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Olympia, Greece

Preliminary Results of the Study of the Building Stone Used at the Archaeological Site

Research Carried Out between September and December 2023

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ABSTRACT

This report presents preliminary results of an ongoing project to identify building stones at Olympia. Through a first geological investigation, 14 different kinds of stone have been identified on a macroscopic scale in the *in situ* remains of the monuments of the Altis. These stones are exclusively sedimentary, except for marble, which appears only twice in monumental architecture. The shelly limestone (*Muschelkalk*), considered to be the local stone used in almost all the monuments, in fact shows high facies variability.

KEYWORDS

geology, stone analysis, buildings, limestones

ZUSAMMENFASSUNG

Dieser Bericht stellt erste Ergebnisse eines laufenden Projektes zur Identifizierung von Steinsorten vor, die in Olympia als Baumaterial benutzt wurden. Im Rahmen

einer ersten geologischen Untersuchung der *in-situ*-Überreste der Bauten in der Altis wurden makroskopisch verschiedene Gesteine identifiziert. Mit Ausnahme von Marmoren, die nur an zwei Stellen in der Monumentalarchitektur vorkommen, handelt es sich ausschließlich um Sedimentgesteine. Der Muschelkalk, der als lokaler Stein für fast alle Monumente verwendet wurde, weist jedoch große Variabilität auf.

SCHLAGWÖRTER
Geologie, Gesteinsuntersuchung, Bauten, Kalksteine

Introduction

1 This report aims to introduce a new research approach to the archaeological site of Olympia (Greece). The varieties of building stones at the site have never been systematically studied; neither their geological characterization nor their precise origin have been clearly established. Also lacking is a study of the materials on the scale of the whole site, which can yield important information on the site's history. The stones used in construction must be studied in close correlation with the site's natural environment to evaluate their provenance and the ways in which resources for stone were exploited. A first geological investigation was conducted during a four-month scholarship in 2023, including one month of fieldwork at Olympia, which focused on stone material in situ in the main buildings of the Altis dating from the Archaic to the Hellenistic period. Except for the marble that is utilized only in two instances at the site during the period studied, all the stones are sedimentary. After a short summary of the investigations already carried out on this subject at Olympia, the report presents the methodological approach chosen and the first results of this ongoing project (see Fig. 1 and 2).

State of the Argument

2 The geologist Hugo Bücking was the first scholar to study building stone beginning in 1881. He distinguished at least ten different types of rock used in Olympia: a local shelly limestone (*Muschelkalk*), the local marly limestone (*Mergelkalk*), conglomerate, sandstone, various hard limestones from the Peloponnese, and marbles (from Sparta, Paros, Penteli, Hymettus, and Euboea)[1]. The geologist Richard Lepsius, who laid the foundations for the study of marble provenance in Greece, also worked at Olympia[2]. He identified marbles from Doliana and Vresthena (near Sparta), the Cyclades (Paros or Naxos), and Mount Penteli in Attica, as well as local stone (shelly limestone, marlstone, and other limestones), a dark limestone of unknown origin (perhaps Eleusis), and some marbles of unknown origin.

3 Subsequent references to the nature or origin of rock are scattered throughout the archaeological bibliography; to this day, material identifications rely mostly upon the results of the old excavations[3]. The architect Wolf Koenigs, who studied the Echo Stoa (Echohalle) between 1976 and 1984, attempted to make more precise distinctions and identified six sub-types of shelly limestone, as well as marble and sandstone[4]. His classifications, however, have not been used systematically in later publications. The architect Klaus Herrmann was also interested in the nature of the stone used in the buildings at Olympia, around the years 1976–1987, but his work was never published[5].

4 The first archaeometric study to be published was conducted in 1988: 15 samples were taken from a 7th century BCE marble perirrhanterion for isotopic analysis to prove Laconian provenance[6]. The first and only work on building materials was carried out and published in 1995 when a more precise geological definition of eight lithofacies[7] at the archaeological site was formulated[8]. At a

1 Bücking 1881, 324.
2 Lepsius 1890, 105–108. 127–131.
3 As noted recently in Hermann 2000, 379; Palagia 2015, 75. E.g.: Dörpfeld 1883, 68 f., was the first to propose that the stone used in the Sicyonian Treasury comes from the Corinthia, based on visual description; since then, the assertion has been considered true but never proved with archaeometric evidence.
4 Koenigs 1984, 7 f.
5 Archives of the DAI, Athens Department, unpublished.
6 Carter 1988.
7 Facies is a term used to denote a sedimentary deposit, distinguished from other types by various attributes (mineralogical, fossil, and so on). The term can be applied to different types of rocks.
8 Varti-Matarangas et al. 1995.

