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Combined Geophysical Survey of an Ancient Hittite Dam: New and Old High-Tech

Abstract: Investigating ancient living conditions in their entirety is becoming increasingly important in archaeology. In the late Bronze Age (1600–1200 B.C.) at the Hittite city of Sarissa, a functioning irrigation system was necessary. The most significant component of the water supply to Sarissa are three dams before the city gates, which could be detected by geophysical survey. Today, archaeological geophysics is faced with mapping large areas of ancient settlements. Geophysical surveying methods are especially suitable for this task. The spectrum of geophysical measurement procedures used in archaeology reaches from geoelectrics and geomagnetics to electromagnetics and georadar. At the Christian-Albrechts-University (CAU) in Kiel, a motorized Multi-Sensor System has been developed and used at the Hittite city of Sarissa (today Kuşaklı) in central Anatolia to measure different physical ground parameters.

Historical Background

Fruit and vegetables can only be cultivated on the Anatolian Plateau with artificial irrigation. Cultivation of grain is possible without artificial irrigation and is therefore widespread. In the late Bronze Age (1600–1200 B.C.) at the Hittite city of Sarissa, a functioning irrigation system was also necessary. The present site, called Kuşaklı, lies 60 km to the south of Sivas in central Anatolia *(Fig. 1)*. Sarissa was founded in the late 16th century B.C.

Computer-aided processing of geophysical data was accompanied by archaeological excavations and soil analysis to allow interdisciplinary research to be carried out. Two granaries and irrigation plants could be detected, as well as temples, public buildings, housing facilities, and so on *(Fig. 2)* (Müller-Karpe 2001). Excavations have been carried out since 1992 by Prof. Dr. Andreas Müller-Karpe (Philipps-Universität Marburg, Germany).

Geophysical Data Acquisition

The new measuring vehicle consists of a four-wheel driven tractor and a modular trailer carrying the sensors *(Figs. 3a, b)*. Geophysical sensors and a GPS system can be mounted on the instrument carrier and driven simultaneously. An array of up to five fluxgate magnetometers spaced at 50 cm intervals is used to record the magnetic field of archaeological objects with a high spatial resolution.

Ground penetrating radar (GPR) is used to investigate the depth of targets and geological layers. For GPR mapping we applied EM impulses of 200 MHz and 400 MHz centre frequency.

By using a GPS system in differential mode with a local base station, centimetre accuracy in positioning can be achieved. The software transmits GPS coordinates in real time to the tractor where the survey area, the path of the vehicle and its actual position are shown to the driver. At the same time, sensor data is captured digitally (Erkul et al. 2004).

Geophysical Results

Using the multi-sensor system we mapped approximately 0.5 km^2 of the area of the former city of Sarissa with geomagnetic-sensors and GPS *(Fig. 4)*. In addition, smaller areas of particular interest were investigated in 3D with DC-geoelectric and GPR measurements *(Fig. 5)*.

Fig. 4 shows an overview of the results from geomagnetic measurements of the Hittite city of Sarissa. Each pixel represents a 20 × 20 cm square. Dark anomalies correspond to positive amplitudes, representing anomalies with higher magnetization, while white anomalies are expressions of lower magnetization. The result of the geomagnetic measurements is overlaid on the topography as a greyscale picture. In the topography, darker zones represent higher gradients and light areas are flat.

Fig. 1. Reconstruction of the Hittite city of Sarissa from archaeological and geophysical surveys (M. Ober).

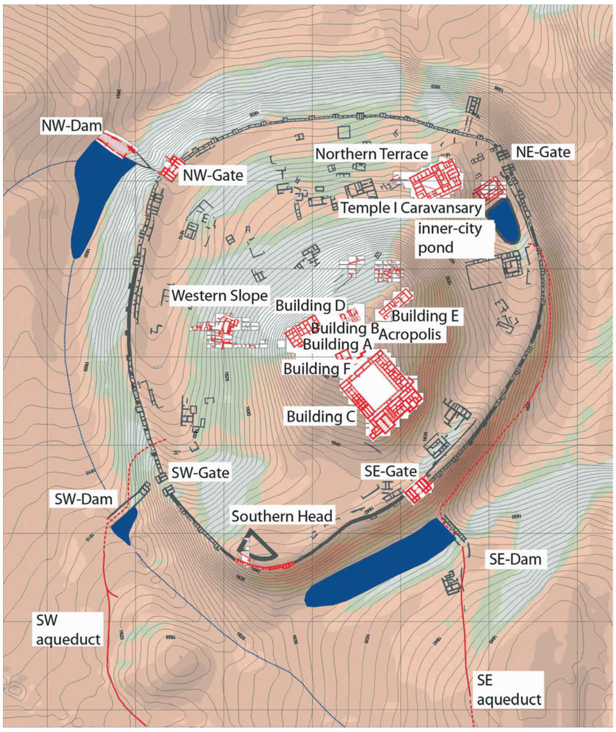

Fig. 2. Map of Sarissa.

