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QUARRYING THE COASTS OF CRETE IN ANTIQUITY; SOME GEOARCHAEOLOGICAL CONSIDERATIONS

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Abstract

The paper discusses three aspects of coastal quarrying in the island of Crete, Aegean Sea, Greece; issues of chronology in regard to the Mean Sea Level in antiquity, issues of ancient technology, and issues of local marble extraction. A series of violent seismic events, the most known being the so-called Early Byzantine Tectonic Paroxysm, affected the morphology of the coastline of Crete, the coastal quarries of which are today either uplifted or sunken. Quarries of aeolianite/sandstone, limestone, marble, and beach rock are related to adjacent rock-cut fish tanks and ship sheds. Traces of the ancient exploitation such as the circular holes observed in the coastal quarries are differentiated according to their dimensions and their natural or manmade form. A preliminary report of a new site, a white marble quarry at Istron (Gulf of Merambello, eastern Crete), is added to the white marble quarries of the area and correlated with the graffiti inscribed on the islet of Prasonēsi or Vryonēsi.

Keywords: *Crete, quarries, wedges, marble, sea-level indicators, technology.*

Περίληψη

Η εργασία πραγματεύεται τρεις όψεις της παράκτιας λατόμησης στην νήσο Κρήτη (Αιγαίο Πέλαγος, Ελλάδα), οι οποίες αφορούν ζητήματα χρονολόγησης *ως προς την Μέση Θαλάσσια Στάθμη κατά την αρχαιότητα, ζητήματα αρχαίας τεχνολογίας, καθώς και εξόρυξης του εγχώριου μαρμάρου. Μια σειρά βίαιων σεισμικών γεγονότων, το γνωστότερο των οποίων είναι ο λεγόμενος Τεκτονικός Παροξυσμός της παλαιοχριστιανικής περιόδου, επηρέασε την μορφολογία της ακτογραμμής στην Κρήτη, με αποτέλεσμα τα παράκτια λατομεία της νήσου να είναι σήμερα είτε ανυψωμένα είτε καταβυθισμένα. Λατομεία αιολιανίτη / ψαμμίτη, ασβεστολίθου, μαρμάρου και ψηφιδοπαγούς αιγιαλού συσχετίζονται με παρακείμενες ιχθυοδεξαμενές και νεωσοίκους που έχουν λαξευτεί στον βράχο. Ίχνη αρχαίας εξόρυξης, όπως οι κυλινδρικές οπές που παρατηρήθηκαν σε παράκτια λατομεία, διαφοροποιήθηκαν ανάλογα με τις διαστάσεις και την φυσική ή τεχνητή μορφή τους. Η προκαταρκτική παρουσίαση ενός λατομείου λευκού μαρμάρου στον Ίστρο, στον κόλπο του Μεραμπέλλου στην ανατολική Κρήτη, προσθέτει μια ακόμα θέση στον κατάλογο των λατομείων λευκού μαρμάρου της περιοχής και συσχετίζεται με τις επιγραφές που χαράχτηκαν στην νησίδα Πρασονήσι ή Βρυονήσι.*

Λέξεις κλειδιά: *Κρήτη, λατομεία, σφήνες, μάρμαρο, δείκτες στάθμης της θάλασσας, τεχνολογία.*

1. Introduction

The mythology of Crete Island is one of Labyrinths and legendary kings. After all, the flourishing Bronze Age civilization (circa 1900-1450 BC) was conventionally named after the mythic king Minos by Sir Arthur Evans (1921, 1) and generally adopted by archaeologists (Compare the terms “Cretan period”, “pre-mycenaean” and “Cretan Camaraic” used by Xanthoudides, 1906, 148, 154). The impact is such that the archaeology of Crete is at some point dominated by the Minoan civilization and certain archaeological myths. The majority of the islands’ published quarries are considered to be (or are) Minoan in date (see Shaw, 1971; Tzedakis et al., 1989), even though the island has been inhabited unceasingly ever since. The fact that some quarries must have operated in the Bronze Age does not necessarily mean that the traces of wedge slots and tool marks still evident on the quarries’ fronts represent that time period. The search for traces of cranes and drills combined with the appearance of cylindrical holes in several coastal parts of Crete has also led to misinterpretations about their function, as in the case of Sir A. Evans (1928, 233). Last but not least is the prevailing myth that Crete lacks marble (Xanthoudidēs, 1906, 150; Boardman, 1982, 31), and that marble was imported in Crete in the Roman period (Paton & Schneider, 1999).

The ancient coastal quarries of Crete (Fig. 1) are of special interest due to the idiomorphic coasts, today either sunken or raised (Spratt I, 1865, 141; Stiros, 2010). In some cases, the ancient quarries at the western part of the island are raised and quarries at the eastern part are partly sunken below modern sea level. It is a general trend, as in Kissamos Bay, that some ancient quarries are uplifted, whereas some Venetian ones are sunk, indicating a continuous tectonic instability of that area.

Fig. 1: Satellite image of the Island of Crete. (Source: NASA *http://eoimages.gsfc.nasa.gov/images/imagerecords/51000/51726/ISS028-E-018562_lrg.jpg*. Astronaut Photograph ISS028-E-18562 acquired on July 22, 2011).

The quarries –usually of limestone and sandstone, but also of marble (see Tziligkaki, 2014, Table of Quarries, 445-462)- represent only an aspect of the activities undertaken by the Cretans in the coasts of the island. For instance, the small, naturally formed cove of Limnē at Akrotēri Peninsula, surrounded by rocky hills, was converted into a real port by the Venetians, the so called Porto-Novo (Theophaneidis, 1950-51, 12). It had a capacity of 40 galleys in 1594 AD, when the Venetians took the decision to have the narrow and shallow rocky entrance -perhaps a result of the geological elevation of the land- opened and deepened (Theophaneidis, 1950-51, 12 n.1). According to Gerola (1932-1940, 120) this project was fulfilled within two months by the “famous as skillful quarrymen Akrotēri inhabitants”. For this reason they were speared from any compulsory labor in the Venetian galleys, a privilege that they continually exercised (*op.cit.*).

