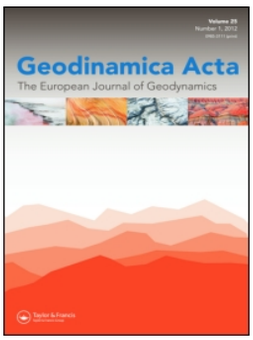

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Abstract

The coastal areas of the island of Delos, located at the centre of the Cyclades archipelago (Greece), are rich in submerged Hellenistic archaeological vestiges. This submersion can be explained by changes in relative sea-level: the recent ^{14}C datings of submerged beachrock occurrences of Delos and the nearby islands of Mykonos and Rhenia suggest that the sea level was at about -2.5 m (± 0.5 m) around 400 BC [1, 2]. Such result has enabled to confirm and refine Negris'early-twentieth-century hypothesis that the submersion can be accounted for by the relative sea-level rise.

From this result, together with bathymetric maps, archaeological studies and stratigraphic data, the Hellenistic coastal landscapes on the western side of Delos have been reconstructed.

The Sacred Harbour (including the Agora of the Competaliasts) and the "Pointe des Pilastres" landscapes (located to the South) resembled those of the current Greek harbours: the paved walkways or esplanades bordering buildings or shops were separated from the sea by a beach onto which boats were drawn. The landscape of the "Maisons au flanc de la Colline" sector (located to the North) seems to have been different. These houses were located on a rocky platform, in a sector exposed to the north swell.

Keywords: sea-level changes, geoarchaeology, Antiquity, Delos, Greece

1. Introduction

Submerged Hellenistic archaeological remains are numerous on the island of Delos, located in the Mykonos-Delos-Rhenia insular group, in the centre of the Cyclades (Fig. 1). The origin of this submersion was the subject of debate at the beginning of the 20th century: against L. Cayeux [3-5], P. Negris [6-8] argued in favour of a sea-level rise during histo-

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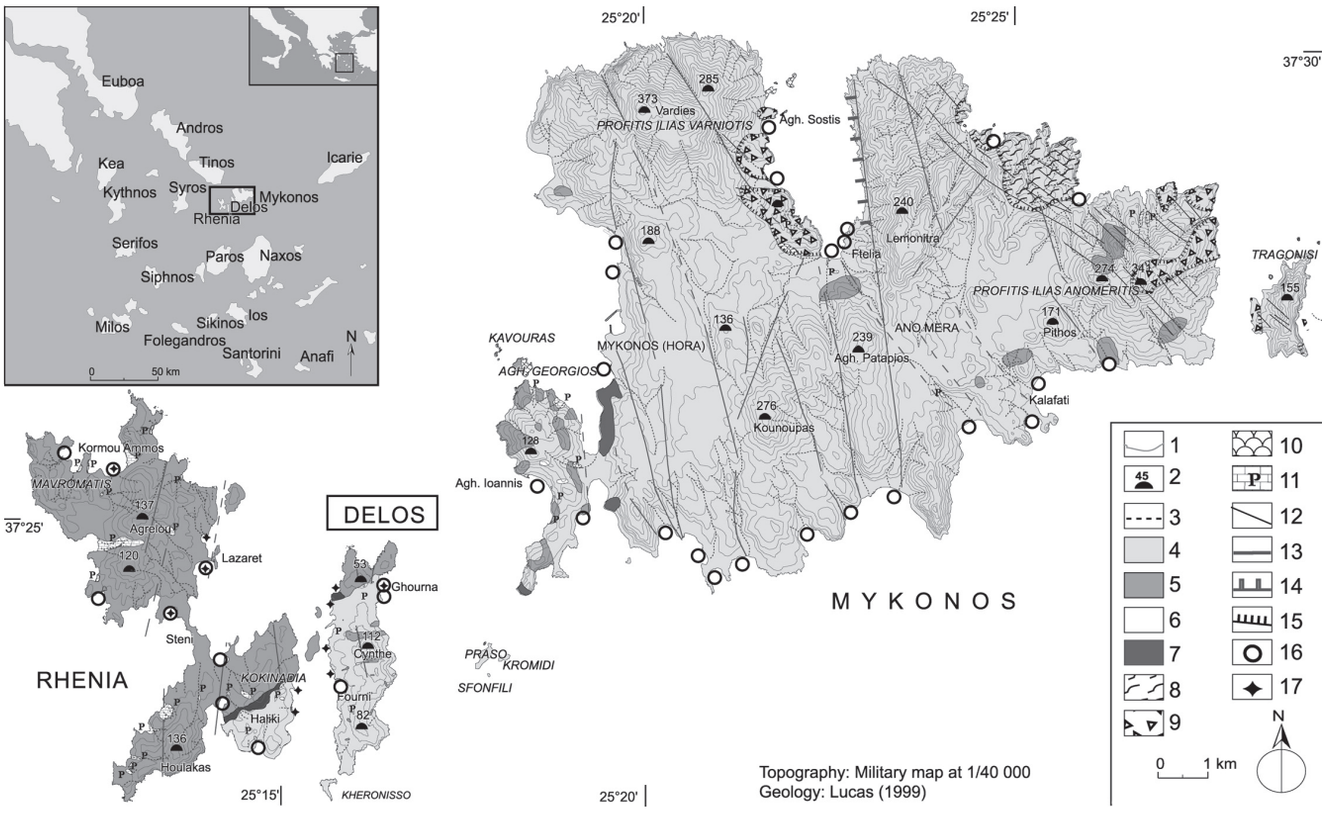


Fig. 1: Geological map of Mykonos, Delos and Rhenias islands
1: elevation contours, 20 m asl. ; **2:** spot height in m ; **3:** ephemeral flow ; **4:** granites ; **5:** gneiss ; **6:** marbles ; **7:** micaschists ; **8:** metavolcanics ; **9:** Miocene molasses ; **10:** Permo-triassic carbonates ; **11:** calcarenites ("poros") ; **12:** barite veins ; **13:** faults, joints and hidden faults, hidden joints ; **14:** normal faults ; **15:** low-angle normal faults ; **16:** beachrocks, cemented pebble bars ; **17:** submerged archaeological vestiges

rical times. Today, archaeologists and geographers agree with P. Negris [9]. In addition, a recent study of the beachrocks in Mykonos-Delos-Rhenia has enabled the rate of submersion to be determined with greater accuracy [1, 2].

