The archaic sanctuary on Despotiko Island (Cyclades): Geological outline and lithological characterization of the building stones, with their possible provenance

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Abstract

Lithological comparisons between building stones of an archaic sanctuary on Despotiko (Cyclades) and geological units mapped on this island enabled a distinction to be made between locally derived and possibly imported material. The most common lithologies used in the main sanctuary building (Building A) were medium-grained white calcite marble with thin, rose-coloured dolomite marble layers (Marble 1), coarse grained, white calcite marble (Marble 2), white mylonitic gneiss and grey granitic gneiss; dark grey banded calcite marble and yellowish calcarenite were rarely used. Excepting Marble 2, all building stones in Building A occur on Despotiko and could originate from the island. The occurrence of nine quarries (presently undated) in the surroundings of the sanctuary, seven in white mylonitic gneiss, one in dark grey calcite marble and one in a white calcite marble resembling Marble 1, support a local provenance. Submerged archaeological structures within Despotiko Bay, a classical marble inscription from the sanctuary and partly submerged agriculture trenches at the east coast of Despotiko all suggest that the relative sea-level there was > 3 m lower in the Early Bronze Age and > 1 m lower during Hellenistic times. If vertical tectonic movements are neglected, the present sea-floor bathymetry indicates that an isthmus linked Despotiko, Kimitiri and Antiparos until at least Hellenistic times.

Der lithologische Vergleich zwischen den Bausteinen eines archaischen Heiligtums auf Despotiko (Kykladen) und den kartierten Gesteinen auf der Insel ermöglicht die Unterscheidung zwischen lokal entnommenen und wahrscheinlich importierten Bausteinen. Die am häufigsten verwendeten Lithologien in Gebäude A des Heiligtums sind weisser, mittelkörniger Kalkmarmor mit dünnen, rosa gefärbten Lagen aus Dolomitmarmor (Marmor 1), weisser, grobkörniger Kalkmarmor (Marmor 2), weisser Mylonitgneis und grauer Granitgneis; dunkelgrauer Kalkkmarmor und gelblicher Kalkarenit wurden nur sehr selten verwendet. Mit Ausnahme von Marmor 2, alle Bausteine von Gebäude A sind auf Despotiko zu finden und können deshalb theoretisch lokal von der Insel stammen. Die Existenz von neun, derzeit undatierten Steinbrüchen in der Umgebung des Heiligtums, sieben im weissen Mylonitgneis, einer in dunkelgrauem Kalkkmarmor und einer in weissem Kalkmarmor – ähnlich Marmor 1 – bietet ein gewichtiges Argument für eine lokale Herkunft von zumindest den meisten der Bausteine. Archäologische Funde am Meeresgrund der Despotiko Bucht, eine antike Marmorinschrift im Heiligtum und teilweise unter Wasser stehende Feldstrukturen an der Ostküste von Despotiko deuten darauf hin, dass der relative Meeresspiegel zur Frühbronzezeit mehr als 3 m tiefer war und während der Hellenistischen Zeit noch immer mehr als 1 m niedriger lag. Wenn man vertikale tektonische Bewegungen nicht berücksichtigt und die heutige Bathymetrie des Meeresgrundes verwendet, dann läßt sich eine Landverbindung zwischen Despotiko, Kimitiri und Antiparos bis mindestens in Hellenistische Zeit rekonstruieren.

1. Introduction

The primary aim of this study was to classify the rock types used in the main building of the archaic sanctuary on Despotiko and to discuss possible local and imported origins for the recognized lithologies, based on comparisons with rocks mapped on the island. A second aim was to reconstruct the former local coastline, based on published data and new observations, which provides important insights into the relationship between the sanctuary, Despotiko Bay and former communication paths.

Such studies inevitable lie in an interdisciplinary space and although geological descriptions have been kept as short and simple as possible, several geologically specific terms cannot be avoided; all of them can be found in geological glossaries (e.g. Neuendorf et al., 2008). Equally, for readers unfamiliar with the chronology of Greek archaeology, the Archaic Period (following the Greek Dark Ages and preceding the Classical Period) represents the time between ca. 750-480 B.C., or, in historical terms, the period approximately between the first Messenian war and the second Persian invasion (Snodgrass, 1980).

The existence of an ancient sanctuary on the presently uninhabited island was first suggested by Fiedler (1841), Bursian (1872) and Schuller (1985), who mentioned large architectural marble blocks on the island. The sanctuary, large parts of which have been excavated since 1997 (Kourayos, 2006), is situated on a gently northeast dipping slope in the northeastern part of Despotiko, in sight of the Despotiko Bay, at the northern limit of the largest, arable land on the island (Fig. 1).

