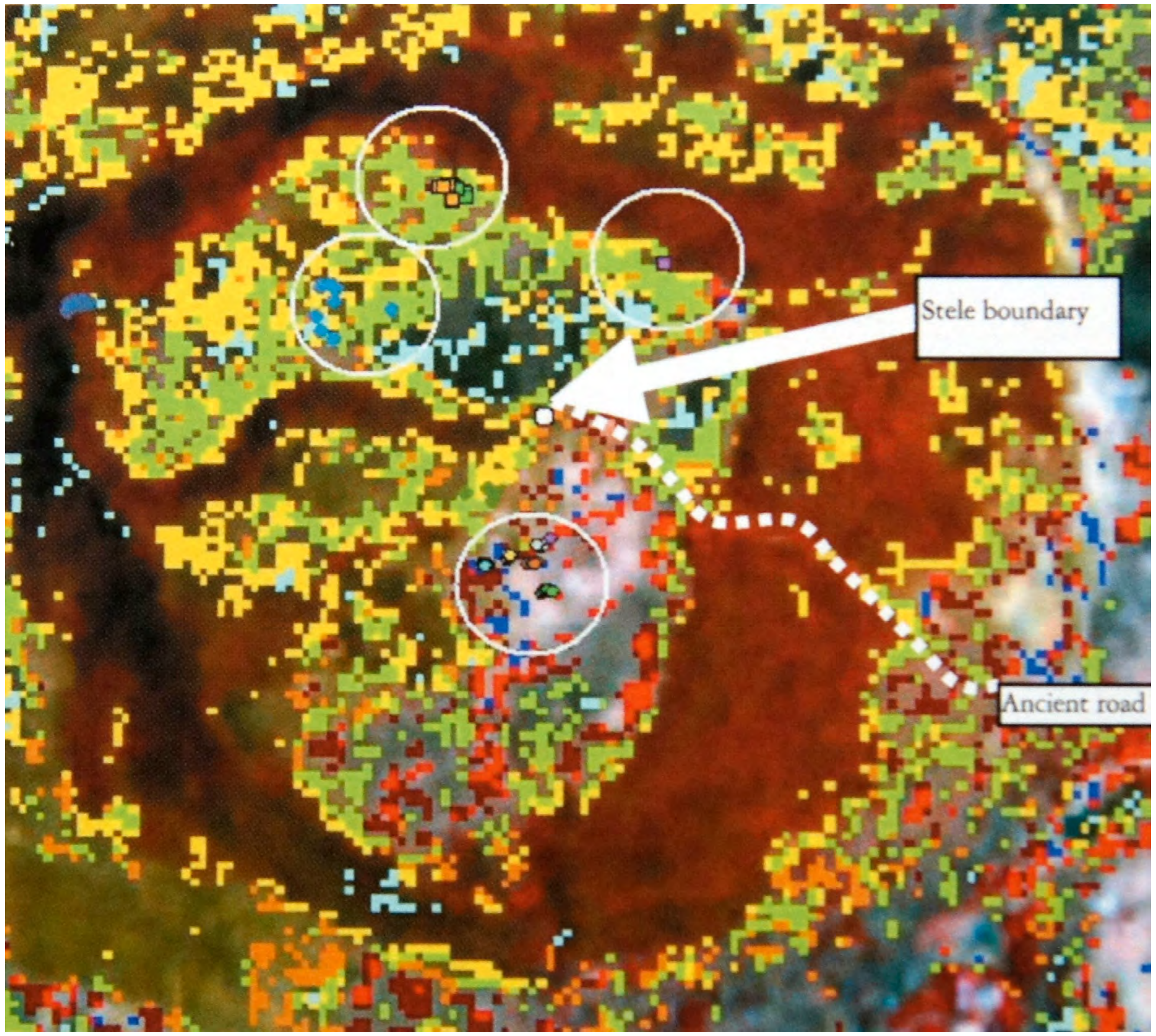
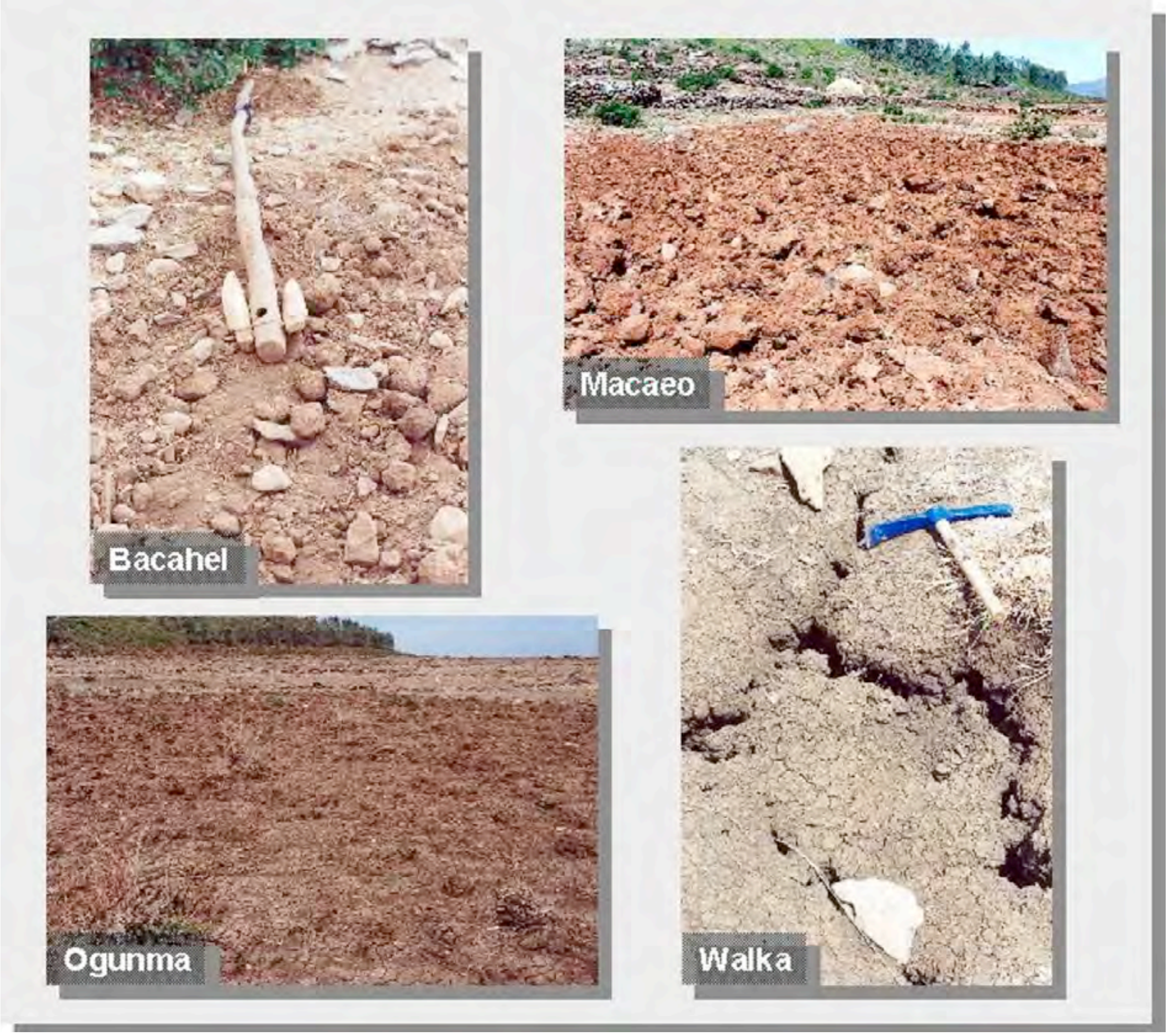


Fig 16. 9 **SPOT XS: supervised classification of the Bieta Giyorgis plateau**



Charakteristics	Soil types			
	Bakahel	Maceo	Ognuma	Walka
FAO classification	Leptosol	Bambisol (ferracil)	Cambisol	Vertisol
Colour	Light brown	Red	Brown	Black
Depth	Very shallow	Shallow	Shallow	Variable
Organic matter content	Very low	Low	Low	High
Texture	Loam	Sandy day loam	Clay loam	Clay
Cracking	Slight	Slight	Slight	Severe
Drainage	Good	Good	Medrate	Poor
Moisture	Low	Low	Moderate	High

Fig 16. 10 **Geological soil classification with their local Ethiopian names**

Classification according to the American geologists Koch and Schmid.

was discovered at Gunda Nebri on the north-eastern side of the hill. A probable ceremonial site, at Tukul Emeni, has been excavated by Mike Di Blasi of Boston University on the north-eastern part of the hill close to the position of the stele. Structures belonging to a possible temple, datable to the proto-Aksumite or first Aksumite period, have been identified at Ona Nagast on the southern part of the hill.

Data fusion

By 'data fusion' we mean the combination of spectral and multispectral data of varying spatial resolutions in a single combined image: for example SPOT panchromatic and Landsat TM, or SPOT XS with an aerial photograph, etc. In the case of Aksum we combined the three bands of the SPOT XS image (B1, 545 nm; B2, 645 nm and B3, 840 nm) with the panchromatic bands of the 1960s aerial photographs so as to retain the high resolution of the panchromatic photographs while

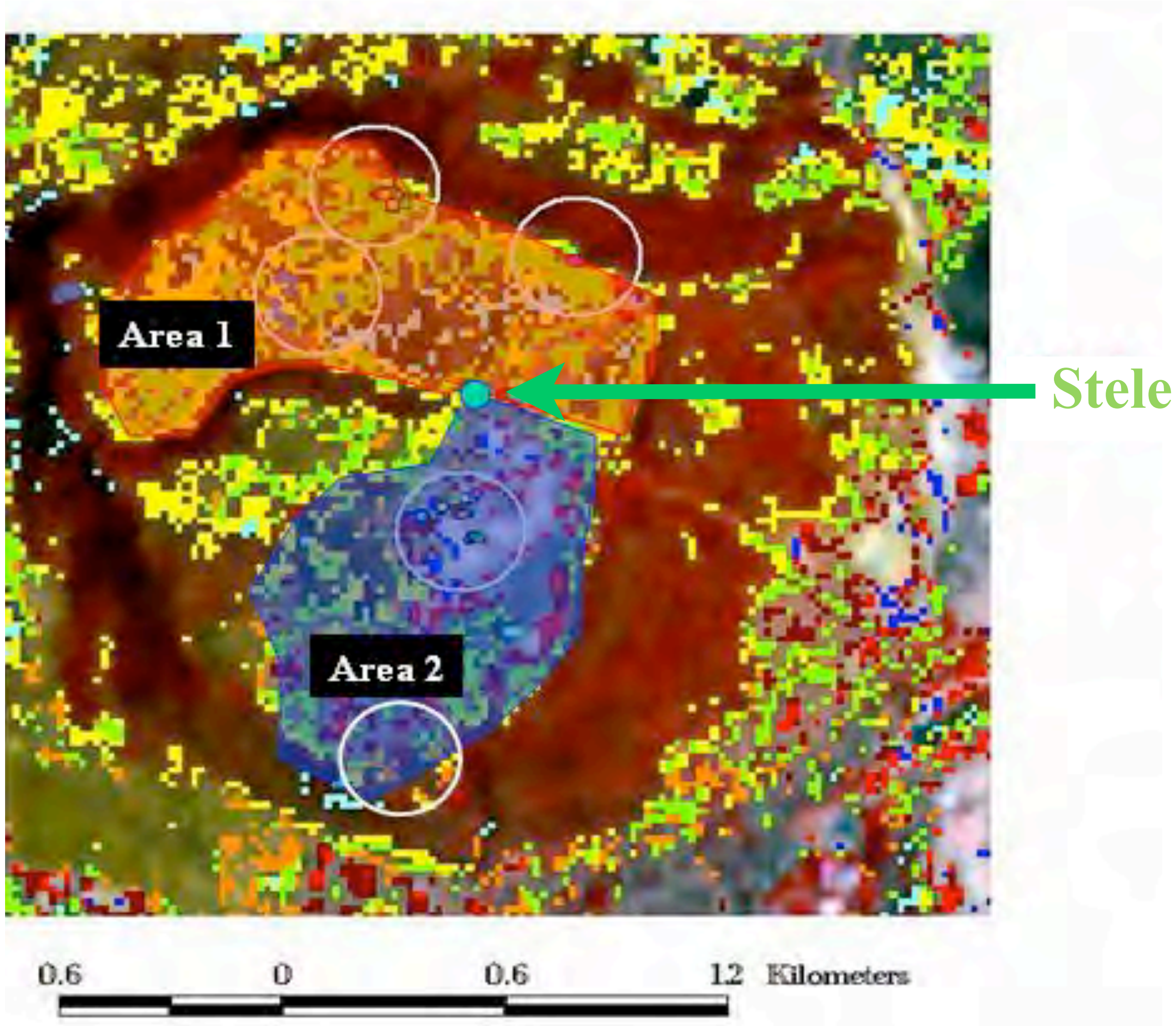


Fig 16. 11 **Analysis of land-use and settlement dynamics based on the on supervised classification**

Area 1, at the north, is hypothetically allocated to sacred and ceremonial functions.

Area 2, in the south, was probably devoted to industrial and settlement functions.

At the centre, separating the two areas, a stele serving as a symbolic boundary marker stands alongside a pre- or proto-historic trackway connecting the high plateau with settlement area on the lowland plain to the east.

also incorporating the spectral bands of the satellite imagery. Even though, clearly, the fusion combines data of different periods, the result is extremely interesting: for example there is a significant difference in the vegetation cover (the eucalyptus forest) between the older air photograph and the more recent SPOT image. In the 1960s not a single eucalyptus tree was present and the **archaeological visibility** of the landscape was excellent. On the contrary, the overprinted satellite image shows very well that the red in the spectral component, representing the eucalyptus trees, covers a large part of the hill (we have calculated it at more then 50% of the surface area). This type of tree is not actually endemic to the area but was introduced in the 1980s by European expeditions to re-populate the area of Aksum. Another advantage of data fusion is the capacity to zoom in and out of the satellite image so as to examine and understand details present in the aerial photo data, and also to compare in multiple resolution the various levels of spatial information (even though, as noted above, this involves data from different time periods).

Conclusions

The contribution of remote sensing and of virtual reality in the Aksum project has opened up new perspectives for reconstruction of the archaeological landscape in terms of spectral classification, predictive mapping, DGPS survey and cultural content.

The multispectral elaboration has had a double purpose: through the fusion of the panchromatic data in the aerial photographs with the multispectral bands in the satellite imagery it has been possible to produce images that combine the colours of the spectral classifications with good spatial resolution. The integration of the two different sources has also made it possible to clarify aspects of the 1960s aerial photographs by providing evidence of recent environmental changes in the landscape. The multispectral classification of the satellite images was directed towards the investigation of the relationship between soils and archaeological site by comparing the spectral signatures of the principal soil types with those in selected training areas. These sample areas involved soils but also in most cases buried or upstanding structures, making it possible to see potential correspondences between soils, terrain and archaeological sites so as to demonstrate or exclude:

- relationships between ancient and modern uses of the soil;
- relationships between anthropogenic/organic aspects of the terrain with buried or semi-buried structures (organic and artificial components can modify the reflectance of the soil);
- relationships between settlement patterns, ancient topography, central places or spatial rankings in the landscape (related, for instance, to religious, sacred or civil power, or to other criteria affecting the distribution and/or character of settlement);
- relationships between archaeological sites and the present-day vegetation;
- relationships between sites and altitude;
- relationships between sites, micro-relief, soil exposure and altitude etc.

The use of DGPS has brought about a considerable increase in the potential of remote sensing in two senses: the creation of a centimetric micro-DTM for the southern part of Bieta Giyorgis and accurate definition of the training areas for the supervised classification of the soils. The differential correction of GPS points has made it possible to revise the earlier topographical results obtained through theodolite-based survey and non-differential GPS. The entire campaign of DGPS survey, covering an area of 107 hectares, collected 90,000 points in only 9 days of work; the resulting DTM produced new and detailed information about the natural and man-made landscape of the study area.

As regards spectral classification, the typical questions directed at systems of remote sensing are: what can these techniques tell us about the diachronic development of settlement systems, the landscape and eco-system? What socio-political, physical or morphological factors have conditioned the ancient population patterns?

To confront all of these questions of this kind it would be necessary to undertake an extended period of spatial analysis. At this preliminary stage, however, it is possible to summarise the principal results from the remote sensing elaborations. The unsupervised and supervised classifications have made it possible to investigate potentially significant relationships between soils and sites, in particular distinguishing six areas of soil and five clusters of archaeological sites. The correspondence of these classifications with the initial geological soil-interpretations opens up interesting prospects for further investigation of the relationships between soils, land use and the distribution of sites and settlements. In particular, on the basis of these classifications and spectral responses, we have been able to group the settlement types into four principal areas.

Finally, further important results have been obtained by integrating the remote sensing data with the ground-based observation: an ancient trackway, visible in the SPOT XS imagery, has been confirmed on the ground-based. This trackway passes very close to a monolithic limestone stele, the archaeological meaning of which is particularly relevant in that it is not associated with a tomb and is therefore plausibly interpretable as a boundary stone or landscape marker.

In conclusion, all of these spatial data, remote sensing procedures and GIS applications have been directed towards the reconstruction of the archaeological landscape of Aksum. Today, starting from these foundations, a VR GIS for the archaeological landscape, that is a GIS constructed for virtual reality applications (written in the C++) is in course of construction at the Virtual Heritage Laboratory of ITABC-CNR in Rome (Forte–Williams 2003). It is intended that this should form the first concrete step in directing multidisciplinary research at the construction and interactive use in real time of a unique environment for the visualisation, immersion and simulation of archaeological data through desktop systems of virtual reality.

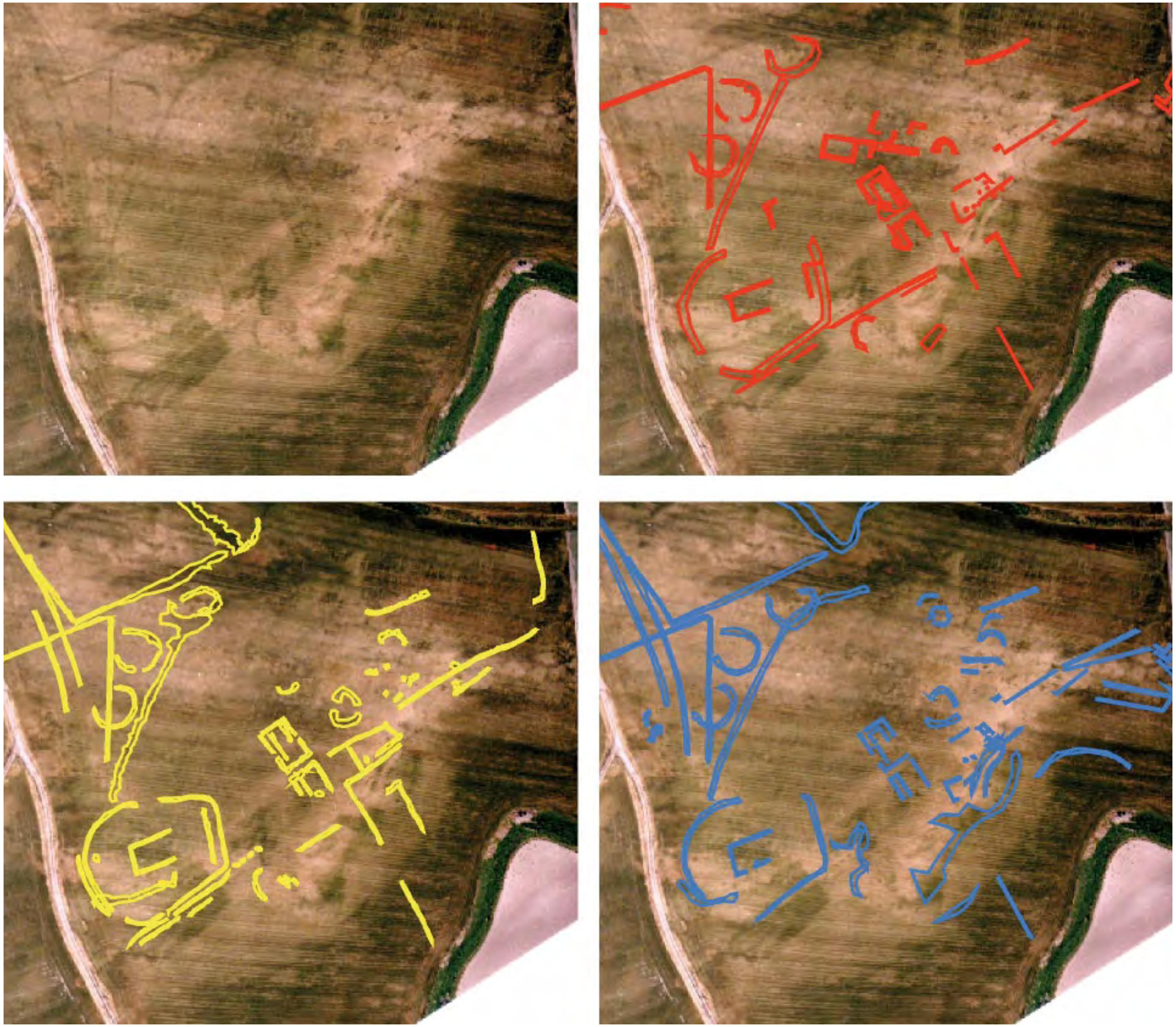
Acknowledgements

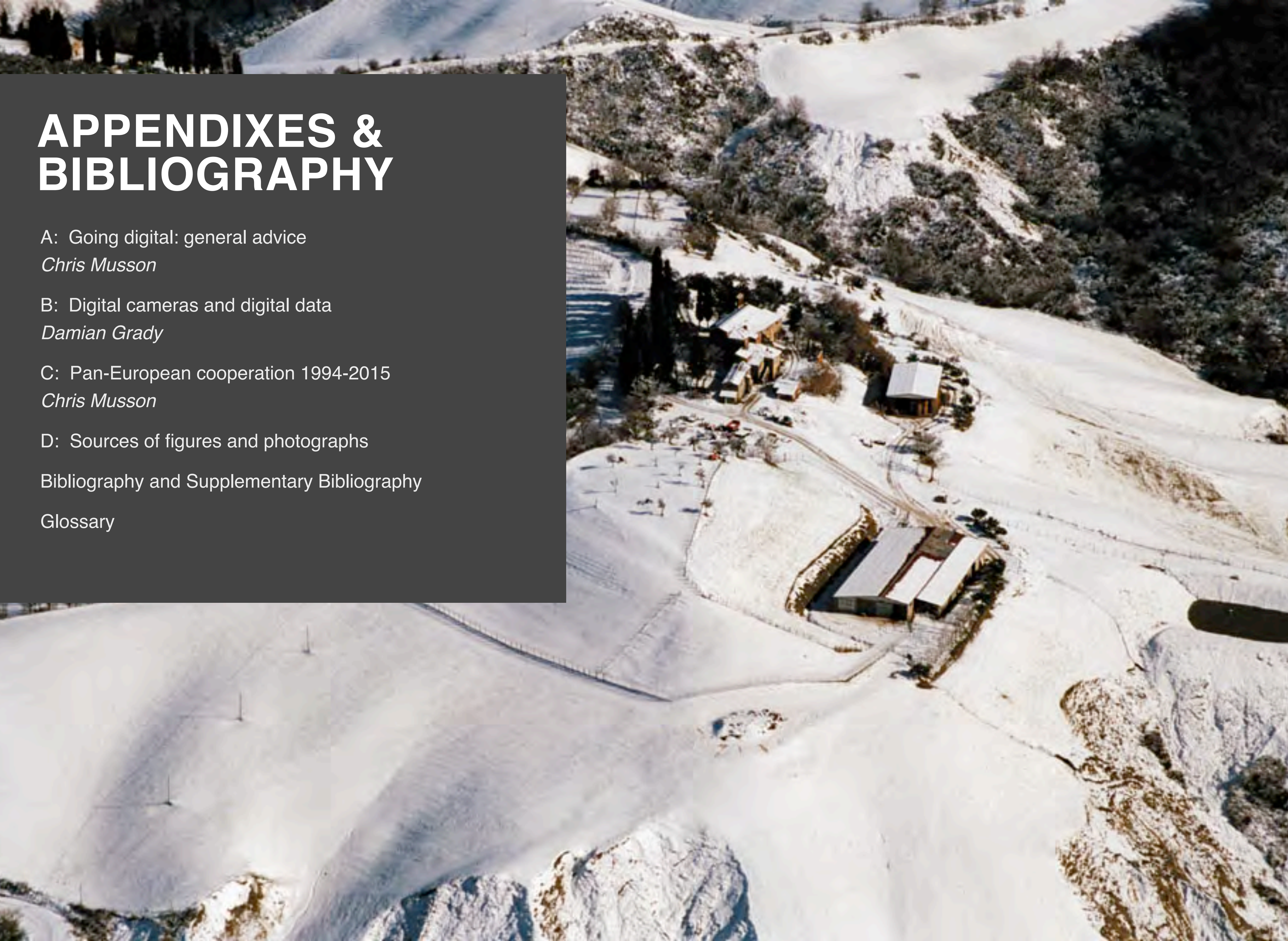
For a detailed up-to-date description of the archaeological research at Aksum see Forte 2003. This contribution has drawn on the work of many colleagues, in particular Rodolfo Fattovich, Monica Foccillo, Andrea Manzo and Cinzia Perlingieri. Archaeological direction of the project is by Kathryn Bard of Boston University and Rodolfo Fattovich of UIO. Particular thanks are due to the American company Terrex, with whom ITABC-CNR has established a scientific collaboration in the development of the software Terra-Vista for archaeological applications; also to the Italian company Tess-Com for making available an experimental version of the software Vtree created by CG2.

POSTSCRIPT

Original photograph (top left) and three interpretations by students at the Foggia School of May 2003.

It is a truism of air photo interpretation that any four photo interpreters, given the same photograph to interpret, will produce at least five different interpretations!





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D: Sources of figures and photographs

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Glossary

APPENDIX A:
GOING DIGITAL: GENERAL ADVICE

Chris Musson

Most of the text for the original version of this book was completed in 2004, when good-quality digital cameras were only just making their way into aerial work. At that time little photo-interpretation and mapping work had been done from primary digital data. Progress has been rapid since then. The long-term or even medium-term availability of traditional cameras and silver-based films is being called into has question. At the same time any detailed advice about digital cameras will go out of date fairly rapidly in the face of new generations of digital cameras, storage media and data-handling equipment. GIS systems will bring – indeed already have brought – new and more efficient methods of data management, storage, processing and exchange. There may be counterbalancing problems with the long-term migration and survival of today's digital images so as to still be readable in fifty or a hundred years' time. But if the images and their related metadata are available after that lapse of time their quality will still be as good on the day they were acquired, which would not be true for colour prints of the same age.

Principles

In the main text (and here) we do not try to predict the changes of the next few years, though we have added or changed words or phrases to acknowledge the almost universal use nowadays – in the air as elsewhere – of digital cameras and primary digital data. Despite this we feel that most of the basic principles of traditional aerial photography will still apply in the digital age, though perhaps achieved in more flexible and time-efficient ways. What are those basic principles?