The Venetians may have overcome the upraised land in just one case, but the reality in the western coasts of Crete is one of ports and fish tanks going out of use. The most characteristic example is that of the port of Phalasarna that remained disused throughout antiquity (Spratt, 1865, II 232-233; Hadjidaki, 2001). Fish tanks in the western part of Crete remain now above sea level. In the location of Haghios Georgios at Korakas (or Koumbeli) in the Akrotēri Peninsula, dated by Raab (2001, 100, Site KK2) in the early Roman period, a fish tank lies today just above the surface of the sea (Moody 1987, Part I, 23).

On the other hand, part of a coastal aeolianite/sandstone quarry in the same area lies now at 1m below sea level, whereas a tidal notch is visible at 1 m to 1,5 m above modern sea level (Raab, 2001, 100). Of course, micro tectonic variations are not excluded, as in the case of Kissamos Bay. The limestone quarry of Viglia (Fig. 2) is now partly submerged, whereas in ~1400 m to the west, the sandstone quarry close to Kalyvianē (Fig. 3) is upraised (Tziligkaki, 2014, site X26,p. 86-89, Fig. X131-X161 for Viglia, and site X31, p.89-90, Fig.X162- X173 for Kalyvianē). In the site of Chōna at Palaiochora (southwestern coast) a coastal millstone quarry is located in the height of the present day sea level (Theodoulou, 2011, 47, Fig. 4; Tziligkaki, 2014, site X44, p. 112).

Fig. 2: Viglia, Kissamos bay (western Crete). Partly submerged limestone quarry. Scale of 0,32 m.

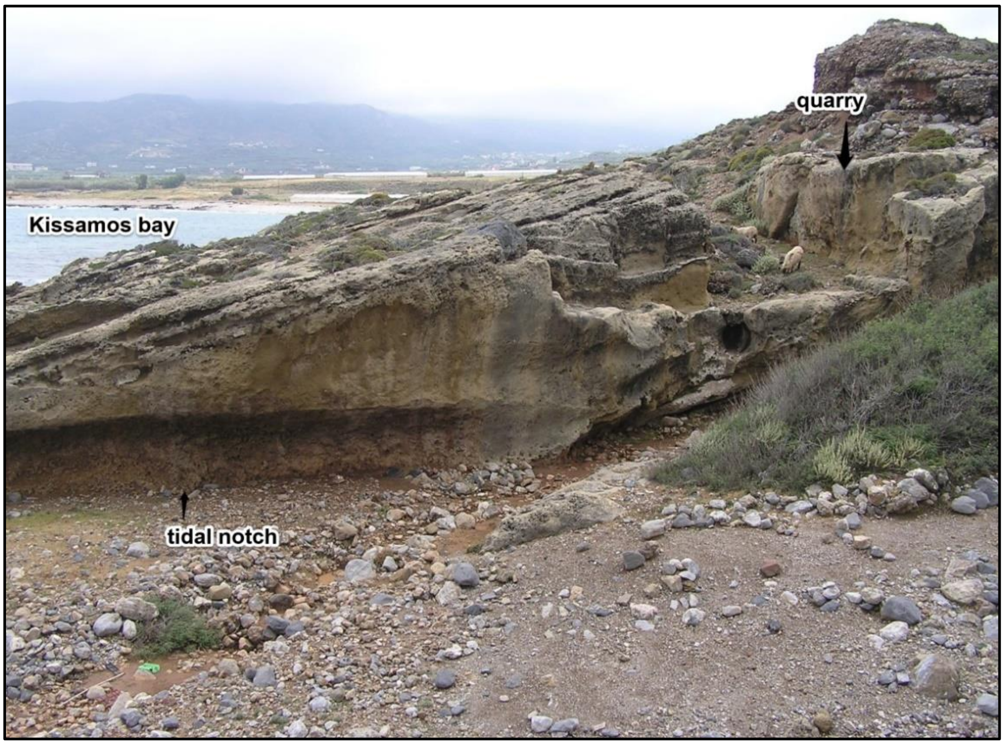

Fig. 3: Kalyvianē, Kissamos bay (western Crete). Upraised coastal sandstone quarry.

2. Method

2.1. Sea level indicators

The sunken coasts of Crete, and therefore the sunken quarries of the island, deserve a different approach, which demands the contribution of Geology. Violent tectonic events, such as the Early Byzantine Tectonic Paroxysm (Spratt, 1856, II 231-233. Laborel et al., 1979; Price, 2002; Stiros, 2010), or the tectonic movements of eastern Crete from the Quaternary until today (Mourtzas, 1990; Mourtzas, 2012b), combined with the phenomenon of eustatism (Poulos, 2011) perplex the identification of the mean sea level in antiquity. According to Pavlopoulos et al. (2011, Table 1, Fig. 5) an uplift is observed in the western and eastern ends of Crete, while the central part of the island subsides, as in the case of Chersonēsos and Matala.

Tide Poles and Automatic Tide Gauges in two ports of modern Crete, Souda Bay to the west and Heraklion port in central Crete, help estimate the changes of sea-level in the coasts of Crete (Hydrographical Service, 1991). In Heraklion port, the mean sea-level in the years 1951-1988, is 0,97 m, whereas in Souda Bay the mean sea level reaches 1,26 m; the maximum high tide at Heraklion reaches 0,37 m, the equivalent at Souda 0,90 m (Hydrographical Service, 1991).