One of the most noticeable magnetic anomalies is the north-western gate (*Fig. 5*, left). High amplitudes (black) indicate that this construction must have burnt down. The gate is positioned exactly to the west of the magnetically and electrically detected north-eastern gate *(Figs. 2, 4)*. The western part of the north-western gate lies in a deep erosion trench, which accounts for the absence of magnetic data in this area.

Additional geoelectrical measurements have been carried out over the NW dam using the dipole-dipole configuration. The result of the resistivity measurements is shown in *Fig. 5* on the right side in the outlined area. This area is also embedded in *Fig. 4.* The north-western gate can be seen as dark anomalies in the geoelectrical measurements suggesting higher resistivity *(Fig. 5).*

Especially interesting is the narrow, approximately 15 m long anomaly of high resistivity that runs out of the southwest edge of the gate. Later it is split into two weaker linear anomalies with a distance of approximately 10 m. After 29 m, the two lines are

Fig. 3a. Tractor with Geomagnetics, b. Tractor with Georadar.

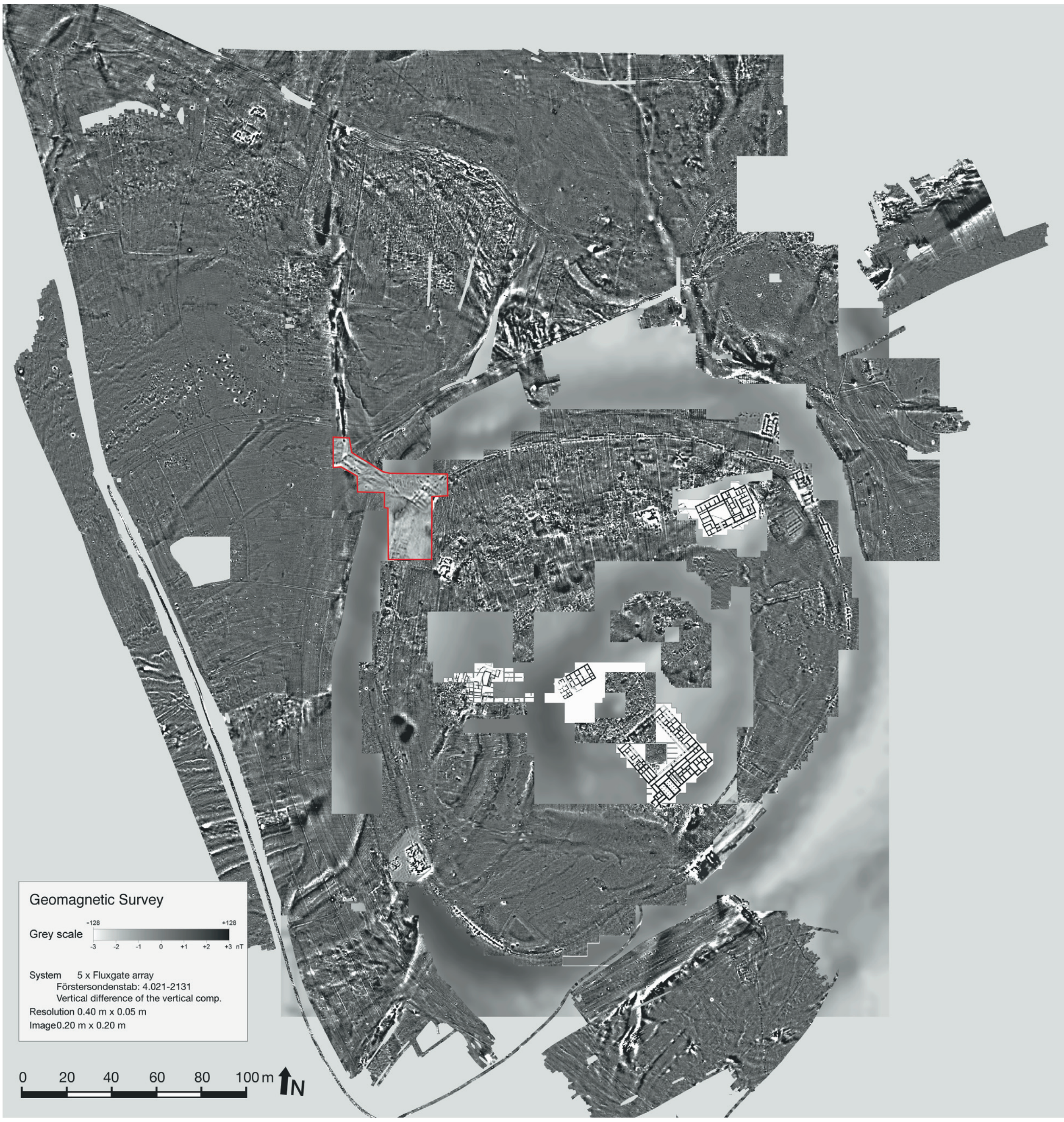

Fig. 4. Geomagnetic map of Sarissa.

disturbed for about 10 m, but are visible again later. After 20 m, it turns to the west and gets wider. The high values of these structures indicate the embankment of the dam.