Always keep your aerial cameras and related equipment in good order, prepared ready for the next flight, however unexpected it might be.

Do not allow your 'aerial' kit to be used for any other purpose, least of all in the dusty conditions of excavation sites.

Always record each site on two separate cameras in the air, so that undetected camera failure or later accidents cannot not rob you of the only record you have made.

Always complete post-flight recording, photo-location, cataloguing and archiving without delay.

Try to ensure the archival storage of your images and (so far as possible) their up-dating to meet future changes in digital technology.

Consider retaining archival-quality prints, on at least a selective basis, even if you decide to work in a predominantly digital environment.

In 'hard copy' archives the prints should always be kept separately from the negatives, so that one or other will survive the any disaster such as fire or flood.

In a digital archive, make sure that images are backed up as soon as practical after download, onto a separate form of data storage (server, external hard drive or top-quality CD), preferably housed in at two separate locations. Until, this has been done, do not erase the images from the memory cards on which they have been recorded.

Become absolutely familiar with the controls and technical capabilities of your camera. These can be fairly complex on digital cameras but the traditional advice still applies – a good camera in the air is one that you already know well from practice on the ground.

Advantages

The most obvious advantage in the use of digital cameras is the immediate availability of the images (even allowing 'dubious' exposures to be checked in the air if need be). Once the images files have been downloaded there is no wait for negatives, slides or prints to be sent to and returned by the photographic laboratory, as was the case with traditional photography.

The images are thus immediately available for on-screen examination, interpretation and mapping or image processing.

Images can be quickly sent, in compressed (usually JPEG) format by email or other means, to those who need them (conservation archaeologists or students at aerial archaeology training schools, for instance).

Images can also be entered with relative ease and speed into pre-established cataloguing systems.

Most good-quality digital cameras allow a wide range of film-speed settings ('sensitivity'), from 100 ISO to 800, 1600 or even higher. The setting can be varied throughout a flight without changing the memory card, so that higher film speeds/sensitivity settings can be used when necessary without the hassle of changing film-stock or arranging for special processing of the films as was the case with traditional photography.

Digital sensors, along with post-flight image processing, offer much better contrast-control than traditional multi-layered emulsions and complex darkroom work. There should be fewer problems with burnt-out highlights or lack of shadow detail when working with good quality digital cameras.

Digital cameras automatically store information (EXIF data) about each image – the time and date it was taken, the focal length and aperture, length of exposure and film-speed setting etc. This may reduce the need to record such information in other ways, while providing more contextual data than was available with traditional photography.

Since the camera records the time when each photo was taken it may be possible to link this to the times automatically recorded on your GPS track or waypoints for the flight. This can be done with accessories fitted to the camera or by subsequent processing with purpose-designed software. Advances in this field are rapid, however, with many modern cameras already having built-in GPS facilities (of variable accuracy, of course, and recording the position from which the site was photographed rather than the position of the site itself).

Digital images, if of suitable resolution, can save much costly scanning when preparing multi-media presentations and hard-copy or internet-based publications.

Problems

A good through-the-lens viewfinder is essential. Digital viewfinders, although they are improving in quality and resolution, are less effective when photographing cropmarks or low-contrast subject, especially when using zoom lenses at relatively small apertures.

It may seem economical to choose a digital camera which can use your existing ‘traditional’ lenses. Most but not all digital cameras, however, use a smaller sensor than the traditional 35mm frame (Fig 4.3). They therefore use only the central part of the image transmitted through the lens. This gives them the effect of having a focal length about 1.5 times that of the same lens used on a traditional 35mm camera. So a standard 50mm lens on a 35mm camera becomes equivalent to about 75-80mm on the a digital camera with other than a ‘full-frame’, sensor the same size as the old 35mm format.

Some traditional lenses produce colour aberrations when used on digital cameras. It may be better to switch to lenses specifically designed for your chosen make of digital camera.

In the early days of digital cameras, used with a set of fixed focal length lenses, the frequent lens-changes often allowed dust or dirt to make its way onto the camera’s sensor, degrading subsequent images and requiring specialist servicing or costly computer programmes to achieve a repair. The danger is reduced nowadays, though not entirely eliminated, most modern digital cameras having some means of shaking off or otherwise removing such foreign bodies.

Even so, it may be better to reduce the risk further by using two identical digital bodies, one mounted almost permanently with the equivalent of a standard 50mm lens, the other with the equivalent of a 100mm lens (about 35mm and 70mm for specifically-designed digital lenses). The only changes then necessary would be an occasional switch to a wide-angle lens for landscape views, or to a longer telephoto for extreme close-ups.

Another method, giving an even wider range of framing options, with no lens-changes at all, is to mount one body with a short zoom (equivalent to, say, 28-90mm on a 35mm camera) and the other with an overlapping but longer zoom (equivalent to 70-210mm or more). Zoom lenses have vastly increased in quality in recent years and the best of them can now almost match the results achieved in earlier days with fixed focal length lenses. But you will be wise to avoid cheap lenses from the bottom end of the market – they will not give you the results you desire.

Some aerial subjects have very low contrast or few sharp boundaries to help the camera's autofocus system. This increases the risk of fuzzy images or inability on the part of the camera to find a satisfactory focus. When buying a digital (or even a traditional) camera you should consult published reviews or internet sites for comments on autofocus performance under such conditions.

Digital sensors mimic the colour-sensitivity of the human eye. Some early sensors also covered parts of the infra-red spectrum that helped traditional black-and-white films to record cropmarks and other features. Most modern sensors no longer do so because the infra-red waves were found to disturb the image during long exposures. On the other hand digital cameras give a full colour image, offsetting some of the monochrome film's problems in representing different colours (such as red and green) as varying shades of grey.

The use of an ultra-violet (UV) filter to combat haze and protect the front element of the lens is still recommended, as is the use of an appropriate lens hood to cut out unwanted reflected light. Circular polarising filters can also be used but they have to be rotated for every individual exposure and so require much expertise on the part of the photographer to give good results. An added complication in their use arises from the fact that some zoom lenses have front elements which rotate during zooming.

Digital camera bodies will go out-of-date even more quickly than their traditional predecessors, especially as regards the resolution or quality of their sensors and in-camera software. So be prepared to update your camera bodies more frequently than might have been the case in the past, perhaps every 2-3 years. Consider this when deciding how much to spend each time you change your equipment.

Lenses, once bought, will probably have a much longer life, provided you maintain their compatibility with your new equipment. A word of caution is necessary, however. The same lens, whether digital or traditional, can perform differently on two different digital bodies, even when made by the same manufacturer. If possible try to consult professional journals and internet sites before you make your purchase.

You will need, or must acquire, competence in handling digital data. There is still much work to be done in the downloading, archiving, backing-up and cataloguing of digital images. But the use of GIS and related systems may generate new and quicker ways of carrying out some of the the post-flight tasks described in Chapter 5.

Archival-quality colour prints are expensive, and likely to remain so. You must consider this when deciding whether to retain hard-copy prints, either routinely or on a selective basis. This may be desirable (if expensive) for safety or for public access in an archive currently based on the use of cheaper black-and-white prints.

Different makes of digital cameras use different digital formats for recording and transfer of the recorded data. The RAW format is capable recording every element of the image which reaches the camera's sensor. But different makes of camera use different versions of the RAW format; these may become obsolete over time, making long-term reading of the data difficult or impossible. You must consider from the outset the need to transfer your data to alternative formats and storage media.

The safest way – perhaps the only way – to ensure long-term survival of digital data is to make sure that you donate or copy your images to an organisation (perhaps a national archive) which has the resources (and determination) to ensure this for all of its digital data is stored and if necessary 'refreshed' in a way that will ensure its continued readability in the longer term..

For further advice on digital cameras and the handling of digital images see Appendix B.

Acknowledgements

These notes owe much to the experience and technical advice of Otto Braasch, Michael Doneus, Damian Grady and Klaus Leidorf, who all took the plunge into digital photography some time before the present author.

APPENDIX B:
DIGITAL CAMERAS AND DATA HANDLING

Damian Grady, English Heritage[1]

Background

This Appendix is based, with minor alterations and additions by Chris Musson, on guidance issued to organisations or individuals carrying out aerial work in association with English Heritage (EH). The advice, however, may prove useful to others contemplating an involvement with digital air photography and the handling of the resulting image files.

While black-and-white negative film is still considered the most durable medium for long term archival storage, the rapid rate of development and innovation in digital imaging technology has all but ended the demand for the wet film process as professional and amateur photographers have switched to digital photography.

Digital photography involves more than buying a digital camera. The processing, storage, dissemination and time spent undertaking these tasks are just as important as taking the photographs. The English Heritage archive, currently known as the National Monuments Record (NMR), and the aerial reconnaissance teams have developed flowlines and standards for the capture, post-flight treatment and long-term archiving of digitally captured aerial images.

The following advice is based on the current standards set by the EH archive for the long-term storage of digital photographs and the lessons learnt by the EH aerial reconnaissance teams when using digital cameras. Apart from the archival standards set by the archive, other factors discussed below will undoubtedly change as camera technology improves. So advice on such things must be expected to change over time as these improvements are made.

1 Damian Grady, Aerial Reconnaissance Manager – Remote Sensing Team, English Heritage, The Engine House, Fire Fly Avenue, Swindon, SN2 2EH. Readers should contact the author directly if they require copies of the original document or for further advice on any of the points discussed (damian.grady@english-heritage.org.uk).

Cameras

The cameras use by the EH reconnaissance teams in recent years have been top-grade Canon and Nikon models with best-quality zoom lenses from the same manufacturers, The advice offered in the following paragraphs is based on accumulated experience with this equipment but most of the lessons learned have a general application in terms of digital cameras and the handling of digital data.

The cameras used by the EH reconnaissance teams have so-called ‘full-frame’ sensors, which are the same size as the individual frames in traditional 35mm cameras. While this level is desirable for the very best quality of aerial work it is recognised that the considerable costs involved may force many individuals, and some organisations, to rely on cameras bodies (and related lenses) which use smaller sensors, of the size illustrated earlier in this book (Fig 4.3). At the ‘semi-professional’ level of quality this kind of camera can indeed perform well in the air, subject to one over-riding piece of advice: buy the best equipment that you can possibly afford, particulary when contemplating lenses that may form the basis of your aerial activities for many years to come.

Whatever the size of the sensor, sufficient image quality will require a **minimum** sensor **resolution** of 12 megapixels. All professional and most semi-professional cameras now offer at least this level of resolution. But check that the advertised number of pixels refers to ‘effective’ rather than to ‘interpolated’ pixels. Interpolation involves the camera adding ‘neutral’ pixels to the image. Cameras with this facility should be set to use the effective rather than interpolated pixel resolutions.

As just mentioned, many digital cameras use a **sensor** which has an area smaller than that of a 35mm negative. This means that with lenses designed for use with traditional 35mm cameras the area covered by the image will be smaller than the old 35mm frame, leading to the common misconception that the focal length of the lens has effectively been increased. In fact the focal length remains unchanged, the sensor is simply capturing a smaller part of the image that is transmitted through the lens. Lenses designed specifically for smaller-sensor cameras will often list in their technical specifications an ‘equivalent focal length’ compared with the old 35mm standards.

During lens changes digital sensors easily attract **dust**, which is then difficult to remove. Camera manufacturers recommend that you do not clean the sensor yourself as this may irreparably damage the sensor. Instead they suggest that you send the camera to them, or to a qualified camera maintenance firm. In either case this can be time-consuming and expensive process. Cleaning kits are available, however, and with care it is possible to remove dust without damaging the sensor. It is up to you to decide whether you want to take the risk.

Most recent cameras now incorporate an automatic sensor-cleaning function but this should not be relied on. Instead, the best advice is to keep lens-changes to a minimum. This is easiest to implement if two cameras, equipped with lenses of different focal lengths, can be employed, as recommended in Chapter 4 and Appendix A. To test if a sensor is contaminated with dust you should set the camera to aperture-priority, and f22, and then take a photograph of a white piece of paper. Download the images and check for dust particles. While it is possible to digitally remove dust marks from the images this is a time-consuming process, to be avoided if at all possible.

As ever, you should pay particular attention to the quality and capabilities of the lenses that you buy with or for your camera(s). Most manufacturers produce good quality **zoom lenses** in ranges suitable for aerial survey work. If resources allow, buy two digital cameras with differing lengths of good-quality zoom lenses. If you are buying a significant amount of expensive camera equipment many suppliers will allow you to try out (in your case in the air, of course) before you complete the deal. Try to negotiate this with the supplier if you possibly can.

Currently the EH reconnaissance teams use matching pairs of full-frame Nikon cameras, one equipped with a 24-70mm f2.8 zoom lens and the other with a 70-200mm f2.8 image-stabilised zoom. For smaller-format sensors the equivalent focal lengths would be 16-50mm and 50-150mm, or thereabouts.

Image-stabilisation, either in the camera body or in the matching lenses, is a considerable advantage in the air, where the aircraft and camera are in constant motion. Most stabilising systems allow significantly slower shutter speeds to be used than would normally be recommended for aerial work. This can be particularly useful when operating in dull or fading light.

If the camera has a ‘digital’ zoom function do not use this as all this does is reduce the part of the frame that is recorded and then interpolate extra pixels to maintain the apparent pixel count in the resulting image. Always use the your cameras in optical zoom setting.

The design of many modern zoom lenses means that it is not possible to fix the focus ring at infinity (∞) setting with sticky tape, as has been practiced by many aerial photographers in the past. So it is important to assess the quality of the **auto-focus** function before buying a camera. Assiduous reference to technical reviews on the internet will warn you whether or in what conditions the auto-focus facility of your contemplated purchase is likely to struggle. The main problem in aerial reconnaissance occurs when there is little contrast between the subject and its background, as with green-on-green cropmarks or when working in dull or fading light at the end of the day. ‘Single-point’ and ‘centre-weighted’ auto-focus settings will not always function reliably in these conditions, so it is better to choose a camera that offers a reliable ‘multi-point’ auto focus facility. This will ensure that the focus can ‘grab’ an area with sufficient contrast for the auto-focus to function properly. If the auto-focus is sluggish when used with an image-stabilised (IS) lens, the benefit of the stabilising functionality will be negated.

The capacity of the **memory card** depends on the budget available, but a very important factor when making the choice is the ‘write-speed’. In choosing the camera you should look for a model that can shoot a minimum of 5 RAW frames per second (fps) and has a buffer rate of at least 2fps. But the effective buffer rate can be increased two- or three-fold by a using memory card that has a fast write-speed.

When swapping memory cards between different makes of camera it is important to re-format the memory card every time the change is made.

Many of the professional SLR cameras can be heavy, especially in combination with the lenses mentioned above, so it is important to ensure neck or hand **straps** are used at all times when in the air.

Make sure that you equip each lens with a good-quality **ultra violet (UV)** filter. This not only to reduces the effect on the image of atmospheric haze but also to help protect the carefully-coated front element of your expensive lens from greasy finger-prints or other kinds of physical damage. Do not buy cheap filters and fit them to your expensive lenses. Also, check the exposed surface of the filter regularly and replace it if shows any sign of scratches or other damage. Replace it if need be – the cost of a new filter will be less damaging to your pocket, and professional reputation, than finding that your results have been degraded by your failure to do so.

The majority of professional and semi-professional cameras come with re-chargeable **batteries** designed specifically for that particular model. It is advisable to buy at least one spare battery per camera, and to ensure that they are kept charged ready for use whenever you need them. Battery life can be extended by switching off the preview screen on the camera back if you have the facility to do so. Also by letting the camera use its 'sleep' mode during longish breaks in photography, rather than switching it on and off.

Camera Settings

Ensure you are familiar with all the buttons and dials on your camera; they can be easily knocked in the air and accidentally changed. Therefore check the read-out of essential settings regularly throughout each sortie, and possibly place insulating tape over any that you know know must ***not*** be change during flight.

When selecting the image file type it is recommended that the camera's **RAW** image format be used (RAW is not an acronym – it simply indicates the 'raw' data that has been received by the sensor but not processed in any way by the camera's internal software). RAW images are captured at the maximum quality the camera is capable of recording. When a **JPEG** (Joint Photographic Experts Group) image is created a certain amount of the RAW data is discarded as a matter of course, depending on the compression setting on the camera.

Another major advantage of RAW format is that, because **all** of the image data is preserved, post-processing can include adjustments to such things as colour temperature, contrast and exposure compensation, thereby retaining maximum photographic quality. There is also a concern that JPEG artefacts may affect the future usability of software for image enhancement, especially those recent software packages or internet-based systems that use automatic pixel recognition to create 3D models or 'point-clouds' from multiple images.

There is currently no recognised industry standard for RAW images so the EH archive has decided that for their own work the standard format for long term archiving should be **TIFF** (see later in these notes for more details on RAW-to-TIFF conversion).

Most cameras can be set to simultaneously record RAW and JPEG versions of the same image. Recording in JPEG at the same time as a RAW can help save time later. The smaller JPEG files are ideal for keeping as a visual index, for use in email messages or for making reference prints for filing or distribution. However, in situations where images are taken in quick succession the camera buffer rate and the write-speed and capacity of the memory card may be overwhelmed. In these circumstances only the JPEG version may be recorded, the more valuable RAW equivalent being effectively discarded. Managing two sets of similar images can make the post-processing workflow more complicated but it is a matter of individual or institutional choice to decide whether to use both formats simultaneously in the air or alternatively to create JPEG files from the original RAW images at a later stage in the post-flight.

When converting from a traditional to a digital camera it is important to understand the effect of the new camera's settings for **white balance, colour saturation and contrast**. The effect of these settings will vary from one make of camera to another, as will the moment-by-moment or hour-by-hour conditions in which the photographs are taken. This applies especially to the **white balance** setting. Once in the air it is worth experimenting with different settings. If the resulting images are not very good they can be altered when you are back on the ground, but in the long term you will achieve better results – and save a lot of post-processing time – by working out through personal or shared experience which settings are best for your own camera.

Sharpening should not be used if the final images are to be stored in an archive. Sharpening is 'output device dependant'. In other words a desktop printer will require different sharpening requirements to laboratory or publication printing. Sharpening should therefore be part of the printing process rather than of the capture/conversion process. Sharpening at the image-capture stage can also cause problems when the resulting files are rectified for mapping. Most camera manufacturers assume that the user will require some level of sharpening, therefore when they use terms such as 'Standard' when describing basic image settings/parameters there will be a default level of sharpness included. It is very important that you fully understand how sharpness is set on the camera and then turn it off or set the level to zero.

Set the **colour space** to **AdobeRGB** rather than any other setting that your camera may offer. This provides a very large range of colours compared to sRGB (for instance) and is a requirement for the EH archive.

As explained in Chapter 4 and Appendix A, a significant advantage offered by digital cameras is the ability to change the **ISO** ('film-speed' or 'sensitivity') setting from one frame to the next. However, the displays on some cameras do not constantly show the ISO setting, so it is worth checking that this has been set correctly before taking off and periodically thereafter during flight. It is worthwhile experimenting with different settings. For instance it may be sensible to use the faster 200 ISO setting rather than 100 if you are working in dull light or using a zoom lens that does not have an open-aperture setting better than (say) f3.5. Also, in low light, it is normally better to increase the ISO rating rather than decrease the shutter speed. In really ‘tight’ situations, of course, you might need to use both adjustments (and take a larger number of shots in the expectation that some at least will be sharp and well exposed).

When using **shutter priority** setting, which gives priority to the length of exposure (normally 1/500 second or faster) you should make sure to double-check that the camera has not been set to modify the set speed to a longer exposure time if the light levels become too low to provide an adequately exposed image. You need at all times to be in full control of the camera’s operation as far as shuter speed is concerned.

If available, enable the **auto-rotate** option on your camera. This will save time after the flight because the camera’s internal software will then automatically rotate the image so that ‘tall’ views do not need post-processing to avoid their appearing ‘on their side’ during subsequent viewing.

At an early stage it is advisable to make a decision about whether to set the **time** on the camera’s built-in clock to **UTC** (Coordinated Universal Time) rather than to the ‘local’ time for the country or season of year in which you are operating. It is easy to forget to change the time setting in March and October when the clocks in many countries move forward or back by one hour in relation to the previous day.

Immediately before every flight the camera’s time should also be synchronised, to the second if possible, with your other camera and with any GPS equipment that you may (or rather should) be carrying. The time of the readings on your GPS is provided by the satellite signals that it uses to calculate your global position, so you should synchronise the camera’s time reading to that of the GPS rather than trying to do the opposite.

Check regularly for updates to the camera’s **firmware** via the manufacturer’s website. This is the software that is inside the camera and controls many of its functions. The updates may help the camera (and therefore you) to perform even better than before. They can be downloaded into your computer from the manufacturer’s website and from there by cable into your camera. When you carry out this process, however, be sure to make a note of all the settings that you yourself have entered into the camera. You will then be able to restore your preferances if the new firmware re-sets the camera to ‘factory settings’.

Downloading and backing up

Downloading many large images is best done by inserting the memory card into a **card reader** attached by means of a USB cable to your computer. This will increase the speed of transfer by anything up to 40 times compared with attaching the camera to the computer through the cable supplied with it on purchase. Using a card reader will also save wear and tear on the camera’s connector socket and will not run the risk of draining your battery part way through the transfer process (thereby potentially corrupting or losing some of your data).

Once the images have been downloaded it is advisable to **back up** all of the data before any post-processing is undertaken. This should preferably be done to a **portable hard drive** ('external drive') and additionally to a second hard drive that can routinely be kept in a different (and therefore safer) location. At the very least you should acquire the habit of not wiping or re-formatting used memory cards until post-processing has been completed and the resulting files made ready for archiving.

Experience has shown that some of the software provided with digital cameras for downloading and processing images is not entirely reliable and can occasionally corrupt images. It is therefore desirable to make a portable hard drive a standard part of your equipment, again to be used for no other purpose than your aerial work. Drives of 500GB or even 1000GB capacity can now be obtained for very reasonable prices. But, again, choose a reputable make rather than going for the lowest price available on the internet – your images are the sum of all your efforts and experience and you should not place them at risk by using inferior equipment at any stage in the process.

The next step is to **delete any unwanted images**, for instance if they are not sharp or are faulty in any other way. You may also eliminate images that are irrecoverably under- or over-exposed, along with those that record 'missed' targets or things that you have eventually decided are not archaeological – or at least are not worth keeping in the archive for one reason or another.

Post-processing of the images

Before editing images we strongly advise that your monitor should be **colour calibrated**. Without this the images that you produce may require further alteration on other computers or on printers other than your own. Ideally a calibrated monitor should be kept in a room with constant light levels. Leaving aside specially designed darkrooms, however, most offices are unlikely to provide constant light levels. It is therefore advisable to calibrate the monitor before processing any large number of images and not to do this kind of work at times when ambient light levels are severe or rapidly changing. The calibration process can be completed in a matter of minutes using software and attachments that cost no more than about £200-£1000 (250-1250€) at 2012 prices. (See Explanatory Note 1 at the end of this Appendix for information on hardware, software and settings currently recommended by EH for monitor calibration.)

A wide variety of software can be used for a number of post-processing tasks. The EH aerial reconnaissance teams have not so far found a single piece of software that can be used efficiently for all post-processing tasks. The programmes currently in use (in early 2012) are **Adobe Photoshop CS5** (incorporating **Adobe Bridge** and **Camera RAW**), along with **BreezeBrowser Pro**[2]**.** Digital cameras allocate their own reference numbers to the individual image files

2 Our colleague Geert Verhoeven points out that there exist very good and freely available image editors such as the PhotoShop rival GIMP (http://www.gimp.org), Paint.net (http://www.getpaint.net) or ImageMagick (http://www.imagemagick.org/script/index.php). For RAW processing, one can also use RawTherapee (http://rawtherapee.com). Image browsing and cataloguing can be performed for free with Picasa (http://picasa.google.com/intl/en). Mention should also be made of Irwin Scollar's Radcor, LuminCor and CastCor (http://www.uni-koeln.de/~al001/radcor.html).

and to the folders in which they are grouped. The numbering systems differ from one make of camera to another so for this and other reasons it will almost certainly be necessary to carry out **re-numbering** before the files can be submitted to the archive for permanent storage. Most image processing software will do this quickly to a format of your own or your parent archive's choosing. The numbering system used in EH, for instance, follows a relatively simple sequence of BatchNo_FrameNo (so, for example, 21345_045 for the forty-fifth frame in BatchNo 21345). A group of batch numbers is allocated by the archive to the aerial reconnaissance team so that they can use a new number for each flight that they undertake. Whatever numbering system you use, try not to make the unique reference number for each image too long.

Any images lodged with the EH archive must include **IPTC** and **EXIF data**. EXIF (EXchangeable Image File) data, is created automatically by the camera for each image; it includes important information such as the date, time, focal length and other camera settings when each photograph was taken. IPTC (International Press Telecommunications Council) data has to be created for each photograph so as to provide future users with essential information such as authorship, source and copyright status of the image. The form and content of the IPTC data, as used in EH, is described in Explanatory Note 2 at the end of this Appendix.

For permanent archiving, RAW images need to be converted to **TIFF** (Tagged Image File Format), one of the industry-standard archival-quality formats for long-term storage. So before converting the RAW images to TIFF you should make any necessary adjustments to white balance, saturation, contrast, exposure etc. But remember to ensure that any 'sharpening' settings are set to zero and be aware of any other setting in your conversion software that is in reality a form of sharpening (such as Clarity in Adobe Camera RAW).

Once you are happy with the quality of the adjusted RAW images you should then make the conversion to **8bit TIFF**. If any tonal adjustments are required in Photoshop, i.e. to Levels or Curves, it is best to convert initially to a **16bit (per channel) TIFF** as this will allow you to retain as much tonal information as possible, thereby avoiding a jagged or 'comb' histogram. Byte order should be 'PC' if given the choice. Once the alterations are complete you can then convert to 8bit.

The EH archive requires 'finished' images, ready-to-go if requested by a customer. Thus it is assumed that no further adjustment will be required and that the 8bit format will therefore meet the customer's needs. The choice of 8bit rather than 16bit TIFFs was made so as to keep file sizes down. A full-format (20+ megapixel) digital camera produces RAW images of about 20-30MB, which convert into 8-bit and 16bit TIFF images of approximately 70MB and 140MB. The equivalent values for the smaller 12-15 megapixel sensors on semi-professional cameras are 10-15MB for the RAW images and about 35 and 70MB for the resulting 8bit and 16bit TIFFs.

The EH archive requirements for digital images can be summarised as follows:

- All images must be in 8bit TIFF format

- All images must have a colour space of AdobeRGB
- No images should have been sharpened
- All images must contain EXIF and IPTC data

(After full cataloguing in the archive further items may be added, such as the date of the photography and the grid-reference of any site illustrated in the image. But this is a matter for each organisation to decide when defining its own standards for IPTC data.)

Archiving

Once conversion to TIFF has been completed you will need to decide whether to archive the RAW images as well as the TIFFs. Most archives will reject JPEG files as being inherently unsatisfactory for long-term storage. So if you capture these as well as RAW images during flight you will need to treat them as part of your 'locally' stored data. The same applies to any JPEGs that you choose to create during the post-flight processes, along with any intermediate stages in post-processing if you want to retain these.

