Mem. Descr. Carta Geol. d'It.
LII (1994), pp. 295-308

Paleo-geography of Weichsel and Holocene shore lines of the Arrabida Coast, central Portugal

Paleogeografia delle linee di riva weichseliane e oloceniche nella costa dell'Arrabida, Portogallo centrale

REGNAULD H. (*), GOUERY P. (**), FEREIRA O. (***), SALIEGES J.F. (****), GOMES N. (***)

ABSTRACT – The Arrabida mountain in the center of Portugal is a limestone anticline extended along an East/West axis. Its height reaches 502 m. The southern slope of this anticline is faulted by normal faults and disturbed by diapiric folds thought it drops almost directly into the Atlantic Ocean. This produces a series of complicated cliffs and fault scarps of various types (RAMOS *et alii*, 1993). They extend down to a depth of 25 m below sea level. The base of the submarine part of these cliffs is buried under sediment as it is close to the Sado river estuary, whereas it is free from sediment when it is located along the wave exposed part of the coast line. So the exposed and sheltered parts of the shore and submarine slope present contrasted morphologies.

The emersed part of the cliffs is characterized by marks of a high sea stand at + 7 m and of an other at + 20 m. Some submarine dives have permitted to discover marks of a low sea level (at – 7 m) and discontinuous evidences of lower sea stands at – 12 m and – 20 m. The – 7 m level might date from 5000 B.P. (RODRIGUES & DIAS, 1989). These submarine sea stands are clearly identified from the monitoring of some definite geomorphological features such as: cliff notch, wave cut abrasion platform, potholes scaled by *Lithotamnium sp.* and *Lithophyllum sp.*; sea stacks, isolated from the main cliff. The – 12 m submarine sea stand is inferred from local observations of potholes and notches, the -20 m sea level is proposed out of the remnant of wave cut platform and notch, but is still questionable.

All these geomorphological features are quite similar to those we observe on the present shore line and on the + 7 m high stand. Thought, abrasional forms are not located one below the other along successive sea stands suggesting that wave exposed areas were not in the same place during the different periods. Alternative reconstructions of palaeo dynamics are thus presented for the – 7 m and the + 7 m levels (figure 9). A proposal for a chronology is presented in figure 10.

KEY WORDS: Sea level, paleo-geography, shore lines, Weichsel, Holocene, Central Portugal.

RIASSUNTO – Il Monte Arrabida, nel centro del Portogallo, è una anticlinale estesa lungo un asse Est-Ovest. La sua altezza raggiunge 502 m. Il versante meridionale è fagliato con faglie normali e interessato da pieghe diapiriche e si immerge quasi direttamente nell'Oceano Atlantico. Ciò produce una serie di falesie complesse e di scarpate di faglia di vario tipo (RAMOS *et alii*, 1993). Queste si estendono sotto il livello marino fino a profondità di 25 m.

La base della parte sottomarina di queste falesie è sepolta sotto i sedimenti avvicinandosi all'estuario del fiume Sado, mentre è libera da depositi quando è localizzata lungo zone di costa esposte all'azione delle onde. Così le parti di costa e di scarpata sottomarina presentano morfologie diverse e contrastanti a seconda se siano esposte o riparate.

La parte emersa delle falesie è caratterizzata da solchi di alto stazionamento a + 7 m e a + 20 m.

Alcune immersioni hanno permesso di scoprire solchi di un basso stazionamento a – 7 m ed evidenze discontinue di basso stazionamento a – 12 m e a – 20 m. Il livello di – 7 m potrebbe datare 5000 anni b.p. (RODRIGUES & DIAS, 1989). Questi stazionamenti del livello marino sono chiaramente identificati dal rilevamento di alcune forme come: solco di battente, piattaforma d'abrasione marina, cavità d'erosione incrostate da *Lithotamnium sp.* e *Lithophyllum sp.*, faraglioni isolati dalla falesia principale.

Lo stazionamento sottomarino a – 12 m è dedotto da osservazioni locali di cavità e solchi di battente, quello a – 20 m è ipotizzato anche senza resti di piattaforma d'abrasione e solchi, ma è tuttora discutibile. Tutte queste forme sono abbastanza simili a quelle osservate sulla costa attuale e sullo stazionamento a + 17 m.

La considerazione che le forme di abrasione non sono localizzate una sotto l'altra lungo successivi stazionamenti del mare suggerisce che le aree esposte all'azione delle onde non erano nei medesimi luoghi durante i diversi periodi. Così ricostruzioni alternative delle paleo-dinamiche sono presentate per i livelli a – 7 m e a + 7 m (fig. 9). In figura 10 è presentata una proposta di cronologia.