The presence of submerged tidal notches and beach rocks at the coasts provide evidence for the existence of old shores that have been fossilized, and for neotectonic movements (Evelpidou, 2011, 30-32; Pirazzoli & Evelpidou, 2013, Fig. 1). The vertex of the U-shaped or V-shaped profile of the tidal notches helps roughly estimate the possible duration of relative sea-level stability that is necessary for the inward deepening of the notch profiles (Evelpidou, 2011, Fig.8; Pirazzoli & Evelpidou, 2013, 377). Not every sunken archaeological remain provides a safe sea level change indicator (Pirazzoli, 1988, 162-164; Lambeck et al., 2004, 564; Evelpidou, 2011, 32-33). The proximity of installations such as breakwaters, jetties, ship sheds or fish tanks provide sufficient sea-level indicators, as long as the measurements take into consideration certain parameters, such as the tide. Measurements of the emerged part with respect to the average sea level, the estimated time of construction and abandonment, as well as the evaluation of both the height and functional depth to the mean sea level, play an important role in understanding mean sea level changes in correlation to archaeological remains (Auriemma & Solinas, 2009).

In cases of sunken breakwaters and jetties, the measurements concerning the depth below modern sea-level should be taken from the highest surviving point of the construction (see Evelpidou et al., 2018), unless otherwise indicated, as in the case of Kouremenos (eastern Crete), where the uppermost surviving part of the breakwater, which lies -1,50 m below modern sea level, is considered to be later or even modern (Simosi, 1988, 21, 22 Fig.2, 26-27). The functional height for harbors is estimated at 0,6-1,0m above Mean Sea Level, for breakwaters at 0,6 m above Mean Sea Level (Antonioli et al., 2007; Pavlopoulos et al., 2011). In the port of Hellenistic Phalasarna (western Crete) both quays protruded from the sea level of 335 BC around 0,40 m. (Hadjidaki, 2001, 156), a significant datum for the estimation of the Mean Sea Level in sunken Hellenistic harbor installations. The functional height for fish tanks is estimated at 0,6 m above Mean Sea Level (Antonioli et al., 2007; Pavlopoulos et al., 2011). The existence of the sluice gate provides an excellent sea-level indicator for the Roman period (Lambeck et al., 2004, 566 Fig.3 B-D; Evelpidou, 2011, 33-35, Fig.13). Normally, the functional height for coastal quarries is estimated about 0,30 m above Mean Sea Level (Lambeck et al., 2004; Pavlopoulos et al., 2011). But in Sicily, the sluice gate of a sunken fish tank helped the archaeologists deduce that the functional height of the Roman quarry's floor (nowadays sunken) would be estimated around 0,60 m above sea level (Scicchitano et al., 2012).

On the other hand, the same progress has not been made as far as the ship sheds are concerned. The original dry length of the rock-cut slipways' ramp "is a complicated issue that interrelated with the determination of relative sea level changes since antiquity", admits Baika (2013a, 244). Measurements taken with sheer reference to the modern sea – level have not provided so far any insight to the ancient mean sea level and the actual part of the slips that were underwater in antiquity.

The reported rock-cut ship sheds and fish tanks from Crete are located in the vicinity of coastal quarries; close to the modern Rhethymnon port, a ship shed, the quarries of Koumbes and further to the west the quarry of Petres are situated (see Tziligkaki, 2014, sites P7 and P1 respectively). The ship shed and the eleven fish tanks at Matala lie in the vicinity of the large quarry in the acropolis of Matala (Shaw & Shaw, 1995, 336 site 11, 635, Pl. 7.3B and Pl.7.50; Tziligkaki, 2014, site H45). At "Sta Ferma" (close to Ierapetra) the fish tank is situated close to a quarry, whether coastal or not is not reported (Davaras, 1975, 153; Tziligkaki, 2014, site Λ74). The fish tanks at Chersonēsos could be correlated with the beach rock quarry (see 3.1.1, Fig. 4). In the site of Itanos, a quarry, now sunken at a depth of -3m, lies close to a quarried beach rock formation which now lies underwater, at a depth of between -3 and -4 m (Baika, 2013c, 569). With the exception of Mourtzas' research (see *infra*) about the fish tanks at Matala and Sta Ferma, that correlated the sunken antiquities with sunken shores, the rest of the coastal installations need a readjustment of the measurements taken in relation to a geophysical and geomorphological research (coring and tracing of tidal notches). An analogous research was undertaken in Naxos Island (Cyclades, Aegean), where the quarried beach rock formation at Mikrē Vigla was correlated with drillings and submerged tidal notches (see Evelpidou et al., 2018).

2.2 Tool marks

Installations such as quarries and ship sheds are difficult to date, mainly because of the continuity in their use. An excavation is difficult to be conducted on the rocky coasts, because of the waves that have washed away soil and pottery. The tool marks left on the rocky surfaces seem to be sufficient evidence so far for establishing the date of construction (on defining different quarrying phases by means of the mark left by the tools' edge, see Bessac, 1993, 213; Tziligkaki, 2014, 31-38, 503-507).

2.3. Quarries of marble

The operation of modern quarries in Crete can help trace ancient ones. It is common practice for the modern quarries to be located in the site of ancient quarries or at least close to them (Tziligkaki, 2014, 513). The quarry of grey marble in the site of Dichali, in the village of Haghios Kyrillos in the Mesara Plain, is the most characteristic case of a modern quarry that has destroyed the ancient phases due to its continuous use (Tziligkaki, 2014, site H57, 513).

3. Fieldwork in ancient and old Quarries - Results

3.1 Beach rocks

Beach rock has been quarried as building material in three cases so far, in Late Minoan Zakros (Shaw, 1971, 27; Kelletat, 1979, 38-39), Itanos (Baika, 2013c), and in the western bay of Limenas Chersonesou (Kelletat, 1979, 22). In the western bay of Limenas Chersonēsou (a site with Hellenistic, Roman and Early Christian relics) thirteen rectangular blocks of beach rock remain *in situ*, still attached to the rock, but not extracted although the channels separating one from the other were cut (Fig. 4). The blocks are 0,90 m long and ca. 0,35 m wide. Their height cannot be measured due to the accumulation of sand and the waves. The width of the channels ranges from 0,08 m to 0,10 m (Tziligkaki, 2014, site H34). In Itanos, a site in northeastern Crete with relics dating from the archaic to the Early Byzantine period, five parallel compartments, whose depth ranges from 0,40 m to 0,80 m, are quarried in the submerged beach rock shoreline. They are located at a depth of -3m to -4 m (Baika, 2013c, 569).