As noted above, each camera manufacturer uses its own RAW format so there is no industry standard suitable for long term archiving. Most professional and semi-professional photographers treat the RAW image as the equivalent of the negative in traditional black-and-white photography. So if you have the storage capacity to do so it is recommended that you archive the RAW as well as the TIFF images. Note that the TIFF images **must** be archived as this is an industry-standard format that is likely to be readable in the long term, unlike the non-standardised RAW formats used by current camera manufacturers.

Post-photography processing: workflow summary

- Download images and back up to one or more separate hard drives
- Edit out unwanted shots, and rotate images if necessary
- Batch re-number the images
- Batch caption the images by adding IPTC entries
- Make any changes to white balance, exposure, etc
- Batch convert to TIFF
- Make any further adjustment in Photoshop or equivalent software if required
- Save ready to archive
- Dispatch to archive
- Archive

Recommended equipment for digital aerial photography

- One, or preferably two, full-frame or semi-progessional digital cameras, with minimum 12 megapixel sensor, fast multi-point auto-focus capability and good quality zoom lens (or lenses).
- Ultra-violet (UV) filter for every lens.
- Spare batteries, maintained fully charged.
- Large-capacity memory cards with fastest available write-speed.
- PC with fast processor and large amount of storage space.

- Good quality colour management monitor and colour calibration device
- Card reader.
- At least one external hard drive but preferably two.
- Hardware and software for calibrating the monitor.
- Post-processing software capable of batch re-numbering, editing RAW files and batch conversion to TIFF and JPEG.
- Photoshop or equivalent for image manipulation.

Explanatory Note 1:

Current EH hardware and software standard for colour calibration

Within any organisation there may be merit in achieving colour-consistency in images across the whole of the organisation's operations. This is the reason for adoption of the following procedure and colour settings within EH's own operations and in any associated work by outside bodies.

Hardware

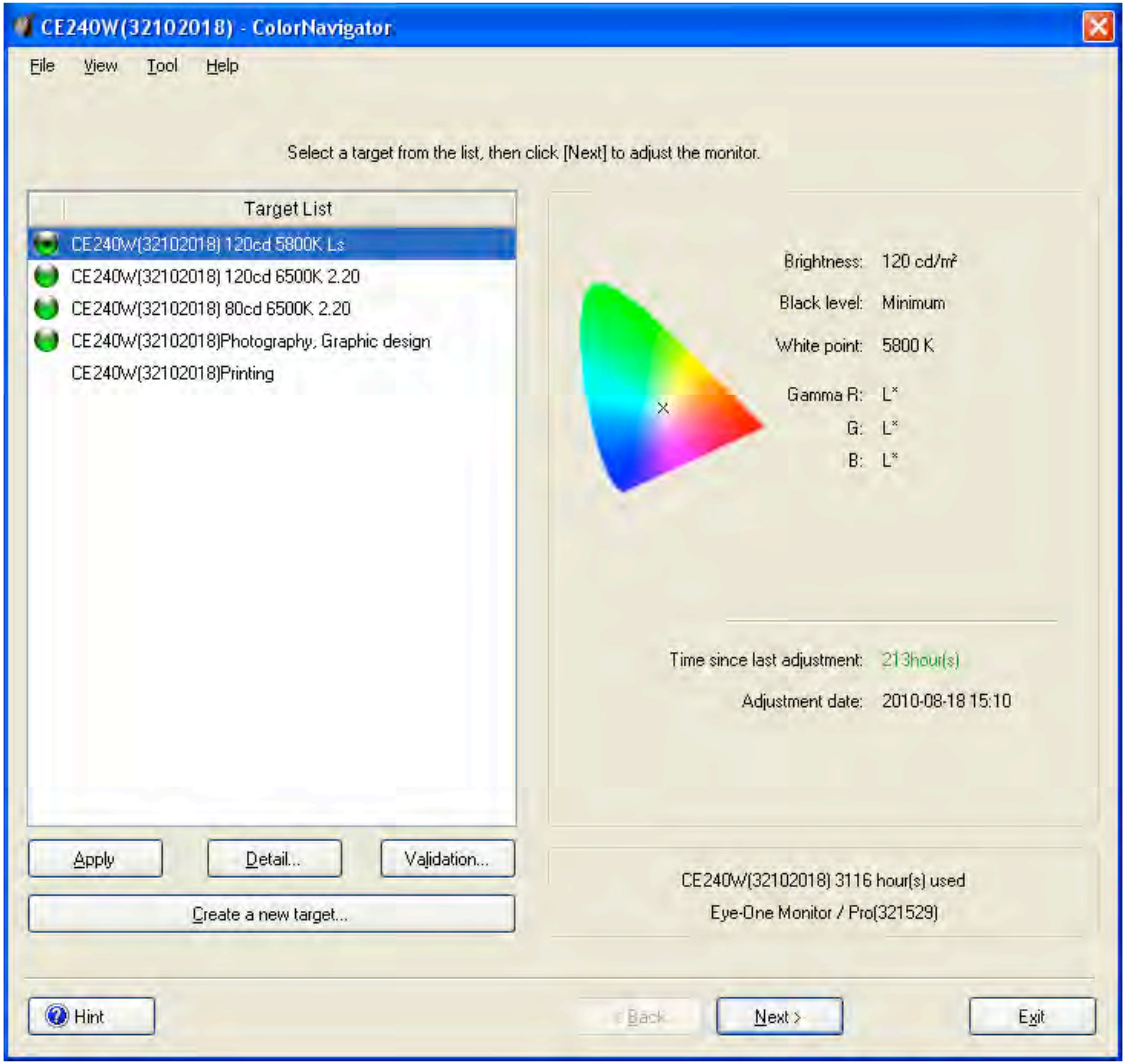
Eizo ColorEdge Calibration Monitor with hood
X-Rite Eye-One Pro or X-Rite i1Dislpay2 calibration device.

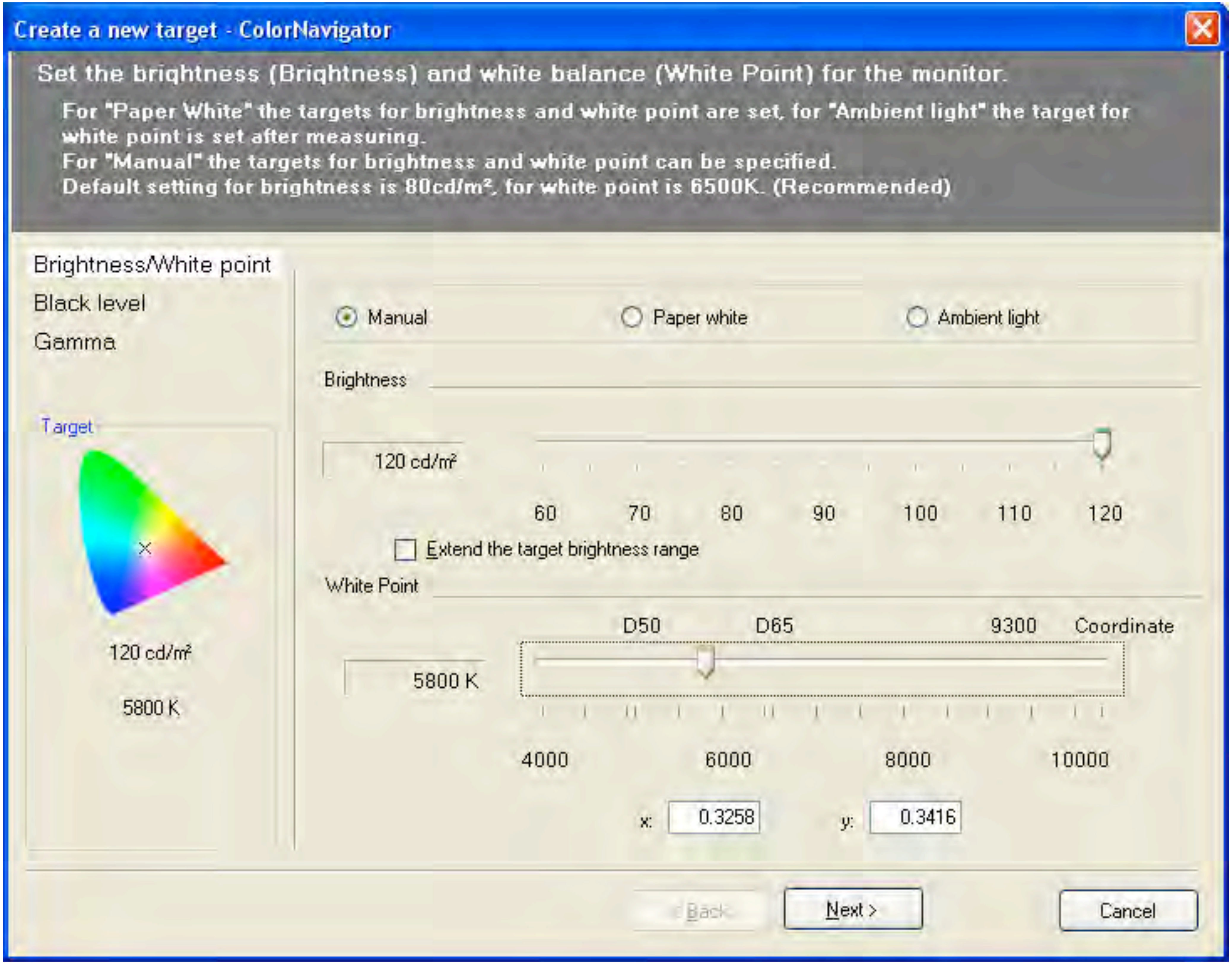
Software

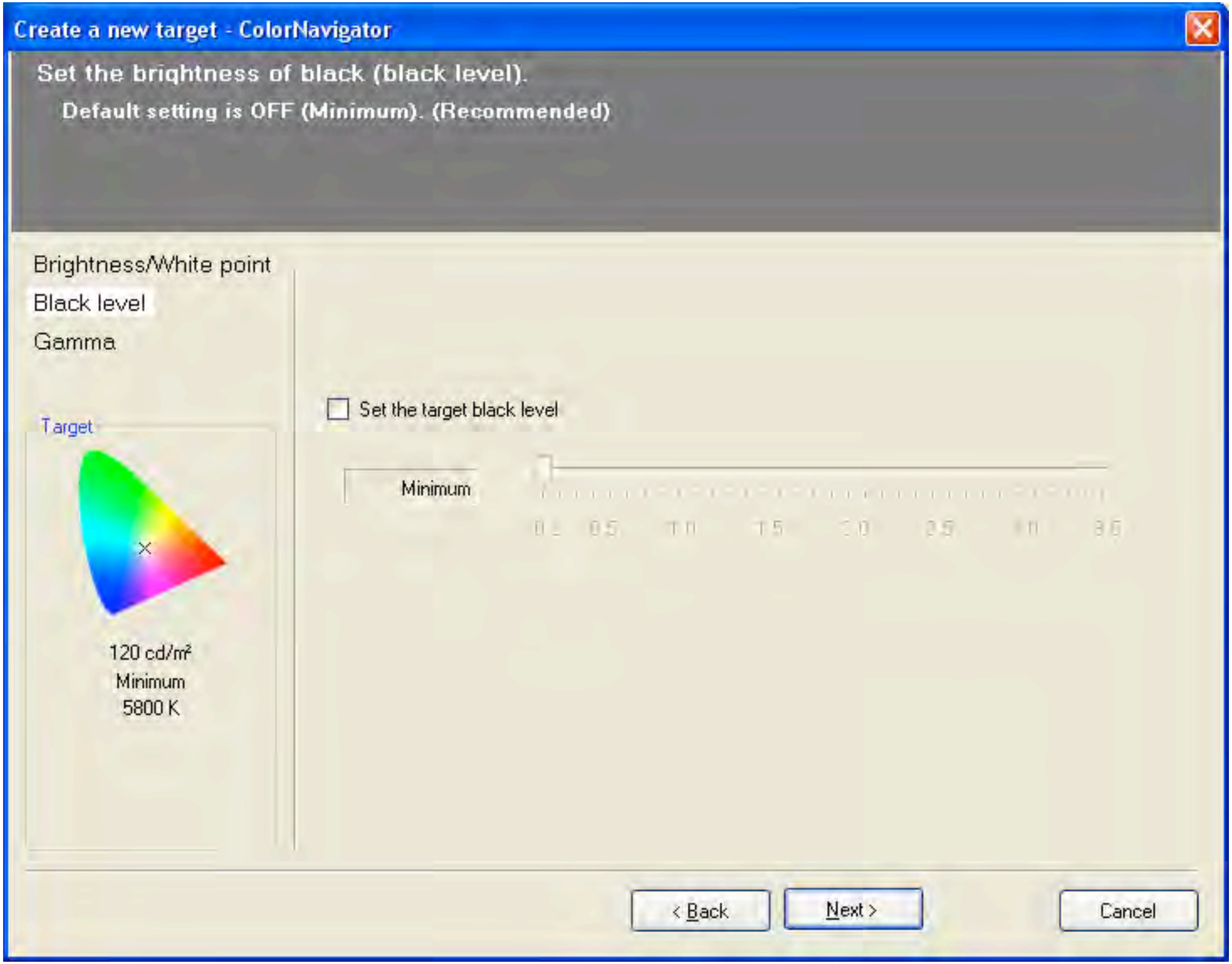
Eizo ColorNavigator

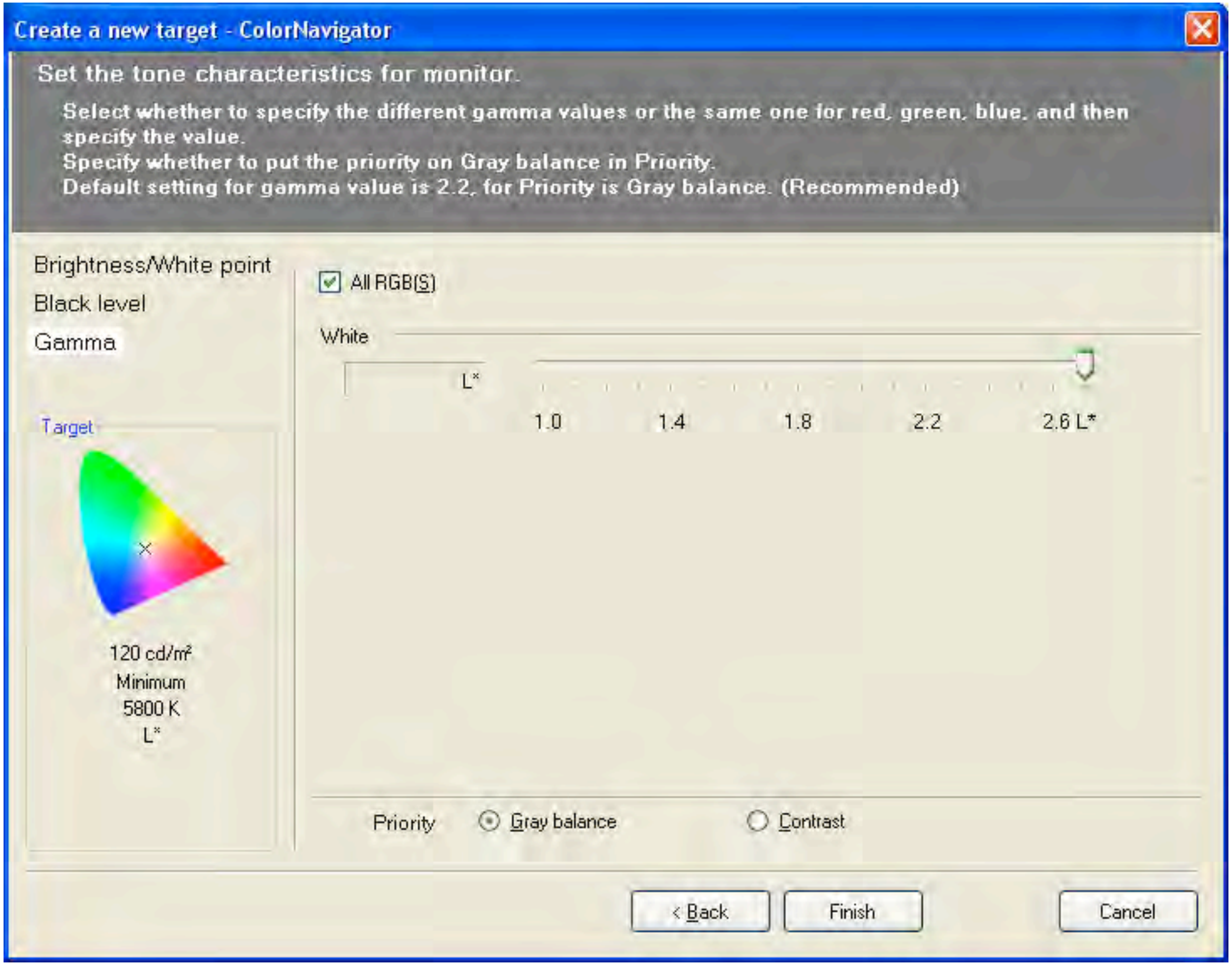
EH Calibration settings for ColorNavigator software are shown on the next four pages.

Press ‘Create a new target’ and set the following:




Create a new target - ColorNavigator
Set the brightness (Brightness) and white balance (White Point) for the monitor.
For "Paper White" the targets for brightness and white point are set, for "Ambient light" the target for white point is set after measuring.
For "Manual" the targets for brightness and white point can be specified.
Default setting for brightness is 80cd/m², for white point is 6500K. (Recommended)
Brightness/White point
Black level
Gamma
Target
120 cd/m²
5800 K
Manual
Paper white
Ambient light
Brightness
120 cd/m²
60
70
80
90
100
110
120
Extend the target brightness range
White Point
D50
D65
9300
Coordinate
5800 K
4000
6000
8000
10000
x:
0.3258
y:
0.3416
< Back
Next >
Cancel


Create a new target - ColorNavigator
Set the brightness of black (black level).
Default setting is OFF (Minimum). (Recommended)
Brightness/White point
Black level
Gamma
Target
120 cd/m²
Minimum
5800 K
Set the target black level
Minimum
< Back
Next >
Cancel



Once the calibration is finished Save as CE240W(32102018) 120CD 5800k Ls.

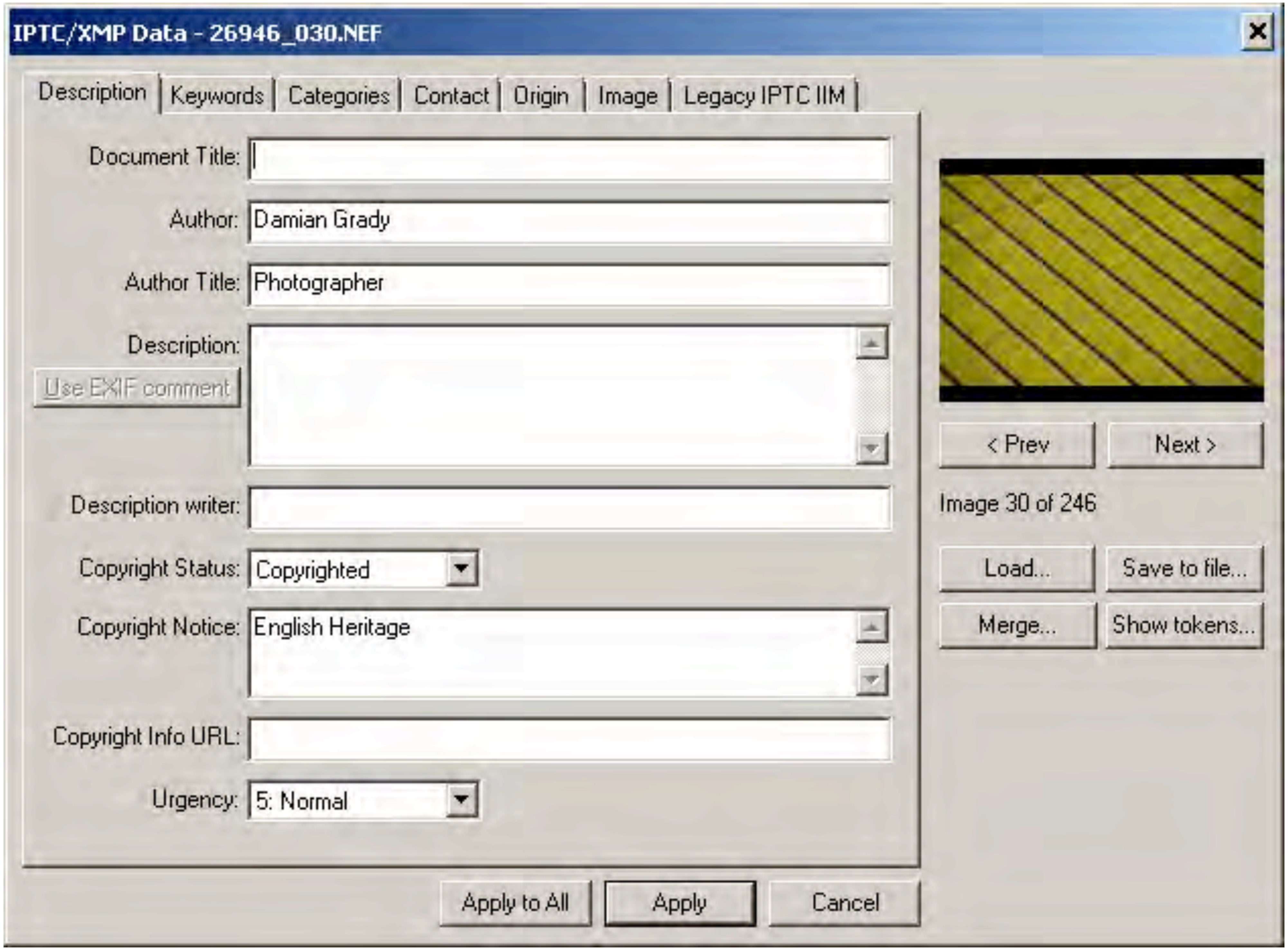
Next time you run the software choose the above option and press ‘Next’ which should take you straight to calibrating the monitor.

Once you are familiar with the process you should be able to complete it in no more than 5-10 minutes before each new session of image processing.

Explanatory Note 2

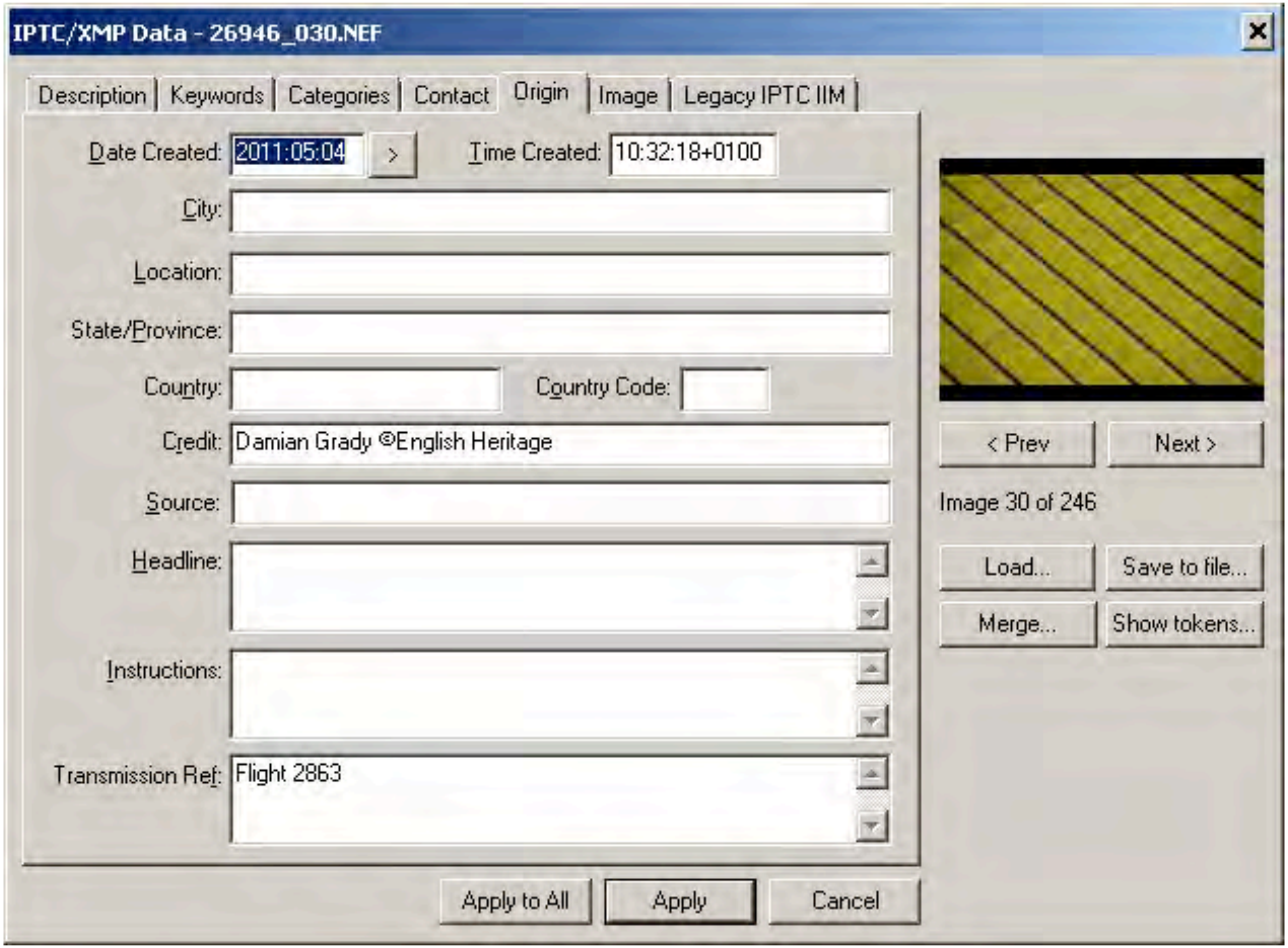
IPTC Data required by the English Heritage Archive

As a minimum the following fields should be entered in the IPTC fields under the Description tab: Author, Author Title, Copyright status and Copyright notice. See below for an example. Input table style and field names may vary depending on the software used.



In BreezeBrowser Pro under the Origin Tab the flight number is entered into the Transmission field and the photographer credited with the copyright notice.

Once the images from a flight have been catalogued additional data is added to the description and keyword fields.



APPENDIX C: PAN-EUROPEAN COOPERATION 1994-2015

Chris Musson

The Potsdam Conference and training schools in Hungary and Poland, 1994-1998

References have been made throughout Part 1 of the book to aerial archaeology training schools and to a series of international projects part-funded by the Culture Programme of the European Union. This Appendix summarises the growing path of pan-European cooperation in the years since a seminal two-day conference at Kleinmachnow, near Potsdam, in September 1994 (Kunow 1995). The meeting was presented with first-hand accounts of aerial archaeology initiatives across central and eastern Europe in the wake of the communist collapse in 1989-91, along with contributions from established aerial archaeologists in Germany, France, Austria and the United Kingdom. This clear demonstration of a growing Continental concern with aerial archaeology was strongly fostered at this stage and later by the committee and members of the Aerial Archaeology Research Group, then a mainly British organisation but already taking tentative steps towards its truly pan-European character today.