Using this relative sea-level trend together with bathymetric maps, archaeological studies and stratigraphic data, the ancient coastal landscapes of Delos have been reconstructed. The present study focuses on the western side of the island, where the Hellenistic Sacred Harbour, houses and docks are located (Fig. 2).

2. Geographical and archaeological setting

The small island of Delos is mainly constituted by Miocene granite of the Mykonos-Delos-Rhenia metamorphic core complex [10] (Fig. 1). The insular group is located at the centre of the Aegean back arc basin, which must always have been affected by a North-South extension which started to form during the lower Miocene [11]. This extension is probably associated with a subsidence process of the Cyclades plateau. The major North-South faults cutting the insular group (Fig. 1) are generally dated back to the Pliocene [12]. They are not likely to have been affected by substantial tectonic movements since this time [13]. Moreover, no trace of neotectonic activity was identified during our field observations.

The coastal landscapes of Mykonos-Delos-Rhenia are dominated by cliffs and pseudo-cliffs (Fig. 2). The daily tidal range is small (0.2-0.3 m), although intra-annual variations due to seasonal barometric fluctuations can reach 0.5 m. Biological markers (vermetids, in particular) were used to determine the height of the present intertidal zone.

The bays are surrounded by sandy or shingle beaches, rich in reworked archaeological material. In most of these bays are two or three submerged beachrock lines, separated by sandy areas, stacked between 0 and -3.8 m (Fig. 1). These fossil beachrocks are formed in the intertidal zone through carbonate cementation of sands during shoreline stabilisation. The submerged beachrock lines of Mykonos-Delos-Rhenia result from two or three periods of coastline stabilisation. They contain early diagenetic cements [14-16] which have been ^{14}C dated using the AMS method. The datings show that the sea level was -2.5 m (± 0.5 m) around 400 BC [1, 2].

The oldest identified harbour constructions were built during the period from 314 BC to 167 BC, when trade started to develop in the city of Delos [17]. They were widened when the city became a free port, in 167 BC. At the heyday of the city, in the 1st century BC, the main coastal constructions were located on the North-West of the island. The present study focuses on the landscapes of the Sacred Harbour bay, the "Maisons au flanc de la

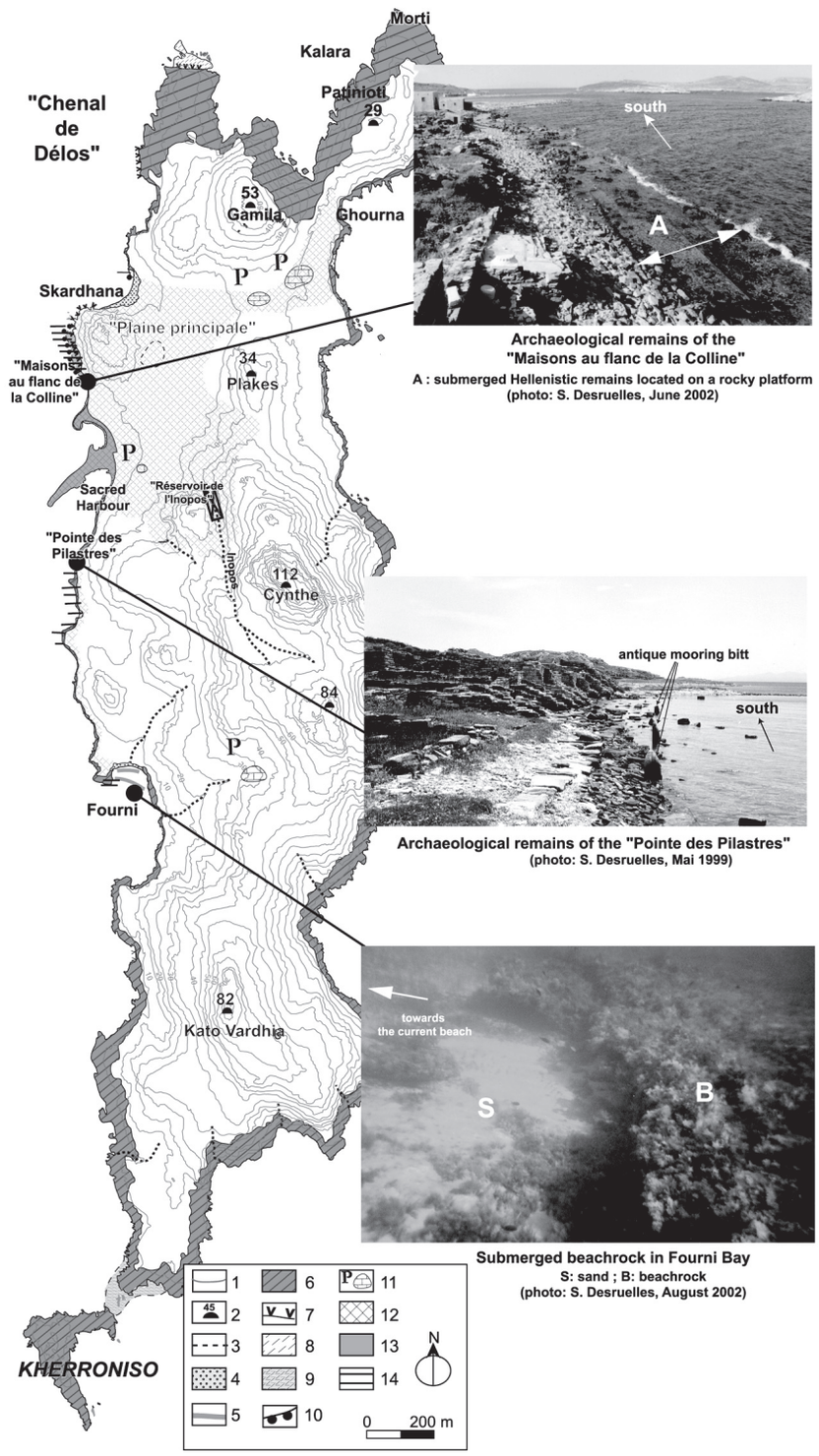


Fig. 2: Location of the archaeological remains and beachrocks on Delos
1: elevation contours, 5 m asl. ;
2: spot height in meter ;
3: ephemeral flow ;
4: beach ;
5: submerged beachrock ;
6: pseudo-cliff ;
7: cliff ;
8: rocky platform ;
9: submerged rocky platform ;
10: submerged slope ;
11: calcarenites ("poros") ;
12: modified zone: buildings, fill... ;
13: modern fill ;
14: submerged archaeological vestiges

Colline" sector located further to the North and the "Pointe des Pilastres" sector to the South (Fig. 2).