3.2 Fish-tanks

The examination of sunken fish tanks in the central Tyrrhenian coast (Italy) concluded that at the time of their construction (from about 100 BC to 100 AD) the sea levels were between 1,1m and 1,8m lower than today (Lambeck et al., 2004, 564-6, 571). The results are consistent with the ones provided by the examination of fish tanks in the southern coasts of central and eastern Crete. Mourtzas (2012a; id. 2012b) estimated the mean sea level of the sandy coasts of Matala in the 1st and 2nd c. AD, based on the study of eleven sunken fish tanks at Matala bay. The coastal submersion in central and eastern Crete is connected to the earthquake of 1604, due to the fact that Buondelmonti fully describes the fish tanks when he visited Matala in 1415 (Buondelmonti, 1981, 110, lines 169ff), whereas Captain T.A.B. Spratt (1865) interprets them as sunken tombs (Mourtzas, 2012a, 893; Mourtzas, 2012b, 2404). Mourtzas' research concluded that the mean sea level at the sandy beaches of Mesara and Matala in the 1st and 2nd c. AD was 1,25m lower than the modern one (Mourtzas, 2012a, 892, 894; Mourtzas, 2012 b, 2404, 2405, Fig.9). The earthquake of 1604 AD caused the coastal submersion by -1,25 m, which resulted to a sea transgression 30 m long (Mourtzas, 2012a, 894).

Fig. 4: Limenas Chersonēsou (north Crete, Herakleion Prefecture). Beach rock quarry in the western bay. Scale of a 1 euro coin (lower left).

At the site of “Sta Ferma”, close to Ierapetra, Davaras (1975) reported a rock-cut fish tank. Eventually Mourtzas (1987, 99, 100 Fig. 2, 102 Fig. 3) identified a system of three rectangular tanks, which he interpreted as salt-pan and fish tank. During his underwater survey he spotted an old sunken shore in a depth of -1,30 m. This datum shows that the sea level in the Roman times was at least 1m lower than the modern one, in order for those constructions to function (Mourtzas, 1987, 101, 103 Fig. 7, 104).

A pair of fish-tanks is reported from the area of Mochlos (Leatham & Hood, 1958-59, 265. The island itself has antiquities that date to the Bronze Age and the Early Byzantine period, see Soles & Davaras, 1992, 442). Their floor are about 1,50 m below modern sea level. A fragment of stone slab with regular perforations found in the eastern fish-tank is the sluice gate (Leatham & Hood, 1958-1959, 265, 275, Pl. 63a; for the placement of the sluice gate, see Lambeck et al., 2004, Fig.3 B, D). The floors of three fish-tanks at Chersonēsos, arranged in a row, now lie between 1,95m and 2,20m below modern sea level (Leatham & Hood, 1958-1959, 265, Fig.2 nr.14). In the site of Peleki at Kato Zakros a fish tank, now submerged, lies close to a sandstone quarry (Nakasis, 1987, 85-86; Papageorgakis et al., 1994, 159).

On the other hand, the existence of Roman fish tanks in the modern city of Sēteia, as suggested by Davaras (1974) is rejected by Papageorgakis et al. (1994, 149) and Mourtzas (2012b). They support that these are the relics of an aeolianite quarry whose floor lies nowadays from -0,40 m to -1 m (*op.cit.*).

3.3 Ship sheds

Single rock-cut slipways and ship sheds have been found at Trypētos Seteia [Davaras, 1967; Baika, 2013a, 238 Fig. A12.4 (a)], at Matala in the southern coast (Crile & Davaras, 1963; Blackman, 1973; Shaw & Shaw, 1995, 75; Theodoulou, 2011, 44; Baika, 2013 a, 237, 239 Fig. A12.5; Gerding, 2013) and Rhethymnon (Baika, 2013 b). The longitudinal groove in the slipways R1 and R3 of Rhethymnon (“keel-slot”) has been interpreted “as a base for the installation of a longitudinal wooden runner on which the keel of the ship could slide during hauling and launching operations” (Baika, 2013 a, 241, 242

Fig. A12.7). At Rhethymnon the sea ward extremity of the “keel-slot” of the Northern rock-cut slipway lies 0,10 m below sea-level (Baika, 2013b, 501, 503 Fig. B19.2, 504). The three rock-cut slipways are now attributed probably to the Classical or rather to the Hellenistic period (Baika, 2013b, 506).

The rock-cut floor of Trypētos’ slipway at Seteia (eastern Crete) continues below the present sea level for a length of almost 2 m before it is cut off (Baika, 2013a, 245, 247 Fig. A12.11; Baika, 2013d, 519, 521 Fig. B21.2). Sockets of considerable dimensions at regular intervals of 1-1.10 m have been observed along the sides of the slipway that now is underwater (Baika, 2013a, 245; Baika, 2013d, 520, 521 Fig. B21.2). The slipway is considered to be contemporary to the Hellenistic city excavated nearby, and therefore it is tentatively dated to the period ranging from the early 3rd to the mid-2nd century BC (Baika, 2013d, 522).

The lowest part of the Matala slipway has been cut or eroded away, but its side walls continue into the water for some distance (Gerding, 2013, 390). In Itanos, in the bay of the valley extending to the south of the eastern acropolis, parallel longitudinal cuttings, like “keel-marks” were traced in a depth of -5m in the surface of a hardened sandy shore (Baika, 2013c, 569).