The contacts made at the Potsdam conference, and the enthusiasm already engendered by the pioneering flights of Otto Braasch, René Goguey and their local collaborators in countries once sealed behind the Iron Curtain led in 1996 to the first of a series of international training schools, in this case based on a grass strip at Siofok Kiliti, alongside Lake Balaton in central Hungary. Despite logistical problems with remaining bureaucracy from the Soviet era this school established the basic format of those that were to follow over the next decade and more, equal attention being paid over a week or so of intensive instruction to in-air experience of survey and ground-based training in photo-interpretation and mapping. This school was financed from a variety of sources, as was a second, following much the same pattern, at Leszno in Poland two years later in 1998.

Projects within the Culture 2000 Programme of the European Union, 2001-2007

Important new contacts were made at a ‘Summer School’ on Remote Sensing in Archaeology, promoted by the University of Siena in December 1999, at which Professor Francovich first suggested the possibility of holding an aerial archaeology training school in Italy. That ambition came to fruition, with an associated specialist workshop, in the early summer of 2001 as part of a new stage in European cooperation and funding, initiated through the first of three successive projects within the Culture 2000 Programme of the European Union.

This first project, entitled Conservation through Aerial Archaeology and involving an expenditure of about €140,000, was funded more or less equally by the European Union and the participating organisations. It was intended to last three years from the beginning of 2001but was in practice cut short after twelve months as a result of policy-changes within the Culture Programme. Partner organisations in the UK, Germany, Italy and Austria, introduced a theme that was further developed in the following two projects – the concept that aerial archaeology not only provides a means of discovery and recording but can also act as a spur to public and official appreciation of heritage sites and landscapes, and hence to their better protection and conservation in the face of development threats in both urban or rural contexts.

In addition to the Siena training school the project promoted or helped to organise international conferences in the UK, Poland and Germany, as well as smaller meetings in Lithuania, Austria and Germany, all of them attracting wide participation from across Europe. A residue of funds from this project, along with grants from a variety of other bodies, allowed a second Italian training school to be held in association with the University of Foggia in May 2003. (For the final report on the project see the web address for Conservation through Aerial Archaeology in the Supplementary Bibliography.)

This initial Culture 2000 exercise was followed in 2004-2007 by a more ambitious three-year project entitled European Landscapes: past, present and future, with sixteen partners in twelve countries across Europe. This time the scheme, worth over €900,000 in total, ran its full course, with a variety of activities and programmes tailored to meet the needs and capacities of the organisations involved. The project helped to initiate or enhance flying programmes in several countries and provided funding for a further six training schools in Italy, Germany and the UK. Conferences and intensive workshops were held in Finland, two of the Baltic states, Denmark, Poland, Romania and Italy and enquiries were made into historical archives of aerial photographs and air-photo maps. The project significantly widened the exchange of skills and experience across Europe and established beyond doubt that mutual support and cooperation can produce results beyond the capabilities of institutions or countries working individually (see web address for European Landscapes in the Supplementary Bibliography).

Pan-European cooperation through the ArchaeoLandscapes Project, 2010-2015

In 2010 an even more ambitious five-year scheme, entitled ArchaeoLandscapes Europe (ArcLand for short), was launched within the Culture 2007-2013 Programme, the total cost of €5m again being shared equally by the EU and the 35 participating universities, museums and heritage bodies drawn from 24 countries across Europe (plus the Aerial Archaeology Research Group which had again played a key role in initiating the project application). At the time of writing, in the early autumn of 2012, the total number of institutions associated with the project in one way or another has risen to over 60, covering all but a handful of countries within the expanded European Union as well as two from other parts of the world. The overall aim and eight key 'Actions' being tackled systematically over the five years of the project from September 2010 to the autumn of 2015 are described below.

The ultimate aim is the better use throughout Europe of aerial survey and other forms of remote sensing to promote understanding, conservation and public enjoyment of the shared landscape and archaeological heritage of the countries of the European Union.

Through partners in almost every part of Europe the project is mounting a concerted attack on systemic shortcomings and unrealized potential in a field which can enrich the lives of countless citizens across the length and breadth of the Continent.

The project's long-term legacy will be better appreciation of the landscape and archaeological heritage of Europe, closer contact between heritage professionals and the general public, more effective conservation of the shared cultural heritage, the international sharing of skills and employment opportunities, better public and professional education, the wider use of archive resources and modern survey techniques, and higher professional standards in landscape exploration and conservation. The project partners are seeking to achieve these objectives in eight specific ways:

1. By creating an ultimately self-supporting European Landscape Heritage Network to provide leadership, coordination and advice on the use for heritage purposes of aerial photography, remote sensing and landscape studies for heritage purposes.
2. By using traditional and innovative means to publicize the value of aerial survey, remote sensing and landscape studies amongst the general public, students, teachers and all those who explore, enjoy or care for cultural landscapes and heritage sites across Europe.
3. By promoting the exchange of people, skills and understanding across Europe through meetings, workshops, exchange visits, placements and opportunities for specialist training and employment.
4. By enhancing the teaching of remote sensing and landscape studies across Europe through courses for students and teachers, and in the long term through the establishment of a European Masters degree in remote sensing and heritage management.
5. By researching, assessing and publicizing the potential of existing air-photo archives across Europe with a view to their better exploitation for heritage interpretation and landscape conservation.
6. By providing support for aerial survey, remote sensing and landscape studies in countries relatively new to their use, especially in northern, eastern and southern Europe.
7. By further exploring the uses of laser, satellite and other forms of remote sensing and web-based geographical systems in archaeological and landscape research, conservation and public education.
8. By providing technical guidance and advice on best practice in aerial survey, remote sensing and landscape studies across Europe, with a particular emphasis on conservation and heritage management.

An invitation

All non-profit organisations and institutions that have a concern for heritage sites and landscapes, and for the use of aerial survey and other forms of remote sensing in exploration, interpretation and conservation, are invited to associate themselves with the project and (from 2015) with the resulting European Network, so as to continue and expand the initiatives and opportunities created by international cooperation over the past two decades. For contact details see the project's website at *www.archaeolandscapes.eu*. For individuals, as distinct from institutions, a parallel route lies in joining the Aerial Archaeology Research Group (AARG) through the 'membership' section of the group's website at *www.univie.ac.at/aarg*.

APPENDIX D: SOURCES OF PHOTOGRAPHS AND FIGURES

The authors are particularly grateful to Otto Braasch but also to all of the other archaeologists, photographers, photo interpreters and draughtsmen who have contributed illustrations to this book. Where not given in the caption the author's name and parent organisation (or the copyright-holder) are listed below. The University of Siena (LAP&T) holds a full list of the original photo numbers and sources of the drawings.

Abbreviations

CNR-ITABC: Consiglio Nazionale delle Ricerche – Istituto per le Tecnologie Applicate ai Beni Culturali, Rome.

LAP&T: Laboratorio dell'Archeologia dei Paesaggi e Telerilevamento, University of Siena.

RCAHMW: Royal Commission on the Ancient and Historical Monuments of Wales.

RCHME: Royal Commission on the Historical Monuments of England.

Foggia School: taken at the Foggia training school in May 2003.

Siena School: taken at the Siena training school of May 2001.

Sources

(T) = top, (B) = bottom, (C) = centre, (L) = left, (R) = right.

Aerofototaca Nazionale (ICCD), Roma: 1.2(L), 1.12.
Alfieri, Edera (by kind permission of): 1.9(R).
Allen, G.W.G.: 1.5 ©Ashmolean Museum, Oxford, UK: 1.5.
Allen, G.W.G.: 1.4(L). ©Oxfordshire Architectural & Historical Society, Oxford, UK.
Archaeological Services WYAS (©Alison Deegan), West Yorkshire Archaeology Service, Leeds, UK: 2.20.
"Archeologia aerea", I, by kind permission of Giuseppe Ceraudo: 1.7.

Ashmolean Museum, Oxford, UK: 1.4(T), 1.5.

Bacilieri, Cinzia, Air Photo Services Ltd, Cambridge, UK: 7.8(B).

Barbieri, Cinzia, Siena School: 10.51, 10.75.

Beck, G., Department of Geography, University of Durham, UK: 15.1 to 15.3.

Bewley, Bob: 10.15.

Bianchini, Lorenzo, Siena School: 5.3g, 7.4c, 10.46.

Braasch, Otto: 2.6(B), 2.9 (BR), 2.11, 2.12(R), 2.17, 2.24(BL, BR), 2.26d, 5.3a,e, 5.10(L), 6.2(R), 10.6(T), 10.8, 10.9, 10.13, 10.14, 10.19, 10.20, 10.26, 10.27(T), 10.30(B), 10.42, 10.49, 10.52(R), 10.55, 10.61, 10.63, 10.77.

Braasch, Otto (with Riley, Derrick): 1.9(L), 2.6(BR), 2.14(R), 9.3(R), 10.3, 10.5, 10.10, 10.11, 10.24, 10.30(TR), 10.40, 10.43(L), 10.44, 10.71 to 10.73, 10.87.

Braasch, Otto, Foggia School: 10.29, 10.31(B).

Braasch, Otto, Siena School: 2.19, 7.4b, 7.4e, 10.5(B), 10.6(C), 10.18, 10.21(B), 10.29, 10.34(T), 10.52(L), 10.54.

Bradford, J., Williams-Hunt, P.R.: 1.8, 10.30(TL) (both from "Antiquity" 20, 1946).

Cambridge University Committee for Aerial Photography, UK: 1.1, 2.3, 2.4, 2.17(Crown Copyright).

Campana, Stefano, LAP&T, University of Siena at Grosseto: Title page, 1.15, 2.15(L), 2.26(except d), 4.4, 5.1c-e, 5.2, 5.3c, 5.13(R), 7.4d, 7.7 (photo: IGM), 10.16, 10.23, 10.25, 10.28(T), 10.32(L), 10.36, 10.37, 10.38, 10.64, 10.67, 10.71, 10.76, 10.77, 10.79, 10.81, 11.1 to 11.10.

Campana, Stefano, Siena School, 7.13(B), 10.78.

Cherstich, Luca, Siena School: 2.6(TR), 7.4a, 10.23.

Cosci, Marcello, University of Siena: 12.1 to 12.10.

Cox, Chris, UK: 1.13, 8.2.

Deegan, Alison, Air Photo Interpreter, Clayton, Bradford, UK: 2.21.

Del Verme, Laura, Siena School: 10.53.

De Silva, Michele,Siena School: 5.3f, 10.34(B), 10.50.

Dolci, Matteo, Siena School: 7.4f, 10.2, 10.4, 10.21(T).

Donati, Enrico, Siena School: 10.5(B), 10.20, 10.58.

Donati, Enrico, University of Siena: 5.8.

Doneus, Michael, Institute of Archaeology, Vienna, Austria: 2.13, 10.47 (Foggia School), 10.50 (Foggia School), 13.1, 13.3 to 13.6.

Driver, Toby: 4.3, 4.5. ©RCAHMW, Aberystwyth, UK.

English Heritage, Swindon, UK: 1.14, 1.16.

Felici, Cristina, LAP&T, University of Siena: 10.16, 10.17, 10.22.

Ferrari, Alessandro, Siena School: 10.1, 10.85.

Forte, Maurizio, CNR-ITABC, Rome: 16.1 to 16.11.

Gattiglia, Gabriele, Siena School: 5.3(R), 5.10(R), 10.27(B).

Green, Charles: 2.7 (after B Bennison), 2.16, 2.20, 2.25. ©RCAHMW.

Grosman, Darja, University of Ljubljana, Slovenia: 1.11, 4.6(R).

Horne, Pete, English Heritage: 2.9(T), 5.1b (Siena School), 8.5, 8.6.

Horne, Pete/MacLeod, Dave, English Heritage: 9.12.

Jackson, Andrew, ACTPix, Rhayader, UK: 4.3.

Leidorf, Klaus, Luftbild Archeologie, Landshut, Germany: 6.2(L), 10.35, 10.48(R), 10.56, 10.59, 10.61, 10.62.

Leidorf, Klaus, Siena School: 10.68, 10.83.

Lewis, Brian, University of Leicester, UK: 7.14 (photo Chris Musson).

MacLeod, Dave/Horne, Pete, English Heritage: 4.1(TL).

Meridian Air Maps Ltd, ©NorthYorkshire County Council, Northallerton, UK: 2.1(R).

Monti, Alberto, Siena Scool: 10.6(B).

Musson, Chris: 4.1(R), 4.2, 5.3b, 5.4, 5.6 (based on Whimster 1989), 7.6, 10.31(T), 10.41, 10.42(B), 10.66.

Musson, Chris, ©Clwyd-Powys Archaeological Trust, Welshpool, UK: 2.5, 2.8(T), 2.8(C), 2.11(T), 2.23, 2.24(T), 3.1a, 5.7.

Musson, Chris, ©Herefordshire County Council, Hereford, UK: 3.1h, 5.13(L), 5.14.

Musson, Chris, ©RCAHMW, Aberystwyth, UK: 2.8(B), 2.22, 5.15, 10.33.

Musson, Chris, Siena School: 10.28(R), 10.32(R), 10.76.

Musson, Chris, ©Woolhope Naturalists Field Club, UK: 2.12, 2.14(L), 3.1b-g, 5.11.

Palmer, Rog, Air Photo Services Ltd, Cambridge, UK: 6.3 (Siena School), 6.4 (photo: D.Riley), 7.1 to 7.3, 7.5, 7.8(T), 7.9 to 7.12, 7.13 (photos: Siena School), 8.1, 8.3, 8.4, 8.7 to 8.10, 9.2, 9.3(T, Siena School), 9.5, 9.9 to 9.11.

Palmer, Rog, ©RCHME, Swindon, UK: 9.1.

Pescarin, Sofia, Siena School: 10.43(R).

Perrici, Francesco, LAP&T, University of Siena: 2.10, 5.1a, 5.1f , 5.5, 5.9, 5.12, 5.26.

Piccarreta, Fabio, Ceraudo, Giuseppe, University of Lecce: 1.10, 2.2, 10.57.

Poidebard, A: 1.6 (from Poidebard 1934).

Riley, Derrick: 2.1(T), 9.4, 9.6.

Riley, Derrick (with Braasch, Otto), Riley Collection, University of Sheffield, UK: 6.4, 9.3(BL), 10.12, 10.45.

Scollar, Irwin, Bonn, Germany: 1.3.

Foggia School: photo interpretations by advanced students at the Foggia School.

Shell, Colin, University of Cambridge, UK: 14.1, 14.4 to 14.6, 14.9 to 14.14, 14.18.

Stagno, Anna, Siena School: (L), 10.78, 10.80(L).

Stoertz, Cathy: (from Stoertz 1997.). ©RCHME, Swindon, UK: 9.8

Vanstone, Valentine (after a painting by): 1.2(R)

Whimster, R.P. (from Whimster 1989). ©RCHME, Swindon, UK: 6.1, 9.7.

BIBLIOGRAPHY

Sources cited in the main text

ADAMESTEANU 1957 = D. Adamesteanu, *Fotografia aerea ed i problemmi archeologici della Sicilia, Atti del V Convegno Nazionale della Società Italiana di Fotogrammetria e Fopografia, Palemo, 1957*, in “Bollettino Società Italiana di Fotogrammetria e Topografia”, 2-3, pp 76-85.

ALFIERI–VALVASSORI 1957 = N. Alfieri, V. Valvassori*, La scoperta dell’abitato di Spina, apparecchi e tecnica relativi alle prospezioni che hanno portato alla scoperta della città etrusca di Spina*, in “Inedita”, 2-3, pp. 83-95, volume 2 (1956).

ALLEN 1938 = G.W.G. Allen*, Marks seen from the Air in the Crops near Dorchester, Oxon.*, in “Oxoniensia”, 3, pp. 8-10.

ALLEN 1984 = G.W.G. Allen, *Discovery from the Air*, in “Aerial Archaeology”, 10, East Dereham, UK.

ALLEN 1991 = M.J. Allen, *Analyzing the Landscape: a Geographical Approach to Archaeological Problems*, in J. Schofield, *Interpreting Artefact Scatters. Contributions to Ploughzone Archaeology*, Oxford, pp.39-58.

ALVISI 1989 = G. Alvisi, *La fotografia aerea nell’indagine archeologica*, Rome.

ASTON 1985 = M. Aston, *Interpreting the Landscape. Landscape Archaeology in Local Studies*, London.

ASTON–ROWLEY 1974 = M. Aston, T. Rowley, *Landscape Archaeology: An Introduction to Fieldwork Techniques on post-roman Landscapes*, Newtown Abbot.

ASTON 1985 = M. Aston, *Interpreting the Landscape. Landscape Archaeology in Local Studies*, London.

BANNING 2002 = E.B. Banning, *Archaeological Survey*, New York.

BARADEZ 1949 = J.L. Baradez, *Fossatum Africae, recherches aériennes sur l'organisation des confins sahariens à l'époque romaine,* Paris*.*

BARBER 2011 = M. Barber, *A History of Aerial Photography and Archaeology. Mata Hari’s glass eye and other stories*, English Heritage, Swindon.

BARD ET ALII 1997 = K.A. Bard, R. Fattovich, A. Manzo, C. Perlingieri, *Archaeological Investigations at Bieta Giyorgis (Aksum), Ethiopia: 1993, 1994 and 1995 Field Seasons*, in “Journal of Field Archaeology”, 24, pp. 387-403.

BARD ET ALII 2000 = K.A. Bard, M. Coltorti, M. DiBlasi, F. Dramis , R. Fattovich, *The Environmental History of Tigray (Northern Ethiopia) during the Holocene: A Preliminary Outline*, in “African Archaeological Review”, 17(2), pp. 65-86.

BARNES 2003 = I. Barnes, *Aerial remote-sensing techniques used in the management of archaeological monuments on the British Army’s Salisbury Plain Training Area, Wiltshire, UK*, in “Archaeological Prospection”, 10, pp. 83-90.

BEAZELEY 1920 = G.A. Beazeley, *Surveys in Mesopotamia during the War*, in “Geographical Journal”, LV, pp. 109-127.

BECK ET ALII 2002 = A. Beck, G. Philip, D. Donoghue, N. Galiatsatos, *Evaluation of integrated high and medium scale satellite imagery to archaeology in semi-arid environments,* in *Proceedings of the Conference Space Applications for Heritage Conservation*, European Space Agency, Strasbourg [published on CD: SP-515].

BERESFORD–ST JOSEPH 1979 (and various other editions) = M. Beresford, J.K.S. St Joseph, *Medieval England: an aerial survey*, Cambridge.

BEWLEY 2000 = R.H. Bewley, *Aerial survey in the Danebury area, 1981-1997*, in B. Cunliffe, *The Danebury environs programme: the prehistory of a Wessex landscape. Volume 1: Introduction*, Oxford, pp. 20-28.

BEWLEY 2001 = R.H. Bewley*, Understanding England’s Historic Landscapes: an aerial perspective*, in “Landscapes”, 2 (1), pp. 74-84.

Bewley 2002 = R. Bewley, *Aerial Survey: learning from a hundred years of experience?*, in R.H. Bewley, W. Rączcowski (eds), *Aerial Archaeology: Developing Future Practice*, NATO Science Series I: Life and Behavioural Sciences, 337, Amsterdam, pp. 11-18.

Bewley 2003 = R.H. Bewley, *Aerial survey for archaeology*, in "Photogrammetric Record", 18(104), pp. 273-292.

Bewley 2005 = R. Bewley, *Aerial Archaeology. The first century*, in J. Bourgeois, M. Meganck (eds.), *Aerial Photography and Archaeology 2003 – A Century of Information, Papers presented during the Conference held at the Ghent University December 10th -12th December 2003*, Ghent, pp. 15-30.

Bewley–Rączcowski 2002 = R.H. Bewley, W. Rączcowski (eds), *Aerial Archaeology: Developing Future Practice*, NATO Science Series I: Life and Behavioural Sciences, 337, Amsterdam.

Bewley et alii 1999 = R. Bewley, D. Donoghue, V. Gaffney, M. Van Leusen, A. Wise, *Archiving Aerial Photography and Remote Sensing Data: A Guide to Good Practice*, Oxford.

Bewley et alii 2005 = R.H. Bewley, S.P. Crutchley, C.A. Shell, *New light on an ancient landscape: LiDAR survey in the Stonehenge World Heritage Site*, in "Antiquity", 79 (305), pp. 636-647.

Bowden 1999 = M. Bowden (ed.), *Unravelling the landscape: an inquisitive approach to archaeology*, Stroud, UK.

Bradford 1947 = J.S.P. Bradford, *Etruria from the air*, in "Antiquity", 21, pp.74-83.

Bradford 1949 = J.S.P. Bradford, *'Buried landscapes' in southern Italy*, in "Antiquity", 23, pp. 58-72.

Bradford 1950 = J.S.P. Bradford, *The Apulia expedition: an interim report*, in "Antiquity", 24, pp. 84-95.

Bradford 1957 = J.S.P. Bradford, *Ancient Landscapes*, London.

Bradford–Williams-Hunt 1946 = J.S.P. Bradford, P.R. Williams-Hunt, *Siticulosa Apulia*, in "Antiquity", 20, pp. 191-200.

Bradley et alii 1994 = R. Bradley, R. Entwhistle, F. Raymond, *Prehistoric land divisions on Salisbury Plain: the work of the Wessex Linear Ditches Project,* English Heritage, London.

Britnell 1989 = W.J. Britnell, *The Collfryn hillslope enclosure, Llansantffraid Deuddwr, Powys: excavations 1980-1982*, in "Proceedings of the Prehistoric Society", 55, pp. 89-134.

Brown 1987 = A. Brown, *Fieldwork for Archaeologists and Local Historians*, London.

Brown 2004 = Keri. A. Brown, *Aerial Archaeology of the Tavoliere: The Italian Air Photographic Record and the Riley Archive*, in "Accordia Research Papers", 9 (2001-2003), Accordia Research Institute, University of London, pp. 123-146.

Bruni 2003 = S. Bruni (ed.), *Il porto urbano di Pisa: la fase etrusca, il contesto e il relitto ellenistico*, Milano.

Butzer 1982 = K.W. Butzer 1982, *Archaeology as Human Ecology*, New York.

Cambi 2000 = F. Cambi, *Quando i campi hanno pochi significati da estrarre: visibilità archeologica, storia istituzionale, multi-stage work*, in R. Francovich, H. Patterson (eds.), *Extracting Meaning from Ploughsoil Assemblages*, Oxford, pp. 72-76.

Cambi 2003 = F. Cambi, *Archeologia dei paesaggi antichi: fonti e diagnostica*, Roma.

Cambi–Terrenato 1994 = F. Cambi, N. Terrenato, *Introduzione all'archeologia dei paesaggi*, Urbino.

Camilli 2004a = A. Camilli, *Le strutture "portuali" dello scavo di Pisa-San Rossore*, in Various Authors, *Anser. Anciennes Routes Maritimes Mediterranéennes. Le strutture dei porti e degli approdi antichi, II seminario (Roma-Ostia antica 16-17 aprile 2004)*, Soveria Mannelli, pp. 67-86.

Camilli 2004b = A. Camilli, *Il cantiere delle navi antiche di Pisa. Note sull'ambiente e sulla periodizzazione del deposito*, in "Archaeologia Maritima Mediterranea", 2004 (1), pp. 53-75.

Campana 2005a = S. Campana, *Looking to the future: una strategia per l'archeologia dei paesaggi toscani. Sviluppo e implementazione di soluzioni technologiche integrate*, in Musson *et alii*, *In Volo nel Passato. Aerofotografia e cartografia archeologica*, Firenze, pp. 232-261.

Campana 2005b = S. Campana, *Tecnologie GPS e personal data assistant applicati all'archeologia dei paesaggi*, in "Archeologia e Calcolatori", 16, pp. 177-198.

Campana–Forte 2001 = S. Campana, M. Forte (eds.), *Remote Sensing in Archaeology*. *XI International School in Archaeology, Certosa di Pontignano, 6-11 December 1999*, Florence.

Campana–Forte 2006 = S. Campana, M. Forte (eds.), *From Space to Place. Proceedings of the 2nd International Conference on Remote Sensing in Archaeology*, BAR International Series 1568, Oxford.

Campana–Francovich 2005 = Campana S., Francovich R., *Seeing The Unseen. Buried Archaeological Landscapes In Tuscany*, in E. Baltsavias, A.Gruen, L.Van Gool, M.Pateraki (eds.), *Recording, modeling and visualization of cultural landscape*, London, pp.67-76.

Campana–Francovich 2006 = S. Campana, R. Francovich (eds.), *Laser Scanner e GPS: Paesaggi Archeologici e Tecnologie Digitali 1*, Florence.

Campana–Francovich 2007 = S. Campana, R. Francovich, *Understanding archaeological landscapes: steps towards an improved integration of survey methods in the reconstruction of subsurface sites in South Tuscany*, in J. Wiseman, F. El-Baz, *Remote Sensing in Archaeology*, New York, pp. 239-261.

Campana–Piro 2009 = S. Campana, S. Piro (eds.), *Seeing the Unseen. Geophysics and Landscape Archaeology*, London.

Campana–Pranzini 2001 = S. Campana, E. Pranzini, *Il Telerilevamento in Archeologia,* in Campana–Forte, 2001, pp. 17-62.

Castagnoli 1956 = F. Castagnoli, *Ippodamo di Mileto e l'urbanistica a pianta ortogonale*, Rome.

Castagnoli 1958 = F. Castagnoli, *Le richerche sui resti della centuriazione*, Rome.

Castagnoli 1961 = F. Castagnoli, *Contributi della fotografia aerea agli studi di Topografia Antica in Italia, Atti del Settimo Congresso Internazionale di Archeologia Classica*, Rom.

Castagnoli 1969 = F. Castagnoli, *La Prospezione aerea negli studi di topografia antica*, in "Quaderni de "La Ricerca Scientifica"", 60, p. 7 sgg.

Cavalli–Pignatti 2001 = R.M. Cavalli , S. Pignatti , *Il telerilevamento iperspettrale da aereo per lo studio dei beni archeologici: applicazione dei dati iperspettrali MIVIS*, in S. Campana, M. Forte (eds.), *Remote Sensing in Archaeology*. *XI International School in Archaeology, Certosa di Pontignano, 6-11 December 1999*, Florence, pp. 221-232.

Ceraudo 2003 = G. Ceraudo, *Fotografia aerea: tecniche, applicazioni e fotointerpretazione*, in M. Guaitoli (ed.), *Lo sguardo di Icaro. Le collezioni dell'Aerofototeca Nazionale per la conoscenza del territorio*, Rome, pp. 75-85.

Ceraudo 2004 = G. Ceraudo, *Un secolo e un lustro di fotografia aerea archeologica in Italia (1899-2004)*, in "Archeologia Aerea. Studi di Aerotopografia Archeologica", I, pp. 47-68.

Ceraudo 2005 = G. Ceraudo, *105 years of Archaeological Aerial Photographyin Italy 1899-2004*, in J. Bourgeois, M. Meganck (eds.), *Aerial Photography and Archaeology 2003 – A Century of Information, Papers presented during the Conference held at the Ghent University December 10th -12th December 2003*, Ghent, pp. 73-86.