The modern toponym of this area is Μάνδρα (Mándra, which means farmstead).

The complex consists of a main building (Building A) with 5 rooms (A1-A5), situated on the west side of a rectangular court with several more buildings on the north side (Kourayos, 2006, figs. 1 & 19). Additional buildings exist towards the northeast, closer to the coast. Most buildings date to the Archaic and Classical periods, although finds from younger periods witness later activities in this area. Southeast of Building A, several buildings with small, irregular rooms of inferior masonry quality and abundant re-used archaic/classical building stones date from the medieval period (Kourayos, 2006, fig. 16).

2. Geological outline of Despotiko

Despotiko is a small, uninhabited island, southwest of Antiparos in the central Aegean (Fig. 2) with a surface area of 7.65 km². At present, the only natural occurrences of fresh water during the summer are two small water seeps in the northwest of the island. First reports on the geology were by Fiedler (1841); Αναστασόπουλου (1963) published the first geological map of the island. Tectonically, Despotiko, Antiparos and Paros belong to the Attic-Cycladic Crystalline of the Central Hellenides, a stack of metamorphic nappes, mainly comprising variable types of gneisses, schists, marbles and amphibolites tectonically overlain by slices of unmetamorphosed sediments, along low-angle normal faults (Αναστασόπουλου, 1963; Dürr et al., 1978; Papanikolaou, 1979; Gautier and Brun, 1993).

Structurally, Despotiko is characterized by a foliation dipping at low angles towards the southwest. Folds have only rarely been observed; usually they are isoclinal, with axes paralleling a SW-plunging stretching lineation. These rocks are cut by steep, northwest-southeast trending brittle faults, some of them showing displacements of several hundred meters (Fig. 2).

In the following section, the main lithologies on Despotiko are described, starting in the footwall and moving to the hanging wall (Fig. 2). Dark to pale grey, strongly foliated, mylonitic granite gneiss consisting of alkali and plagioclase feldspars, variable amounts of biotite and relatively little white mica form the structurally lowest levels in the north and northeast of the island. Within this gneiss, cross-cutting pegmatite dikes are abundant, becoming progressively more deformed and rotated towards parallelism with the foliation nearer the hanging wall. The gneiss is overlain by a prominent white, strongly foliated, mylonitic gneiss, consisting of alkali feldspar, greenish-white mica, sericite and quartz, and thence by medium-grained, white calcite marble, followed by greenish-white, coarser grained gneiss and an alternation of chlorite epidote schist, chlorite epidote gneiss, retrogressed amphibolite and thin marble layers. Some small serpentinite lenses occur. The structurally highest levels, in the south and southwest of the island, comprise several tens of metres of white to yellowish white, fine grained dolomite marble with thin, folded layers of dark grey, carbonaceous calcite marble.

This metamorphic succession has been cut by six early Pliocene (Innocenti et al., 1982) rhyolitic volcanic vents, with very rare occurrences of obsidian, usually smaller than 1 cm in size. Associated rhyolitic pyroclastic rocks cover the whole southern part of Antiparos, where two occurrences of volcanic rocks with up to 5 cm sized obsidian clasts have been found (Bent, 1884; Αναστασόπουλου, 1963; Cann et al., 1968; Georgiadis, 2008). Yellowish, porous sandstones dominated by well-rounded, well-sorted fragments of marine organism and minor siliciclastic components, have been found in many places overlying the crystalline rocks. The similarity of the lithologies on Despotiko, Antiparos and Paros makes detailed provenance studies of building stones extremely difficult.

3. Evidence for late Holocene coastline changes around Despotiko Bay

Despotiko is separated from Antiparos by a 700 m wide strait with a minimum depth of about 1 m, linking them with the intervening islet of Kimitiri (0.08 km²; Figs. 1, 3). The extreme shallowness of the strait suggests the possibility of a link between Antiparos and Despotiko in ancient times.

Melting of continental ice and thermal expansion of sea-water since the Late Glacial Maximum (ca. 20,000 years ago) has raised the global sea-level by ca. 125 m (Chappell and Shackleton, 1986; Fleming et al., 1998; Caputo, 2007). On a

Figure 1: Overview of the Despotiko Bay. View towards west-northwest, showing, from left to right Despotiko, Kimitiri and Antiparos islands. The outline of Sifnos is vaguely visible in the left background. The location of the parallel trenches above sea-level is indicated by the letter “A”, those under the present sea-level by “B”.

local scale, relative sea-level trends were also strongly influenced by tectonic movements, glacio-isostatic far-field effects and hydro-isostatic (Lambeck, 1996), as well as by erosion and sedimentation (Morrison, 1968). For high-resolution local sea-level reconstructions, detailed examinations of geomorphic (e.g. fossil tidal notches, beach rock) and archaeological (e.g. submerged quarries and buildings) former sealevel indicators are recommended (Papathanassopoulos and Schilardi, 1981; Pirazzoli, 2005). Especially in the Aegean region, which comprises several tectonic blocks having different vertical movement histories, sea-level reconstructions have to be carried out in detail and at a local scale (Mourtzas and Marinos, 1994). Submerged archaeological structures originally built on dry land usually indicate only the minimum relative sea-level changes since their construction or last use. There are only a few archaeological constructions, such as Roman fish tanks, that provide precise data for reconstructing former sea-level histories (Lambeck et al., 2004).