3.4 Cylindrical holes

To the north and east of Achlada at Haghia Pelagia, Epting (1969, 51, 53) noticed some hollow channels, some holes in the shape of tubes, which sometimes protruded up to 0,15 m from the surface of the sandstone. He interprets them as remnants of previous dunes that were covered with plants. The sand was cylindrically cemented around them with the help of the material that disintegrated from the numbed roots (Epting, 1969, 53). The same circular holes appear in the shore, at the coastal sandstone quarry of Stavros (Fig. 5) at Akrotēri Peninsula and at Nirou Chani (Tziligkaki, 2014, 504). Some of them may be artificial, but in general they should be interpreted as the roots and trunks of coastal vegetation that grew on the dunes before they were fossilized. The same applies to the coastal quarry of Malia (Shaw 1971, 36-38; Guest-Papamanoli, 1989, 115). Some of those cylindrical holes have an ovoid section; their diameter reaches almost 0,10 m - 0,15 m and their depth 0,20 m. Their inner surface is smooth, yellow and harder than the surrounding rock (Guest-Papamanoli, 1989, 115, 117 Fig.4). According to Guest-Papamanoli (1989, 115,122) some of these holes could have been opened by the quarrymen, in particular by the Minoans for the insertion of poles and wooden beams. It is even reported that some with an ovoid section were finished, in order to become square (Guest-Papamanoli 1989, 122). An exception to these relatively small-sized tubular holes is a very large cylindrical one whose diameter measures 1,35 m and its depth 0,50 m - 0,60 m. Nowadays it is full of sand (Fig. 6. Usually, the cylindrical holes of 0,18 m - 0,23 m, reach 1,00 m in depth, a characteristic that was noticed in a similar case at Potamos beach, Malia).

Fig. 5: Stavros, Akrotēri Peninsula (western Crete). Circular holes in the area of the coastal sandstone quarry. Scale of 0,32 m.

Fig. 6: Malia, Potamos beach. Cylindrical hole (1,35 m in diameter), now full of sand, in the area of the sandstone quarries.

On the contrary, certain circular holes of 0,04 m in diameter reported from coastal and inland quarries are indeed traces of quarrying activity (Tziligkaki, 2014, 504-506 with reference to Cretan sites). The one found in the coastal limestone quarry of Petres (Fig. 7) is very similar to the one found in the limestone quarry of Vrysidia at Eleutherna, at an altitude of 345 m in central

Crete (Tziligkaki, 2014, site P1 for Petres, and site P24 for Vrysidia). The usual practice was to insert wooden cylindrical wedges that would help the rock to fracture; a practice used in Poland and medieval whetstone quarries at Crete (see Dworakowska, 1987, 28; Mamakis, 2004, 113, 116). In the Northeastern islands of Greece, Lēmnos, Lesvos and Chios, the medieval tool used for the opening of holes is called *tsokos* (a tool with two points) or *velones* (see Digital Charter).

Fig. 7: Petres (north Crete, Rhethymnon Prefecture). Circular hole (0,04 m in diameter) in the coastal limestone quarry. Scale 1:2.

The small diameter of these holes is very indicative of the aforementioned use. The possibility that these cylindrical wedges were also metallic is enforced by the find in the new quarry site at Istron (Fig. 9).

3.5 Marble

The existence of various types of marble on Crete is not a myth, at least not among geologists (Vidakis et al., 2001). Excavation reports mention the use of marble on Crete since the Bronze Age (Lazzarini et al., 2002). Various types of marble, such as white, red, black, white with black veins and grey with white veins, were used for floors, column bases and perhaps for wall revetment in the “palace complex” of Archanes (Sakellarakis & Sapouna – Sakellaraki, 1997, 140). Whether imported or not it is not mentioned).

The Geological Map of Greece, *Antiskarion* Sheet, marks grey marbles (mr1) in the area of Haghios Kyrillos (Davis & Bonneau, 1972). The grey marble quarry that operated since antiquity at the location Dichali in Haghios Kyrillos at Mesara Plain, mostly known with the commercial name of “Phaistos marble” (www.kmarbles.com. Lazzarini (2002) suggests the name “Marmo Gortinio”), provided columns for ancient Gortyna. Its existence was already known in 1903 (Nouchakis, 1903, 133). Up until Lazzarini’s (2002) publication almost all studies referring to the marble parts of Gortyn’s monuments referred to a “grey granite” (Spratt, 1865, II, 35; Nouchakis, 1903, 133; Sanders, 1982, 63, 73, 80, 81; Ricciardi, 1986-87, 95; Paton & Schneider, 1999, 284. Di Vita 2000, XLVIII Fig.25).

The most known types of Cretan marble according to Tsirambidis (1996, 262-266) are: Doxaro semi-white, Aloides semi-white, Agia semi-white, Achlade grey-white, Moundros grey, Haghios Kyrillos grey, Phaistos grey-black, Damasta grey-black, Moundros black, Agia black, Haghios Vassilios red, Vasilikon coloured banded. The Cretan marbles exhibit a quite high indicator of hydro absorbency, low resistance in pressure, bending, and damage due to friction in comparison with the marbles of Paros, Naxos and Pentelikon (Tziligkaki, 2005, 369 Pl. II, with data based on Tsirambidis, 1996). Perhaps this is one of the reasons why these were not widely preferred in antiquity. The aforementioned types of marble have been exploited till recent times, with the exception of one quarry that remains intact since antiquity; the white marble quarry in eastern Crete, at the site of “Kionia” or “the Rods of Digenis”, seems to have operated at least since the 7th /6th c. BC (Platōn, 1953a, 297; Platōn, 1953b, 489) until the Roman conquest of Crete in 67 BC (Durkin & Lister, 1983, 82-83. The Third Period of the Athenian Pnyx is now dated around 340 BC according to Rotroff & Camp, 1996, and not in the early 4th c. BC, as assumed by Dworakowska, 1975, 42-44 and Durkin & Lister, 1983). Two coastal white marble quarries in the area of Istron in eastern Crete reveal some interesting aspects of quarrying in the 1st and 2nd centuries AD.