Fig. 1: Equipment for macroscopic geological study of the building stone. Left: photo of the site, with scale and printed map of the stones of the building being studied (Buleuterion) for compiling data. Right: view through a mineralogist's magnifying glass (up to x10), classic equipment for description in fieldwork

1997 conference, K. Herrmann presented a summary of the use of Parian marbles at Olympia but noted the absence of precise scientific analyses for identifying marble[9]. Ana Maria Abraldes' thesis, completed in 1996, studied the export of Pentelic marble[10] and provided a list of all the monuments and objects made from Pentelic marble for Olympia, but was based only on previous literature. An article published in 1999 discussed the marbles used in the Roman Nymphaeum of Herodes Atticus based on 53 samples, all of Pentelic origin[11].

5 Finally, for the anastylosis of the Philippeion in 2004 and of the Ptolemaic votive monument in 2017, marble samples were taken and sent to the Demokritos Laboratory for provenance analysis, but the results for both structures remain unpublished[12].

Methodology

6 Sedimentary rocks, which represent almost 80% of the Earth's surface, are formed through the accumulation of sediments from pre-existing rocks or organisms that then become cemented[13]. They represent one of the three main categories of rocks existing on Earth, together with igneous (for example, basalt or granite) and metamorphic rocks (marbles).

7 One of the main challenges of geological study in an archaeological context is the terminology of sedimentary rock. Limestone, mudstone, marlstone, sandstone, arenite, calcarenite, conglomerate, travertine, and tufa are all geological terms relating to different classifications, each with a precise definition: a specific grain size, mineralogical composition, and/or origin (associated with the context and processes involved in the stone's formation). The term *poros* that is used in the archaeological literature[14], on the other hand, has no geological meaning;

9 Herrmann 2000.
10 Abraldes 1996.
11 Kane et al. 1999.
12 DAI Athens Archives: unpublished report by Hajo van de Löcht completed in 2008; unpublished report by Yannis Maniatis dated 2010.
13 Folk 1980.
14 Martin 1965, 114.