Morrison (1968) investigated relative sea-level changes around Antiparos and nearby islands. Although he carried out these studies more than 40 years ago, without new geomorphic and archaeological surveys little has to be added on a local scale to his careful observations and thoughtful arguments. Using evidence such as submerged archaeological structures and parallel trenches continuing from land into the shallow sea (interpreted as Hellenistic viticulture trenches), Morrison (1968) inferred a minimum 3 m relative sea-level rise since Neolithic times. Taking into account spring tide sea-levels and also storm

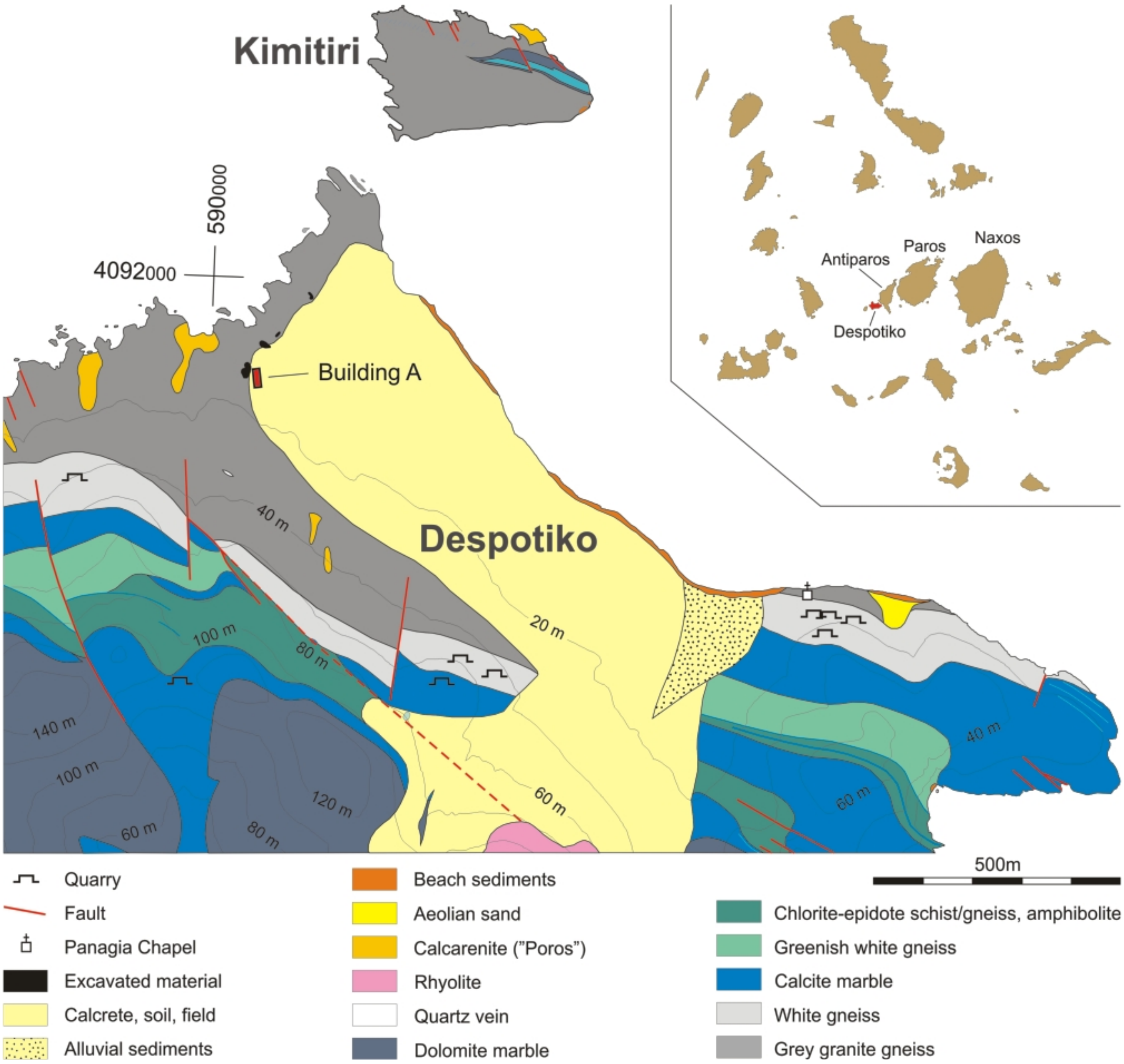

FIGURE 2: Simplified geological map of the northeastern part of Despotiko and Kimitiri showing lithologies in the vicinity of the sanctuary. Note that the quarries more or less form an arc with the sanctuary at its centre. The majority of quarries are found in the white mylonitic gneiss. Topography from 1:5.000 map sheets of the Hellenic Military Geographical Service; contour line distance is 20 m; coordinates in UTM. Inset map shows the central location of Despotiko among the Cycladic islands.

surges (cf. Tsimplis and Blackman, 1997), Morrison (1968) suggested a 5-6 m sea-level rise since the Neolithic as being even more probable.

Archaeological indicators of relative sea-level changes in the Despotiko Bay area itself include Early Bronze Age cist graves presently being eroded by beach processes and continuing down to 3 m water depths (Morrison, 1968) from southeast Kimitiri as well as walls, a well-head and an oven of unknown age at 3 m water depth off-shore from Agios Georgios on Antiparos (Bent, 1884; Morrison, 1968). Numerous parallel furrows occur west of Panagia on Despotiko (Figs. 3, 4, 5); these have not been excavated or dated, but can be compared with the almost identical, partly submerged viticulture trenches from northeast Antiparos (Morrison, 1968) and from several bays in northeast and southwest Paros (Rubensohn, 1901). More trenches are visible in satellite images of the west coast of Paros. The high variability in size, spacing and orientation with respect to the coast line of the trenches was described by Rubensohn (1901) and can be seen in aerial pictures (www.aegeandiving.gr).