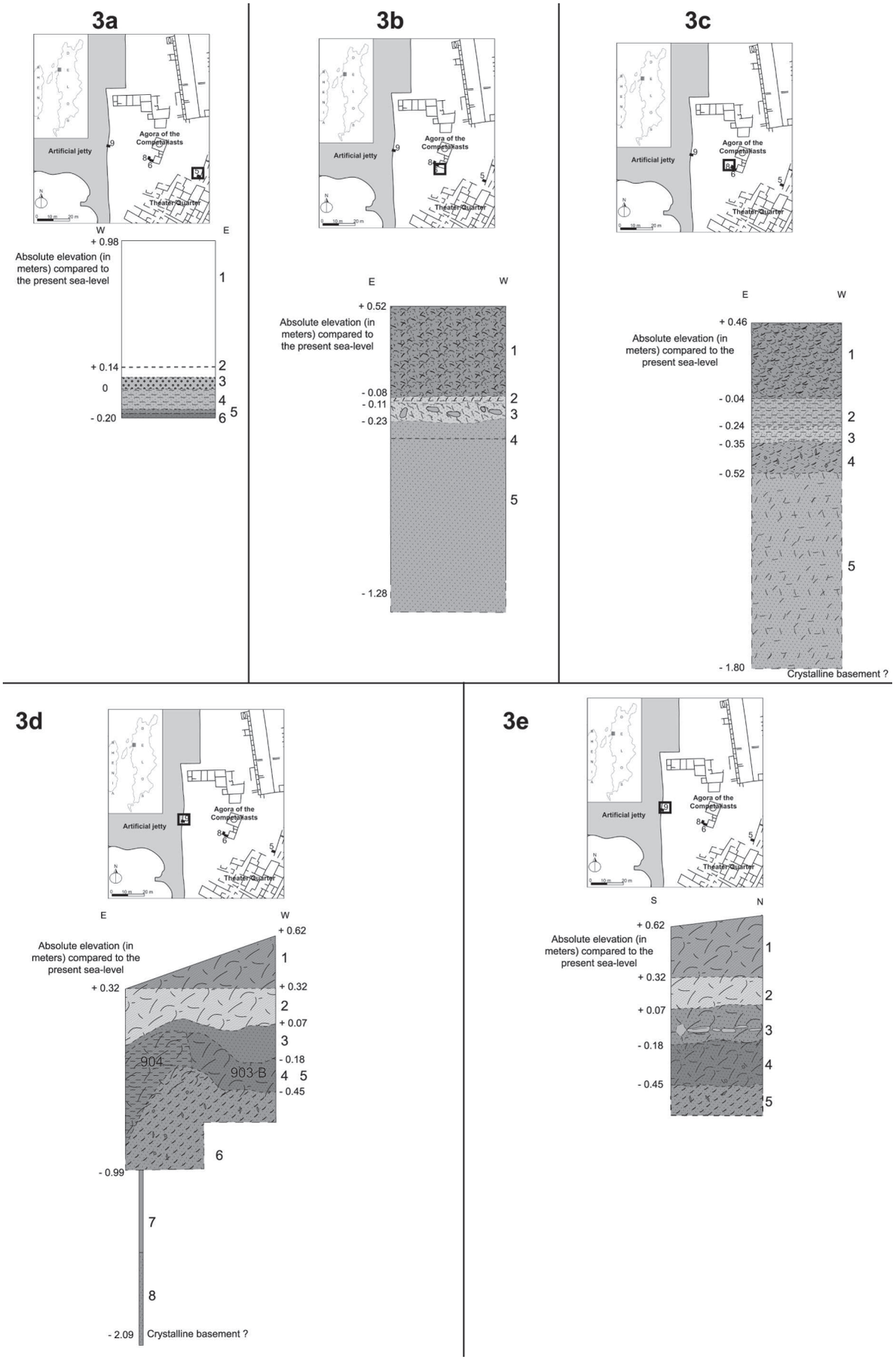
The island of Delos was gradually abandoned, starting in 69 BC. The ruins of the ancient city were excavated by archaeologists from the French School of Athens, beginning in 1873, thus modifying the topography and bathymetry of the Sacred Harbour bay. Excavated material was dumped back into this sector and was used to build a jetty at the beginning of the 20th century. The jetty modified the North-South sediment transit, causing silting in the North of the bay and erosion in the "Pointe des Pilastres" sector.

3. Material and methods

Shoreline and coastal landscape reconstructions of the ancient city of Delos were obtained by cross-comparing the dating of the Mykonos-Delos-Rhenia beachrocks with topography and bathymetry data, studies of archaeological remains, diving observations, archaeological excavations and sedimentological analyses. To remove the effects of the jetty's construction in the Sacred Harbour from our reconstructions, the bathymetric information published by E. Ardaillon [18] were used.

For the study of the Sacred Harbour, the shoreline reconstruction was combined with archaeological excavations. These excavations were carried out in June 2002 on a ESE-WNW transection passing through the ancient Agora of the Competaliasts, from the base of the Theater Hill to the western border of the ancient esplanade [19] (Fig. 3 & 4). Because of the presence of abundant underground water, pumping was required at depths greater than 0.8 meter below the topographical surface. This groundwater perturbed the study of the deepest layers, whose thickness was estimated by means of a drill. These results were cross-compared with the stratigraphy obtained during excavations made in 1995 by C. Hasenohr [20].

Samples were taken from all layers and granulometric analyses were carried out. For each sample, micro-palaeontological analyses of sands (greater than 50 μm fraction) were employed.


