Originalveröffentlichung in: Rammimair, D. et al. (Hg.), Applied mineralogy in research, economy, technology, ecology and culture (Rotterdam 2000) S. 951-954
Applied Mineralogy, Rammlmair et al. (eds) © 2000 Balkema, Rotterdam, ISBN 90 5809 163 5

# A combined isotopic, petrographic, and archaeological provenance study of the marble sources for the Apollo temple of Didyma, W-Anatolia

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ABSTRACT: The temple of Apollo at Didyma, W-Anatolia, has a long building history from ca. 300 B.C. well into the imperial era. Among various other details, inscriptions from the 3rd and 2nd c. B.C. name the quarries around Lake Bafa (Bafa Gölü) ca. 26 km NE of Didyma as its marble source. However, recent petrographical and isotopic analyses of the marbles both from these quarries (representative set of 58 samples) and from the temple (47 samples) have shown that additional sources have been exploited. In the Hellenistic era, imported marble from the Aegean island of Thasos was used in combination with Bafa Gölü marble for the dodekastylos (front hall). During the imperial period, another type of marble was used which most probably comes from the quarries of Marmara (Proconnesos). This has major inferences on our notion of the temple's building history, economics, and project planning.

## 1. INTRODUCTION

The famous oracle temple of Apollo in Didyma, W-Anatolia, has a particularly long building history. Constructions commenced ca. 300 B.C. and albeit continuing building activities well into the imperial era the gigantic monument of about 60 x 118 m floor space with 122 planned columns of nearly 20 m height was never finished. We are exceptionally well informed about the details of these building activities through several inscriptions, from the 3rd and 2nd c. B.C. (Wiegand, Rehm & Harder 1958), which also give the names of two ancient ports from where the marble had been shipped. These ports and the quarries have been identified by Peschlow-Bindokat (1981) at the southern shore of Lake Bafa (Bafa Gölü), ca. 26 km NE of Didyma, which, in antiquity, was an embayment of the Aegean sea. The quarries were the property of the ancient city of Miletus which also owned the sanctuary. It therefore hardly came to anybodies mind to look for additional marble sources for the temple although Peschlow-Bindokat (1981) and German (1981) had already noticed a coarse-crystalline marble they could not locate at Bafa Gölü.

As part of a larger cooperation project with K. Tuchelt from the Deutsches Archäologisches Institut, Berlin, devoted to the geological setting and the natural resources of the sanctuary, we also studied the building materials. It quickly turned out that the marble used for the temple is much more diverse then previously observed.

## 2. GEOLOGY OF THE BAFA GÖLÜ AREA

The marbles at the N-, E-, and S-shores of Bafa Gölü are situated within the contact metamorphic aureole, S, SW, and W of the granitic gneiss core of the approximately 550 Ma old Menderes Massif (Loos & Reischmann 1999). The most recent tectono-metamorphic overprint of the gneisses and the surrounding sediments occurred in the Tertiary, during the Alpine Orogeny. A Palaeozoic and a Mesozoic age have been attributed to the marbles SE and S of Bafa Gölü, respectively (Dürr 1975).

The marbles on the SE- and N-shore of Bafa Gölü occur enclosed in muscovite schists as steeply south to vertically dipping well-defined lenses (max. 40 x 250 m). The quarries on the S-shore are hosted by moderately south-dipping marble lenses, also enclosed in muscovite schists and phyllites. However, the marble lenses on the S-shore are usually smaller and far more irregular in shape compared to the ones on the E-shore. A marked macroscopic petrological discrepancy between the E-shore and the S-shore marbles is the different textural occurrence of dolomite within the predominantly calcitic marbles (cf. German 1981). The S-shore marbles display dolomitic layers of up to 40 cm thickness which have been boudinaged with individual boudins showing (ductile) wrap-around textures along their outer margins and sets of sharp, parallel (brittle) fractures within the individual boudins. Dolomitic portions within the E-shore marble are less abundant and occur as mm-thin, parallel, laterally discontinuous

laminae, or as small-scale, complex, ptygmatic folds within the calcitic marble. These different textural styles vary systematically with the distance to the gneiss contact and thus represent the contact metamorphic gradient.

