Journal of Archaeological Science: Reports 19 (2018) 625–642

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Petrography and mineralogy of the white marble and black stone of Göktepe (Muğla, Turkey) used in antiquity: New data for provenance determination

M. Brilli[a,*], M.P. Lapuente Mercadal[b,c], F. Giustini[a], H. Royo Plumed[c]

[a] Istituto di Geologia Ambientale e Geoingegneria - CNR, 00015 Roma, Italy
[b] Área de Petrología y Geoquímica, Departamento de Ciencias de la Tierra, Universidad de Zaragoza, 50009 Zaragoza, Spain
[c] Unitat d'Estudis Arqueomètrics-UEA, Institut Català d'Arqueologia Clàssica, Tarragona, Spain

ARTICLE INFO

Keywords:
Marble
Petrography
Provenance
Isotopes
Trace elements

ABSTRACT

The discovery near Göktepe (Muğla province, Western Turkey) of an ancient quarrying site of white marbles and black stones has recently been reported by some authors. Assigning the provenance of stone from ancient artifacts to Göktepe is currently possible mainly thanks to chemical, EPR and MGS data. Petrographic description, which many researchers use to characterize ancient marbles, is still incomplete. Several thin sections of both types of stone were thus examined in this study, and also used for cathodoluminescence analysis. As the rock is > 99% calcite, trace minerals could only be detected in some samples by XRD analysis of insoluble residues after acetic acid attack. Data on strontium and manganese contents and carbon and oxygen isotopes were also recorded, for better understanding of some petrographic features.

A new method of grain size characterization was tentatively introduced to improve the description of grain size variability in the white marble. Microstructure and grain size measurements on thin sections of this marble identify two petrographic varieties: the first is extremely fine with signs of dynamic recrystallization, and the second exhibits texture and MGS similar to those of Carrara marble.

Statuary samples of white marble from Villa Adriana (Tivoli, Rome), preliminarily assigned in a previous study partly to Carrara and partly to Göktepe quarry, are reconsidered here.

A certain degree of variability was found in the structures and textures in the thin sections of the Göktepe black stone. It may have undergone transformations at an advanced stage of diagenesis. One important source of this variability seems to be a fluid alteration event, revealed by both isotopic and chemical data and trace mineral assemblages.

1. Introduction

An ancient quarry has recently been discovered near Göktepe (Muğla province) in south-western Turkey, approximately 30 km NE of Muğla and 40 km SW of Aphrodisias (Fig. 1). The area was first reported in 2006 (Yavuz et al., 2009) and later was both archeologically described and scientifically characterized by Attanasio et al. (2009, 2015), who classified both white and black stones as marbles. The site was initially considered to be a relatively small exploited area which, however, produced fine-grained, high-quality sculptural stone, black or white (with a less frequent gray variety), as well as a highly characteristic, two-toned black-and-white stone (Fig. 2). Bruno et al. (2015) estimated that the site could yield an overall gross marble production of 40,000 m^3, of which one-third to half consisted of definitely usable marble. If this estimate is valid, then the site cannot be considered small, but medium at least.

If exploitation was extensive, then also the artifacts produced with this material should be correspondingly abundant. After archeometric studies on the Göktepe stones, Bruno et al. (2015) demonstrated that its use and circulation within the Mediterranean basin, especially during the Roman Imperial Age, was huge, ranging far beyond its geographical region of origin. The above authors reported that they had identified some 160 sculptures made of Göktepe white marble out of 500 statues studied, dispersed over a wide range of locations from Roman Gaul to North Africa, Italy, Greece and Turkey. Both white and black stones seem to have been extensively used for statuary because of their peculiar working qualities, probably due to their fine grain size and compactness. Until now, the white marble of Göktepe has been considered to be used exclusively for sculpture; the black type was certainly used for both statuary and architectural elements, especially column shafts. There are many unfinished columns lying near the quarry fronts (Fig. 2D). Another example appears in the *Odeion* of Aphrodisias, where

* Corresponding author.
E-mail addresses: mauro.brilli@cnr.it (M. Brilli), plapuent@unizar.es (M.P. Lapuente Mercadal), francesca.giustini@igag.cnr.it (F. Giustini), hroyo@icac.cat (H. Royo Plumed).

https://doi.org/10.1016/j.jasrep.2018.03.037
Received 23 August 2017; Received in revised form 15 March 2018; Accepted 31 March 2018