The Despotiko trenches have been mapped on Quickbird satellite imagery (acquired on 18th of May 2003; catalogue ID 1010010001E8AF0A). They are parallel to sub-parallel to each other and to the isolines/isobaths from 12 m a.s.l. to ca. 1 m depth below present-day sea-level, trending west-northwest to east-southeast (Fig. 4). On land, they are only visible in ploughed fields and can be traced for more than 160 m, and, underwater, for 115 m (Fig. 4). The distance between trenches, based on 18 measurements, ranges between miminimum 2.5 m, and maximum 10 m, mean value 6.5 m. Trenches with smaller spacings may represent a younger generation of trenches dug between older ones.

On land, trenches are mostly infilled with soil and are only visible from above. Underwater, where they have been exposed by wave action and currents (Fig. 5), they are ca. 30-80 cm wide and cut into the locally occurring calcrete (Wright and Tucker, 1991). The trenches show quite regular, parallel and almost vertical sides, with bottoms covered by recent sediment (Fig. 5).

Rubensohn (1901) discussed several possible interpretations for the Paros trenches (shipsheds, boat slipways, quarries, salt production) without being convinced by any explanation. Most trenches on Paros and Antiparos are oriented parallel to the coast line and thus are unlikely to represent shipsheds, used to protect the hulls of boats, which are usually almost perpendicular to the shore line, because the boats have been pulled out of water (Blackman, 2003). Peter Nicolaides (Aegean Diving College, www.aegeandiving.gr) interpreted the furrows as constructions for loading marble blocks onto boats, but this is very unlikely on small islands without large quarries, such as Despotiko, or for coast-parallel furrows or those found several metres above the present-day sea-level, as on Despotiko. However, the high variability of the furrow geometry suggests that not all the trenches served the same purpose. Future studies on the trenches should carefully consider the particular relative sea-level during the time of their creation and use to clarify, if specific furrows originally have been intended for sub-aquatic (e.g. aquaculture), peri-tidal (e.g. boat slip ways, shipsheds, salt evaporation) or terrestrial (e.g. agriculture) purposes.