Other differences do not discriminate the two localities as sharply but can serve as general indicators. E-shore marble is generally coarser (German 1981). Crystal sizes often vary extremely in one single sample, but medium crystal sizes are generally 0.8 to 1.0 mm (in rare cases up to 1.5 mm), with maximum crystal sizes of 2.0 mm, sometimes 2.5 mm, and in rare cases even above that size. S-shore marbles show medium crystal sizes of 0.3 to 0.5 mm with maximum crystal sizes rarely exceeding 1.0 mm. Middle to dark grey marble is quite abundant in the western S-shore quarries but scarcely found at the E-shore.

## 3. SAMPLING AND METHODOLOGY

### 3.1 *Sampling*

During the years of 1995 to 1999 we sampled the quarries scattered along the N, E, and S coast of Bafa Gölü for a representative set of samples for both petrographic and isotopic analyses. During the same period we collected samples from the temple, mainly loose fragments of fractured blocks and column drums but also drill cores (10 mm ∅) obtained during the restoration activities.

### 3.2 *Methodology*

Isotope analyses were carried out at the Institut für Geologie, Ruhr-Universität-Bochum. Carbon and oxygen isotopes are noted as delta-values in per mil relative to the PDB standard (Craig 1957).

The petrographic study has been limited to the macroscopic (hand lens) scale since the method had to be applicable to all of the architectural elements of the monument on site.

## 4. ANALYTICAL RESULTS

### 4.1 *Bafa Gölü marbles*

Quarry samples from Bafa Gölü display isotope signatures that plot into a distinct area covering and slightly extending the isotopic field published by Herz (1987; this paper Fig. 1). To date, N-, E-, and S-shore quarries are not generally distinguishable by isotopic analysis although signatures of samples from E-shore quarries nos. I and V (Peschlow-Bindokat 1981 Fig. 64) show particularly limited variations with the highest $\delta^{18}O$ values, and ratios for the S-shore Lefka-Bur-Da quarry area (Peschlow-Bindokat 1981 Fig. 5) similarly plot into a small field immediately adjacent to the former one. For petrographic characteristics see above.

### 4.2 *Temple marbles*

Interpretation of data of a large monument like the temple must operate with suppositions of practicability and historical probability which, if accepted, can at the same time support the interpretation. (i) Written sources confirm that large amounts of marble were taken from the Bafa Gölü quarries, nearby and accessible by boat; those on the S-shore belonged to the owner of the sanctuary, the city of Miletus. Hence, it is appropriate to attribute any marble used at the temple with corresponding petrographic and isotopic characteristics to this source. (ii) It is highly unlikely that single blocks of marble have been ordered from a source otherwise disregarded. Thus, only if certain criteria relate to a larger number of architectural elements can an additional marble source be assumed. (iii) Since overland transport is excessively more expensive than transport by boat, for the large quantities needed any quarry accessible by boat will more likely be the marble source for a temple than one that requires long transport overland. Regarding the Apollo temple we thus can conclude as follows.

S-shore marble from the Lefka-Bur-Da showing the characteristic dolomite boudins is best determinable among the temple marbles. It was used for the krepis (stepped platform), the stairway inside the sekos (walled in open court yard replacing the common roofed temple building proper), the door sills, the sculpted capitals of the sekos pilasters, for column plinths on all sides of the temple and for col-

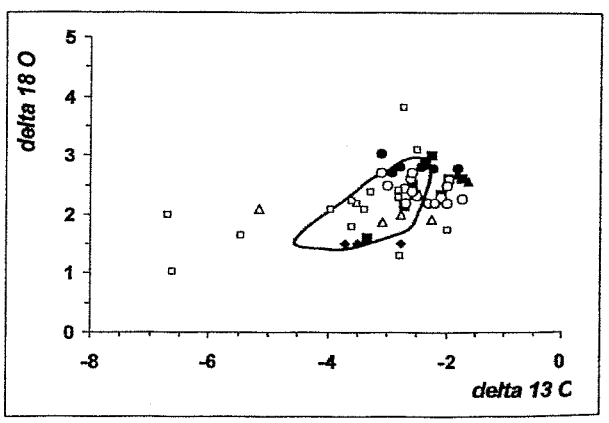


Figure 1. Bafa Gölü quarry samples

| E-shore quarries: | S-shore quarries: |
|---|---|
| quarry I | western part |
| quarry II | Lefka-Bur-Da |
| 6 quarry IV | |
| quarry V | N-shore quarry |

Herakleia field after Herz 1987.

umn drums in the dodekastylos (front hall), in both front colonnades, in the inner N- and in the inner W-colonnades. Isotopic signatures plot well into the Bafa Gölü field (Fig. 2).