3a
Artificial jetty
Agora of the Competaliasts
Theater Quarter
W
E
Absolute elevation (in meters) compared to the present sea-level
+ 0.98
+ 0.14
0
- 0.20
1
2
3
4
5
6
3b
Artificial jetty
Agora of the Competaliasts
Theater Quarter
E
W
Absolute elevation (in meters) compared to the present sea-level
+ 0.52
- 0.08
- 0.11
- 0.23
- 1.28
1
2
3
4
5
3c
Artificial jetty
Agora of the Competaliasts
Theater Quarter
E
W
Absolute elevation (in meters) compared to the present sea-level
+ 0.46
- 0.04
- 0.24
- 0.35
- 0.52
- 1.80
1
2
3
4
5
Crystalline basement ?
3d
Artificial jetty
Agora of the Competaliasts
Theater Quarter
E
W
Absolute elevation (in meters) compared to the present sea-level
+ 0.62
+ 0.32
+ 0.07
- 0.18
- 0.45
- 0.99
- 2.09
904
903 B
1
2
3
4 5
6
7
8
Crystalline basement ?
3e
Artificial jetty
Agora of the Competaliasts
Theater Quarter
S
N
Absolute elevation (in meters) compared to the present sea-level
+ 0.62
+ 0.32
+ 0.07
- 0.18
- 0.45
1
2
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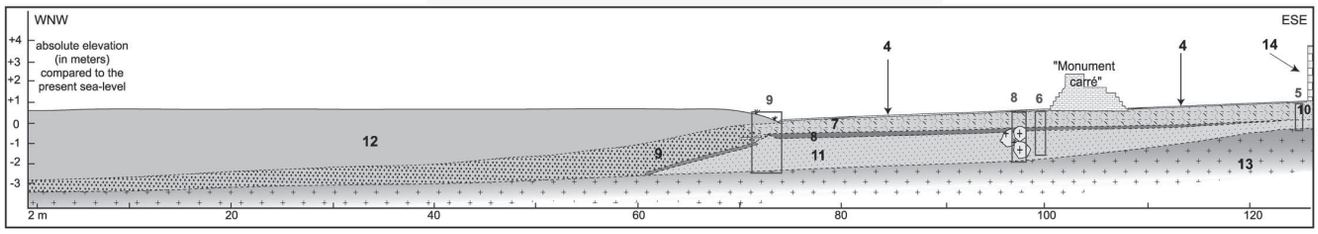

Fig. 3: Archaeological excavations accomplished in 2002 in the Agora of the Competaliasts

3a. Excavation 5, north profile

1: succession of 30 archaeological layers (fills and soils) younger than the 6th century BC ; **2:** water table ; **3:** US 533 - grey-brown (2,5 YR 5/2) coarse sand including fine gravels ; **4:** US 534 - grey-brown (2,5 YR 5/2) clayey sand ; **5:** US 535 - slightly dark greyish brown (2,5 Y 4/2) clayey sand ; **6:** US 536 - clearly brown (2,5 YR 6/2) sand

3b. Excavation 6, south profile

1: US 601 - grey (10 YR 5/1) sandy argillaceous fill, rich in charcoals and shards ; **2:** US 602 - light grey (10 YR 6/1) clayey sand rich in charcoals ; **3:** US 603 - light grey (10 YR 6/1) sand rich in shards and bones, containing some angular rock fragments ; **4:** water table ; **5:** US 604 - dark grey (10 YR 4/1) sand

3c. Excavation 8, south profile

1: US 801 - black (7,5 YR 2/0) loamy sand fill, containing charcoals and shards ; **2:** US 802 - very dark greyish brown (2,5 YR 3/2) sandy argillaceous fill, containing roots and shards ; **3:** US 803 - very dark grey (7,5 YR 3/0) clayey sand, rich in charcoals ; **4:** US 804 - very dark greyish brown (2,5 YR 3/2) loamy sand containing charcoals, shards and a few pieces of altered gneiss ; **5:** US 805 - dark brown sand (7,5 YR 3/2) rich in rounded shards

3d. Excavation 9, south profile

1: US 901 - dark brown loamy sand fill made up of modern top soil, containing roots ; **2:** US 902 - light grey (10 YR 6/1) loamy sand fill containing roots ; **3:** US 903A - very grey sand containing shells and vegetable remains. Presence of a horizontal layer of gneiss blocks and large cobbles ; **4:** US 903B - dark brown loamy sand (10 YR 3/3) containing roots ; **5:** US 904 - very dark greyish brown (10 YR 3/2) clayey sand ; **6:** US 905 - slightly dark greyish brown (2,5 Y 4/2) clayey sand containing small granite fragments, charcoals, grains and olive pits ; **7:** US 906 - argillaceous level ; **8:** US 907 - very dark greyish brown (10 YR 3/2) sand

3e: Excavation 9, west profile

1: US 901 - dark brown loamy sand fill made up of modern top soil, containing roots ; **2:** US 902 - light grey (10 YR 6/1) loamy sand fill containing roots ; **3:** US 903A - very grey sand containing shells and vegetable remains. Presence of a horizontal layer of gneiss blocks and large cobbles ; **4:** US 903B - dark brown loamy sand (10 YR 3/3) containing roots ; **5:** US 905 - slightly dark greyish brown (2,5 Y 4/2) clayey sand containing small granite fragments, charcoals, grains and olive pits

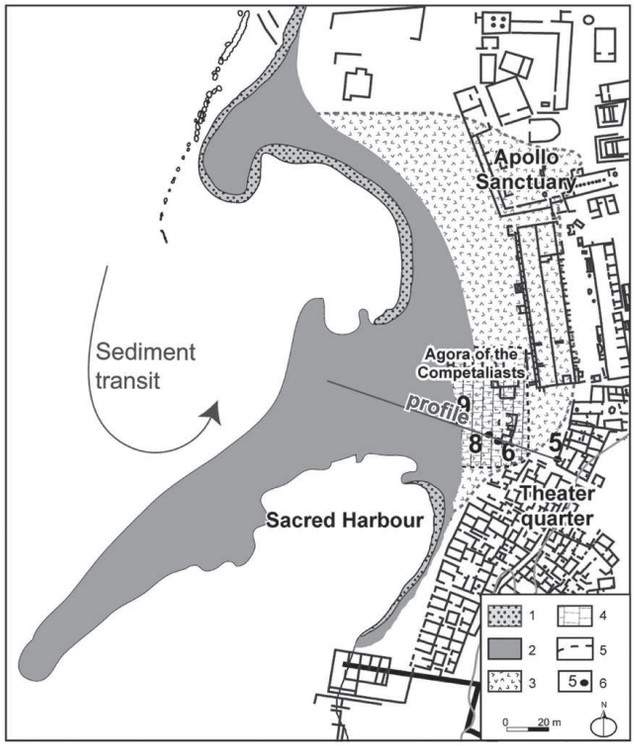

Fig. 4: Present landscape of the Sacred Harbour bay

1: beach ; **2:** modern fill ; **3:** Hellenistic fill ; **4:** paved esplanade of the Agora of the Competaliasts ; **5:** probable limits ; **6:** archaeological excavations carried out in 2002 ; **7:** sandy-argillaceous fill, rich in shards ; **8:** mud (clay, charcoal, organic matter...) ; **9:** sand ; **10:** archaeological layers (fills and soils) younger than the 6th century BC ; **11:** sand generally rich in shards ; **12:** jetty built with excavated materials ; **13:** crystalline basement ; **14:** shop of the Theater Quarter

4. Results

4.1. Landscape reconstruction in the Sacred Harbour bay

4.1.1. Interpretation of archaeological excavations (Fig. 3)

The deepest layer of the four excavations (US 907- Fig. 3d & 3e) has the characteristics of a deposit in a continental environment. It is probably the weathered layer front of a crystalline basement.