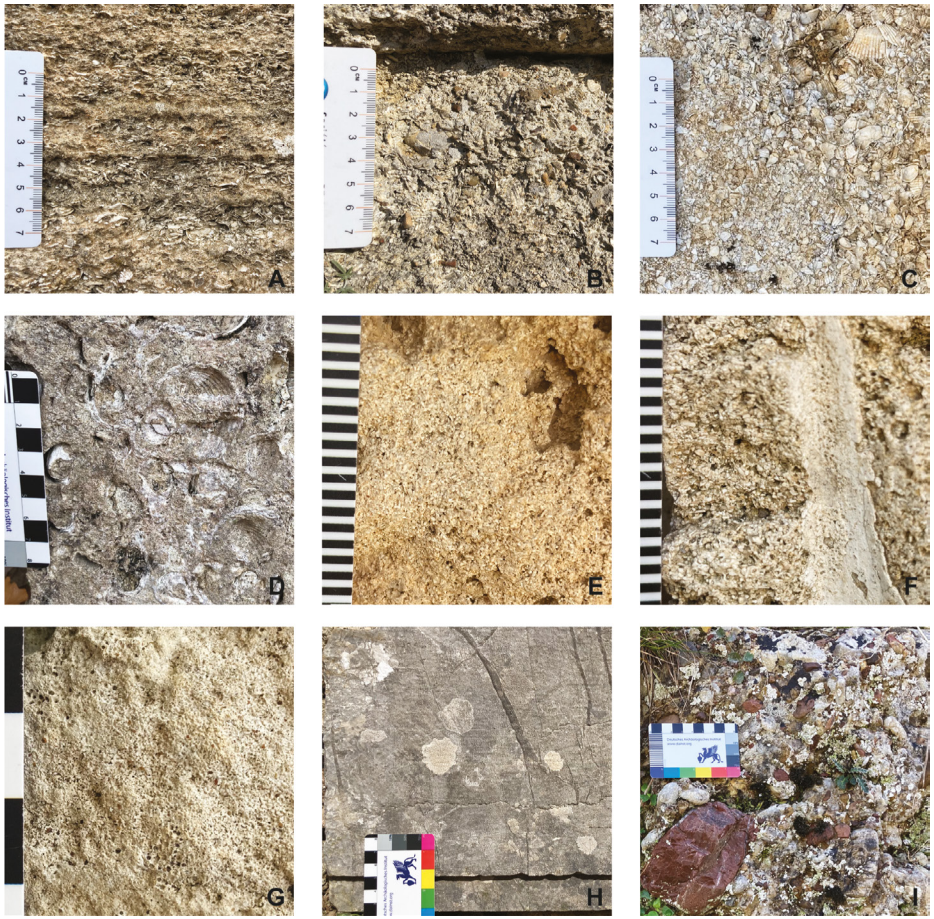

Fig. 2: Examples of some lithofacies used as building stone in the monuments. A, B, C, D: different facies of shelly limestone (Muschelkalk), used in a column of the Hera Temple (A), the foundations of Treasury XI (B), the stylobate of the South-East Building (C), and a capital of the Echo Stoa (D). E, F, G: different arenites used in the column base of the internal colonnade of the South Stoa (E), the capitals of the Gymnasium Propylon (F), and the column base in the Philippeion (G). H: hard grey limestone upper course of the Gymnasium Propylon. I: polygenic conglomerate foundations of the back wall of the South Stoa. Please note that the scale for E and F (1 bar = 1 mm) differs from that of the rest of the images (1 bar = 1 cm)

it usually corresponds to lightweight stones of light colour (white, yellow, or pink), as opposed to marbles, hard limestones, and conglomerates.

8 Thus, the study of sedimentary rocks requires an in-depth description of their composition up to the microscopic scale. During the field study campaign, work was limited to macroscopic determinations with the aid of a magnifying glass (Fig. 1). This is a fundamental step before proceeding to further studies. The emphasis was on texture, sedimentary structures; grain size, form, distribution; macro-paleontological content (fossils); porosity type and distribution; colour and surface alteration. The mineralogical composition and other numerical data (size, proportions) have only been estimated. They will need to be measured systematically, preferably at a microscopic scale, through analyses of rock samples.

First Results

9 The preliminary results of this study show a higher diversity of lithofacies than previously assumed. In Olympia, »shelly limestone« (*Muschelkalk*) is considered the main local material used throughout the site, recognisable by the presence of shells. »Limestone« denotes rocks composed mostly of calcite or aragonite ($CaCO_3$), implying a compositional classification. The exact composition of the stones used at Olympia is still unknown; however, even if the fossil shells are carbonates, the same is not always true of the matrix. Thus, the descriptions here are based only on textural criteria, and stones will be named mainly based on their grain size classification.

10 Different shelly lithofacies are described: the kind and size of the fossils, the nature of the matrix, the proportions of each element, and the like are highly variable, as shown in Fig. 2 (A-D). The finer stratified facies with sand layers (A) differ from the coarse, almost conglomerate facies with lithic inclusions (B). One facies displays almost no matrix and is composed mostly of small (<1 cm) fragments of white bivalve shells with low cohesiveness (C), while another facies presents complete bivalve shells, partly dissolved in a sandy matrix, with the impressions

Fig. 3: Lithological map of Foundations B, C and 1 in the Altis treasuries at Olympia showing different facies and the variability of the shelly facies, which exhibit different characteristics. On QGIS, ongoing work with provisional names (MK=Muschelkalk; SS=Sandstone; S=Stone)

still visible (D). For the moment, these different facies cannot be linked to different origins.

11 Arenites have been observed. These correspond to stones composed of grains ranging in size from 2 mm to 1/16 mm (Fig. 2 E–G). They are usually identified as sandstone (*Sandstein*) in the literature, although sandstone also has a compositional factor (mostly quartz), which for the moment remains unknown. Of the three examples, one shows well-sorted, finely rounded grains, yellowish in colour (E); a second facies is coarser, with unidentified heterogeneous bioclastic grains (F); the third contains pebbles embedded in a matrix of very fine rounded grains (G).

12 Marbles, hard limestones (Figure 2 H), and conglomerates (Fig. 2 I) were also utilised but in smaller quantities and are usually well noted in the literature. A total of 14 different facies have been identified at present in the monuments of Olympia.

13 A new name for each facies will be formulated when more data on the mineralogical composition has been collected. For the present, the different stones described, based on textural criteria, will be compiled into a lithological map that will represent the distribution of the different lithofacies in the monuments of the Altis (Fig. 3). This tool is not yet finished. More detailed investigation of the various shelly lithofacies and other sedimentary stones, involving precision analysis (sometimes of a destructive nature), will be necessary to complete their identification. Afterwards, through the geological study of the environment, these building stones may be linked to natural outcrops or possible quarries.

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IILLUSTRATION CREDITS

Fig. 1: Left: Marilou de Vals, Right: Hakon Rückemann

Fig. 2: Marilou de Vals

Fig. 3: Stone base map elaborated by Markus Wolf; published with his permission

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