Middle- to dark-grey marble from the western S-shore quarries was used for the krepis and inner stairway but only rarely for plinths, column bases, and drums.

The very coarse-crystalline marble noticed already by Peschlow-Bindokat (1981) and German (1981) was used much more widely than previously realised. It is generally white with grey 'clouds'. Calcite crystals vary extremely in size but range mostly between 1.5 - 3.0 mm with conspicuous crystals of maximum sizes of up to 7.0 mm. Only three samples could be taken for isotopic analysis. They plot well away from the Bafa Gölü field and within the field of Thasos Aliki (Fig. 3). This Thasian marble is known to be extremely coarse-crystalline (Sodini et al. 1980), a criterion that does not apply to any of the marbles with overlapping isotopic fields. Thus, this distinctive marble, used for the reveals of the major portal and for column drums of the dodekastylos, must originate from the Aegean island of Thasos.

Another marble type, used exclusively for the outer colonnades, is most obviously distinguishable by its banding in various shades of white and grey. It also shows conspicuous mm- to cm-thick dolomitic bands which, quite differently from the Bafa Gölü marbles, continue laterally with a constant thickness. Medium crystal sizes are between 0.5 and 0.8 mm, maximum crystal sizes only rarely exceed 2.0 mm. Isotopic signatures of the 16 samples taken plot into a field partly overlapping the Bafa Gölü field but clearly exceeding it (Fig. 4). Provided that the banded marbles have a common origin – an assumption highly probable on petrographical, practical, and historical reasons – the signatures suggest either Denizli or Marmara as provenance. The isotopic values would favour Denizli since 5 samples plot outside the isotopic field of Marmara published by Herz (1987) but only two outside the respective field of Denizli. Yet, a field including all of the data published by Manfra et al. (1975) would also include all but one of our plots. According to Monna & Pensabene (1977), only marble from Marmara shows the characteristic banding displayed by the temple marble. On practical and historical reasons as well Marmara is the far more probable source. The quarries near Denizli lie about 200 km inland. Its marble could only have been shipped on the Lykos and Menderes rivers which – if at all – were navigable only during snow melt and the rainy season. Hence, it is generally assumed that except for sarcophagi they were only exploited for local use. In contrast, the Marmara quarries on the island of Prokonnesos lie directly at seashore. They were imperial property, operated by slaves and state prisoners. Together with the abundance and good quality of the marble, this

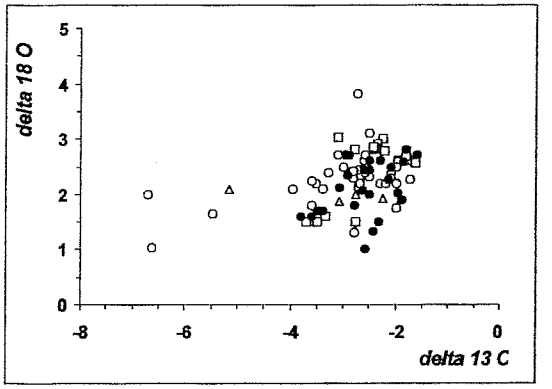


Figure 2. Temple marbles from Bafa-Gölü
temple samples
quarry samples: # – S-shore; 1 – E-shore; – N-shore

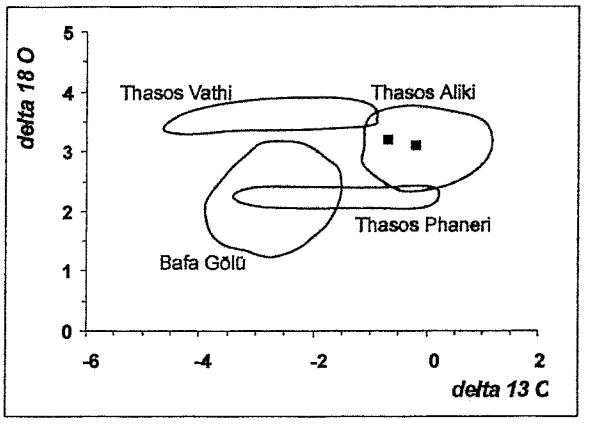


Figure 3. Temple marbles from Thasos
temple samples (two signatures exactly identical)
Thasos fields after Herz 1987; Bafa Gölü field this study