The inferior rock quality of the calcrete as building stone and the virtual lack of this rock type in the sanctuary makes interpretations of the trenches as a former quarry very unlikely on Despotiko. Further, the relative sea-level curve for the Cyclades by Poulos et al. (2009) indicates that the lowermost trenches were not submerged before Roman times and thus were constructed on dry land. Therefore interpretations linking the trenches, some of which would have been at least 12 m above sea-level, to sea-based activities (e.g. shipsheds, salt evaporation installations, aquaculture) are implausible. The

Figure 3: Topographic and bathymetric sketch map of Despotiko Bay. The location of Building A on Despotiko is indicated. The coastline, isolines and isobaths are from the 1:20,000 nautical chart (HNHS 1989); heights in metres above mean sea-level, depths under lowest low water. White (yellow in the online version) indicates land above present sea-level, light grey (light blue in the online version) denotes the outline of the isthmus between Antiparos and Despotiko at 2 m relative lowered sea-level and middle grey (blue in the online version) designates the shape of an isthmus at 5 m relatively lowered sea-level. All these reconstructions are based on present sea-bottom geometry, neglecting tectonic movements. Location of Figure 4 is indicated.

system of parallel, horizontal grooves is much easier to explain as remnants of agriculture work. Based on the excavation of some trenches on Antiparos, Morrison (1968) interpreted them as evidence of Hellenistic viticulture; this was supported by the abundance of locally produced wine amphorae (pers. comm. Colin Renfrew 2009). The reason for cutting the trenches into the calcrete, which must have taken considerable effort, may have been to provide plant roots with space and access to deeper levels of the ground in areas of relatively impenetrable calcrete covered by thin soils.

4. Lithologies of the building stones

Six different lithologies have been recognized in the building stones of Building A at the sanctuary. As no samples have been taken, the lithological descriptions are based only on a macroscopic inspection of in situ material. Further work, based on isotopic studies and petrological investigations are planned.

4.1 Calcite marble 1

A white, sometimes slightly greyish marble (Figs. 6, 7a), mainly consisting of calcite with a mean grain size around 0.5 mm, maximum grain size up to 1 mm. Rare, up to 4 mm large white mica occur within a quite well-developed foliation. Characteristic rose-coloured, irregular, up to 25 mm thick layers of fine grained dolomite marble with a slightly lower weathering resistance compared to the calcite layers occur. Some calcite filled, up to 1 cm thick joints. Undressed surfaces may show thin red weathering coatings.

Marble 1 is the principal lithology for the well dressed, rectangular building stones of the eastern, exterior, façade of Building A (see plan in Kourayos, 2006, fig. 1), which is best preserved in rooms A1 and A2 (Figs. 6, 7a). Additionally, rough blocks of marble 1 have been used for the west wall of room A1 and, together with white mylonitic gneiss, for the interior part of the east wall of A1, the west and south wall of room A2 and the south wall of A4. Large, rough blocks of marble 1 have been utilized as foundation just for the north and west walls of room A1.

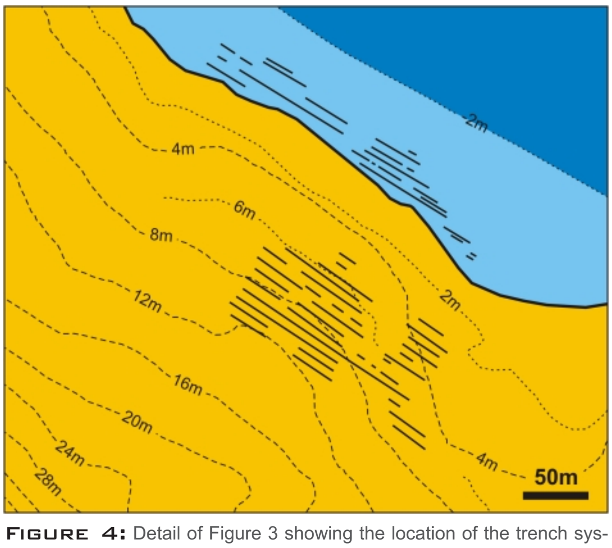

Figure 4: Detail of Figure 3 showing the location of the trench system west of the small Panagia church on the east coast of Despotiko. The furrows have been mapped on Quickbird satellite imagery. On land they are just visible in ploughed fields; their complete distribution is obscured by vegetation.

4.2 Calcite marble 2

White, massive marble (Fig. 6), virtually exclusively comprising calcite, with a hardly recognizable foliation. Some diffuse bluish-grey areas, coloured by carbonaceous matter. Mean grain size around 0.7-1 mm, but can reach up to ca. 4 mm.

All the large thresholds of Building A as well as several statue bases in room A2 comprise calcite marble 2 (Fig. 6).

4.3 Dark grey banded calcite marble

Banded marble showing alternations of thin dark and light grey layers, comprising calcite with some carbonaceous matter. Grain size less than 1 mm. Foliation well developed.

Only a few pieces of this lithology occur. They are rounded and used as rough fill stones in the east wall of room A1.

4.4 White alkali feldspar - greenish white mica - gneiss ("white mylonitic gneiss")

Strikingly white, strongly foliated, mylonitic gneiss (Figs. 6, 7a) consisting of alkali feldspar, greenish-white mica, sericite and quartz. Feldspar is commonly shaped into augen, usually smaller than 10 mm. Fractures are often stained orange-brown by Fe-hydroxides. Small sheared fractures occur, rarely reaching 15 cm length (e.g. west wall of room A3).