Ceraudo 2008 = G. Ceraudo, *Sulle tracce della Via Traiana – Indagini aerotopografiche da* Aecae *a* Herdonia, Foggia.

Ceraudo 2010 = G. Ceraudo, *100 anni di Archeologia aerea in Italia*, in "Archeologia Aerea. Studi di Aerotopografia Archeologica", 4/5, pp. 5-15.

Ciminale et alii 2007 = M. Ciminale, H. Becker, D. Gallo, *Integrated technologies for archaeological investigation; the Celone Valley project*, in "Archaeological Prospection", 14:3, pp.167-181.

Coleman 2007 = S. Coleman, *Taking advantage: vertical aerial photographs commissioned for local authorities*, in J. Mills, R. Palmer (eds.), *Populating Clay Landscapes*, Stroud, pp. 28-33.

Comfort *et alii* 2000 = A. Comfort, C. Abadie-Reynal, R. Ergeç*, Crossing the Euphrates in antiquity: Zeugma seen from space*, in "Anatolian Studies", 50, pp. 99-126.

Compatangelo 1986 = R. Compatangelo, *Archeologia aerea in Campania settentrionale: primi risultati e prospettive*, in "MEFRA", 98, 2, pp. 595-621.

Connor–Palmer 2000 = A. Connor, R. Palmer, *An iron age ditched enclosure system at Limes Farm, Landbeach, Cambridgeshire*, in "Antiquity", 74, pp. 281-282.

Corns–Shaw 2008 = A. Corns, R. Shaw, *The application of vertical aerial photogrammetry in recording and analysis of archaeological landscapes*, in O. Bender, N. Evelpidou, A. Krek, A. Vassilipoulos (eds.) 2008, *Geoinformation Technologies for Geocultural Landscapes: European Perspectives*, CRC Press, London, pp. 47-66.

Cosci 1998 = M. Cosci, *Il Contributo della Fotografia Aerea*, in M.L. di Ceccarelli Lemut, G. Garzella, *La Via Francigena e il Basso Valdarno: vie di terra e d' acqua nel Medioevo*, Pisa, pp. 93-100.

Cosci 2001 = M. Cosci, *Il Contributo della Fotografia Aerea allo Studio ed alla Valorizzazione del Territori: metodi adottati e risultati conseguiti,* in G. Di Gangi, C.M. Lebole (eds.), *La Gestione del Territorio: memoria, partecipazione, sviluppo della cicerca. Atti Convegno Nazionale, Saluzzo, 11-12 novembre 2000*, Dronero, pp. 55-64.

Cowley 2002 = D. Cowley, *A case study in the analysis of patterns of aerial reconnaissance in a lowland area of Southwest Scotland*, in "Archaeological Prospection", 9, pp. 255-265.

Crawford 1923 = O.G.S. Crawford, *Air Survey and Archaeology*, in "Geographical Journal", May 1923, pp. 324-366.

Crawford 1924 = O.G.S. Crawford, *Air Survey and Archaeology,* Ordnance Survey Professional Papers, **7**, London.

CRAWFORD 1928 = O.G.S. Crawford, *Air Survey and Archaeology*, Ordnance Survey, Professional Papers, new series, 7, (second edition), London.

CRAWFORD 1929 = O.G.S. Crawford, *Air Photography for Archaeologists*, Ordnance Survey Professional Papers, new series, 12, London.

CRAWFORD–KEILLER 1928 = O.G.S. Crawford, A. Keiller, *Wessex from the Air*, Oxford.

CROWSON ET ALII 2000 = A. Crowson, T. Lane, J. Reeve, *Fenland Management Project excavations 1991-1995*, Lincolnshire Archaeology and Heritage Report Series, 3.

CRUTCHLEY–CROW 2009 = S. Crutchley, P. Crow, *The Light Fantastic: using airborne laser scanning in archaeological survey*, Swindon: English Heritage. Also as free pdf download (2010) at www.english-heritage.org.uk/publications/light-fantastic/

CUARTERO ET ALII 2004 = A. Cuartero, A.M. Felicísimo, F.J. Ariza, *Accuracy of DEM generation from Terra-Aster stereo data*, in "International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences", 35, part B2, pp. 559-563.

CUNLIFFE 2000 = B. Cunliffe, *The Danebury environs programme: the prehistory of a Wessex landscape. Volume 1: Introduction*, Oxford.

CUNLIFFE–POOLE 2000 = B. Cunliffe, C. Poole (eds.), *The Danebury environs programme: the prehistory of a Wessex landscape*. Volume 2: parts 1-7, Oxford.

D'ANDRIA 1997 = F. D'Andria (ed.), *Metodologie di catalogazione dei beni archeologici, Beni archeologici – Conoscenza e tecnologie,* Vol 1.2, Lecce-Bari.

DABAS 2009 = M. Dabas, *Theory and practice of the new fast electrical imaging system ARP©*, in S. Campana, S. Pio (eds.), *Seeing the Unseen. Geophysics and Landscape Archaeology*, London, pp. 105-126.

DAVID ET ALII 2001 = B. David, J. Brayer, I.J, McNiven, A. Watchman, *Why digital enhancement of rock paintings works: rescaling and saturating colours*, in "Antiquity", 75, pp. 781-792.

DEEGAN 2001 = A. Deegan*, Composite Evidence from Aerial and Geophysical Survey and Excavation*, in I. Roberts, A. Burgess, D. Berg (eds), *A New Link to the Past. The Archaeological Landscape of the M1-A1 Link Road*, Yorkshire Archaeology 7, Leeds, pp. 29-35.

DELLA ROCCA ET ALII 1987 = B. Della Rocca, R. Mazzanti, E. Pranzini, *Studio Geomorfologico della Pianura di Pisa,* in "Geogr. Fis. Din. Quat", 10, pp. 56-84.

Deuel 1971 = L. Deuel, *Flights into Yesterday. The Story of Aerial Archaeology*, London.

DEVEREUX ET ALII 2005 = B.J. Devereux, G.S. Amable, P. Crow, A.D. Cliff, *The potential of airborne lidar for detection of archaeological features under woodland canopies*, in "Antiquity" 79-305, pp.648-660.

DONEUS 1996 = M. Doneus, *Photogrammetrical Applications to Aerial Archaeology at the Institute for Prehistory of the University of Vienna, Austria*, in "International Archives of Photogrammetry and Remote Sensing", XXXI, Part B5, Commission V, Vienna, pp. 124-129.

DONEUS 2000 = M. Doneus, *Vertical and oblique photographs*, in "AARGnews", 20, pp. 33-39.

DONEUS 2001A = M. Doneus, *Precision mapping and interpretation of oblique aerial photographs*, in "Archaeological Prospection", 8, pp. 13-27.

DONEUS 2001B = M. Doneus, *The impact of vertical photographs on analysis of archaeological landscapes*, in M. Doneus, A. Eder-Hinterleitner, W. Neubauer (eds), *Archaeological Prospection: fourth international conference on archaeological prospection. Vienna, 19-23 September 2001*, Vienna, pp. 94-96.

DONEUS 2004 = M. Doneus, *Aerial Archaeology in the Landscape of Carnuntum*, in "Archeologia Aerea. Studi di Aerotopografia Archeologica", I, Rome, pp. 215-234.

DONEUS–BRIESE 2006 = M. Doneus, C. Briese, *Full-waveform airborne laser scanning as a tool for archaeological reconnaissance*, in S. Campana, M. Forte (eds.), *From Space to Place. Proceedings of the 2nd International Conference on Remote Sensing in Archaeology*, BAR International Series 1568, Oxford, pp. 99-106.

DONEUS–BRIESE 2011 = M. Doneus, C. Briese, *Airborne Laser Scanning in forested areas – potential and limitations of an archaeological prospection technique*, in D.C. Cowley (ed.) 2011, *Remote Sensing for Archaeological Heritage Management*, Brussels, pp. 59-76.

DONEUS–NEUBAUER 1998 = M. Doneus, W. Neubauer*, 2D combination of prospection data*, in "Archaeological Prospection", 5, pp. 29-56.

DONEUS ET ALII 2001 = M. Doneus, A. Eder-Hinterleitner, W. Neubauer, *The excursion sites: Roman Carnuntum – prospecting the largest archaeological landscape in Austria*, in M. Doneus, A. Eder-Hinterleitner, W. Neubauer (eds), *Archaeological Prospection: fourth international conference on archaeological prospection. Vienna, 19-23 September 2001*, Vienna, pp. 47-55.

DONEUS ET ALII 2002 = M. Doneus, N. Doneus, W. Neubauer, *Integrated archaeological interpretation of combined prospection data, Zwingendorf (Austria) – a case study*, in R.H. Bewley, W. Rączcowski (eds), *Aerial Archaeology: Developing Future Practice*, NATO Science Series I: Life and Behavioural Sciences, 337, Amsterdam, pp. 149-165.

DONEUS ET ALII 2008 = M. Doneus, C. Briese, M. Fera, M. Janner, *Archaeological prospection of forested areas using full-waveform airborne laser scanning*, "Journal of Archaeological Science", 35, pp. 882-893.

DONEUS ET ALII 2012 (in press) = M. Doneus, C. Gugl, N. Doneus, *Die Canabae von Carnuntum – ein Modell für römische Lagervorstädte. Von der Luftbildprospektion zur siedlungsarchäologischen Synthese*, in "Der Römische Limes in Österreich", 47.

Donoghue et alii 2002 = D.N.M. Donoghue, N. Galiatsatos, G. Philip, A.R. Beck, *Satellite imagery for archaeological applications: a case study from the Orontes Valley, Syria*, in Bewley–Rączkowski, 2002, pp. 211-223.

Donoghue 2001 = D.N.M. Donoghue, *Multispectral Remote Sensing for Archaeology*, in S. Campana, M. Forte (eds.), *Remote Sensing in Archaeology*. *XI International School in Archaeology, Certosa di Pontignano, 6-11 December 1999*, Florence, pp. 181-192.

Downey 1980 = *A History of Archaeological Air Photography in Great Britain,* "Orbit", I, The Aerial Archaeology Foundation, London.

Driver–Musson 2001 = T. Driver, C. Musson, *Aerial Archaeology and Air Photo Mapping in Britain*, in S. Campana, M. Forte (eds.), *Remote Sensing in Archaeology*. *XI International School in Archaeology, Certosa di Pontignano, 6-11 December 1999*, Florence, pp. 257-272.

Ebert 1992 = J. Ebert, *Distributional Archaeology*, New York.

Evans–Jones 1977 = R. Evans, R.J.A. Jones, *Crop marks and soils at two archaeological sites in Britain*, in "Journal of Archaeological Science", 4, pp. 63-76.

Fattovich 1997 = R. Fattovich, *Archaeology and Historical Dynamics: the Case of Bieta Giyorgis (Aksum), Ethiopia*, in "Annali dell'Istituto Universitario Orientale di Napoli", 57 (1-2), pp. 48-79.

Fattovich–Bard 1993 = R. Fattovich, K.A. Bard, *Scavi archeologici nella zona di Aksum. C. Ona Enda Aboi Zaguè (Bieta Giyorgis)*, in "Rassegna di Studi Etiopici", 35, pp. 41-71.

Fattovich et alii 2000 = R. Fattovich, K.A. Bard, L. Petrassi, V. Pisano, *The Aksum Archaeological Area: a Preliminary Assessment*, Istituto Universitario Orientale, Naples.

Felici 2001 = C. Felici, *Carta archeologica della provincia di Siena. Pienza*, Volume VI, Siena.

Finzi et alii 2005 = E. Finzi, R.G. Francese, G. Morelli, *High-resolution geophysical investigation of the archaeological site "Le Pozze" in the surroundings of the town of Lonato (Brescia, Northern Italy)*, in S. Piro (ed.), *Proceedings of the 6th International Conference on Archaeological Prospection*, Rome, pp. 215-219.

Fleming 2006 = A. Fleming, *Post-processual Landscape Archaeology: a Critique*, in "Cambridge Archeological Journal", 16.3, pp. 267-280.

Foley 1981 = R.A. Foley, *Off-site archaeology: an alternative approach for the short-sited*, in I. Hodder, G. Isaac, N. Hammond (eds.), *Patterns of the Past: Studies in Honour of David Clarke*, Cambridge, pp.157-183.

Forte 2001 = M. Forte, *Telerilevamento e paesaggi archeologici tridimensionali*, in Campana–Forte, 2001, pp. 95-141.

Forte 2002 = M. Forte, *GIS, aerial photographs and microtopography in archaeology: methods and applications*, in R.H. Bewley, W. Rączcowski (eds), *Aerial Archaeology: Developing Future Practice*, NATO Science Series I: Life and Behavioural Sciences, 337, Amsterdam, pp. 196-210.

Forte 2003 = M. Forte, *The Remote Sensing project for the archaeological Landscape of Askum (Ethiopia)*, in M. Forte, P.R. Williams (eds), *The reconstruction of Archaeological Landscapes through Digital Technologies, Proceedings of the 1st Italy-United States Workshop, Boston, Massachusetts, USA, November 1-3, 2001*, BAR International Series 1151, Oxford, pp. 81-93.

Forte–Kay 2003 = M. Forte, S.J. Kay, *Remote Sensing, GIS and Virtual Reconstruction of Archaeological Landscapes*, in M. Forte, P.R. Williams (eds), *The reconstruction of Archaeological Landscapes through Digital Technologies, Proceedings of the 1st Italy-United States Workshop, Boston, Massachusetts, USA, November 1-3, 2001*, BAR International Series 1151, Oxford, pp. 109-116.

Forte–Williams 2003 = M. Forte, P.R. Williams (eds), *The reconstruction of Archaeological Landscapes through Digital Technologies, Proceedings of the 1st Italy-United States Workshop, Boston, Massachusetts, USA, November 1-3, 2001*, BAR International Series 1151, Oxford.

Forte et alii 2001 = M. Forte, K.A. Bard, R. Fattovich, M. Foccillo, A. Manzo, C. Perlingieri, *The Aksum Project (Ethiopia): GIS, Remote Sensing Applications and Virtual Reality*, in Z. Stančič, T. Veljanovski (eds), *Computing Archaeology for Understanding the Past - CAA 2000*, BAR, S931, Oxford, pp. 241-251.

Fowler 1996 = M.J.F. Fowler, *High-resolution satellite imagery in archaeological application: a Russian satellite photograph of the Stonehenge region*, in "Antiquity", 70, pp: 667-671.

Fowler–Curtis 1995 = M.J.F. Fowler, H. Curtis, *Stonehenge from 230 Kilometres*, in "AARGnews", 11, pp. 8-16.

Francovich 2004 = R. Francovich, *Villaggi dell'altomedioevo: invisibilità sociale e labilità archeologica*, in M. Valenti, *Insediamento altomedievale nelle campagne toscane. Paesaggi, popolamento e villaggi tra VI e X secolo*, Florence, pp. 9-13.

Francovich–Hodges 2003 = R. Francovich, R. Hodges R. 2003, *Villa to village: the Transformation of the Roman Countryside in Italy c.400-1000*, London.

Francovich–Patterson 2000 = R. Francovich, H. Patterson (eds.), *Extracting Meaning from Ploughsoil Assemblages*, Oxford.

Frere–St Joseph 1983 = S.S. Frere, J.K.S. St Joseph, *Roman Britain from the air*, Cambridge.

Gaffney–Gater 2003 = C. Gaffney, J. Gater, *Revealing the buried past: geophysics for archaeologists*, Stroud, UK.

Gamble 2007 = C. Gamble, *Archaeology: The Basics*, Second edition, London.

GOING 2002 = J. C. Going, *A neglected Asset. German Aerial Photography of the Second World War Period*, in Bewley–Rączkowski 2002, pp.23-30.

GUAITOLI 1997 = M. Guaitoli, *Attività dell'Unità operativa Topografia antica*, in D'Andria, *Metodologie di catalogazione dei beni archeologici, Beni archeologici – Conoscenza e tecnologie, Vol 1.2*, pp. 9-50.

GUAITOLI 2003 = M. Guaitoli (ed.), *Lo sguardo di Icaro. Le collezioni dell'Aerofototeca Nazionale per la conoscenza del territorio*, Rome.

HAIGH 1993 = J.G.B. Haigh, *A new issue of AERIAL – Version 4.20*, in "AARGnews", **7**, pp. 22-25.

HAIGH 1996 = J.G.B. Haigh, *Another member of the AERIAL software family*, "AARGnews", 12, pp. 26-33.

HAIGH 1998 = J.G.B. Haigh*, Rectification of aerial images under Microsoft Windows*, in "Archaeological Computing Newsletter", 51, pp. 12-20.

HAIGH 1999 = J.G.B. Haigh, *Developing rectification programs for small computers*, in "Archaeological Prospection", **7**, pp. 1-16.

HAIGH 2003 = J.G.B. Haigh, From Photographs to Maps. A Ccollaborative Development, in J. Bourgeois, M. Meganck (eds.) 2003, *Aerial Photography and Archaeology 2003 – A Century of Information, Papers presented during the Conference held at the Ghent University December 10th -12th December 2003*, Ghent, pp. 201-211.

HALL 1996 = D.N. Hall, *The Fenland Project, Number 10*: *The Isle of Ely and Wisbech*, in "East Anglian Archaeology", 79.

HAMEROW 2004 = H. Hamerow, *Anglo-Saxon settlements in a post-roman landscape*, in G.P. Brogiolo, A. Chavarria, *Dopo la fine delle ville: le champagne dal VI al IX secolo*, *Proceedings of the workshop (Gavi, 8-11 May 2004)*, Mantova, pp. 327-334.

HASELGROVE ET ALII 1985 = C. Haselgrove, M. Millet, I. Smith, *Archaeology from the Ploughsoil. Studies in the Collection and Interpretation of Field Survey data*, Sheffield.

HILL–EVANS 1972 = J.N Hill, R.K. Evans, *A model for classification and typology*, in D.L. Clarke (ed.), *Models in Archaeology*, London.

HODDER ET ALII 1981 = I. Hodder, G. Isaac, N. Hammond (eds.), *Patterns of the Past: Studies in Honour of David Clarke*, Cambridge.

HOLDEN ET ALII 2002 = N. Holden, P. Horne, R. Bewley, *High resolution digital airborne mapping and archaeology*, in R.H. Bewley, W. Rączcowski (eds), *Aerial Archaeology: Developing Future Practice*, NATO Science Series I: Life and Behavioural Sciences, 337, Amsterdam, pp. 173-180.

HORNE 2009 = P. Horne, *A Strategy for the National Mapping Programme English Heritage Research Department Internal Document*. Free pdf download at www.english-heritage.org.uk/professional/research/landscapes-and-areas/national-mapping-programme/nmp-future/

HORNE 2011 = P. Horne, *The English Heritage National Mapping Programme*, in D.C. Cowley (ed.), *Remote Sensing for Archaeological Heritage Management*, Brussels, pp. 143-151.

HORNE–MACLEOD 2001 = P. Horne, D. MacLeod, *Unravelling a Wharfedale Landscape: a Case Study in Field Enhanced Aerial Survey*, in "Landscapes", Vol. 2, No. 1, pp. 65-82.

HUDSON 1984 = K. Hudson, *Industrial History from the Air*, Cambridge.

JAMES 2002 = N. James, *The Cold War*, in "Antiquity", 76, pp. 664-665.

JAUMANN–NEUKUM 1996 = R. Jaumann, G. Neukum, *The high resolution stereo camera (HRSC) for Mars 96: Results of outdoor tests*, in "International Archives of Photogrammetry and Remote Sensing", 31, pp. 349-354.

JOBST 1983 = W. Jobst, *Provinzhauptstadt Carnuntum: Österreichs größte archäologische Landschaft*, Himberg.

JOHNSON–ROSE 1994 = N. Johnson, P. Rose, *Bodmin Moor: an archaeological survey. Volume 1: the human landscape to c.1800*, English Heritage Archaeological Reports, 24**,** RCHME Supplementary Series, 11, London.

JONES 1978 = P. Jones, *An approach to stone settlement typology of the late iron age: stone walling on the Klip River 27 10 S, 29 10 E*, in "African Studies", 37, pp. 83-97.

JONES 1987 = G.D.B. JONES, *Apulia Vol I: Neolithic Settlement in the Tavoliere*, London.

JONES–EVANS 1975 = R.J.A. Jones, R. Evans, *Soil and crop marks in the recognition of archaeological sites by air photography*, in D.R Wilson (ed.), *Aerial reconnaissance for archaeology*, CBA Research Report 12, London, pp. 1-11.

KENNEDY 1989 = D. Kennedy (ed.), *Into the Sun. Essays In Air Photography In Archaeology In Honour Of Derrick Riley*, Sheffield.

KENNEDY 1998 = D. Kennedy, *Declassified satellite photographs and archaeology in the Middle East: case studies from Turkey*, in "Antiquity", 72, pp. 553-561.

LIEBESCHUETZ 2007 = W. Liebeschuetz, *L'aristocrazia in occidente tra il 400 e il 700*, in G.P. Brogiolo, A. Chavarria, *I Longobardi. Dalla caduta dell'impero all'alba dell'Italia* (catalogue of the exibition), Milan.

LILLESAND–KIEFER 2000 = T.M. Lillesand, R.W. Kiefer, *Remote Sensing and image interpretation*, New York.

LITTMANN ET ALII 1913 = E. Littmann, D. Krencker, T. von Lüpke, *Deutsche-Aksum Expedition, I-IV*, Berlin.

LOCK–MOLYNEAUX 2006 = G. Lock, B.L. Molyneaux (eds.) 2006, *Confronting Scale in Archaeology: Issues of Theory and Practice*, New York.

LUGLI 1939 = G. Lugli*, Saggi di esplorazione archeologica a mezzo della topografia archeologica*, Rome.

LUGLI 1940 = G. Lugli, *L'importanza del rilievo aereo negli studi di topografia archeologica*, in *Atti del V Congresso Nazionale di Studi Romani*, II, Rome, pp. 143ff.

MAGGS 1976 = T. Maggs, *Iron age patterns and Sotho history on the southern Highveld: South Africa*, in "World Archaeology", **7**, pp. 318-332.

MANGIAVACCHI 2004 = M. Mangiavacchi, *Archivio del Consorzio di Bonifica della Val d'Orcia. Immagini fotografiche per la lettura del territorio*, Firenze.

MARQUARDT–CRUMLEY 1987 = W.H. Marquardt, C.L. Crumley, *Regional Dynamics: Burgundian Landscapes in Historical Perspective*, San Diego.

MCMANAMON 1984 = F.P. McManamon, *Discovering Sites Unseen*, in M.B. Schiffer (ed.), *Advances in Archaeological Methods and Theory*, New York, pp. 223-292.

MARCHISIO ET ALII 1998 = M. Marchisio, M. Cosci, L. D'Onofrio, *A geophysical study of the palaeo-beds of the rivers in the plain of Pisa,* in *Atti IV Meeting EEGS*, Barcelona*.*

MARCHISIO ET ALII 1999A = M. Marchisio, M. Cosci, L. D'Onofrio, *Studio Geofisico dei Paleoalvei dei Fiumi nella Pianura di Pisa,* in *Atti 18° Convegno GNGTS*, Rome*.*

MARCHISIO ET ALII 1999B = M. Marchisio, M. Cosci, L. D'Onofrio, *Ricostruzione degli Antichi Corsi Fluviali nella Pianura di Pisa con Metodi Geofisici*, in "Science and Technology for Cultural Heritage", 8, Rome-Pisa.

MASON 1968 = R.J. Mason, *Transvaal and Natal iron age settlement revealed by aerial photography and excavation*, in "African Studies", 27, pp. 167-180.

MILLS–PALMER 2007 = J. Mills, R. Palmer (eds.), *Populating Clay Landscapes*, Stroud.

MONTESQUIEU 1971 = C. L. de Montesquieu, *Viaggio in Italia*, Bari.

MUELLER 1975 = J.W. Mueller (ed.), *Sampling in Archaeology*, Tucson.

MURPHY–MYTUM (FORTHCOMING) = K. Murphy, H. Mytum, *Iron Age enclosed settlements in west Wales*, in "Proceedings of the Prehistoric Society".

MUSSON 2004 = C. Musson, *The Aerial Archaeology Research Group (AARG) and Aerial Survey Training Schools in Hungary, Poland and Italy, 1996-2003*, in "Archeologia Aerea. Studi di Aerotopografia Archeologica", I, pp. 81-90.

MUSSON – RADCLIFFE 2010 = C. Musson, F Franchin Radcliffe, *Lost and Found: John Bradford and aerial photographs of Italy and elsewhere from the 1940s*, in D.C. Cowley, R.A. Standring, M.J. Abicht (eds.), *Landscapes through the Lens. Aerial Photographs and Historic Environment*, Oxford and Oakville, pp. 65-76.

MUSSON–WHIMSTER 1992 = C. Musson, R.P. Whimster, *Air Photography and the Study of Ancient Landscapes in Britain*, in M. Bernardi (eds.), *Archeologia del Paesaggio*, Florence, pp. 443-480.

MUSSON ET ALII 2005 = C. Musson, R. Palmer, S. Campana, *In Volo nel Passato. Aerofotografia e cartografia archeologica*, Firenze.

NEUBAUER–EDER-HINTERLEITNER 1997 = W. Neubauer, A. Eder-Hinterleitner, *3D-Interpretation of postprocessed archaeological magnetic prospection data*, in "Archaeological Prospection", 4, pp. 191-205.

NEUBAUER–EDER-HINTERLEITNER 1997A = W. Neubauer, A. Eder-Hinterleitner, *Resistivity and Magnetics of the Roman Town Carnuntum, Austria: An Example of Combined Interpretation of Prospection Data*, in "Archaeological Prospection", 4, pp. 179-189.

NEUBAUER ET ALII, 1998 = W. Neubauer, A. Eder-Hinterleitner, S. S. Seren, M. Doneus, P. Melichar, *Kombination archäologisch-geophysikalischer Prospektionsmethoden am Beispiel der römischen Zivilstadt Carnuntum*, in "Archaeologia Austriaca", 82-83, 1998-1999, pp. 1-26.

NEUBAUER ET ALII, 2002 = W. Neubauer, A. Eder-Hinterleitner, S. Seren, P. Melichar, *Georadar in the Roman Civil Town Carnuntum, Austria: An approach on archaeological interpretation of GPR data*, in "Archaeological Prospection", 9, pp. 135-156.

NORMAN–ST JOSEPH 1969 = E.R. Norman, J.K.S. St Joseph, *The Early Development of Irish Society: the evidence of aerial photography*, Cambridge.

OLTEAN 2002 = I.A. Oltean, *The use of satellite imagery for the transcription of oblique aerial photographs*, in R.H. Bewley, W. Rączcowski (eds), *Aerial Archaeology: Developing Future Practice*, NATO Science Series I: Life and Behavioural Sciences, 337, Amsterdam, 2002, pp. 224-232.

ORTON 2000 = C. Orton, *Sampling in Archaeology*, Cambridge.

PALMER 1976 = R. Palmer, *A method of transcribing archaeological sites from oblique aerial photographs*, in "Journal of Archaeological Science", 3, pp. 391-394.

PALMER 1977 = R. Palmer, *A computer method for transcribing information graphically from oblique aerial photographs to maps*, in "Journal of Archaeological Science", 4, pp. 283-290.