Above this layer, layers US 905 and US 535 (Fig. 3a), probably deposited by the river Inopos, are poor in foraminifera. Layers US 805 (Fig. 3c) and US 536, which are sandy and rich in foraminifera, are similar. The sandy layer US 604 (Fig. 3b) may be associated with the latter layers, in spite of its paucity in foraminifera. These three layers, which contain elements of both marine and continental origin, have a high content of wind-blown sand and contain fragments of cemented sands resulting partially from the erosion of calcarenites located upstream (Fig. 2).

Layers US 805, US 536 and US 604 are covered by more clayey layers (US 904, US 804-803 and US 603-602). These

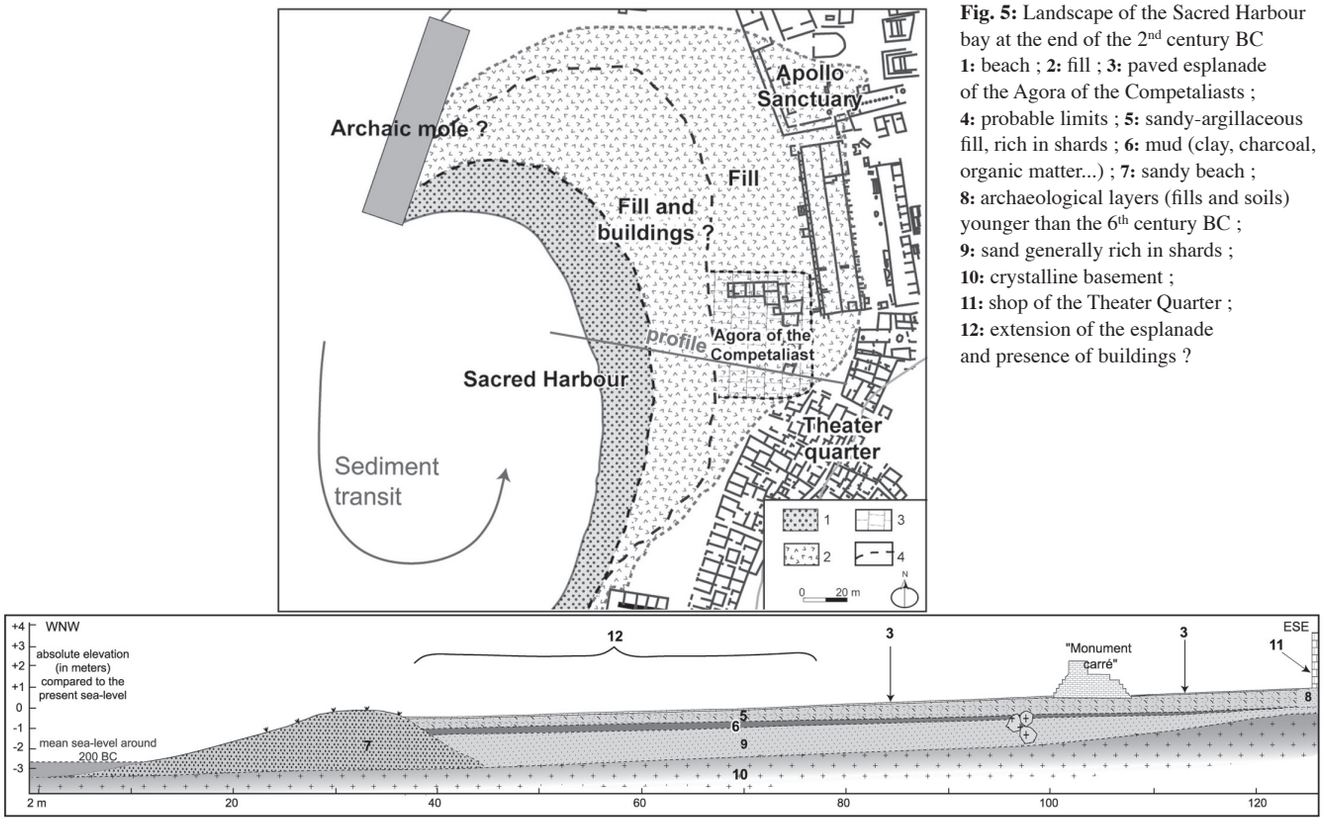

Fig. 5: Landscape of the Sacred Harbour bay at the end of the 2nd century BC
1: beach ; **2:** fill ; **3:** paved esplanade of the Agora of the Competaliasts ; **4:** probable limits ; **5:** sandy-argillaceous fill, rich in shards ; **6:** mud (clay, charcoal, organic matter...) ; **7:** sandy beach ; **8:** archaeological layers (fills and soils) younger than the 6th century BC ; **9:** sand generally rich in shards ; **10:** crystalline basement ; **11:** shop of the Theater Quarter ; **12:** extension of the esplanade and presence of buildings ?

are characterised by a wealth of anthropogenic fragments (in particular charcoal, grains, olive pits, and fish-bone) in addition to organic matter. Foraminifera are less numerous and the shells are more damaged. On the other hand, quartz grains are less damaged, except in US 904. With the exception of the latter layer, the deposit seems to have occurred in a continental environment. These properties suggest the presence of a coastal marsh, influenced by the sea water to the West (US 904).

The westernmost layer of all excavations (US 903A-Fig. 3d) seems to have settled out in a marine environment.

4.1.2. The ancient landscapes of the Sacred Harbour bay

In order to reconstruct landscapes in the bay of the Sacred habour, the interpretation of the excavations was cross-compared with the shoreline reconstructions stemming from the study of the relative sea-level variations in Mykonos-Delos-Rhenia.