White mylonitic gneiss is the principal stone used for the rectangular slabs of the pavements, where preserved. This is due to its ideal petrological properties for this purpose: (i) it breaks easily along the foliation; (ii) foliation surfaces are even, but relatively rough, and therefore not slippery; (iii) it has a high abrasion resistance compared to marble and does not become polished as fast as marble. The pavement in front of rooms A3-A5 comprises carefully split, rectangular slabs of white mylonitic gneiss; this rock type is also used for the stylobate (the top step of the stepped platform of Greek temples on which columns are placed) at the eastside of building A.

White mylonitic gneiss with smaller amounts of marble 1 was commonly used for the internal sides of all east walls and is also the main lithology for foundations (Figs. 6, 7a). Additionally, white mylonitic gneiss was used together with marble 1 in the south walls of room A1 and A2, as well as in the west wall of room A5 and strongly dominates the south and west walls of room A3. Finally, it is also found in the west wall of room A5, where a few traces of mortar may have been preserved. Large, irregular slabs of white mylonitic gneiss, split along the foliation and joints (see Figure 8), were used as foundation for the north wall of room A1 (together with large white marble blocks), south and east walls of room A1, south and east walls of room A3 and for the east wall of room A4. Roughly dressed white mylonitic gneiss also occurs in the foundation of the west wall of room A3.

4.5 Grey alkali feldspar - plagioclase - biotite - granite gneiss ("grey granite gneiss")

Dark grey to pale grey, strongly foliated mylonitic orthogneiss with a well-developed mineral stretching lineation (L/S tectonite) comprising alkali and plagioclase feldspars, quartz, variable amounts of biotite and only minor amounts of white mica. Alkali feldspars generally form augen that usually are larger than 10 mm. Small sheared fractures may be present.

Roughly dressed grey granite gneiss was mainly used for foundation, such as under the west walls of rooms A1 and A2. Small pieces have been found in the filling of the two-leaf masonry of the west wall of room A1.

4.6 Yellowish calcarenite ("Poros")

This is a porous sandstone dominated by well-rounded and well-sorted fragments of marine organisms, with only a minor siliciclastic components. Mean grain size of around 0.7 mm, with thin layers of angular, siliciclastic particles up to 10 mm in size. Weakly cementated.

Poros as building stone is mentioned by Pausanias (book 5, chapter 10.3) and the broad use of this term by archaeologists was already criticised by Lepsius (1890) since it includes a large variety of lithologies. According to Papageorgakis and Mposkos (1988) the term "póros" or "porólithos" is used in Greece for easy workable building stones with a high porosity, usually travertine (see Lepsius, 1890, 128) or Quaternary coastal sandstone, but may also include porous weathered volcanic rock (Mitzopulos, 1889). In this paper, the term poros is restricted to Quaternary coastal calcarenites (Cayeux, 1907). Although several large calcarenite blocks with unclear associations occur, especially in room A2, the only calcarenite stone used in Building A has been found in the south wall of room A4.

5. Discussion

5.1 Palaeogeographic implication of the sea-level reconstruction

Using the present seafloor bathymetry (HNHS, 1989), the sea level rise of > 3 m since the Neolithic suggested by Morrison (1968) and neglecting tectonic movements indicates a broad land connection between Antiparos, Kimitiri and Despotiko before that time (Fig. 3). Taking the more likely 5-6 m of relative sea-level rise (Morrison, 1968), Paros, Antiparos, Kimitiri and Despotiko would have formed a single island at that time (the "Greater Paros" of Broodbank 2000).

Probable Early Bronze Age cist graves off Kimitiri, in 3 m water depths provide strong evidence for a land connection between Antiparos and Despotiko still at that time. A Classical marble inscription found at the excavation site of Mandra on Despotiko reading ΕΣΤΙΑΣ ΙΣΘΜΙΑΣ (Hestias Isthmias, which essentially means "for Hestia of the Isthmus") may indicate that an isthmus still existed in Classical times (Kourayos, 2006) and probably even later, if the Hellenistic age (Morrison, 1968) of the viticulture trenches on Antiparos is also valid for the very similar trenches on Despotiko (Fig. 3). This reconstruction of the local sea-level rise is in good agreement with the sea-level curve proposed for the whole Cycladic island group by Poulos et al. (2009, fig. 4a) with sea-levels of ca. 5 m below the present position at 5,500 BP and still around -2 m at 2000 BP.