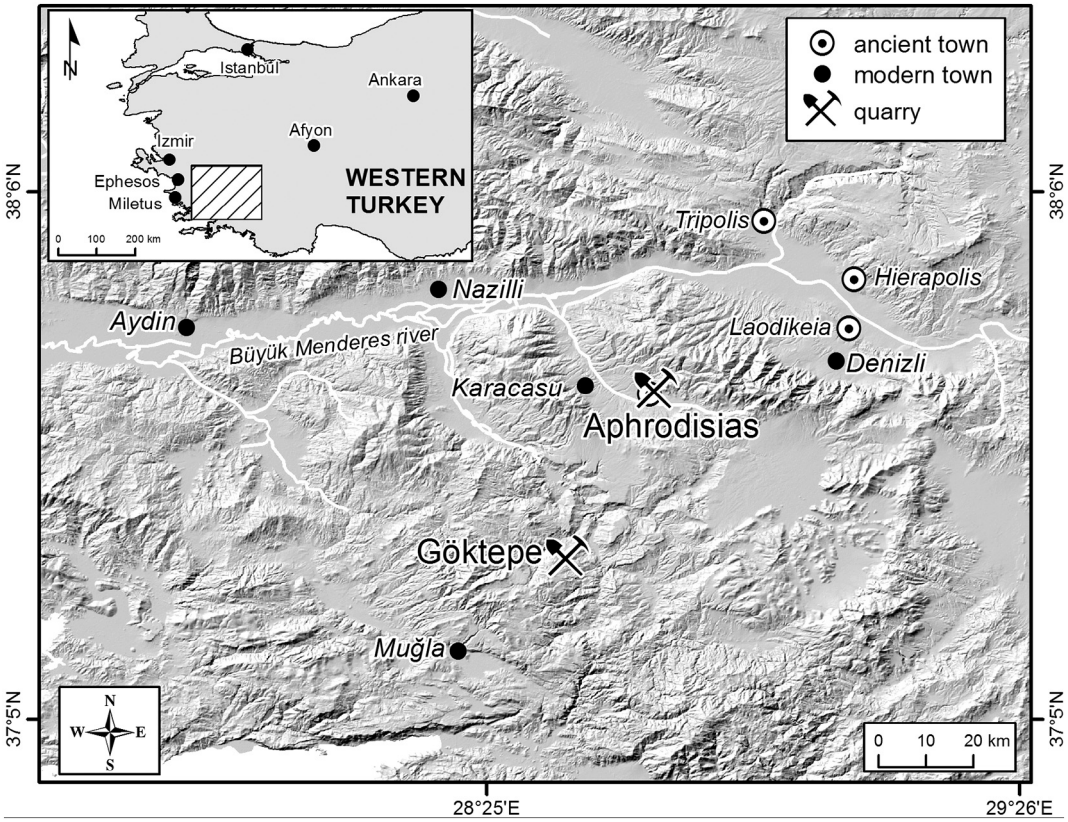

Fig. 1. Map of the location of the Göktepe quarry.

fragmentary spiral black columns assigned to the Göktepe stone are placed on the *scaenae frons* (Yavuz et al., 2009).

1.1. The Göktepe black stone

According to Bruno et al. (2015), the black stone of Göktepe can be identified with the typical, so-called *nero antico*, which Faustino Corsi (1845) identified with the black marble quarried in the Mani Peninsula near Cape Tenaros (south Peloponnese, Greece) and also called *marmor Taenarium* for that reason. Gnoli (1971) believed the black stone came from Djebel Aziz, a few kilometers south-west of the ancient Chartago (Tunisia), where a large quarry front reveals ancient activity. *Nero antico* probably pertains more to an appearance than to a provenance, and it may be more correct to think that the term refers to a certain number of different types of stone with the same uniform black aspect. Almost all the marble of sculptures and artifacts with the appearance of *nero antico*, with few exceptions, were attributed by Bruno et al. (2015) to the Göktepe quarries. The reasons for this are that, even without in-depth scientific proof, macroscopic identification is relatively easy, mainly because the authors contend that there are few alternatives and, in some cases, the Göktepe black stone is characterized by yellowish cross-shaped calcitic veins, which facilitate identification (Fig. 2F). Although the importance of Göktepe black stone may be viewed as predominating over the black stones used in antiquity, identification on this basis does not aid demonstration of its supremacy. Archeometric investigation is always advisable when a safe provenance attribution of black stone artifacts must be established (in addition, the above-mentioned calcitic veins indicating Göktepe origin are rarely present).

The black stones exploited in antiquity are not so scarce and the macroscopic differences are often very subtle, making the distinction among the various provenances impossible in several cases. In geological terms, real black marbles are not very abundant as far as we know, and in any case they have been exploited to a limited extent (not including the gray varieties, of which there are many). There are black marbles from Cape Tenaros, Mylasa, Halicarnassus (Lazzarini, 2007), Aphrodisias (Long, 2012), a black variety from the island of Lesbos (Lazzarini, 2007), and the very probable existence of an ancient black quarry near Laodikeia, supplying the many columns which have been found there. Black limestone used in antiquity was more abundantly exploited; some of the provenances are still unknown and, only including those of better quality, it is possible to identify limestones from Ain el Ksir and Djebel Aziz in Tunisia, the Greek island of Chios (Brilli et al., 2010) and Teos on the Sığacık peninsula in Turkey (Pensabene and Lazzarini, 1998). Databases concerning black stones (Attanasio et al., 2009, 2012, 2015, 2017; Yavuz et al., 2009; Brilli et al., 2010; Lazzarini, 2013) have greatly contributed to the studies of provenance of the stone of black artifacts and they have also highlighted a number of problems concerning their nomenclature and geological nature. These difficulties are due to different points of approach and directly affect the study of black artifacts, especially when petrographic study is not addressed. The first concerns the use of the old nomenclature (*nero antico*, *bigio antico*, *bigio morato*). As already mentioned, this terminology was probably originally intended to describe the appearance of the archeological pieces carved in black, or in different gray scale stones with different surface finish, but not necessarily designed to relate each one directly to a single specific source. Moreover, earlier scholars may have made mistakes in the visual inspection of some emblematic statuary. However, as such terminology was commonly used in texts on archaeology and art history, the current scientific analytical approach aims at relating each old name with one or several stone sources, to define them precisely and relate the names to their geological properties, with the final aim of using them when analyses are not available. Within this framework, the recent contribution of Attanasio et al. (2017) on *bigio antico* offers an approach for the whole ancient 'black' decorative stones with the aim of resolving the problem. Their classification, based on the use of stones (sculptural or