PAROLE CHIAVE: livello marino, paleo-geografia, linea di costa, Weichseliano, Olocene, Portogallo centrale.

(*) URA 141 CNRS, Géographie, Université de Rennes 2, 6 avenue G.Berger, 35043 Rennes cedex, France Herve.Regnauld@UHB.FR.
(**) URA 1687 CNRS, Géographie, Université de Rennes 2, 6 avenue G.Berger, 35043 Rennes cedex, France.
(***) Projecto DISEPLA, Instituto Hidrografico, Rua das Trinas, 49, 1296, Lisboa Codex, Portugal.
(****) Laboratoire LODYC, Université de Paris VI, 2, Place Jussieu, 75005 Paris, France.

1. – INTRODUCTION

The Arrabida Mountain (figure 1) is a coastal relief, culminating at 502 m located south of Lisboa, between the estuaries of the Tagus and of the Sado. It is the only part of the western Portugal which presents an West/East trend and which is in a sheltered position from the atlantic waves. The Arrabida is an isolated fragment of a marginal bulge on a passive margin, that started its opening during the Jurassic. The latest and most important deformation took place during the Tortonian and was produced by a compressive N-S trend. Present tectonic mobility is attested by earthquakes, active faults in the submarine surroundings and geomorphological features which are studied in this paper.

2. – PALEO SEA STANDS AND HYDRODYNAMICS RECONSTITUTION.

Six different sea levels are known on the southern flank of the Arrabida mountain (ERLIDES, 1992; RAMOS PEREIRA, 1988). They are broken by active faults, safe one and are, locally, buried by slope deposits, gelifracts and breccia. A tentative reconstruction of their morphological history allows to draw hypothesies about late Quaternary sea level and tectonics.

2.1. – PHYSIOGRAPHY OF THE PALEO SEA LEVELS

The higest level (figure 2) is known as "Cabo Espichel surface" and has a debatable origin. According to DAVEAU *et alii* (1981), it is a marine form of undetermined age. Field work is presently being performed to solve this question. This abrasion surface is probably the Quaternary evolution of a long lasting polygenic coastal form dating back to the Oligocene. The + 20 m sea level is well identified by erosional forms, in Cha Os Navegantes (sea location on figure 9) and is buried under later dune sands and slope deposits. It has been broken by faults and is, in fact, between 18 and 21 m The + 7 m level may be followed from Cabo Espichel to Figueira Brava, a grotto in which prehistoric remains have been dated of 30 000 B.P. (TELLES ANTUNES, 1991). This level is an abrasion platform, with a notch in which sand, pebbles and some isolated shells are found. It is covered by slope deposits which, in turn, are eroded by karstic dissolution. Some faults deform this level with a general result of a tilting to the West (RAMOS PEREIRA *et alii*, 1993).Though its altitude varies from + 7 m to + 4 m between Baralha and Cabo Espichel this level is designed under the general term of + 7 m level.

The – 7 m sea stand is submarine. It is identified by many different features such as notches, sea stacks, potholes and abrasion platforms. It has been discovered during dives and has been identified in 12 sites all along the coast. Though no exhaustive exploration has been done between these sites, we infer that this sea stand is continuous. No evidence of deformation save one (figure 6) was ever noticed and the depth is almost constant (6,80 to 7,10 m) for the notch. Several signs of sea levels have been found at – 12 m and – 21 m in the Cabo Espichel surroundings. They include notches and potholes but they are not found in all the sites. The – 21 m notch corresponds with the depth of the moving sandy bank that buries the foot of the submarine cliff. It might be the submarine remodelling of an ancient form. The – 12 m is probably a sea stand, the remains of which have been later eroded. We do not have enough data to study these two levels. In the later discussion they are not taken into account.

The same geomorphic features have thus been identified along the different sea levels. Each of them gives an information about paleo conditions of morphogenesis. If different features are found one above an other we may infer that hydrodynamics have changed from one stage to an other. Figures 3 to 8 present diagrammatic blocs of some of the diving sites and allow such a comparison. They are located on figure 9.