Figure 5: Photograph of one trench west of Panagia on Despotiko exposed by waves and currents. View towards northwest, towards the present farmstead. The trenches are some decimetres wide with quite regular, parallel and almost vertical sides. They have been cut into calcrete; the lower part is not exposed.

The existence of an isthmus would not only have altered the communication paths between the two islands, but Despotiko Bay would also have been even better protected from northwest winds than at present. Despotiko is situated almost exactly in the centre of the Cyclades (as defined nowadays), more so than Delos. This advantageous location, combined with a spacious and protected bay, may explain its former importance as stepping-stone in the Aegean Sea (Broodbank, 2000; Kourayos, 2006).

In addition, modern Despotiko has usually been tentatively equated (e.g. Cramer, 1828, 406; Bursian 1872, 482-483; Kou-

Figure 6: East wall of room A2. The large threshold on the left comprises the massive, coarse grained, slightly greyish marble 2. Marble 1 of the well dressed building stones of the east façade is easily distinguished by its well developed foliation and thin, rose-coloured dolomite layers. Foundation stones are made of white, strongly foliated, mylonitic gneiss. Several orange-brown coloured fractures indicate that the stones have been separated in the quarry along the fractures and these fracture surfaces have hardly been modified later (for colours see the online version of this paper).

rayos, 2006) with the island of ΠΡΕΠΕΣΙΝΘΟΣ (Prepesinthos) in the lists of Cycladic islands in the Geographica by Strabo (book 10, chapter 5, section 3) and in the Naturalis Historia by Pliny the Elder, (book 4, chapter 22) in the translations by Hamilton and Falconer (1856) and Bostock and Riley (1855), respectively. The probable existence of a land connection between Despotiko and Antiparos until at least Hellenistic time would indicate that Despotiko was just a peninsula of Antiparos at that time and not a separate island. Consequently it probably would not have been mentioned by Strabo or Pliny. Thus the sea-level reconstruction, in combination with the ambivalent ancient island listings, recommends a critical reconsideration of this identification.

5.2 Provenance of the building stones

Establishing the provenance of building stones is necessarily based on comparisons of lithological properties between rock artefacts and their potential natural occurrences. The reliability of provenance determination therefore depends on the number and quality of compared rock properties (e.g. optical inspection, thin-section observations, chemical and isotopic analyses, as well as fluid inclusion studies (for Parian white marble see Borschneck et al. 2000; Maniatis and Polikreti, 2000; Schmid et al., 2000; Attanasio et al., 2006; Prochaska et al., 2007 and references cited therein) and on the quality of the geological mapping of the area.

A preliminary 1:10,000 geological map of Despotiko by the author provides essential information about the distribution of different rock types on the island (Fig. 2). This shows that all rock types used in Building A except for marble 2 could theoretically have originated from the island. However, due to the proximity of the sanctuary to the coast, the origin of building stones from neighbouring islands is a possibility. The likely existence of an isthmus (see discussion above) indicates that similar rocks on Antiparos could have been brought to the site by land at that time.

The presence of several small open cast quarries near the sanctuary strongly supports a local origin for at least some of the building stones. Although none show unequivocal traces of tool marks related to quarrying work, the rocks could have been separated along natural joints and foliation planes by levering (Bloxam and Heldal, 2008), as the appearance of many of the undressed rock slabs used in the foundation suggests. Hence extensive tool marks are not to be expected. Furthermore, the rock surfaces in the quarries are strongly weathered, possibly obliterating or obscuring any tool marks.

Seven quarries have been observed in white mylonitic gneiss (Figs. 2, 8), one in dark grey, banded calcite marble and one in calcite marble similar to marble 1 (Fig. 2). At present, the age of these quarries is unclear, but the strongly weathered rock surfaces and dense cover with lichens suggest that they are not young. The quarries which are at maximum of 1.2 km from the sanctuary (Fig. 2) represent potential source areas for the building stones of the sanctuary.

5.2.1 Calcite Marble 1

Calcite marble similar to marble 1 is common in the southern part of Despotiko where it can be found in several layers alternating with mica schist. Based on visual comparison, the lowermost marble layer, just above the white mylonitic gneiss looks very similar to marble 1 of Building A. The closest and lithologically most similar occurrences are at the northern slope of Raches, just 250 m from the sanctuary towards the south-southwest (Fig. 2). Another outcrop with a very similar marble (Fig. 7b) is at Cape Koutsouros in the easternmost part of Despotiko (Figs. 2, 3), which is additionally easily accessible for transporting building stones by boat.