PALMER 1983 = R. Palmer, *Analysis of settlement features in the landscape of prehistoric Wessex*, in G.S. Maxwell (ed), *The Impact of Aerial Reconnaissance on Archaeology,* CBA Research Report 49, London, pp. 41-53.

PALMER 1984 = R. Palmer, *Danebury: an aerial photographic interpretation of its environs,* Royal Commission on the Historical Monuments of England, Supplementary Series, 6, London.

PALMER 1996 = R. Palmer, *Integration of air photo interpretation and field survey projects*, in “Archaeological Prospection”, 2 (1995), pp. 167-176.

PALMER 1997 = R. Palmer, *Air photo interpretation and the Lincolnshire Fenland*, in “Landscape History”, 18, pp. 5-16.

PALMER 2000 = R. Palmer, *A view from above: can computers help aerial survey?*, in G. Lock, K. Smith (eds.), *On the theory and practice of archaeological computing*. *Oxford University Committee for Archaeology Monograph* 51, Oxford, pp. 107-131.

PALMER 2007 = R. Palmer, *Seventy-five years v. ninety minutes: implications of the 1996 Bedfordshire vertical aerial survey on our perceptions of clayland archaeology*, in Mills–Palmer 2007, pp. 88-103.

PALMER ET ALII 2009 = R. Palmer, I. Oberländer-Târnoveanu, C. Bem (eds.), *Arheologie Aerianâ în România şi în Europa,* CIMEC: Bucharest.

PALUMBO 1992 = G. Palumbo, *JADIS (Jordan Antiquities Database and Information System): An example of national archaeological inventory and GIS applications*, in J. Andresen, T. Madsen, I. Scollar (eds), *Computing the past: computer applications and quantitative methods in archaeology*, Aarhus, pp. 183-188.

PERRY 1970 = B.T. Perry, *Iron Age enclosures and settlements on the Hampshire chalklands*, in “Archaeological Journal”, 126 (1969), pp. 29-43.

PHILIP ET ALII 2002 = G. Philip, D. Donoghue, A. Beck, N. Galiatsatos, *CORONA satellite photography: an archaeological application from the Middle East*, in “Antiquity”, 76, pp. 109-118.

PHILLIPSON 1998 = D.W. Phillipson, *Ancient Ethiopia. Aksum: Its Antecedents and Successors*, London.

PICCARRETA 1987 = F. Piccarreta, *Manuale di Fotografia Aerea. Uso Archeologico*, Roma.

PICCARRETA–CERAUDO 2000 = F. Piccarreta, G. Creaudo*, Manuale di Aerofotografia Archeologica. Metodologia, techniche e applicazioni*, Bari.

PIRO 2005 = S. Piro (ed.), *Proceedings of the 6th International Conference on Archaeological Prospection*, Rome.

POCOBELLI 2003 = G.F. Pocobelli, *Ortofotopiano storico del territorio di Vulci*, in M. Guaitoli (ed.), *Lo sguardo di Icaro. Le collezioni dell’Aerofototeca Nazionale per la conoscenza del territorio*, Rome, pp. 147-156.

POCOBELLI 2004 = G.F. Pocobelli*, Vulci: il contributo della fotografia aerea all conscenza dell’area urbana*, in G. Ceraudo, F. Piccarreta (eds.), “Archeologia Aerea. Studi di Aerotopografia Archeologica”, I, pp. 127-143.

POCOBELLI 2007 = G.F. Pocobelli, *Il territorio suburbano di Vulci attraverso le evidenze aerofotografiche. Viabilità e necropoli*, in G. Ceraudo, F. Piccarreta (eds.), in “Archeologia Aerea. Studi di Aerotopografia Archeologica”, II, pp. 167-185.

POIDEBARD 1934 = A. Poidebard, *La Trace de Rome dans le Désert de Syrie*, Paris.

POIDEBARD 1939 = A. Poidebard, *Un gran port disparu, Tyr, recherches aériennes et sous-marines, 1934-1936*, Paris.

POIDEBARD 1945 = A. Poidebard, avec la collaboration de R. Mouterde, J. Lauffray, S. Mazloum, *Le Limes de Chalcis. Organisation de la Steppe en Haute Syrie Romaine*. *Documents aériens et épigraphiques*, Paris.

POIDEBARD 1951A = A. Poidebard*, Notes sur les recherches opérées dans le port de Saïda de 1946 a 1950*, in “Syria”, XXVI, pp. 208ff.

POIDEBARD 1951B = A. Poidebard (avec la collaboration de J. Lauffray), *Sidon: aménagements antiques du port de Saida. Etude aérienne, au sol et sous-marine 1940-1950*, Beirut.

POWLESLAND 2001 = D. Powlesland, *The Heslerton parish project. An integrated multi-sensor approach to the archaeological study of Eastern Yorkshire, England*, in S. Campana, M. Forte (eds.), *Remote Sensing in Archaeology*. *XI International School in Archaeology, Certosa di Pontignano, 6-11 December 1999*, Florence, pp. 233-255.

POWLESLAND 2006 = D. Powlesland, *Redefining past landscapes: 30 years of remote sensing in the Vale of Pickering*, in S. Campana, M. Forte (eds.), *Remote Sensing in Archaeology*. *XI International School in Archaeology, Certosa di Pontignano, 6-11 December 1999*, Florence, pp. 197-202.

POWLESLAND 2009 = D. Powlesland, *Why Bother? Large scale geomagnetic survey and the quest for Real Archaeology*, in S. Campana, S. Piro 2009, *Seeing the Unseen. Geophysics and Landscape Archaeology*, London, pp. 167–182.

POWLESLAND 2010 = D. Powlesland, *Identifying, Mapping and Managing Unmanageable: the implications of long term multi-sensor research into the archaeology of the Vale of Pickering, Yorkshire, England*, in S. Campana, M. Forte, C. Liuzza (eds.), *Space, Time, Place. Third International Conference on Remote Sensing in Archaeology, 17th-21st August 2009, Tiruchirappalli, Tamil Nadu, India*, BAR International Series 2118, pp. 9-16.

POWLESLAND 2011 = D. Powlesland, *Identifying the Unimaginable ~ Managing the Unmanageable*, in D.C. Cowley (ed.), *Remote Sensing for Archaeological Heritage Management*, Brussels, pp. 17-32.

POWLESLAND ET ALII 1997 = D. Powlesland, J. Lyall, D. Donoghue, *Enhancing the record through remote sensing: the application and integration of multi-sensor, non-invasive remote sensing techniques for the enhancement of the Sites and Monuments Record, Heslerton Parish Project, N. Yorkshire*, *England,* in “Internet Archaeology”, 2, http://intarch.ac.uk/journal/issue2/powlesland/index .html

RABUS ET ALII 2003 = B. Rabus, M. Eineder, A. Roth, R. Bamler, *The shuttle radar topography mission – a new class of digital elevation models acquired by spaceborne radar*, in “Journal of Photogrammetry and Remote Sensing”, 57, pp. 241-262.

RADCLIFFE 2006 = F. Franchin Radcliffe (ed.), *Paesaggi sepolti in Daunia – John Bradford e la ricerca archeologica dal cielo 1945/1957. Buried landscapes in Daunia – John Bradford and archaeological research from the air 1945/1957* (in Italian and English), Foggia.

RADCLIFFE–MUSSON 2007 = F. Franchin Radcliffe, C. Musson, *John Bradford: his Life and Legacy*, in “Archeologia Aerea. Studi di Aerotopografia Archeologica”, II, pp. 39-63.

RAFFESTIN 1987 = C. Raffestin, *Carta e potere o dalla duplicazione alla sostituzione*, in *Cartografia e Istituzioni in età moderna*, Atti del convegno, Genova, Imperia, Albenga, Savona, La Spezia, 3-8 novembre 1986. Roma 1987, pp. 23-31.

RCHME 1960 = Royal Commission on the Historical Monuments of England, *A Matter of Time*, London.

RENFREW–BAHN 2008 = C. Renfrew, P. Bahn, *Archaeology: Theories, Methods and Practice*, London.

REDFERN 1997 = S. Redfern, *Computer assisted classification from aerial photographs*, in “AARGnews”, 14, pp. 33-38.

REDFERN 1998 = S. Redfern, *An approach to automated morphological-topographical classification*, in “AARGnews”, 17, pp. 31-37.

RILEY 1942 = D.N. Riley, *Crop marks in the Upper Thames valley seen from the air during 1942*, in “Oxoniensia”, 7, pp. 111-114.

RILEY 1944 = D.N. Riley, *The Technique of air-archaeology*, in “Archaeological Journal”, 101, pp. 1-16.

RILEY 1945 = D.N. Riley, *Aerial reconnaissance of the Fen basin*, in “Antiquity”, 19, pp. 145-153.

RILEY 1980 = D.N. Riley, *Early Landscape from the Air*, Sheffield.

RILEY 1987 = D.N. Riley, *Air Photography and Archaeology*, London.

RILEY 1992 = D.N. Riley, *New aerial reconnaissance in Apulia*, in “Papers of the British School at Rome”, LX, pp. 291-307.

RILEY ET ALII 1985 = D.N. Riley, D.A. Edwards, T. Gates, J.N. Hampton, R.P. Whimster, *The mapping of archaeological evidence from air photographs*, in “Aerial Archaeology”, 11, pp. 1-30.

RIPPLE 1986 = W.J. Ripple, *Spectral reflectance relationships to leaf water stress*, in “Photogrammetric Engineering and Remote Sensing”, 52, pp. 1669-75.

ROBBINS 1997 = G. Robbins, *Cropmark landsapes and domestic space*, in “Assemblage”, 3, University of Sheffield.

ROUGHLEY 2004 = C. Roughley, *The Neolithic Landscape of the Carnac Region, Brittany: new insights from digital approaches*, in “Proceedings of the Prehistoric Society”, 70, pp. 153-172.

ROUGHLEY–SHELL 2004 = C. Roughley, C.A. Shell, *Views of Carnac: Applications of Visibility Analysis and Dynamic Visualisation for Understanding the Neolithic Monuments of Southern Brittany,* in “Internet Archaeology”, 16, (http://intarch.ac.uk/journal/issue16/roughley_index.html)

SCHIAPARELLI 1929-1933 = L. Schiaparelli, *Codice Diplomatico Longobardo*, Roma.

SCHIFFER 1984 = M.B. Schiffer (ed.), *Advances in Archaeological Methods and Theory*, New York.

SCHIFFER 1987 = M.B. Schiffer, *Formation Processes of the Archaeological Record*, Albuquerque.

SCHMIDT 1940 = E.F. Schmidt, *Flights over ancient cities of Iran*, Chicago.

SCHMIEDT 1964 = G. Schmiedt, *Atlante aerofotografico delle sedi umane in Italia: parte I, l’utillizzazione delle fotografie aeree nello studio degli insedimenti*, Florence.

SCHMIEDT 1970 = G. Schmiedt, *Atlante aerofotografico delle sedi umane in Italia: parte II, le sedi antiche scomparse*, Forence.

SCHMIEDT 1974 = G. Schmiedt, *Atlante aerofotografico delle sedi umane in Italia: parte III, la centuriazione*, Florence.

SCHOFIELD 1991 = J. Schofield, *Interpreting Artefact Scatters. Contributions to Ploughzone Archaeology*, Oxford.

SCOLLAR 1975 = I. Scollar, *Transformation of extreme oblique aerial photographs to maps or plans by conventional means or by computer*, in D.R. Wilson (ed.), *Aerial Reconnaissance for Archaeology,* CBA Research Report 12, London, pp. 52-59.

SCOLLAR 1998A = I. Scollar, *AirPhoto – a WinNT/Win95 program for geometric processing of archaeological air photos*, in “AARGnews”, 16, pp. 37-38.

SCOLLAR 1998B = I. Scollar, *AirPhoto – a WinNT/Win95 program for geometric processing of archaeological air photos*, in “Archaeological Computing Newsletter”, 51, pp. 23-25.

SCOLLAR 2002 = I. Scollar, *Making things look vertical*, in Bewley–Rączkowski, 2002, pp. 166-172.

SCOLLAR ET ALII 1990 = I. Scollar, A. Tabbagh, A. Hesse, I. Herzog, *Archaeological Prospecting and Remote Sensing*, Cambridge.

SCOLLAR ET ALII 2008 = I. Scollar, R. Palmer, M. Doneus, J. Haigh, K. MacLeod, D. Cowley, *A beginner's guide to transformation programs*, "AAARGnews", 36, pp. 11-18.

SHAW–CORNS 2011 = R. Shaw, A. Corns, *High resolution LiDAR specifically for archaeology: are we fully exploiting this valuable resource?*, in D.C. Cowley (ed.) 2011, *Remote Sensing for Archaeological Heritage Management*, Brussels, pp. 77-86.

SHELL 2002 = C.A. Shell, *Airborne high resolution digital visible, infra-red and thermal sensing for archaeology*, in R.H. Bewley, W. Rączcowski (eds), *Aerial Archaeology: Developing Future Practice*, NATO Science Series I: Life and Behavioural Sciences, 337, Amsterdam, 2002, pp. 181-195.

SHELL–ROUGHLEY 2004 = C.A. Shell, C. Roughley, *Exploring the Loughcrew landscape: a new approach with airborne Lidar*, in "Archaeology Ireland", 18, no.2, Issue no. 68, pp. 20-23.

SILVESTER 2001 = R.J. Silvester, *Recent research on late prehistoric and Romano-British enclosures in Montgomeryshire*, "Montgomeryshire Collections", 99, pp. 1-27.

SITTLER–SCHELLBERG 2006 = B. Sittler, S. Schellberg , *The potential of LIDAR in assessing elements of cultural heritage hidden under forest or overgrown by vegetation: Possibilities and limits in detecting microrelief structures for archaeological surveys*, in S. Campana, M. Forte (eds.), *From Space to Place. Proceedings of the 2nd International Conference on Remote Sensing in Archaeology*, BAR International Series 1568, Oxford, pp.117-122.

SMITH 1974 = C.A. Smith, *A morphological analysis of late prehistoric and Romano-British settlements in north-west Wales*, in "Proceedings of the Prehistoric Society", 40, pp. 157-169.

SMITH ET ALII 2004 = S.L. Smith, D.A. Holland, P.A. Longley, *The Importance of Understanding Error in Lidar Digital Eétion Models*, in "International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences", 34, part B4, pp. 996-1001.

STOERTZ 1997 = C. Stoertz, *Ancient landscapes of the Yorkshire Wolds*, Swindon.

STOLZE 1882 = F. Stolze, *Persepolis, die achaemenidischen und sasanidischen Denkmäler und Inschriften von Persepolis, Istakhr, Pasargadae, Shâpûr*, Berlin.

SYDORIAK ALLEN 2000 = K.M. Sydoriak Allen, *Consideration of Scale in Modelling Settlement Pattern Using GIS: an Iroquois Example*, in Wescott–Brandon 2000, pp. 101-112.

TERRENATO 2000 = N. Terrenato, *The visibility of sites and the interpretation of field survey results: towards an analysis of incomplete distributions*, in Francovich–Patterson 2000, pp. 60-71.

TORELLI 2000 = M. Torelli (ed.), *Gli Etruschi*, Catalogue of the exibition, Venice.

TOZZI 2004 = P.Tozzi, *I Luoghi degli Uomini. La foto aerea e i paesaggi antichi*, Pavia.

TOZZI–HARARI 1984 = P. Tozzi, M. Harari, *Eraclea Veneta. Immagine di una città sepolta*, Parma.

TOZZI–HARARI 1990 = P. Tozzi, M. Harari, *Tempi di un territorio. Atlante aerofotografico delle Valli Grandi Veronesi*, Parma.

TRIER ET ALII 2009A = Ø.D. Trier, S.Ø Larsen, R. Solberg, *Automatic detection of circular structures in high-resolution satellite images of agricultural land*, "Archaeological Prospection", 16, pp. 1-15.

TRIER ET ALII 2009B = Ø.D. Trier, S.Ø Larsen, R. Solberg, *Finding burial mounds from space: automatic detection of circular soil marks and crop marks in QuickBird imagery of agricultural land in south-east Norway*, "AARGnews", 39, pp. 18-24.

TROW 2003 = S. Trow, *Ploughing through history*, in "Green Futures", 41, p. 46.

VALENTI 2004 = M. Valenti, *Insediamento altomedievale nelle campagne toscane. Paesaggi, popolamento e villaggi tra VI e X secolo*, Florence.

WARNER ET ALII 1996 = W.S. Warner, R.W. Graham, R.E. Read, *Small Format Aerial Photography*, Caithness, UK.

WEIGAND 1920 = T. Weigand, *Wissenschaftliche Veröffentlichungen des deutsch-türkischen Denkmalschutz-kommandos, I, Sinai*, Berlin-Leipzig.

WESCOTT–BRANDON 2000 = K.I. Wescott, R.J. Brandon (eds.), *Practical Application of GIS for Archaeologists. A predictive modelling kit*, London.

WHIMSTER 1989 = R. Whimster, *The Emerging Past: air photography and the buried landscape*, London.

WILSON 1982 = D.R. Wilson, *Air Photo Interpretation for archaeologists*, London.

WILSON 1987 = D.R. Wilson, *Reading the palimpsest: landscape studies and air-photography*, in "Landscape History", 9, pp. 5-26.

WILSON 1995 = D.R. Wilson, *History of aerial archaeology – success and failure*, in J. Kunow (ed), *Luftbildarchäologie in Ost- und Mitteleuropa/ Aerial Archaeology in Eastern and Central Europe*, Forschungen zur Archäologie im Land Brandenburg, 3, pp. 13-22.

WILSON 2000 = D.R. Wilson, *Air Photo Interpretation for Archaeologists*, (revised) Stroud.

WINTON–HORNE 2010 = H. Winton, P. Horne, *National archives for national programmes: NMP and the English Heritage aerial photograph collection*, in D.C. Cowley, R.A. Standring, M.J. Abicht (eds.), *Landscapes through the Lens. Aerial Photographs and Historic Environment*, Oxford and Oakville, pp. 7-18.

WISEMAN–EL-BAZ 2007 = J. Wiseman, F. El-Baz, *Remote Sensing in Archaeology*, New York.

WOOLLEY 1937 (and many later reprints) = Sir Leonard Woolley, Digging up the Past, Middlesex, UK.

YOUNG 1994 = R. Young, *'Destruction is only one facet' … A study of formation processes and the generation of distribution patterns for later prehistory in Northern England*, "Landscape History", 16, pp. 5-16.

Web references (accessed and verified August 2012)

Aerial Archaeology Research Group (AARG) **www.univie.ac.at/aarg**

Aerofototeca Nazionale www.iccd.beniculturali.it/index.php?it/98/fototeca-nazionale

AirPhoto (computer programme) www.uni-koeln.de/~AL001/basp.html

ArchaeoLandscapes Europe project www.archaeolandscapes.eu

ER (ERDAS) www.erdas.com/products/ERDASERMapper/ERDASERViewer/Details.aspx

Geosetter http://geosetter.de/ and http://geosetter.de/en/

IGM (Istitito Geografico Militare) www.igmi.org

MrSid (Lizard Tech) www.lizardtech.com/

NMPE (National Mapping Programme for England), English Heritage, Swindon. Policy documents and reports on the individual survey projects can be accessed at: www.english-heritage.org.uk/professional/research/landscapes-and-areas/national-mapping-programme/

Supplementary Bibliography 2012

Recent and general interest publications

The following sources provide general or specific information – or ideas and arguments – which are of relevance across Europe. From the main bibliography one may also point to Bradford 1957, Bewley–Rączcowski 2002, Kennedy 1989, Riley 1980 and 1987, Mills–Palmer 2007 and Wilson 1982, 2000. A general reading list for beginners in aerial archaeology can be found on the AARG website at www.univie.ac.at/aarg/php/books/aerial-archaeology-beginners-list. All web entries in this and the main bibliography were accessed and verified in August 2012.

BECKER 1996 = H. Becker (ed.), Archäologische Prospektion – Luftbildarchäologie und Geophysik, Arbeitshefte des des Bayerischen Landesamtes fūr Denkmalpflege, 49, Munich.

BOURGEOIS–MEGANCK 2005 = J. Bourgeois, M. Meganck (eds.), Aerial Photography and Archaeology 2003 – A Century of Information, Papers presented during the Conference held at the Ghent University December 10th -12th December 2003, Ghent.

BROPHY–COWLEY 2005 = K. Brophy, D. Cowley, From the Air – Understanding Aerial Archaeology, Stroud, UK.

CAMPANA ET ALII 2010 = S. Campana, M. Forte, C. Liuzza (eds.), Space, Time, Place. Third International Conference on Remote Sensing in Archaeology, 17th-21st August 2009, Tiruchirappalli, Tamil Nadu, India, BAR International Series 2118.

COWLEY 2011 = D.C. Cowley (ed.), Remote Sensing for Archaeological Heritage Management, Brussels.

COWLEY–STICHELBAUT 2012 = D. Cowley, B. Stichelbaut, Historic aerial photographic archives for European archaeology: applications, potential and issues, in "European Journal of Archaeology", 15, pp. 217-236.

COWLEY ET ALII 2010 = D.C. Cowley, R.A. Standring, M.J. Abicht (eds.), Landscapes through the Lens. Aerial Photographs and Historic Environment, Oxford and Oakville.

HANSON–OLTEAN (IN PRESS FOR AUTUMN 2012) = W.S. Hanson, I.A. Oltean, Archaeology from Historical Aerial and Satellite Archives, New York.

KUNOW 1995 = J. Kunow (ed.), Luftbildarchäologie in Ost- und Mitteleuropa. Aerial Archaeology in Eastern and Central Europe, Potsdam.

Leva 1990 = C. Leva (ed.), Aerial Photography and Geophysical Prospection in archaeology. Proceedings of the Second International Symposium, Brussels 8-XI-1986, Brussels.

Maxwell 1983 = G.S. Maxwell (ed.), The impact of aerial reconnaissance on archeology, CBA Research Report No 49, London.

Palmer–Cowley 2010 = R. Palmer, D. Cowley, Interpreting Aerial Imagery – developing best practice, in S. Campana, M. Forte, C. Liuzza (eds.), Space, Time, Place. Third International Conference on Remote Sensing in Archaeology, 17th-21st August 2009, Tiruchirappalli, Tamil Nadu, India, BAR International Series 2118, pp. 129-135.

Stichelbaut et alii 2009 = B. Stichelbaut, J. Bourgeois, N. Saunders, P. Chielens (eds.), Images of Conflict: Military Aerial Photography and Archaeology, Newcastle upon Tyne.

Wilson 1975 = D.R. Wilson, Aerial reconnaissance for archaeology, CBA Research Report No 12, London.

Verhoeven 2011 = G. Verhoeven, Taking computer vision aloft – archaeological three-dimensional reconstructions from aerial photographs with PhotoScan, “Archaeological Prospection”, 18, pp. 67-73.

Verhoeven et alii 2012 = G. Verhoeven, M. Doneus, Ch. Briese, F. Vermeulen, Mapping by matching: a computer vision-based approach to fast and accurate georeferencing of archaeological aerial photographs, in “Journal of Archaeological Science”, 39, pp. 2060-2070.

Projects within the Culture Programme of the European Union

Conservation through Aerial Archaeology (2001) www.univie.ac.at/aarg/aerarch/papers/cult2000report.pdf

European Landscapes: past, present and future (2004-2007) www.muzarp.poznan.pl/EuLandscapes/assets/pdfs/Final_Report_EU_LANDS_lower_res.pdf.

ArchaeoLandscapes Europe, also known as ArcLAND (2010-2015) www.archaeolandscapes.eu.

Selected sources for the countries of Europe

The United Kingdom and Italy are fairly well covered in Chapter 1 and in the main Bibliography. The following entries provide introductory reading for the rest of Europe. Where a country is not listed this is because it has proved impossible to identify sources through local contacts or basic search on the internet.

AUSTRIA

Information supplied by Michael Doneus.

Doneus 1995 = M. Doneus, Luftbildarchäologie und Photogrammetrie am Institut für Ur- und Frügeschichte in Wien, in J. Kunow (ed.), Luftbildarchäologie in Ost- und Mitteleuropa. Aerial Archaeology in Eastern and Central Europe, Potsdam, pp. 123-132.

Doneus–Doneus 2008 = N. Doneus, M. Doneus, Surface-Collected Data from the Air – towards a Prospecting Toolcase for Archaeological Landscapes, in P. Pospechová, P. Wittgrúber (eds.), Carnuntum-Gerulata, Mestské múzeum v Pezinku, Bratislava, pp. 184-190.

Doneus–Gugl 2006 = M. Doneus, C. Gugl, Das Bebauungsschema der praetentura-Ost aufgrund der Grabungsbefunde und der Luftbilder, in C. Gugl, R. Kastler (eds.), Legionslager Carnuntum, in “Der Römische Limes in Österreich”, 45, Wien, pp. 449-456.

Doneus–Lippert 2007 = M. Doneus, A. Lippert, Luftbildarchäologische Forschungen in der Südoststeiermark – Vorbericht, in “Schild von Steier”, 20, pp. 69-76.

Doneus et alii 2007 = M. Doneus, Ch. Briese, M. Fera, U. Fornwagner, M. Griebl, M. Janner, M-C. Zingerle, Documentation and Analysis of Archaeological Sites Using Aerial Reconnaissance and Airborne Laser Scanning, in A. Georgoupulos, (ed.), Anticipating the future of the cultural past. Proceedings of the XXIst International Symposium CIPA, Athens 2007, in “The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences”, XXXVI-5/C53, 2007, pp. 275-280.

Doneus et alii 2011 = M. Doneus, W. Neubauer, G. Verhoeven, C. Briese, Advancing archaeological airborne remote sensing, in M.G. Drahor, M.A. Berge (eds.), Archaeological Prospection. 9th International Conference on Archaeological Prospection. September 19-24, 2011 Izmir-Turkey, Istanbul, pp. 12-15.

Doneus et alii (in press) 2012 = M. Doneus, C. Gugl, N. Doneus, Die Canabae von Carnuntum – ein Modell für römische Lagervorstädte. Von der Luftbildprospektion zur siedlungsarchäologischen Synthese, in “Der Römische Limes in Österreich”, 47.

Gugl–Doneus 2011 = C. Gugl, M. Doneus, Zur Wasserversorgung der Zivilstadt von Carnuntum, in F. Humer, A. Konecny (eds.), Römische Thermen – Forschung und Präsentation. Akten des internationalen Kolloquiums, veranstaltet vom Archäologischen Park Carnuntum und der Gesellschaft der Freunde Carnuntums 17-18 September 2009, St. Pölten, pp. 107-120.

Gugl et alii 2008 = C. Gugl, M. Doneus, N. Doneus, Roman field boundaries in west Pannonia – diversity of a system, in R. Compatangelo, J-R. Bertrand, J. Chapman, P-Y. Laffont (eds.), Landmarks and Socio-Economic Systems. Proceedings of the Le Mans COST Conference (7th-9th December 2006), Rennes, pp. 113-125.

Verhoeven–Doneus 2011 = G. Verhoeven, M. Doneus, Balancing on the borderline - A low-cost approach to visualise the Red Edge shift for the benefit of aerial archaeology, in “Archaeological Prospection” 18, pp. 267-278.