At the end of the 4th century BC, assuming the relative sea-level to have been 2.5 m (± 0.5 m) below its present height [1, 2], the shoreline would have been located approximately 60 m to the West of the 1896 shoreline. In the centre of the Sacred Harbour bay, the river Inopos temporarily flowed until the building of a damp-reservoir upstream (Fig. 2). A coastal marsh, separated from the sea by a sand bar, received underground and surface flows from the Inopos. The water of this temporary marsh was fresh, or brackish.

Reconstruction of the bounds of this temporary marsh is difficult. To the South-East, it was probably bordered by the slope of the Theater Hill. To the North-East, the coastal plain was built up: this is where the Apollo Sanctuary was located [21]. To the South, the limits of the marsh can be deduced from the position of an archaic monument in the XIIA street block of the Quarter Theater [22] and from the presence of archaic occupation levels in the XIIB street block [23]. To the West, the excavations did not allow the exact location of the sand bar to be determined. From bathymetric data, it can be assumed that it was 60 m to the West of the visible border of the ancient paved esplanade. Furthermore, an archaic mole was probably located at the North-West end of the bay [24].

In the 2nd century BC, a fill was settled on top of the mud layer of the coastal swamp in the centre of the bay [3, 4, 25] (Fig. 5), probably to improve stabilisation of this terrain in preparation for the management of the coast extending from the Agora of the Competaliasts to the Agora of Theophrastos. The limits of the paved esplanade are not exactly known.

The archaeological excavations did not exhume any structure which could be unquestionably identified as a plunging quay. According to our reconstruction, boats were drawn onto the beach. This practice resembles that of contemporary Greek harbours and other places in the Mediterranean where the tidal range does not exceed 0.5 m [26]. The landscape reconstruction of the Sacred Harbour bay indicates the presence of a vast esplanade, and buildings bordering a beach, during the 2nd century BC (Fig. 5).

The elevation of the relative sea-level unavoidably caused silting of a part of the Agora of the Competaliasts and erosion to the West, until the beginning of the 20th century and the construction of the jetty. This could explain the marine influence observed in the US 903A and US 904 (Fig. 3d & 3e). The map published by E. Ardaillon [18] suggests that the depositing of these layers is related to the position of the shoreline at the end of the 19th century.

Layers US 901 and US 902 are connected to the construction of the jetty at the beginning of the 20th century. Moreover, the contribution of excavated material in Skardhana and Sacred Harbour bays (Fig. 2) to the sediment transit led to the migration of the shoreline a few metres westward (Fig. 4).

4.2. The "Maisons au flanc de la Colline" sector

In this sector, which extends from the "Maisons au flanc de la Colline" to the "Bassin Pâris" (Fig. 6), the houses were built at the beginning of the 2nd century BC [17] on a rocky platform exposed to the north swell (wave energy is strong up to a height of approximately 2 m above mean sea level).

This rocky platform is 1.33 m below the present sea-level. A submerged scarp, the base of which is 2.8 m below the present sea-level, borders this rocky platform (Fig. 6). No structure such as a dike or jetty was found at the base of this scarp, which probably was a cliff in the Antiquity. In the 2nd century BC a houses floor was located at approximately 1.2 m above the mean sea level reconstructed using the beachrocks (Fig. 6). The presence of blocks along the base of the submerged cliff, which could be reached by the sea, probably indicates the presence of a structure for protection against the waves. However, the buildings could be subjected to strong swells, as is the case today for buildings located on the seaside of the "small Venice" quarter in the town of Mykonos (Fig. 1).

A rocky headland at the South of this rocky platform may have been reinforced in archaic epoch [21], to protect the Sacred Harbour from strong swells and to divert the north current (Fig. 5).

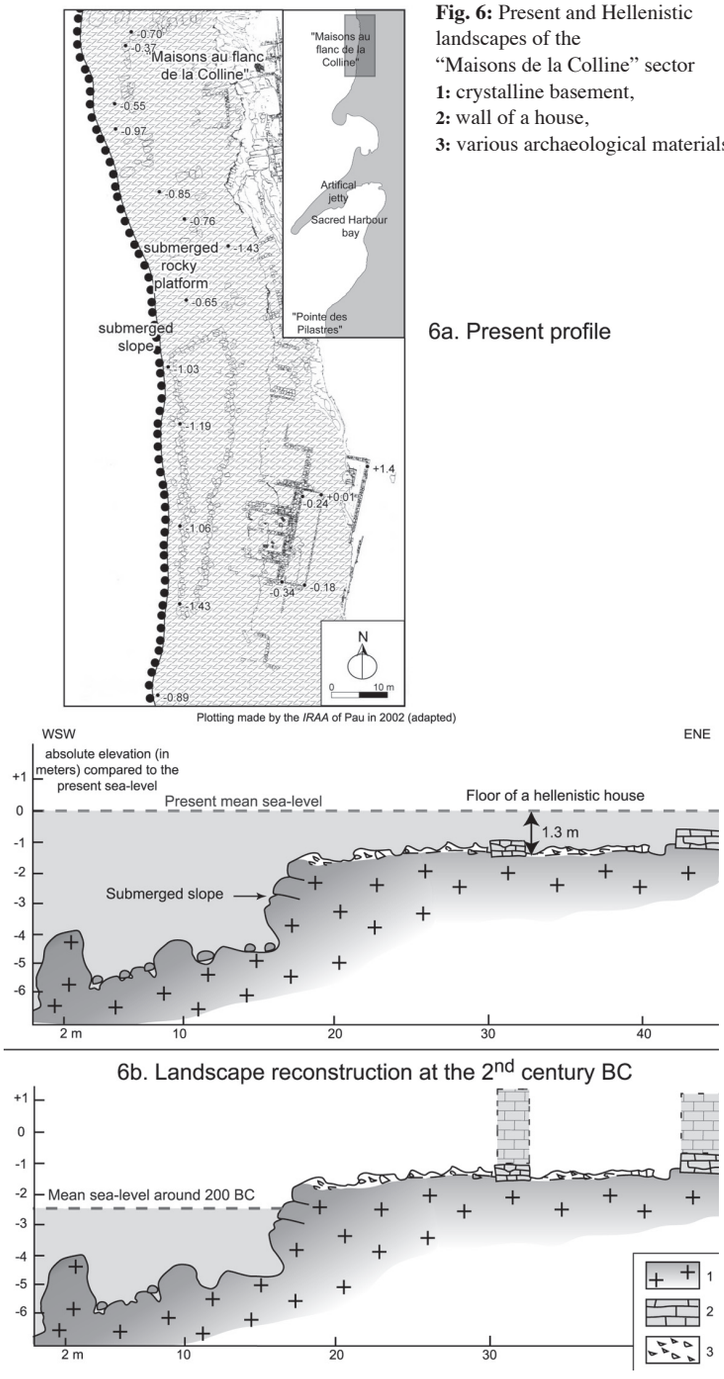

Fig. 6: Present and Hellenistic landscapes of the "Maisons de la Colline" sector
1: crystalline basement,
2: wall of a house,
3: various archaeological materials