With this supplementary information, a precise localisation of the gate and the adjacent dam was possible. The detailed maps *(Fig. 5)* show geomagnetic, geoelectric and georadar results in this area. Anomalies of large stones inside the dam embankment can be seen. In the georadar we observe good reflections, in geoelectric higher resistivity and in geomagnetic lower amplitudes (white) along the dam embankment.

Results of Archaeological Excavations

Three dams in front of the city gates represent the most significant components of the water supply to Sarissa. In particular, the northwest dam reveals brilliant technical achievement. Today, the former reservoirs are filled with sediment and nothing of

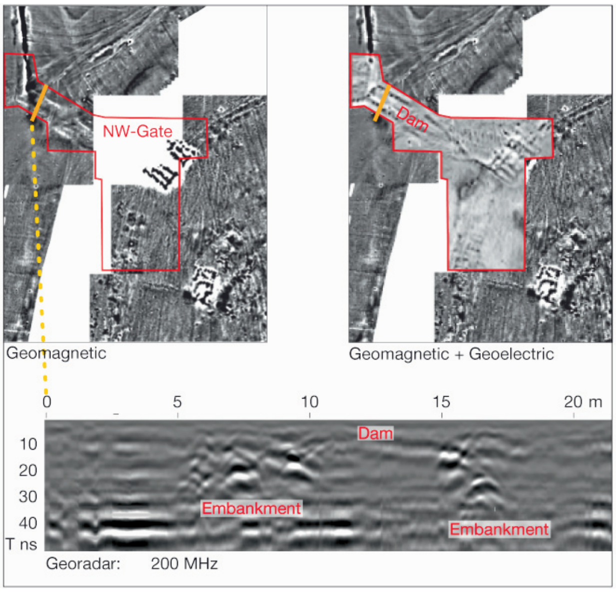

Fig. 5. Geophysical results of the dam area.

Fig. 6. Excavation of the dam.

the past constructions is visible on the surface, but the main structures could be detected by geophysical survey.

At the beginning of the examination, two sections perpendicular to the dam were opened. They were 1.5 m wide and 16 to 20 m long. The design, depth and construction of the dam could be revealed through these sections. Additionally, we also hoped to verify the multi-phase structure of the dam embankment. As it happened, two phases of the embankment were detected which could be separated stratigraphically and hence chronologically (Hüser 1996) *(Fig. 7)*.

Fig. 7 shows a section through the dam. Inside the first dam construction, archaeologists found a ditch filled with clay (dark grey). The ditch ends in the bedrock (limestone), so this was an effective method for isolation and reducing water loss. In the magnetic data, we can correlate this ditch with a band of higher amplitudes (dark).

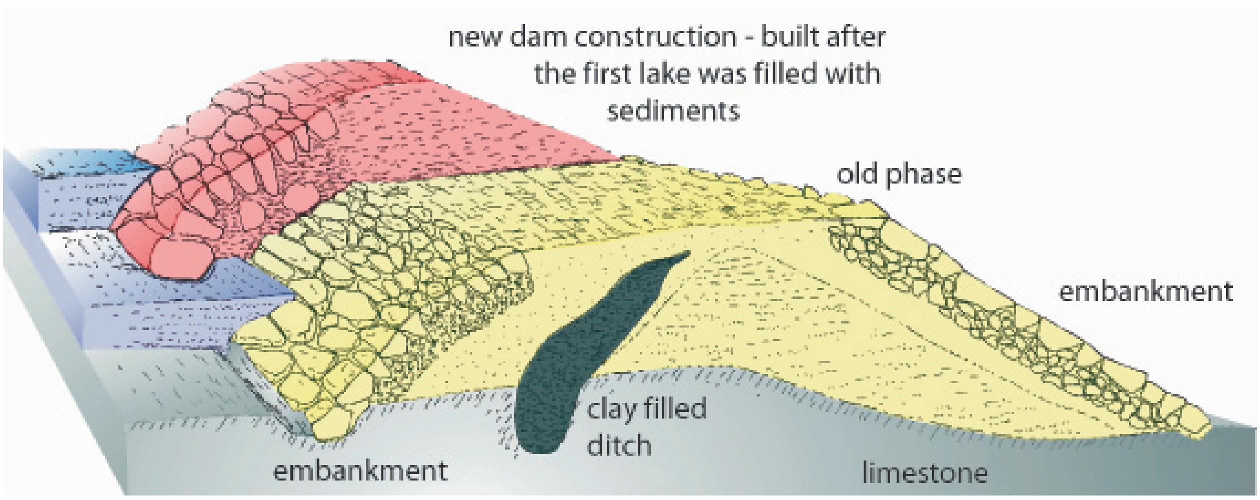

Fig. 7. Section through the dam.

The left side of the dam *(Fig. 7)* is the boundary of the lake and its gradient is about 35°. The valley side of the dam embankment is steeper and has a gradient of about 50°. Both embankments are founded on sandstone.

Additional information on the reconstruction of the dam *(Fig. 7)* was gained from drill holes.

Acknowledgements

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