BELGIUM

Information supplied by Birger Stichelbaut.

Ampe et alii 1996 = C. Ampe, J. Bourgeois, P. Crombé, L. Fockedey, R. Langohr, M. Meganck, J. Semey, M. Van Strydonck, K. Verlaeckt, The circular view. Aerial Photography and the discovery of Bronze Age funerary monuments in East- and West-Flanders (Belgium), in “Germania”, 74, pp. 45-94.

Bourgeois–Meganck 2005 = J. Bourgeois, M. Meganck (eds.), Aerial Photography and Archaeology 2003 – A Century of Information, Papers presented during the Conference held at the Ghent University December 10th -12th December 2003, Ghent.

Bourgeois et alii 1999 = J. Bourgeois, P. Crombé, J. Semey, Prospection archéologique aérienne en Belgique occidentale: résultats e perspectives, in Bréart, F. Nowicki, C. Leva, Archéologie Aérienne. Hommage a Roger Agache, Actes du colloque international tenu a Amiens (France) du 15 au 18 octobre 1992, “Revue Archéologique de Picardie”, 17, Amiens, pp. 123-139.

Bourgeois et alii 2002 = J. Bourgeois, M. Meganck, J. Semey, R. Pelegrin, M. Lodewijckx, Flemish aerial archaeology in the last 20 years: past and future perspectives, in R.H. Bewley, W. Rączcowski (eds), Aerial Archaeology: Developing Future Practice, NATO Science Series I: Life and Behavioural Sciences, 337, Amsterdam, pp. 76-83.

Bourgeois et alii 2005 = J. Bourgeois, M. Meganck, J. Semey, Almost a Century of Aerial Photography in Belgium. An Overview, in J. Bourgeois, M. Meganck (eds.), Aerial Photography and Archaeology 2003 – A Century of Information, Papers presented during the Conference held at the Ghent University December 10th -12th December 2003, Ghent, pp. 7-48.

Cowley–Stichelbaut 2012 = D. Cowley, B. Stichelbaut, Historic aerial photographic archives for European archaeology: applications, potential and issues, in “European Journal of Archaeology”, 15, pp. 217-236.

Leva 1973 = C. Leva, Archéologie aérienne en Belgique, in “Dossiers de l’Archéologie”, 1, pp. 40-45.

Leva 1990 = C. Leva (ed.), Aerial Photography and Geophysical Prospection in Archaeology. Proceedings of the Second International Symposium, Brussels 8-XI-1986, Brussels.

Leva 1992 = C. Leva, Prospections aériennes de voies romaines en Belgique, in B. Bréart, F. Nowicki, C. Leva, Archéologie Aérienne. Hommage a Roger Agache, Actes du colloque international tenu a Amiens (France) du 15 au 18 octobre 1992, “Revue Archéologique de Picardie”, 17, Amiens, pp. 111-122.

Leva–Hus 1990 = C. Leva, J.J. Hus, Recent archaeological discoveries in Belgium by low-level aerial photography and geophysical survey, in D.R. Wilson (ed.) Aerial reconnaissance for archaeology, CBA Research Report No 12, London, pp. 81-102.

Masters–Stichelbaut 2009 = P. Masters, B. Stichelbaut, From the Air to Beneath the Soil: Revealing/Mapping the Great War Remains at Ploegsteert (Comines-Warneton, Belgium), in “Journal of Archaeological Prospection”, 16:4, pp. 279-285.

Stichelbaut 2006 = B. Stichelbaut, The Application of First World War Aerial Photography to Archaeology: the Belgian Images, in “Antiquity”, 80: 307, pp. 161-172.

Stichelbaut et alii 2009 = B. Stichelbaut, J. Bourgeois, N. Saunders, P. Chielens (eds.), Images of Conflict: Military Aerial Photography and Archaeology, Newcastle-upon-Tyne.

Stichelbaut 2011 = B. Stichelbaut, The First Thirty Kilometres of the Western Front 1914-1918: an aerial archaeological approach with historical remote sensing data, in “Journal of Archaeological Prospection”, 18, pp. 57-65.

Stichelbaut–Bourgeois 2009 = B. Stichelbaut, J. Bourgeois, The Overlooked Aerial imagery of World War One: a Unique Source for Conflict and Landscape Archaeology, in “Photogrammetrie - Fernerkundung – Geoinformation”, 3, pp. 231-240.

Stichelbaut et alii 2011 = B. Stichelbaut, T. Saey, F. Meeuws, J. Bourgeois, M. Van Meirvenne, World War One Heritage in Belgium: combining historical aerial photography and EMI, in D.C. Cowley (ed.), Remote Sensing for Archaeological Heritage Management, Brussels, pp. 265-273.

Stichelbaut et alii 2010 = B. Stichelbaut, W. Gheyle, J. Bourgeois, The Imperial War Museum's Box Collection, in D.C. Cowley, R.A. Standring, M.J. Abicht (eds.), Landscapes through the Lens. Aerial Photographs and Historic Environment, Oxford and Oakville, pp. 225-236.

Stichelbaut et alii (in press 2012) = B. Stichelbaut B., W. De Clercq, D. Herremans, J. Bourgeois, The Use of Historical Aerial Photographs in West-Flanders for the Detection of Archaeological sites, in W.S. Hanson, I.A. Oltean, Archaeology from Historical Aerial and Satellite Archives, New York.

BULGARIA

Information supplied by Ioana Oltean and Internet search.

Stamenov 2010 = S. Stamenov, Remote Sensing and GIS in Bulgarian Archaeology, in R. Reuter (ed.), Remote Sensing for Science, Education and Natural and Cultural Heritage, (www.earsel.org/?target=publications/proceedings/symposium-2010).

CROATIA

Information from Internet search.

Glavas 2011 = V. Glavas, Problems of reconnaissance of the karst landscape:an example of the northern sub-Velebit littoral, Croatia, in “AARGnews”, 43, pp. 24-29.

For the DITECUR (Digital technologies in cultural landscape research) workshop held at Zagreb in January-February 2012 see http://ffzg.unizg.hr/ditecur/

CYPRUS

Information supplied by Sorin Hermon.

No specifically air-photographic references are available for Cyprus but for work in adjacent areas of study see the following publications.

Amico et alii 2010 = N. Amico, A. Angelini, A. D’Andrea, R. Gabrielli, G. Iannone, Integrating 3D data acquisition techniques for comprehensive study of the ancient Hellenistic-Roman Theatre of Paphos, Cyprus, in F. Javier Melero, P. Cano, J. Revelles (eds.), Fusion of Cultures, Abstracts of the XXXVIII Annual Conference on Computer Applications and Quantitative Methods in Archaeology, CAA 2010, Granada, Spain, April 6-9, pp. 461-464.

Georgiou–Hermon 2011 = R. Georgiou, S. Hermon, A London’s Charter Visualization: The Hellenistic-Roman Theatre in Paphos, in Proceedings of Short and Project Papers, VAST 2011, Prato, Italy, pp. 53-56.

Given et alii 1999 = M. Given, A.B. Knapp, N. Meyer, T.E. Gregory, V. Kassianidou, J. Noller, L. Wells, N. Urwin, H. Wright, The Sydney Cyprus Survey Project: An Interdisciplinary Investigation of Long-Term Change in the North Central Troodos, Cyprus, in “Journal of Field Archaeology”, 26:1, pp. 19-39.

CZECH REPUBLIC

Information supplied by Martin Gojda.

Gojda 1997 = M. Gojda, Aerial Archaeology in Bohemia, Prague.

Godja 2002 = M. Gojda, Aerial archaeology in Bohemia at the turn of the twenty first century: integration of landscape studies and non-destructive archaeology, in Bewley–Rączkowski, 2002, pp. 68-75.

Gojda 2004 = M. Gojda, Ancient Landscape, Settlement Dynamics and Non-Destructive Archaeology. Czech Research Project 1997-2002, Prague.

Gojda 2007 = M. Gojda, Lety do minulosti - Flights into the Past. Exhibition guidebook. Prague: National Museum (Czech – English edition).

Gojda 2008 = M. Gojda, Military activities on Rome‘s frontier: the evidence of aerial archaeology, in V. Salač, J. Bemmann (eds.) 2008, Mitteleuropa zur Zeit Marbods, Prague-Bonn, pp. 577-594.

Gojda 2010 = M. Gojda (ed.), Studie k dálkovému průzkumu v archeologii - Studies in Remote Sensing for Archaeology, Pilsen (Czech-English edition).

Gojda 2011= M. Gojda, Remote sensing for the integrated study and management of sites and monuments - a Central European perspective and Czech case study, in D. Cowley (ed.), Remote Sensing for Archaeological Heritage Management, EAC Occasional Paper No. 5, Budapest, pp. 215-227.

Gojda–Hejcman 2012: = M. Gojda, M. Hejcman, Cropmarks in main field crops enable the identification of a wide spectrum of buried features on archaeological sites in Central Europe, in “Journal of Archaeological Science”, 39(6), pp. 1655-1664.

Gojda–Trefný 2011 = M. Gojda, M. Trefný (eds.), Archeologie krajiny pod Řípem – Archaeology in the Landscape around the Hill of Říp, Pilsen (Czech-English edition).

Also see Gojda 2007, Flights into the Past, film about aerial archaeology in Central Europe and elsewhere, available at www.kar.zcu.cz then click to Videoarchiv KAR.

DENMARK

Information supplied by Lis Helles Olesen.

Eriksen–Olesen 2002 = P. Eriksen, L. Helles Olesen, Fortiden set fra himlen. Luftfotoarkæologi i Vestjylland (Looking at the past from the air. Aerial archaeology in Western Jutland), Holstebro.

Johansen–Laursen 2007 = K.L. Johansen, S.T. Laursen, Gravhøje set fra luften: en kildekritisk undersøgelse, in “Kuml” 2007, pp. 47-72.

Olesen 2004 = L. Helles Olesen, Aerial archaeology in Denmark, in “AARGnews” 28, pp. 28-35.

Olesen 2010 = L. Helles Olesen, De første resultater i projektet „Fortiden set fra himlen – luftfotoarkæologi i Danmark”, in “Holstebro Museum Årsskrift”, pp. 34-41. http://www.fortidensetfrahimlen.dk/artikler-om-luftfotoarkaeologi.html

Olesen 2010 = L. Helles Olesen, The use of aerial photographs in the study of Early Iron Age settlement patterns in Western Jutland, Denmark, in D.C. Cowley. R.A. Standring, M.J. Abicht (eds.), Landscapes through the Lens – Aerial Photographs and Historic Environment, Oxford/Oakville, pp. 19-31. http://www.fortidensetfrahimlen.dk/artikler-om-luftfotoarkaeologi.html

Olesen 2011 = L. Helles Olesen, An aerial view of the past - Aerial archaeology in Denmark, in D.C. Cowley (ed.), Remote Sensing for Archaeological Heritage Management. Proceedings of the 11th EAC Heritage Management Symposium, Reykjavik, Iceland, 25-27 March 2010, pp. 275-282. http://www.fortidensetfrahimlen.dk/artikler-om-luftfotoarkaeologi.html

Olesen-Klinkby 2012 = L. Helles Olesen, K Jøstad Klinkby, Fredede fortidsminder fra luften. Muligheder for registrering fra luften, Holstebro.

Olesen et alii 2011 = L. Helles Olesen, H. Dupont, C. Dam, Luftfotos over Danmark. Luftfotoserier I private og offentlige arkiver, Holstebro.

Vinter 2011 = M. Vinter, Kortlægning af marksystemer fra jernalderen. En kildekritisk vurdering af luftfotografiers anvendelighed, in “Kuml” 2011, pp. 83-114.

ESTONIA

Information supplied by Ants Kraut.

Kraut 2007 = A. Kraut, Heritage Survey in Estonia. Aerial and ground-based evidence in partnership, in European Landscapes: past, present and future. Culture 2000 Project Final Report, pp. 18-21. Pdf download at http://www.muzarp.poznan.pl/EuLandscapes/assets/pdfs/Final Report_EU_LANDS_lower_res.pdf

Lidar data and orthophotos are available for the whole of Estonia on the geoportal of the Estonian Land Board at http://geoportal.maaamet.ee/eng/Maps-and-Data/Topographic-data/Elevation-data-p308.html and ...... -p09.html

FINLAND

Information supplied by Nina Heiska.

Adel 2010 = V. Adel (ed.), Pirkan maan alta 11, Tampereen museoiden julkaisuja 112. www.tampere.fi/material/attachments/p/5vVX4YVFx/Pirkan_maan_alta_11.pdf

Siiriäinen 1970 = A. Siiriäinen, Ilmakuvien käyttö arkeologiassa, “Ilmakuvien tulkinta”, Helsinki: Insinöörien koulutuskeskus, pp. 1-5.

Taivainen 2005 = J. Taivainen, Ajatuksia Retulansaaren rautakauden – keskiajan asutuksesta ja elinkeinoista, in “Arx Tavastica”, 12, pp. 2-17.

The accumulated air photographic archives of the National Land Survey of Finland are now freely available on the internet at: http://www.maanmittauslaitos.fi/en/tiedotteet/2011/12/national-land-survey-opens-topographic-datasets-1-may-2012-free-use

FRANCE

Information compiled by Chris Musson from Internet search etc.

See entries for Baradez and Poidebard in the main Bibliography.

Discoveries from the air have been reported and illustrated in issues of the popular journal Archéologia, Issues No1, 1973 (115 pages), Issue No132, 1979 (full issue), Issue No195, 1984 (8 pages).

Agache 1962 = R. Agache, Vues aériennes de la Somme et recherches du passé, Bulletin Spécial de la Société de Préhistoire du Nord, Amiens.

Agache 1964 = R. Agache, Archéologie aérienne de la Somme, Bulletin Spécial de la Société de Préhistoire du Nord, Amiens.

Agache 1970 = R. Agache, Détection aérienne de vestiges protohistoriques, gallo-romains et medièvaux dans le Bassin de las Somme, Bulletin Spécial de la Société de Préhistoire du Nord, Amiens.

Agache 1975 = R. Agache, Aerial reconnaissance in northern France, in D.R. Wilson, Aerial reconnaissance for archaeology, CBA Research Report No 12, London, pp. 70-80.

Agache 2002 = R. Agache, L’archéologie aérienne, in Encyclopaedia Universalis, t.2, Paris, t.2 pp.808-813.

Bréart et alii 1999 = B. Bréart, F. Nowicki, C. Leva, Archéologie Aérienne. Hommage a Roger Agache, Actes du colloque international tenu a Amiens (France) du 15 au 18 octobre 1992, “Revue Archéologique de Picardie” 17, Amiens.

Chevallier 1963 = R. Chevallier (ed.), Colloque international d’archéologie aérienne, Paris.

Chevallier 1964 = R. Chevallier, L’avion à la découverte du passé, Paris.

Dassié 1978 = J. Dassié, Manuel d’archéologie aérienne, Paris.

Goguey 1968 = R. Goguey, De l'aviation à l'archéologie: recherches sur les techniques e les methodes de l'archéologie aérienne, Paris.

Goguey 1995 = R. Goguey, Archéologie aérienne de la Seine au Danube. Quelques aspects des récentes recherches sur la Burgogne e la Hongrie, in J. Kunow (ed.), Luftbildarchäologie in Ost- und Mitteleuropa. Aerial Archaeology in Eastern and Central Europe, Potsdam, pp. 227-235.

Lambot 1996 = B. Lambot, Cartes postales aériennes de Champagne-Ardenne – 3000 ans d'histoire vus du ciel, Reims.

St Joseph 1962 = J.K.S. St Joseph, Air reconnaissance in northern France, in "Antiquity", 36, pp.74-89.

GERMANY

Information supplied by Otto Braasch, Ralf Schwartz, Andrea Zeeb-Lanz, Ronald Heynowski and Joachim Wacker.

See *Kunow 1995* (above); also Stolze 1882 and Weigand 1920 in the main Bibliography.

Becker 1996 = H. Becker (ed.), Archäologische Prospektion – Luftbildarchäologie und Geophysik, "Arbeitshefte des Bayerischen Landesamtes für Denkmalpflege", 49, Munich. (With magnificent aerial photographs throughout the volume.)

Braasch 1983 = O. Braasch, Luftbildarchäologie in Süddeutschland. Spuren aus römischer Zeit, Stuttgart.

Braasch 1996 = O. Braasch, Luftbildarchäologie, ein Wintermärchen?, in Becker 1996, pp. 55-65.

Braasch 2005 = O. Braasch, Vom heiteren Himmel …. Luftbildarchäologie, Esslingen am Neckar.

Braasch–Wetzel 2001 = O. Braasch, G. Wetzel, Archäologische Flugprospektion, in Denkmalpflege in Land Brandenburg 1990-2000, Bericht des Brandenburgischen Landesamtes für Archäologischen Landesmuseums 2, Worms.

Christlein–Braasch 1982 = R. Christlein, O. Braasch, Das unterirdische Bayern, Stuttgart.

Dietrich et alii 1993 = R. Dietrich, F.R. Herrmann, P. Ille, Zeitspuren, Luftbildarchäologie in Hessen, Wiesbaden.

Ille 1993 = P.Ille, Methoden der Luftbildarchäologie. Beispiele und Ergebnisse der Luftbildarchäologie in Hessen. Zeitspuren – Luftbildarchäologie in Hessen, Wiesbaden.

Leidorf 1996 = K. Leidorf, Luftbildarchäologie – Geschichte und Methode, in Becker 1996, pp. 33-44.

Planck et alii 1994 = P. Planck, O. Braasch, J. Oexle, H. Schlichtherle, Unterirdisches Baden-Württemberg. 2500 Jahre Geschichte und Archäologie im Luftbild, Stuttgart.

Schwarz 2003 = R. Schwarz, Pilotstudien. 12 Jahre Luftbildarchäologie in Sachsen-Anhalt, Halle.

Schwartz –Wetzel 2005 = R. Schwarz, G. Wetzel, Archeologia lotnicza w Niemczech – z historii badan [Aerial archaeology in Germany – a short history], in J. Nowakowski, A. Prinke, W. Rączowski (eds.), Biskupin … i co dalej? Zdjecia lotnicze w polskiej archeologii. Biskupin … and what next? Aerial photographs in Polish archaeology, Poznań, pp. 413–438.

Weyhmann 2008 = I. Weyhmann, Methodische Grundlagen der Luftbildarchäologie in Sachsen, in "Arbeits- und Forschungsberichte zur sächsischen Bodendenkmalpflege", 48/49 (2006/2007), pp. 283-310.

GREECE

Information from Gianluca Cantoro, Darja Grosman and Internet search.

Cantoro 2010 = G. Cantoro, A modern Ikaros: diagnostic methodologies and new approaches in defined contexts. Case studies in Crete (Greece), PhD thesis, University of Foggia, Department of Human Sciences (DISCUM).

Cooper–Myers 1981 = F.A. Cooper, J.W. Myers, Reconnaissance of a Greek mountain city, in "Journal of Field Archaeology", 8, pp. 123-134.

Gaston et alii 2010 = C. Gaston, T. Gomrée, M. Pomadère, 'Gone with the Wind'. Aerial Photography of Bâtiment Pi, Malia, Crete (Bronze Age), in "AARGnews", 40, pp. 17-24.

Goossens–De Dapper 1990 = R. Goossens, M. De Dapper, The use of Black and White Aerial Pictures for the Detection of Supposed Ancient Conservation Terraces, Southern Evvia – Greece, in C. Leva (ed.), Aerial Photography and Geophysical Prospection in Archaeology. Proceedings of the Second International Symposium, Brussels 8-XI-1986, Brussels, pp. 111-118.

Grosman 2007 = D. Grosman, Aerial Reconnaissance in Boeotia: Preliminary Report on the 2006 Test Season, University of Ljubljana research report, circulated to specialist libraries. Replace or supplement this with a later report?

Grosman 2007 = D. Grosman, Forest fires and aerial reconnaissance in Boeotia, in "TEIRESIAS, A Review and Bibliography of Boiotian Studies", 37 (Part 2), pp. 20-24. http://www.mcgill.ca/classics/sites/mcgill.ca.classics/files/Teiresias_2007-2.pdf

Jameson 1974 = M. Jameson, The excavation of a drowned temple, in "Scientific American", 231, pp. 110-119.

KAIMARIS ET ALII 2008 = D. Kaimaris, O. Georgoula, G. Karadedos, P. Patias, Military trenches or Ancient Fortification Constructions, in "AARGnews", 36, pp. 33-41 (and as internet publication at www.univie.ac.at/aarg/php/cms/AARG-news/aarg-news-36).

KAIMARIS ET ALII 2009 = D. Kaimaris, O. Georgoula, G. Karadedos, P. Patias, 2009, Aerial and Remote Sensing Archaeology in Eastern Macedonia, Greece, in 22nd CIPA Symposium, October 11-15, 2009, Kyoto, Japan (internet publication http://cipa.icomos.org/index.php?id=64).

KAIMARIS 2011 = D. Kaimaris, Location of Defensive Military Trenches in Central and Northern Greece, in "Archaeological Prospection", 18:3, pp. 223–229.

LONGO ET ALII 2009 = F. Longo, M. Bredaki, M. Benzi (eds.), Progetto Festòs. Ricognizioni Archeologiche di Superficie: Le Campagne 2007-2009, in "Annuario della Scuola Archeologica di Atene", 87:2 , pp. 935-978.

MASCA 1971 = MASCA (Museum Applied Science Center for Archaeology), Aerial photography: Porto Cheli, Greece, in "MASCA Newsletter", 7 (2), p. 2.

MYERS 1978 = J.W. Myers, Balloon survey field season, 1977, in "Journal of Field Archaeology", 5, pp. 145-159.

MYERS 1993 = J.W. Myers, Travelling with blimp and camera, in "Newsletter of the American School of Classical Studies at Athens", 32, pp. 11-12.

MYERS–MYERS 1990 = J.W. Myers, E.E. Myers, Low-Altitude Aerial Photography in Crete, in "Expedition", 32(3), pp. 31-33.

MYERS ET ALII 1992 = J.W. Myers, E.E. Myers, G. Cadogan, The Aerial Atlas of Ancient Crete, Berkeley: University of California Press.

PATIAS ET ALII 2007 = P. Patias, Chr. Saatsoglou-Paliadeli, O. Georgoula, M. Pateraki, A. Stamnas, N. Kyriakou, Photogrammetric documentation and digital representation of the Macedonian palace in Vergina-Aegeae, in XXI International CIPA Symposium, 01-06 October 2007, Athens, Greece (internet publication at http://cipa.icomos.org/index.php?id=63).

SLAPŠAK 2007 = B. Slapšak, The Late Classical/Hellenistic City Wall of Thespiae, in "TEIRESIAS, A Review and Bibliography of Boiotian Studies", 37 (Part 2), pp. 11-20. http://www.mcgill.ca/classics/sites/mcgill.ca.classics/files/Teiresias_2007-2.pdf

STOKER 2011 = A. Stoker, Comments on flying, observations and photographs, 2011, in "AARGnews", p. 44.

TOKMAKIDIS–SKARLATOS–2002 = K. Tokmakidis, D. Skarlatos, Mapping excavations and archaeological sites using close range photos, in "International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences", 34.5, pp. 459-462.

THEODORIDOU ET ALII 2000 = S. Theodoridou , K. Tokmakidis, D. Skarlatos, Use of radio-controlled model helicopters in archaeology surveying and in building construction industry, in International Archives of Photogrammetry and Remote Sensing, XXXIII, Part B5 (internet publication at http://www.isprs.org/proceedings/xxxiii/congress/part5/825_XXXIII-part5.pdf)

WHITTLESEY 1973 = J. Whittlesey, Balloon, "Flying Mattresses" and Photography, in "Expedition", 15 (2), p. 2.

HUNGARY

Information supplied by Gabor Bertok.

See contributions from 2004 onwards by Z. Czajlik and Zs. Miklós on aerial archaeology and recent discoveries in Hungary in the yearbook Régészeti Kutatások Magyarországon (Archaeological Investigations in Hungary).

ANDERS ET ALII 2009 = A. Anders, M. Szabó, P. Raczky (eds.), Régészeti dimenziók. Tanulmányok az ELTE BTK Régészettudományi Intézetének tudományos műhelyéből, in "Bibliotheca Archaeologica", 3, Budapest.

BERTÓK 2000 = G. Bertók, "Item a Sopianas Bregetione m. p. CXS: Iovia XXXII m. p. ..." (Adalékok a Dél-Dunántúl római kori településtörténetéhez: Iovia lokalizációja – New Data on the Settlement History of Southern Transdanubia: the Localization of Iovia), in "Wosinsky Mór Megyei Múzeum Évkönyve", XXII, pp. 101-112.

BERTÓK ET ALII 2008 = G. Bertók, Cs. Gáti, O. Vajda, Előzetes jelentés a Szemely-Hegyes lelőhelyen (Baranya megye) található neolitikus körárok-rendszer kutatásáról (Preliminary report on the research at the neolithic Kreisgrabenanlage at Szemely - Hegyes, Baranya County, Hungary), in "Archaeologiai Értesítő", 133, pp. 85-106.

BERTÓK–GÁTI 2011 = G. Bertók, Cs. Gáti, Neue Angaben zur spätneolithischen Siedlungsstruktur in Südosttransdanubien, in "Acta Archaeologica Academiae Scientiarum Hungaricae", 62.1, pp. 1-28.

BÖDÖCS 2009 = A. Bödöcs, Útkutatás a levegőből (The research of roads from the air), in Anders et alii 2009, pp. 37-48.

CZAJLIK 2009 = Z. Czajlik, Légi régészet Magyarországon, in Anders et alii, pp. 23-36. [A summary of aerial photography history and methodology at Eötvös Loránd University.]

CZAJLIK 2008 = Z. Czajlik, Aerial archaeology in the research of burial tumuli, in "CommArchHung", 28, pp. 95-107.

CZAJLIK ET ALII 2011 = Z. Czajlik, L. RRupnik, M. Lozonczi, L. Timár, Aerial archaeological survey of a buried landscape: The Tóköz Project, in D.C. Cowley (ed.), Remote Sensing for Archaeological Heritage Management, Brussels, pp. 235-241.

Goguey–Szabó 1995 = R. Goguey, M. Szabó, L’histoire vue du ciel. Photographie aérienne et archéologie en France et en Hongrie – Légi fényképezés és régészet Franciaországban ás Magyarországon, Budapest.

Miklós 2007 = Zs. Miklós, Tolna megye várai, Budapest. [The fortified sites of Tolna County, from the Neolithic to the Middle Ages, as identified in Tolna County during many years of flying, field walking and excavations].

Miklós–Vizi 2009 = Zs. Miklós, M. Vizi, Ete - (Tolna megye) Egy középkori mezőváros kutatásának közel 200 éve. Ete, a medieval Market Town in County Tolna. Research over the past two hundred Years, in L. Bende, G. Lőrinczy (eds.), Medinától Etéig. Régészeti tanulmányok Csalog József születésének 100. évfordulójára, Szentes, pp. 293-302.

Visy et alii 2011 = Zs. Visy, M. Szabó, A. Priskin, R. Lóki (eds.), A Danube limes program régészeti kutatásai 2008-2011 között. The Danube Limes Project Archaeological Research between 2008-2011, Pécs. [Bilingual report on the latest research, including aerial photography, on the Danube limes.]