4.3. The "Pointe des Pilastres" sector

From the "Pointe des Pilastres" to the "Magasin aux Colonnes", a paved pathway, bordered in particular by shops, houses and docks was built at the end of the 2nd century BC and at the beginning of the 1st century BC [17] (Fig. 7). Underwater observations to the West of this pathway allowed a beach, covered by posidonia and with no archaeological ruins, to be identified. Depths of 2.5 to 3 m were measured between 25 and 30 m westward of the current shoreline (Fig. 7). Some structures (moles ?) cross the beach, perpendicularly to the shoreline.

The reconstruction of this ancient shoreline is hindered by strong coastal erosion. The effects of this erosion are clearly apparent when the present ruins are compared with photographs taken at the beginning of the 20th century [17] (Fig. 2 & 7). This erosion is probably due to the construction of the artificial jetty at the beginning of the 20th century.

The reconstruction indicates the existence, during the Hellenistic period, of a paved pathway bordering a beach, onto which boats were drawn. The structures crossing the beach were probably used for the transport of goods [17, 24] (Fig. 7).

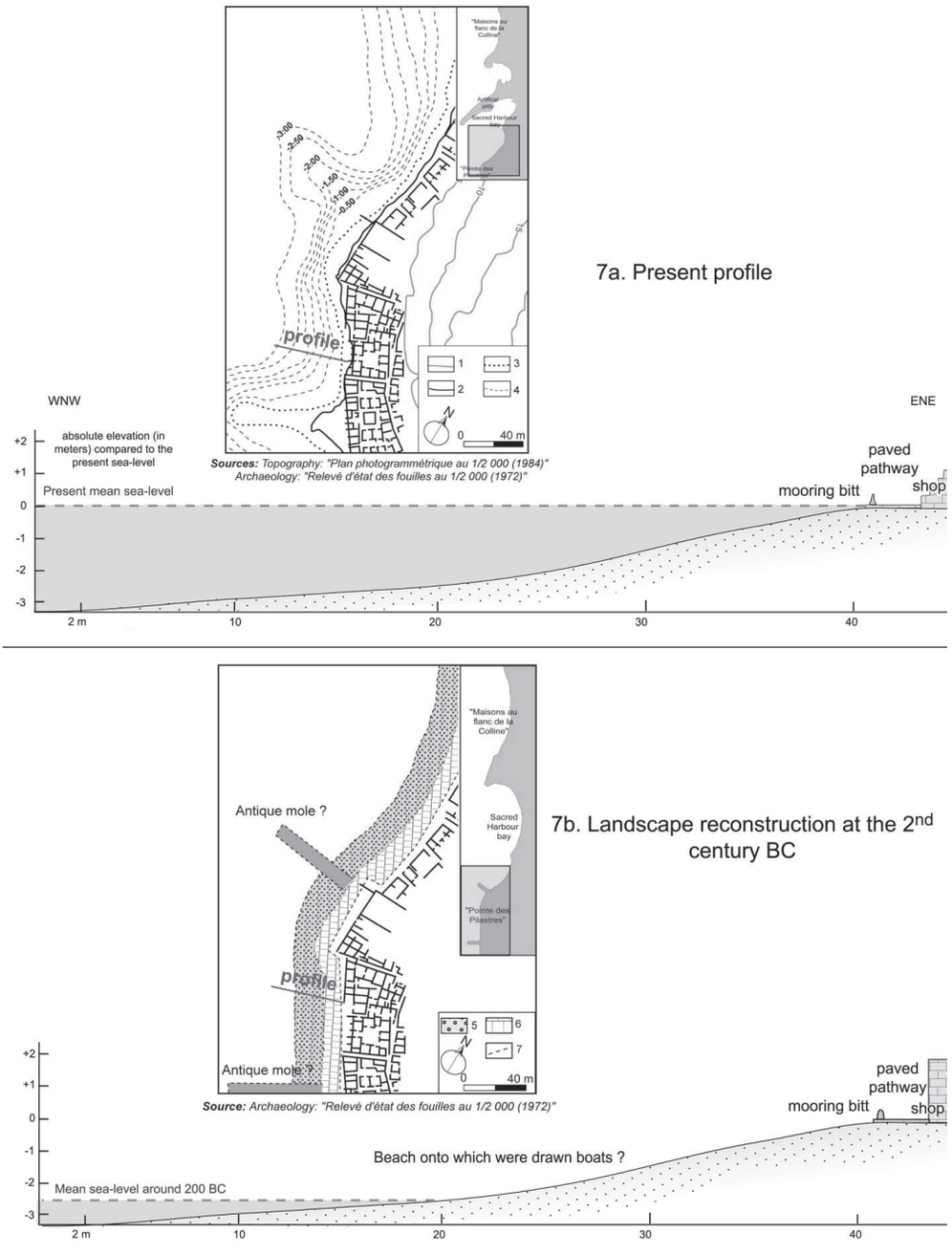

Fig.7: Present and Hellenistic landscapes of the "Pointe des Pilastres" sector
1: elevation contours, 5 m asl. ;
2: present shoreline ;
3: shoreline at the end of the 19th century (according to Ardaillon, 1896) ;
4: isobaths at the end of the 19th century (according to Ardaillon, 1896), 0.5 m asl. ;
5: present beach ;
1**6:** paved pathway ;
7: probable limits

5. Conclusion

Our Hellenistic sea-level reconstruction based upon the study of Mykonos-Delos-Rhenia beachrocks brings new insight into the ancient coastal landscapes of Delos. In the Sacred Harbour and the "Pointe des Pilastres" sectors, paved pathways or esplanades bordering buildings or shops were separated from the sea by a beach onto which boats were drawn. The "Maisons au flanc de la Colline" sector was occupied by houses built on a rocky platform exposed to the north swell.