3.6 The area of Istron

The local stone in the area of Istron (Merambello Gulf) is mainly marble (Platakis, 1981, 142; Langosch et al., 2000, 341; Tziligkaki, 2014, site Λ8. The site has been inhabited since the Final Neolithic, see Hayden et al., 2004). Captain Spratt (1865 I, 139) noticed several marble pieces in the site of Istron, among which half a dozen large ceiling coffers (Hayden et al., 2004, 193 n.14; Hayden et al., 2005, Pl. 6f). In 1415 Buondelmonti (1981, 161) notices that much of the worked marble (blocks, columns and foundations) from Nisi Pandeleēmon was shipped to Herakleion for the construction of churches and mansions. It is possible that the large coffer lying near the chapel of Haghios Pandeleēmon may have been taken from the Hellenistic temple of Athena Polias and reworked in the Byzantine period (Hayden et al., 2004, 193 n.14). A large marble block with *anathyrosis* and worked marble blocks, probably reused, were found on the northern edge of Istron, and probably belong to a large, administrative or religious, Greek (pre-Roman) structure (Hayden et al., 2004, site IS1, 169; Hayden et al., 2005, Pl. 3c).

At Priniatikos Pyrgos, within the Istron River valley, marble Corinthian capitals of probably late 2nd-early 3rd century AD (Hayden et al., 2004, site PR1, 202; Hayden et al., 2005, Fig.12, Pl. 10 d-e), a small rectangular block, monolithic marble columns, either fluted or smooth, whose preserved length reaches 2,50m, can be associated with Roman buildings (Hayden et al., 2004, 203; Hayden et al., 2005, Pl. 10f). They are made of white or creamy in color marble, whose provenance is likely to be a small marble quarry on the top of nearby Ginara (Hayden et al., 2004, 203; Hayden et al., 2005, Fig. 8, Fig.11-12). Near the chapel on the west side of Nisi Pandeleēmon a large coffer, probably re-worked in the late Roman/ Early Byzantine period, may be made of this same quarry (Hayden et al., 2004, 203, 216 n.23; Hayden et al., 2005, Pl. 6f). A fragment of a probable marble altar screen and a large ceiling coffer are of the same grey marble (Hayden et al., 2004, 203; Hayden et al., 2005, Pl. 10c).

The sunken white marble quarry to the east of Istron

This coastal quarry lies in a distance of 14 km, to the east of Haghios Nikolaos, a little distance to the west of Gournia. The quarry area has been quite damaged by intensive cultivation and dynamite explosion, that is the reason why the collection of surface pottery cannot be particularly trustworthy; nevertheless Harrison (1990, 148) dates the quarry from the early 1st c. till the late 2nd AD on the basis of very distinctive profiles of sherds. The marble is white crystalline, coarse grained with pale and not regular orange veins (Harrison, 1990, 149). Its exposed parts appear significant staining and oxidation, which is owed to their iron content (Harrison, 1990, 149). The marble quarry appears as a protrusion between veins of the common Cretan gray porous limestone. Both the marble and the limestone are covered by conglomerate that mainly consists of broken marble and other rock fragments (Harrison, 1990, 149). The quarry's maximum height is almost 5,60 m above sea level in the SW corner, whereas other parts are sunken more than 1 m in the water. The deepest sunken location was spotted in a depth of -1,80 m in a distance of 10,20 m from the NW corner (Harrison, 1990, 148). A submarine research in the small limestone promontory at the western side of the sandy beach of Istron proved the submersion of this area since antiquity; two submerged tidal notches at a depth of -0,70 m and -1,90 m were identified, which must correspond to the two submerged shorelines of the bay in a depth of -0,60 m and -1,50 m (Mourtzas, 1990, 297, Fig. 83c).

4. Discussion

Normally, cylindrical holes of larger diameter, i.e. 0,18 m - 0,20 m and 0,30-0,35 m deep, are intended for the insertion of wooden poles that support the quarried material to be lowered with the help of ropes tied around them (Papageorgakis, 1963, 569, pl. I Fig. 2 for the marble quarries at Zasteni, Tissaion Mountain in Thessaly. For a reconstructed case from Pentelikon quarries with square or rectangular holes, see Korres, 1994, 103 n.28; Orlandos II 1994, 91 Fig.32). Such holes are observed in the fringes of roads used for the transportation of the quarried stones. In other cases, they are interpreted as holes for the insertion of poles that belonged to a crane; in the Hellenistic House-A at Eleutherna, cylindrical holes of 0,20 m - 0,30 m diameter found in the quarried and levelled floor of the house, are attributed to wooden cranes that helped hoist the big rectangular blocks (Kalpaxis et al., 1994, 51, Pl. 12.1, Pl. 15.3. Their depth is not mentioned).

Apart from the aforementioned cases, the present paper differentiates between the cylindrical holes found in coastal sandstone quarries (a result of fossilization of dunes) and the holes made by quarrymen to help the stone fracture. The “deep circular borings” and the “large vertical drill – hole” reported from the Greco-Roman quarries in Knossos (Hood & Smyth, 1981, 54 n.264 and 266, 61 n.363) and from the aeolianite quarry of Korakas or Koumbeli in the Akrotēri Peninsula (Moody, 1987, Part II, site KK3) could be interpreted as holes for the insertion of cylindrical wedges.