5.2.2 Calcite Marble 2

The provenance of marble 2 from the island seems unlikely because its maximum grain size (up to 4 mm) is much larger than that of any marble on Despotiko. Additionally, the pro-

Figure 7: Comparison between building stones with outcrop lithologies on Despotiko. a) Two building stones from Building A consisting of marble 1 (centre and left part) from the east façade of room A1. Note the carefully dressed surfaces, the white, slightly greyish colour and especially the characteristic rose-coloured layers of fine grained dolomite marble. The building stones below and to the right comprise white mylonitic gneiss. b) Outcrop photograph of marble from Cape Koutsouros (for location see Figure 3), comprising white, medium grained calcite marble with well developed foliation and characteristic rose coloured, thin dolomite marble layers. Note the close similarity with marble 1 from Building A (for colours see the online version of this paper).

duction of large stone objects like the thresholds in Building A, with lengths around 2 m, usually requires a big quarry to break large blocks from subsurface levels, where weathering is less active. Coarse white marble occurs on Paros and especially on Naxos (Lepsius, 1890) and these islands may represent a possible provenance area for marble 2. Since provenance determination of pure white marble is very difficult (e.g. Maniatis and Polikreti, 2000 and references cited therein) further investigations are clearly needed.

5.2.3 Dark grey banded calcite marble

The closest outcrop of this marble lies on the northern slope of Raches, close to its crest, where a small quarry occurs (Fig. 2). However, rounded and weathered fragments of this grey calcite marble can be found in the debris over the whole northern slope of Raches from the crest down to the sanctuary. Thus, the few, small rounded stones found in the filling of the east wall of room A1 were most like picked from the ground close to the sanctuary.

5.2.4 White mylonitic gneiss

White mylonitic gneiss occurs as a discontinuous layer of variable thickness from the very eastern part of Despotiko across to the west, always directly above the grey granite gneiss (Fig. 2). Several small quarries have been found in this lithology; the closest being just 400 m from the sanctuary, towards the west-southwest (Fig. 8); others lie ca. 700 m to the southeast (Fig. 2). Due to the almost identical appearance of this lithology in the field and the building stones and the proximity of quarries, the white mylonitic gneiss could easily have originated from Despotiko.

5.2.5 Grey granite gneiss

Grey granite gneiss can be found over much of the northern coast of Despotiko; about 25 % of the island consists of this lithology and it occurs below the sanctuary (Fig. 2). Although no quarries have been discovered in this lithology, a local provenance of this rock is likely. However, very similar gneisses also crop out on Antiparos and Paros.

5.2.6 Yellowish calcarenite (“poros”)

Numerous bodies of calcarenite occur along the northern coast of Despotiko with several more outcrops on the south coast and on the northeast coast of Kimitiri (Fig. 2). The closest occurrence is just 100 NW of the sanctuary, with another one is 300 m towards the south-southeast (Fig. 2). All these occurrences represent potential provenance areas for the calcarenite (“poros”) in the sanctuary.

6. Conclusions

Submerged archaeological structures at the sea floor of Despotiko Bay (Morrison, 1968), a Classical marble inscription from the sanctuary reading ΕΣΤΙΑΣ ΙΣΘΜΙΑΣ (Kourayos, 2006) and partly submerged, possibly Hellenistic, agriculture trenches on the east coast of Despotiko, suggest that the relative sea-level in this area was at least 3 m lower during the Early Bronze Age and still more than 1 m lower during Hellenistic time. This implies that an isthmus may have linked Despotiko, Kimitiri and Antiparos at least until Hellenistic time.

Six lithologies have been recognized in the building stones of Building A at the archaic sanctuary at Mandra, on Despotiko. (i) Medium grained white calcite marble with thin, rose-coloured dolomite marble layers (marble 1), (ii) coarse, white calcite marble (marble 2), (iii) white mylonitic gneiss and (iv) grey granite gneiss represent the most important lithologies, while (v) dark grey banded calcite marble and (vi) yellowish calcarenite (“poros”) have been found only rarely.

The well dressed, rectangular and even faces of the eastern façade of Building A are exclusively made of marble 1, which is also commonly used rough or variably dressed for all other walls. The large and very well finished thresholds are solely made of marble 2. Partly dressed or rough white mylonitic gneiss was used for the inner side of the buildings eastern wall as well as for most other walls and represents by far the most common foundation stone.

With exception of marble 2 all rock types of the building stones in Building A of the sanctuary can be found on Despotiko and therefore theoretically could originate from the island. Possibly local provenance of at least some building stones is fur-

Figure 8: Overview photograph of the quarry in white mylonitic gneiss on the northern slope of Raches, 400 m west southwest of the sanctuary (for location see Figures 2 & 3). The quarry is about 16 m long and more than 2 m high. Back bag for scale.

ther supported by nine (presently undated) quarries, seven in white mylonitic gneiss, one in dark grey calcite marble and one in white calcite marble resembling marble 1.

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