Various reconstructed elements could be discussed, and may be determined with greater accuracy by carrying out complementary excavations. In the Sacred Harbour bay, the Hellenistic extension comprising a fill and a paved esplanade towards the West and the North cannot be accurately reconstructed. According to our study, the maritime access of the Apollo Sanctuary is different from that which was admitted until now (with plunging quays), although there is insufficient data for the landscape to be reconstructed. To the North, the protection of the "Maisons au flanc de la Colline" against swell poses a problem. It is unclear whether protective moles were constructed to the West of the rocky platform.

For all of these coastal installations, one could speculate as to whether the inhabitants of Delos suffered from a rise in sea-level during the Hellenistic period.

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References

[1] Desruelles S., Fouache E., Pavlopoulos K., Dalongeville R., Peulvast J.P., Coquinot Y., Potdevin J.L., Variations récentes de la ligne de rivage en Mer Égée et beachrocks dans l'ensemble insulaire Mykonos-Délos-Rhénée (Cyclades, Grèce), Géomorphologie 1 (2004) 5-17.

[2] Fouache E., Desruelles S., Pavlopoulos K., Dalongeville R., Coquinot Y., Peulvast J.P., Potdevin J.L., Beachrocks as indicators of Late Holocene sea-level rise in Mykonos, Delos and Rhenia Islands (Cyclades, Greece), Zeitschrift für Geomorphologie Supplementary volume 137 (2005) 37-43.

[3] Cayeux L., Fixité du niveau de la Méditerranée à l'Époque historique, Annales de Géographie 16 (1907) 107-109.

[4] Cayeux L., Description physique de Délos. Exploration archéologique de Délos IV, Fontemoing et Cie, Paris, 1911, 215 p.

[5] Cayeux L., Les déplacements de la mer à l'époque historique, Revue scientifique 19 (1914) 577-586.

[6] Negris P., Régression et transgression de la mer depuis l'époque glaciaire jusqu'à nos jours, Revue Universitaire des Mines 3 (1903) 249-281.

[7] Negris P., Vestiges archéologiques submergés, Mitteilungen des Deutschen Archäologischen Instituts 29 (1904) 340-363.

[8] Negris P., Nouvelles observations sur la dernière transgression de la Méditerranée, Comptes rendus de l'Académie des Sciences Série II (1904) 379-381.

[9] Duchêne H., Dalongeville R., Bernier P., Transformation du paysage naturel et évolution du littoral dans l'archipel délien, in: Duchêne H., Fraisse P., Dalongeville R., Bernier P. (Eds.), Les paysages portuaires de la Délos antique : recherches sur les installations maritimes, commerciales et urbaines du littoral délien. Exploration archéologique de Délos XXXIX, De Boccard, Paris, 2001, pp.165-176.

[10] Lucas I., Le pluton de Mykonos-Délos-Rhénée (Cyclades, Grèce) : un exemple de mise en place synchrone de l'extension crustale, Thèse de doctorat, Université d'Orléans, 1999, 491 p.

[11] Piper D.J.W., Perissotaris C., Quaternary neotectonics of the South Aegean Arc, Marine Geology 198 (2003) 259-288.

[12] Anastasakis G.C., Dermitzakis M., Post-Middle Miocene paleogeographic evolution of the region, its possible influence on the distribution of the Quaternary mammals of the Cyclades Islands, Neues Jahrbuch für Geologie und Paläontologie, Monatschefte 1 (1990) 1-16.

[13] Hejl E., Riedl H., Weintgartner H., Post-plutonic unroofing and morphogenesis of the Attic-Cycladic complex (Aegea, Greece), Tectonophysics 349 (2002) 37-56.

[14] Purser B.H., Sédimentation et diagenèse des carbonates néritiques récents, tome 1, Editions Technip, Paris, 1980, 366 p.

[15] Bernier P., Dalongeville R., Incidence de l'activité biologique sur la cimentation des sédiments littoraux actuels. L'exemple des îles de Délos et de Rhénée (Cyclades, Grèce), Comptes rendus de l'Académie des Sciences Série II 307 (1988) 1901-1907.

[16] Neumeier U., Le rôle de l'activité microbienne lors de la cimentation précoce des beachrocks (dépôts marins littoraux), Thèse de Doctorat, Université de Genève, Suisse, 1998, 152 p.

[17] Duchêne H., Fraisse P., Dalongeville R., Bernier P., Les paysages portuaires de la Délos antique : recherches sur les installations maritimes, commerciales et urbaines du littoral délien. Exploration archéologique de Délos XXXIX, De Boccard, Paris, 2001, 192 p.

[18] Ardaillon É., Rapport sur les fouilles du port de Délos, Bulletin de Correspondance Hellénique 20 (1896) 428-445.

[19] Hasenohr C., L'Agora des Compétaliastes, rapport sur les campagnes 1999-2003, Bulletin de Correspondance Hellénique 128-129.2 (in press)

[20] Hasenohr C., Agora des Compétaliastes, Bulletin de Correspondance Hellénique 120.2 (1996) 901-910.

[21] Bruneau P., Brunet M., Farnoux A., Moretti J.C., Délos : île sacrée et ville cosmopolite, Ed. CNRS, Paris, 1996, 124 p.

[22] Moretti J.C., Un monument archaïque à Délos sur le front de mer, Revue archéologique 2 (1998) 227-262.

[23] Hasenohr C., L'Agora des Compétaliastes et ses abords à Délos : topographie et histoire d'un secteur occupé de l'époque archaïque aux temps byzantins, Revue des Etudes Anciennes 104 (2002) 85-110.

[24] Pâris J., Contributions à l'étude des ports antiques du monde grec, II. Les établissements maritimes de Délos, Bulletin de Correspondance Hellénique 40 (1916) 5-73.

[25] Vallois R., Les Portiques au sud du Hiéron. 1, Le Portique de Philippe. Exploration archéologique de Délos VII, De Boccard, Paris, 1923, 185 p.

[26] Dalongeville R., Travaux du groupe de recherches sur l'évolution des paysages littoraux de la Méditerranée orientale durant les six derniers millénaires (MAE, ÉFA, CNRS), Bulletin de Correspondance Hellénique 121.2 (1997) 880-881.