The rock-cut shipsheds at Trypētos (Setēia) and Matala, as well as the rock-cut fish tanks in Akrotēri Peninsula, Phalasarna, Matala, Zakros, and Sta Ferma Ierapetras (see Tziligkaki, 2014, cat. nos Λ25, H43, X2, X38, H43, Λ45, Λ74 respectively) presuppose sufficient knowledge in quarrying techniques, since the dimensions of such trenches are not negligible. Could the proximity of quarries and roman fish tanks help date the former? Mourtzas (2012a, 885) considers the quarries and the fish tanks of Matala as contemporary and dates everything to the 1st -2nd century AD. The quarries in the city of Setēia, at Peleki of Kato Zakro , and Sta Ferma of Ierapetra could be compared with analogous cases in the area of Porec in Croatia (site of Kupanja, Červar – Loron complex, see Florido et al. 2011, 106) (Tziligkaki, 2014, 416, 435, cat.nos. Λ24, Λ45, Λ74). They could have been parts of complexes or trade centers of the area whose activity focused in the trade of fish, stone, always in places close to harbors (Tziligkaki, 2014, 507-8). It is questionable, however, whether the same applies to the quarry of Phalasarna which dates to the Hellenistic period (Pirazzoli et al., 1992, 385; Tziligkaki, 2014, 83 cat no. X37). Pirazolli (1988, 168) assumes that the half-finished fish tank close to the quarries operated due to a fissure probably caused by an earthquake, hence the lack of the seaward openings. The sunken part of the aeolianite quarry at Korakas or Koumbeli (Akrotēri Peninsula), which lies close to an upraised fish tank (Moody, 1987, Part 1, 23), could date in the Late-Roman period and requires a new examination (Tziligkaki, 2014, 508).

A transportation of the extracted stone via sea is suggested for the coastal quarry of Petres. Apart from the fact that part of the quarry is now sunken, there is no evidence for the existence of a land route according to the descriptions of Spratt (1856 II) and Kalomenopoulos (1894, 345-346; Tziligkaki, 2014, 117 cat.no. P1. For the quarrying of stone close to the loading area, see Pirazzoli, 1988, 162). The sunken coastline of Matala by -1,25 m and the sea transgression by almost 30 m (Mourtzas, 2012 a, 894) indicate the transportation of the extracted blocks by boat. The safe anchorage provided by the islet Prasonēsi or Vryonēsi in the area of Istron (Merambello Gulf) is discussed below with reference to the transportation of marble.

According to Harrison (1990, 150) the marble coming from the quarry to the east of Istron was probably used for some capitals, bases, architraves and reliefs during the Antonini period in Gortyn and Knossos. Especially at that period of time the Parian marble quarries went out of use; according to Korres (2000, 72) the underground quarry of Nymphs on Paros ceased to operate around the middle of the 2nd c. AD, probably due to a violent co-seismic phenomenon that led to the sinking of the coastline, a sea level rise and sea transgression in the coast (see Evelpidou et al., 2018). Some *spolia* in Basilica A and B at Chersonēsos are reluctantly attributed by Harrison (1990, 150) to this quarry. Sythiakaki (2010, 369) on the other hand, attributes the marble column of the Early Christian Basilica B, made of white snow marble with wide blue-gray and faded veins, to Prokonnēsos' quarries, as a result of Constantinople's control over such peripheral temples. Nevertheless, the existence of local workshops on Crete during the Roman imperial period is deduced by some pieces that are of rather poor quality, as well as by some half-finished works (Karanastasi, 2012, 444; Sporn, 2012, 452, 458ff). The repetition of the same types of statues is observed not only on Crete, but also in sculptures found in North Africa and especially Cyrenaica (Karanastasi, 2012, 446), an area that along with Crete formed the "*Provincia Creta et Cyrenae*" (Karanastasi 2012, 433, n.1). Not to mention that Lazzarini (2002, 228) considers that the "Phaistos marble" also appears in the "Central Roman

Quarter" of Cyrene in the form of columns and capitals, and in Apollonia of Cyrene as revetment slabs. Sir Arthur Evans (1928, 70) mentions a Roman road that led from the marble quarry of Haghios Kyrillos to the port of Lebena, at the south coast of Crete. The possibility of the quarry taking orders from Ierapytna should not be excluded, since the area belongs to its territory (Pharaklas et al. 1998, 146) and the distance between the harbor of Tholos (ancient Larissa, see Tziligkaki, 2014, site Λ12) and Ierapytna is nothing else but the narrowest part of Crete in the N-S axis, i.e. 12 km. Neither should one exclude the sea route between Ierapytna and Gortyn due to the following reasons.

4.1. Istron-Vryonēsi or Prassonēsi

In the vicinity of the quarry reported by Harrison, the rock islet of Prassonēsi or Vryonēsi offers a safe anchor for those travelling from the East and confront a storm (Chapouthier, 1935, 381; Fig. 8). Final Neolithic / Early Minoan I pottery, ceramics dating to the EM II-III periods, a small late Roman monastic community or possibly a watch station with pottery dating at the latest to the 8th or possibly 9th centuries AD, and finally a few venetian sherds, synthesize the mosaic of human activities on the islet (Hayden et al., 2004, 37-8, 63, 238-9, 250 respectively).

However, the most significant evidence on the islet -concerning the present paper- are the graffiti of sailors' names, such as *Εὐθύτιμος, Χρύσιππος, Νίκανδρος εὔπλους*, and the symbol of a dolphin, engraved on the slope of a "rocky wall" that faces the coast (Chapouthier, 1935, 377, Fig. 1; Tziligkaki, 2014, site Λ9, 381-382). These graffiti are quite late in date, if we judge from the form of the Greek letter *sigma* (Σ) as C (Chapouthier, 1935, 377 note 2. The name Dioklēs (ΔΙΟΚΛΗC) inscribed in the marble quarry of Myli, at Animborio in South Euboea exhibits the same form of sigma, and dates to the middle of the 2nd c. AD, according to Lambraki (1980, 47, Fig. 10a).

Fig. 8: Istron area, the islet of Vryonēsi or Prassonēsi (Gulf of Merambello, Crete). View from the SE.