For air photography, geophysics and excavation at the Szemely – Hegyes Late Neolithic henge site see http://korarok.baranya.hu/index.php?lng=e

For the Aerial Archaeology Archive of the University of Pécs see http://plt.btk.pte.hu

ICELAND

Information supplied by Oscar Aldred.

Aldred et alii 2010 = O. Aldred, E.Ó. Hreiðarsdóttir, Ó.G. Sveinbjarnarsson, Aerial archaeology in Iceland: on the precipice, in “Archaeologia Islandica”, 8, pp. 111-121.

Einarsson et alii 2002 = Á. Einarsson, O. Hansson, O. Vésteinsson, An Extensive System of Medieval Earthworks in Northeast Iceland, in “Archaeologia Islandica”, 2, pp. 61-73.

Einarsson–Aldred 2011= Á. Einarsson, O. Aldred, The archaeological landscape of northeast Iceland: a ghost of a Viking society, in D.C. Cowley (ed.), Remote Sensing for Archaeological Heritage Management, Brussels, pp. 243-258.

Ísakson–Helgason 1995 = S.P. Ísakson, Þ.S. Helgason, Vetrarmyndir frá Nesi við Seltjörn og Laugarnesi, in “Árbók hins íslenzka fornleifafélagi”, 1994, pp. 149-161 (with English summary).

Lárusdóttir–Aldred 2008 = B. Lárusdóttir, O. Aldred, Kortlagning fornleifa af gervihnattamyndum. Fornleifastofnun Íslands, Report No FS389-08181, Reykjavík.

Rafnsson 1990 = S. Rafnsson, Eyðibyggð í Hrafnkelsdal og á Brúardölum: Brot úr byggðarsögu Íslands, Reykjavík.

IRELAND

Information supplied by Anthony Corns and George Lambrick.

For an internet-enabled account of the history and state of aerial archaeology in the Republic of Ireland as it stood in 2008, with an extensive list of relevant references, see Lambrick 2008 (below).

Barrett 2002 = G. Barrett, Flights of Discovery. Archaeological Air Survey in Ireland 1989-2000, in “Journal of Irish Archaeology”, 11, pp. 1-29.

Chart 1030 = D.A. Chart, ‘Air Photography in Northern Ireland’, in “Antiquity”, 4, pp. 453-459.

Lambrick 2008 = G. Lambrick, Air and Earth. Aerial Archaeology in Ireland. A Review for the Heritage Council, Dublin. Also available as a pdf download at www.heritagecouncil.ie/fileadmin/user_upload/Publications/Archaeology/Aerial_Archaeology.pdf

Norman–St Joseph 1969 = *E.R. Norman, J.K.S. St Joseph, The Early Development* of Irish Society: the evidence of aerial photography, Cambridge.

Swan 1978 = D.L. Swan, The Hill of Tara Co, Meath: the Evidence of Aerial Photography, in “Journal of the Royal Society of Antiquaries of Ireland”, 108, pp. 51-66.

ITALY

Information compiled by Chris Musson.

Italy enjoys a splendid historical and contemporary description of the country’s record of archaeological air photography and interpretation in the magnificent volume Lo sguaro di Icaro (Guaitoli 2003). Historical summaries are also provided in Ceraudo 2005, 2005 and 2010, as listed in the main Bibliography. The periodic publication “Archeologia Aerea. Studi di Aerotopografia Archeologica”, edited by Giuseppe Ceraudo (with Fabio Piccarreta until Vol 3 in 2008) and now splendidly produced by Claudio Grenzi Editore of Foggia, has since its inception in 2004 provided a wide range of stimulating contributions on aerial archaeology and landscape studies in Italy (and occasionally elsewhere). For a other publications on aerial archaeology in Italy see the citations in Chapter 1 of the present book. Three recent studies using aerial photographs to track the path of Roman roads and to map the ‘lost’ Roman town of Altinum are also worth noting:

Ceraudo 2004 = G. Ceraudo (ed.), Ager Aquinas – Aerotopografia archeologica lungo la valle dell’antico Liris, Roma.

Ceraudo 2008 = G. Ceraudo, Sulle tracce della Via Traiana – Indagini aerotopografiche da Aecae a Herdonia, Foggia.

Mozzi–Ninfo 2009 = P. Mozzi, A. Ninfo, La fotografia aerea obliqua per l'analisi geoarcheologica del territorio della Via Annia, in F. Veronese (ed.), Via Annia: Adria, Padova, Altino, Concordia, Aquileia - progetto di recupero e valorizzazione di un'antica strada romana. Atti della giornata di studio, Padova, 19 giugno 2008, Padova.

LATVIA

Information supplied by Juris Urtāns.

URTĀNS 2000 = J. Urtāns, Aerālā arheoloģija Latvijā un Augšzemes pilskalnu aerālā apsekošana, in A. Šnē, J. Urtāns (eds.), Arheoloģiskie pieminekļi, arheoloģiskās vietas, Rīga, pp. 29-39.

URTĀNS 2000 = J. Urtāns, Aerālā arheoloģija, Riga.

URTĀNS 2002 = J. Urtāns, A Post Medieval dockyard in Ventspils (Latvia): from the air, in the ground and underwater, in R.H. Bewley, W. Rączcowski (eds.), Aerial Archaeology: Developing Future Practice, NATO Science Series I: Life and Behavioural Sciences, 337, Amsterdam, pp. 116-121.

URTĀNS 2005 = J. Urtāns, Fotografia lotnicza w archeologii na Łotwie, in Nowakowski et alii 2005, pp. 495-498.

URTĀNS 2010 = J. Urtāns, Reflections in the ”Devil's Eyes” of Bogs in Latvia, in E. Teters (ed.), Metamorphoses of the World: Traces, Shadows, Reflections, Echoes, and Metaphors. Proceedings of the International Research Conference, Metamind 2010, Riga, pp. 76-84.

LITHUANIA

Information supplied by Romas Jarockis.

JAROCKIS ET ALII 2007 = R. Jarockis, R. Kraujalis, C. Musson (eds.), Past from The Air – Aerial archaeology and landscape Studies in Northern Europe, Vilnius.

JAROCKIS (IN PRESS 2012) = R. Jarockis, Aerial Archaeology in Lithuania, in Archaeological investigations in independent Lithuania, Vilnius.

NETHERLANDS

Information from Internet search.

BRONGERS 1976 = J.A. Brongers, Air photography and Celtic field research in the Netherlands (Nederlandse Oudheden 6), Amersfoort.

KARS ET ALII 2006 = H. Kars, A. Kattenberg, S. Oonk, C. Seuer, The potential of remote sensing, magnetometry and geochemical prospection in the characterization and inspection of archaeological sites and landscapes in the Netherlands, in T. Bloemers, H. Kars, A. Van Der Valk, M. Wijnen (eds.), The Cultural Landscape and Heritage Paradox. Protection and development of the Dutch Archaeological-Historical Landscape and its European Dimension, Amsterdam, pp. 415-430.

METZ 1999 = W.H. Metz, The role of integrating aerial prospection into the preservation of ancient monuments in the Netherlands, in B. Bréart, F. Nowicki, C. Leva, Archéologie Aérienne. Hommage a Roger Agache, Actes du colloque international tenu a Amiens (France) du 15 au 18 octobre 1992, “Revue Archéologique de Picardie” 17, Amiens, pp. 253-259.

SEUER 2006 = C. Seuer, Remote sensing voor archeologishe prospectie en monitoring, Amsterdam (RAAP-rapport 1261).

VRIES-METZ 1986 = W.H. de Vries-Metz, Farmland Reallocation and Aerial Archaeologyin North Holland, The Netherlands, in C. Levá, J.J. Hus, G. Heldenbergh (eds.), Photographie Aérienne et Prospection Géophysique en Archéologie: Deuxième Symposium International, Bruxelles, Samedi 8 Novembre 1986, Brussels, pp. 97-115.

VRIES-METZ 1993 = W.H. de Vries-Metz, Luchtfoto archeologie in oostelijk West Friesland, Amsterdam (PhD thesis, University of Amsterdam).

See also the website of DECARS (Dutch Expertise Centre for Archaeological Remote Sensing), a special interest group formed in 2007with the aim of increasing the use of remote sensing in Dutch archaeology, at www.decars.nl.

NORWAY

Information from Ole Risbøl and Internet search.

FORSETH 2007 = L. Forseth, Flying to the past in north Nord-Trøndelag, in “AARGnews”, 35, September 2007, pp. 18-23.

For the use of remote sensing (lidar) in the Larvik/Vestfold project, Norway, of the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology see http://archpro.lgb.ac.at/larvik-vestfold/larvik-vestfold

POLAND

Information supplied by Włodzimierz Rączcowski.

DOLOTOWSKA ET ALII 2002 = A. Dolotowska, A. Prinke, D. Prinke, Archives for the history of aerial archaeology in Central Europe, paper given at theAnnual Conference of the European Association of Archaeologists, Thessaloniki, Greece, 2002. At www.muzarp.poznan.pl/archweb/archweb_eng/Publications/arch_lot/index/arch_lot.html

KIARSZYS ET ALII 2007 = G. Kiarszys, W. Rączkowski, L. Żuk, In pursuit of the invisible: are there crop-marked sites on clay-like soils in Poland?, in Mills–Palmer 2007, pp. 55-72.

Kobyliński 2005 = Z. Kobyliński, Archeologia lotnicza w Polsce, Warsaw.

Kobyliński 2009 = Z. Kobyliński, Własność dziedzictwa kulturowego, Warsaw.

Krasnodębski 2007 = D. Krasnodębski, Archeologiczna prospekcja lotnicza Podlasia w latach 1996–2006, in “Biuletyn Konserwatorski Województwa Podlaskiego”, 13, pp. 243-262.

Nowakowski et alii 2005 = J. Nowakowski, A. Prinke, W. Rączkowski (eds.), Biskupin... i co dalej? Zdjęcia lotnicze w polskiej archeologii (Biskupin … and what next? Aerial photographs in Polish archaeology), Poznań.

Pietrzak–Rączkowski 2009 = R. Pietrzak, W. Rączkowski, Od przybytku głowa… boli. O kontekście i konsekwencjach odkrycia pierwszej lokacji Szamotuł, in “Szamotuły. Karty z dziejów miasta”, 2, Szamotuły, pp. 9-26.

Rączcowski 2002 = W. Rączcowski, Archeologia lotnicza – metoda wobec teorii, Poznań.

Rączkowski 2007 = W. Rączkowski, Landscapes full of pits: disappointments and prospects for aerial survey in the Baltic Sea region, in Jarockis et alii, pp. 93-108.

Rączkowski 2009 = W. Rączkowski, Zobaczyć ukryte. Zdjęcia lotnicze w archeologii, in “Studia nad dawną Polską”, 2, Gniezno. pp. 133-154.

Rączkowski 2010 = W. Rączkowski, To reconcile water and fire? Some discourse issues on the interpretation of aerial images, in S. Campana, M. Forte, C. Liuzza (eds.), Space, Time, Place. Third International Conference on Remote Sensing in Archaeology, 17th-21st August 2009, Tiruchirappalli, Tamil Nadu, India, BAR International Series 2118, pp. 145-149.

R*ączkowski 2011* = W. Rączkowski, Integrating survey data – Polish AZP and beyond, in Cowley 2011, pp. 153-160.

PORTUGAL

Information from Internet search.

Verhoeven et alii (in press 2012) = G. Verhoeven, D. Taelman, F. Vermeulen, Computer vision-based orthophoto mapping of complex archaeological sites: the ancient quarry of Pitaranha (Portugal-Spain), in “Archaeometry”.

ROMANIA

Information from Irina Oberländer-Târnoveanu and Rog Palmer.

Hanson–Oltean 2002 = W.S.Hanson, I.A. Oltean, Recent aerial survey in Westen Transylvania: problems and potential, in R.H. Bewley, W. Rączcowski (eds.), Aerial Archaeology: Developing Future Practice, NATO Science Series I: Life and Behavioural Sciences, 337, Amsterdam, pp. 109-115.

Oberländer-Târnoveanu 2010 = I. Oberländer-Târnoveanu, Proiecte de arheologie aeriană în România (Aerial Archaeology Projects in Romania), “Angustia”, 14, pp. 389-412.

Oberländer-Târnoveanu–Bem 2011 = I. Oberländer-Târnoveanu, C. Bem, Flying in a Rainy Spring: Romanian Surveys in 2011, in “AARGnews”, 43 (September 2011), pp. 33-36.

Palmer et alii 2009 = R. Palmer, I. Oberländer-Târnoveanu, C. Bem (eds.), Arheologie Aerianâ în România şi în Europa, CIMEC, Bucharest.

For CIMEC (the Institute for Cultural Memory, Bucharest) see, www.cimec.ro and http://map.cimec.ro/LocalizareExacta/mapserver.html

SERBIA

Information from Ivan Bugarski and Darja Grosman.

Babović 1992 = M. Babović, Mogućnost primene aeroarheoloških metoda, in “Arheologija i prirodne nauke”, 64, Beograd, pp. 181-189.

Deroko 1951 = A. Deroko, Srednjovekovni utvrđeni karavanseraj u Ramu, in “Starinar”, II, pp. 150-152.

Đorđević 1996 = M. Đorđević, Contributions to the Study of the Roman Limes in South Banat, in P. Petrović, S. Dušanić (eds.), Roman Limes on the Middle and Lower Danube, Belgrade, pp. 125-133.

Grbić 1935 = M. Grbić, Izveštaj o radu na iskopavanju rimske Basijane kod Donjih Petrovaca, in “Glasnik Istoriskog društva u Novom Sadu”, VIII/3, pp. 483-486.

Grbić 1951 = M. Grbić, Gradište kod Kikinde. Nastavak radova u 1948 godini, in “Starinar”, II, pp.133-138.

Jovanović et alii 2012 = D.B. Jovanović, D. Grosman, B. Mušič, P. Novaković, Revisonary research of the site of Vatin - Bela Bara, in Research, preservation and presentation of Banat heritage. Proceedings of the regional conference Vršac 2011. Cross Border Cooperation Romania-Serbia 2011, pp. 49-58.

Mano-Zisi 1955 = Đ. Mano-Zisi, Iskopavanja na Caričinu gradu, in “Starinar”, III-IV (1952-1953), pp. 127-168.

Pavlović et alii 1999-2000 = R. Pavlović, M. Marković, D. Madas, Prikupljanje arheoloških podataka metodama daljinske detekcije, in “Glasnik Srpskog arheološkog društva”, 15-16, pp. 379-388.

SLOVAKIA

Information from Ivan Kuzma.

Kuzma 1995 = I. Kuzma, Luftbildarchäologie in der Slowakei, in Kunow 1995, pp. 251-258.

Kuzma, 2005 = I. Kuzma, Kruhové priekopové útvary na Slovensku - aktuálny stav, in “Otázky neolitu a eneolitu našich krajín 2004”, Nitra, pp.185-223.

Kuzma 2007 = I. Kuzma, Aerial Archaeology in Slovakia, in “Studijné Zvesti, Archeologické Ústavu Slovenskej Akadémie Vied”, 41, Nitra, pp. 11-39.

Kuzma 2010 = I. Kuzma, Letecká archeológia, in K. Kuzmová (ed.): Klasická archeológia a exaktné vedy. Výskumné metódy a techniky, II, Trnava, pp. 23-106.

Kuzma 2011a = I. Kuzma, Aerial Prospection in the Danube Region on the Territory of Slovakia, in M. Lodewijckx, R. Pelegrin (eds.), A View from the Air - Aerial Archaeology and Remote Sensing Techniques: Results and Opportunities, BAR International Series 2288, Oxford, pp. 87-112.

Kuzma 2011b = I. Kuzma, Luftbildprospektion an der Donau, in G. Kovács, G. Kulcsár (eds.), Ten thousand Years along the Middle Danube: Life and Early Communities from Prehistory to History, Budapest, pp. 51-60.

Kuzma –Tirpák 2011 = I. Kuzma, J. Tirpák, Kreisgrabenanlagen in der Slowakei, in “Tagungen des Landesmuseums für Vorgeschichte”, Halle, pp. 55-86.

SLOVENIA

Information from Darja Grosman.

Grosman 1998 = D. Grosman, Arheološka aerofotografija, in M. Krevs, D. Perko, T. Podobnikar, Z. Stančič (eds.), “Geografski informacijski sistemi v Sloveniji”, 1997-1998, pp. 253–263.

Grosman 2000 = D. Grosman, Two examples of using combined prospecting techniques, in M. Pasquinucci, F. Trémont, Non-destructive techniques applied to landscape archaeology, Oxford, pp.245-255.

Grosman 2001 = D. Grosman, Air photo transcription of archaeological features in specific and marginal environments, in B. Slapšak (ed.), On the good use of geographic information systems in archaeological landscape studies: proceedings of the COST G2 WG2 Round Table, Ljubljana, 18 to 20 December 1998, Luxembourg, pp. 145–155.

Grosman 2002 = D. Grosman, Aerial archaeology in extreme environmental conditions: Slovenia, in R.H. Bewley, W. Rączcowski (eds), Aerial Archaeology:Developing Future Practice, NATO Science Series I: Life and Behavioural Sciences, 337, Amsterdam, pp. 95-104.

Slapšak–Grosman 2010 = B. Slapšak, D. Grosman, Pojem in postopki terenskega preverjanja pri neinvazivnih raziskavah v arheologiji. The Notion and Methods of Ground-Truthing in Non-Invasive Archaeological Research, in “Arheo”, 27, Ljubljana, pp. 7-13.

SPAIN

Information by Jose Carlos Sánchez Pardo and Rog Palmer.

Charro Lobato 2012 = C. Charro Lobato, A picture is worth a thousand words… at least at the Aerial Archaeology Training School in Merida!, in “AARGnews”, 45, pp. 11-13.

Sánches Pardo–Fumadó Ortega 2006 = J.C. Sánches Pardo, I. Fumadó Ortega , Aerial archaeology in Spain: historiography and expectations, in S. Campana, M. Forte (eds.), From Space to Place. 2nd International Conference on Remote Sensing in Archaeology. Proceedings of the 2nd International Workshop, CNR, Rome, Italy, December 4-7, 2006, BAR International Series 1568, Archaeopress, Oxford, pp. 65-71(abstract, pp. xli-xlii).

SWEDEN

Information provided by Ole Risbøl and Internet search.

Ericsson et alii 1992 = E. Ericsson, G. Rausing, J. Norrman, P.U. Hörberg, L. Hansen, Flygspaning efter historia. Flygarkeologins mål och metoder, Christinehof.

Normann 1995 = J. Normann, Organising a flying programme in Sweden, in Kunow 1995, pp.65-66.

Normann–Edvinger 1990 = J. Normann, K. Edvinger, Aerial Archaeology in Sweden, in C. Leva (ed.), Aerial Photography and Geophysical Prospection in Archaeology. Proceedings of the Second International Symposium, Brussels, 8-XI-1986, pp. 197-206.

SWITZERLAND

Information compiled by Chris Musson.

Nagy 1995 = P. Nagy, Luftbildarchäologie in Kanton Zürich – Aufbau und Organisation, in Kunow 1995, Luftbildarchäologie in Ost- und Mitteleuropa. Aerial Archaeology in Eastern and Central Europe, pp. 271-276.

TURKEY

Information supplied by Gianluca Cantoro and Rog Palmer.

Ceković 2012 = M. Ceković, First Aerial Archaeology Research and Training School in Turkey 20 – 30th July 2012, in “AARGnews”, 45, pp. 17-18.

UNITED KINGDOM

Information compiled by Chris Musson.

Three recent publications have presented the results of aerial survey and interpretation to a general audience.

Cowley–Crawford 2005 = D. Cowley, J. Crawford, Above Scotland – The National Collection of Aerial Photography, RCAHMS, Edinburgh.

Driver 2007 = T. Driver, Pembrokeshire – Historic Landscapes from the Air, RCAHM(Wales), Aberystwyth. And a revised edition issued 2008.

Driver–Davis 2012 = T. Driver, O. Davis, Cymru Hanesyddol o’r Awyr. Historic Wales from the Air, RCAHM(Wales), Aberystwyth.

See also the publications of English Heritage arising from projects within the National Mapping Programme for England (NMPE). These are available, with related policy statements, at www.english-heritage.org.uk/professional/research/landscapes-and-areas/ national-mapping-programme/

For a history of aerial photography for archaeology in England see the following publication: Barber 2011 = M. Barber, A History of Aerial Photography and Archaeology. Mata Hari’s glass eye and other stories, English Heritage, Swindon.

GLOSSARY

The wording used in this book draws on more than 80 years of exploratory aerial survey and archaeological air photography in Britain and other parts of Europe. In Italy, until the early years of ther new century, the emphasis had been on the interpretation and mapping of archaeological information from pre-existing vertical air photographs. The two traditions have developed rather differing terminologies and in other parts of Europe slightly different terms or concepts may have come into use. Without prejudice to these variations this book has adopted terms which are now in fairly consistent use internationally, such as earthwork, soilmark, cropmark and pattern, short words for ideas which are fundamental to the discussion of present-day aerial archaeology.

AERIAL, AirPhoto
Software programs for the transformation of aerial photographs and of information derived from them. Although originally written for use with oblique photographs, both programs can also be used with good effect when dealing with vertical images.

Aerial archaeologist
An archaeologist who specialises in one or more of the processes of aerial archaeology, whether in the air or on the ground.

Aerial archaeology
The combined processes of aerial survey, air photography, air photo interpretation, mapping, record creation and use of the resulting information. A set of techniques, not a subject in its own right.

Aerial evidence, aerial information
Any evidence or information seen or deduced from the air or from aerial photographs.

Air photo interpretation
The processes of reading and analysing air photographs for their archaeological and other content.

Anomaly
Any mark seen from the air or noted on an aerial photograph which suggests the presence of human activity or of topographical or other

features which might (or might not) have an archaeological origin or influence. Sometimes used interchangeably with the word ‘trace’.

Archaeological landscapes
The recorded or interpreted evidence of past landscapes, encompassing the inter-relationship between sites, communication routes, agricultural and settlement patterns and the contemporary topographical and ecological environment.

Archaeological visibility
The extent to which local conditions allow archaeological information to be seen and recorded from the air.

Complex
A clearly related group of ‘features’ or ‘sites’, often quite large in extent, perhaps capable of a variety of functional and chronological explanations. The word itself is neutral as regards dating or function.

Control point
Any fixed point that can be clearly identified both on a map and on matching aerial photographs. Control points are crucial for linking a photograph to a map during the process of transformation.

Cropmarks
Changes in the colour or height of crops or other vegetation which indicate the underlying presence of natural or archaeological features. Particular kinds of cropmarks may also be referred to as germination marks, grassmarks, parchmarks, vegetation marks or weedmarks.

Earthworks
Any micro-relief or topographical variation suggesting the physical survival of archaeological features (banks, ditches, walls etc).

Enclosure
A general term for any space enclosed or defended by walls, banks, ditches or palisades. The word carries no assumption about function or dating.

Feature
A broad term indicating any kind of archaeological (or on occasions non-archaeological) entity, such as a bank, ditch, pit or posthole. Also used on occasions for marks seen on air photographs.

Exploratory aerial survey
Aerial survey carried out by archaeologists using oblique aerial photography from light aircraft, microlights or helicopters. As distinct from the survey of specific blocks of land using specialist aircraft and vertical air photography. Sometimes also referred to as ‘free-ranging’, ‘active’ or ‘oblique’ aerial survey.

Germination marks
Cropmarks seen as variations in colour, crop height or plant density during the early stages of germination and crop growth.

Grassmarks
Cropmarks seen in grass, usually after prolonged summer drought. See also ‘parchmark’.

Hillfort
A general term for a defended or enclosed settlement on a hilltop, clifftop, promontory or ridge. The term carries no intrinsic assumption about dating – in Britain the most commonly ascribed dating is the pre-Roman Iron Age but both earlier and later chronologies are possible, especially on Continental Europe.

Landscape
See Archaeological Landscape above.

Mapping
The production of drawn representations (digital or otherwise) based on the interpretation of transformed aerial photographs or on information interpreted and drawn before transformation.

Mismatch
Differences in position (or 'errors') between control points on a transformed photograph and those on a map. Mismatch values are calculated and displayed by the transformation programs AirPhoto and AERIAL. They indicate the 'goodness of fit' of the transformation.

Oblique aerial photographs
Aerial photographs taken at an angle to the ground surface, usually using a handheld camera from a non-specialist light aircraft.

Parchmarks
Cropmark seen as variations of colour and/or crop height in grassland affected by prolonged drought.

Pattern
The cumulative inter-relationship between those parts of a site or landscape which establish its general morphological character. Patterns consist of a combination of shapes, sizes, directions and colours which establish or reveal consistencies or inconsitencies, continuities or discontinuities. The recognition of such patterns is one of the archaeologist's primary skills in exploring, recording and interpreting the evidence of the past.

Photogrammetry
The creation of accurate maps, plans and three-dimensional models from vertical (and more recently oblique) aerial photographs using specialist equipment. A technique also much used on the ground.

Record creation
The creation of textual or other non-graphical records to accompany mapped information or to describe archaeological features, sites or landscapes.

Remote sensing
The collection of archaeological or other data by processes such as geophysical survey, aerial photography, laser scanning (lidar) or other forms of airborne or satellite-based recording.

Ring-ditch
A single or multiple cropmark or soilmark, approximately circular or penannular in shape, indicating the presence beneath the soil of one or more circular ditches. A general type which might derive from ritual, funerary, domestic, industrial or even military activity of a very wide range of dates.

Shadow mark, shadow site
Any site, or indication of a site or other feature (such as topography), revealed by the effects of light and shade. Thus also ‘shadow photography’.

Site
Any archaeological entity identifiable from the air or in the field. ‘Sites’ may range from a single stone to a castle or a wide-spreading field system. ‘Sites’ do not exist in isolation but only as parts of broader ancient landscapes also involving communication routes, field systems, boundary works and a wide variety of other natural or man-made topographical features.

Soilmark
Changes in the colour, reflectance or dampness of bare soil which might indicate the presence of archaeological sites, features or other sub-surface variations, either natural or man-made.

Target
Any location, landscape, townscape, building complex, site or other feature (whether archaeological, topographical or natural) photographed, or intended to be photographed, during archaeological air survey.

Trace
Any mark seen from the air or noted on an aerial photograph which suggests human activity or which indicates topographical or other features that may have influenced human activity (or the survival of evidence for it). Sometimes used interchangeably with the ‘anomaly’.

Transformation
The transformation or ‘rectification’ of an air photograph, or of information derived from an air photograph, to match a map or other form of topographic control.

Vegetation mark
Any difference in the colour, height, density or plant species of the local vegetation that might indicate the underlying presence of buried archaeological or natural features.

Vertical air photographs
Photographs taken with a camera mounted in an aircraft to view directly downwards. The exposures are normally made automatically, using specialist cameras and aircraft, so as to create overlapping images that can be viewed in three dimensions through the use of a stereoscope or specialist plotting equipment.

Weedmarks
Cropmarks created, or emphasised, by the presence of weeds of various kinds in either pasture or cultivated fields.

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