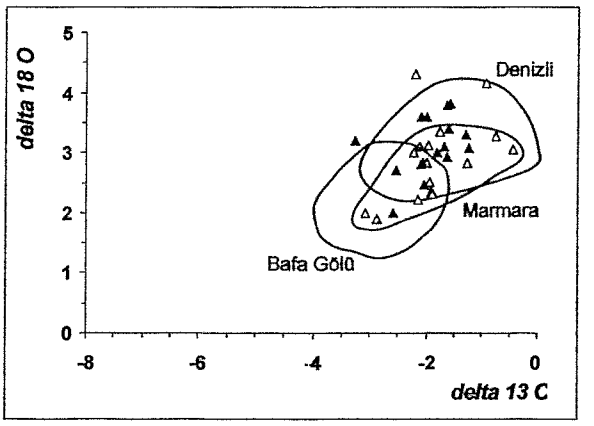


Figure 4. Temple marbles from Marmara
– temple samples
– quarry samples after Manfra et. al 1975
Marmara & Denizli fields after Herz 1987

made them the most productive exporter of marble in the Roman empire. The rest of the marble used for the temple most probably comes from the Bafa Gölü area since its petrographic as well as its isotopic

characteristics correspond (Fig. 2). As noted above, there are no unambiguous criteria for the distinction between E-shore quarries and the purer and whiter marbles from the N- and S-shores. However, since there is quite a quantity of pure, white marble with medium and maximum crystallinities that exceed those of the average white N- and S-shore marbles a certain percentage of this marble probably originates from the E-shore quarries (cf. German 1981). At least two samples also show $\delta^{18}O$ ratios unparalleled among the samples from N- and S-shore quarries but characteristic of E-shore quarries I and V (Fig. 1 & 2).

## 5. HISTORICAL IMPLICATIONS

Unlike its 6th c. B.C. predecessor for which only marble from the Aegean island of Naxos was used (publication of data in prep.), the later temple of Apollo at Didyma was built from marble of different provenances. The present study has confirmed that a great amount of marble comes from the quarries on the S-shore of Bafa Gölü owned by the city of Miletus, major financier of the building activities, but also from the E-shore, which – at least traditionally – belonged to the city of Herakleia.

Nevertheless, the marble from the Bafa Gölü quarries did not suffice, as is shown by the importa tion of Thasian marble. Its distribution within the dodekastylos – often mixed with Bafa Gölü marble in one single column – suggests that Thasian marble was supplemented to speed up building activities in the 2nd c. B.C. Only one to two groups of labourers could work at the same time in most of the small Milesian quarries. Since this is not a fact to be particularly proud of it is rather unsurprising that it is not mentioned in the inscriptions.

During the early empire, when, in a new effort, the outer E-, most of the N-, and the easternmost S-colonnades were erected, the local supply was supplemented and, perhaps, for the N-side, substituted by marble from the imperial quarries of Marmara. It had the advantage of easy and relatively economical accessibility but also of high quality. Whereas the western Milesian quarries produced predominantly grey marbles which may not have suited the patrons on aesthetic reasons, the eastern Milesian marble with its numerous dolomitic boudins was particularly hard to work. On the other hand, the high quality Herakleia marble may well have been too luxurious and too expensive. In Diocletian's price edict from the beginning of the 4th c. A.D. it is calculated at 75 *denari* per square foot whereas Marmara marble was almost half that price with only 40 *denari* (Monna & Pensabene 1977).

## 6. CONCLUSIONS

Combined isotopic and petrographic analyses of marble samples have proven to be particularly successful in attributing certain architectural elements of a temple to their quarry provenances when compared with published data and considered in terms of practicability and historical probability. In the present case, it could be shown that marble from the quarries around the Bafa Gölü, known to have been exploited for the construction of the temple of Apollon at Didyma, was indeed supplemented by imported marble from the Aegean island of Thasos during the 2nd c. B.C. and, during the Roman empire, by Proconnesian marble of Marmara, with major inferences for the sanctuaries project planning.

## ACKNOWLEDGEMENTS

We are particularly indebted to K. Tuchelt for his responsiveness and support during our cooperation project. We also owe special thanks to L. Haselberger, Chr. Kronewirth, Semih Tulay, and the Turkish government representatives.

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