Analogous graffiti have been observed in coastal quarries, such as in the marble quarries of Alykē on Thasos Island; they are attributed to mariners who were employed in the transportation of the marble blocks (*IG* XII, 8, 581-586. Chapouthier, 1935, 378). Another example comes from the foot of the Akrokerauneia Mountains in Epirus; in the cove named *εἰς τά Γράμματα* (= at the Letters) numerous graffiti of sailors /mariners have covered slopes that have been quarried (Heuzey & Daumet, 1876, 406-408; Chapouthier, 1935, 378, n.4). The securing of a safe anchorage in the islet of Prasonēsi implies the inability of the ships to securely approach the coast of Istron. This suspicion is further strengthened by the submarine geological research by Mourtzas (Mourtzas, 1990, 297, Fig. 83 c); the fluctuations observed not only in the form but also in the depth of the shorelines at Istron are considered to be a result of the strong waves to which the coast is exposed ("of course micro tectonic movements are not excluded"). The strong north winds prevailing in the Merambello Gulf are also pointed out by Captain T.A. B. Spratt who sailed around Crete in 1865 (Spratt I, 1865, 214). The depth of the ancient quarry spotted by Harrison seems to provide a trustworthy indicator for the date of the deep submerged coast, which was traced at a depth of -1,90 m. The sunken part of the quarry could be compared to the eleven submerged rock-cut fish tanks explored at Matala bay in the south coast of Crete by Mourtzas (2012a; Mourtzas, 2012b).

4.2 New quarry site at Istron

A metallic, most likely iron, cylindrical wedge of unknown age is still *in situ* at a cube of marble in a private beach at the western bay of Istron, (Fig.9). The stratigraphy is the same as in the coastal marble quarry reported by Harrison. The marble is white covered by conglomerate. Small pieces of white marble are included in the matrix. The sunken rocks lying in a distance of a few meters from the breaker apparently are not beach rock. Aligned rectangular blocks of white marble –as it seems- lie in the bottom of the sea at an estimated depth of -2 m. In one case, channels cut between blocks that have not yet been extracted are still visible. Scattered marble pieces are lying in the beach, full of white marble pebbles, or thrown between the huge rough blocks that form the small mole to the east of the bay. Marble blocks of different shape and form were used for the construction of a retaining wall that supports the amenities of the hotel, which was constructed in 1983. Could these blocks be the result of the quarry's destruction? The huge cube of marble, whose visible height measures almost 2 m., standing in situ at the beach, resembles analogous cubes of sandstone left intact at the coastal quarries of Stavros at Akrotēri (Fig. 10). It is suggested that they were a sort of indicators for the amount of cubic meters extracted from the site (Tziligkaki, 2014, site X5, 60-61).

Fig. 9: Istron, western bay (Merambello Gulf, Crete). Cube of white marble, almost 2 m in visible height, with a metallic cylindrical wedge *in situ*, at the beach.

Fig. 10: Stavros, Akrotēri Peninsula (western Crete). Cube of sandstone, left intact at the quarries, perhaps a sort of indicator for the amount of cubic metres extracted from the site. Notice the tidal notch in its base, an indication of past flooding (Kelletat, 1979).

5. Conclusions

An interdisciplinary study on the coastal quarries of Crete, which are usually situated in proximity to rock-cut fish tanks and ship sheds, could shed more light on the Mean Sea Level in antiquity. Data from the northeastern Crete variegate; in Sēteia the deepest underwater part of the quarry lies at -1 m., in Itanos a quarry lies at -3 m. In western Crete local fluctuations in the Mean Sea Level are observed in the Akrotēri Peninsula and Kissamos bay, where neighboring quarries appear the one sunken and the other uplifted.

The excavations in Phalasarna (western Crete) revealed that the functional height of the quays in the year 335 BC is estimated around 0,40 m. Up until now, the functional height of the Cretan ship sheds has not been examined, nor are the tool marks left on the rock catalogued.

The tools discussed in the present paper concern the ones that drilled the cylindrical hole in the coastal quarry of Petres (Rhethymnon Prefecture). The metallic cylindrical wedge found in situ at the new site at Istron visualizes their function for the breaching of the rock.

The new quarry site of white marble in the Istron area is added to the known ones and raises their number to three (counting from West to East): at the hill of Ginara, at the western bay of Istron close to Vryonēsi or Prassonēsi, and close to Gournia. The roman works of art ascribed to local workshops can now be correlated with specific marble quarries of Crete.

Transportation of white marble via sea is deduced in the area of Istron due to the islet of Vryonēsi or Prassonēsi that offered a safe anchorage in an area exposed to strong waves. The graffiti found at the islet recall analogous inscribed names of mariners in the coastal quarries of Alykē (Thasos Island) and Akrokerauneia Mountains in Epirus (modern Albania). Sea transportation is also supposed for the limestone quarry at Matala; the ancient shoreline is now sunken by -1,25 m. As a result the sea has transgressed to the coast in a width covering around 30 m.

The mean sea level in the Roman period is estimated in a depth of -1,25 m to -1,30 m, according to the underwater surveys of sunken fish tanks at Matala and at “Sta Ferma” (Ierapetra), both in the south coast of Crete. Unfortunately, the exact time span of their operation is not known. Davaras found no pottery nearby, whereas Mourtzas *a priori* accepts a date in the first two centuries of the Christian era.

Despite these drawbacks this seems to be the mean sea level in the Roman period. The marble quarry at Istron published by Harrison (1990) provides more solid chronological data; a) the sherds dating from the early 1st c. till the late 2nd c. AD, and b) the deepest point of the nowadays submerged quarry at -1,80 m. The data relate to the sunken tidal notch found at -1,90 m in the same area and the fossil coast at -1,50 m. Whether the new site at Istron belongs to the same period, remains to be examined in the near future. A coordinated research of geologists and archaeologists could provide excellent results on the chronology of the submerged quarries of Istron area.

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