2.1.1. – *Site 1 (figure 3), East of Cabo Espichel, maximum depth: 25m.*

The + 20 m level is absent, the + 7 m level is at + 4 m, (tilted to the West) and corresponds to an abrasion platform and a small notch. It is also altered by karstic dolines. The 0 sea level (present sea level) is also an abrasion bench, 0,1 to 0.5 m large with a 0.1 to 0.05 m notch. The – 7 m level is a wide bench (more than 2 m) following exactly the shape of preexisting ravines that extend from the karstic caves. During the + 7 m sea stand the water table was able to produce these outflows and a later regression carved ravines out of these. The – 7 m level was then superimposed on a dissected topography and is obviously younger.It has been created after the + 7 m, after a low stand with cold climate,

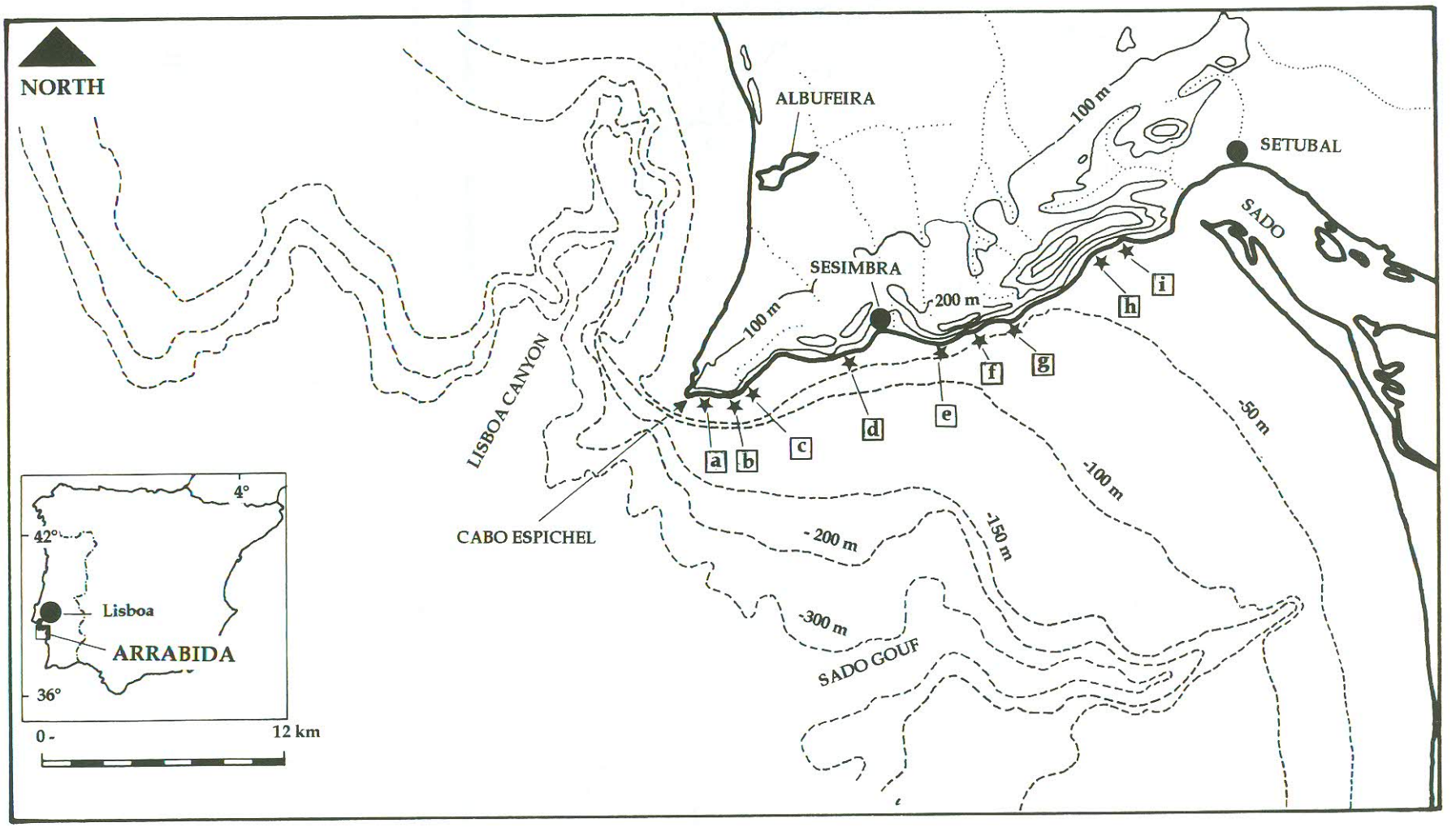

Fig. 1 – Location of the Arrabida coast line. Dives are designed by letters, a to i. In each site three to seven dives were performed.
Ubicazione della costa dell'Arrabida. I punti di immersione sono indicati con le lettere da a ad i. In ogni punto sono state effettuate un numero variabile da 3 a 7 immersioni.

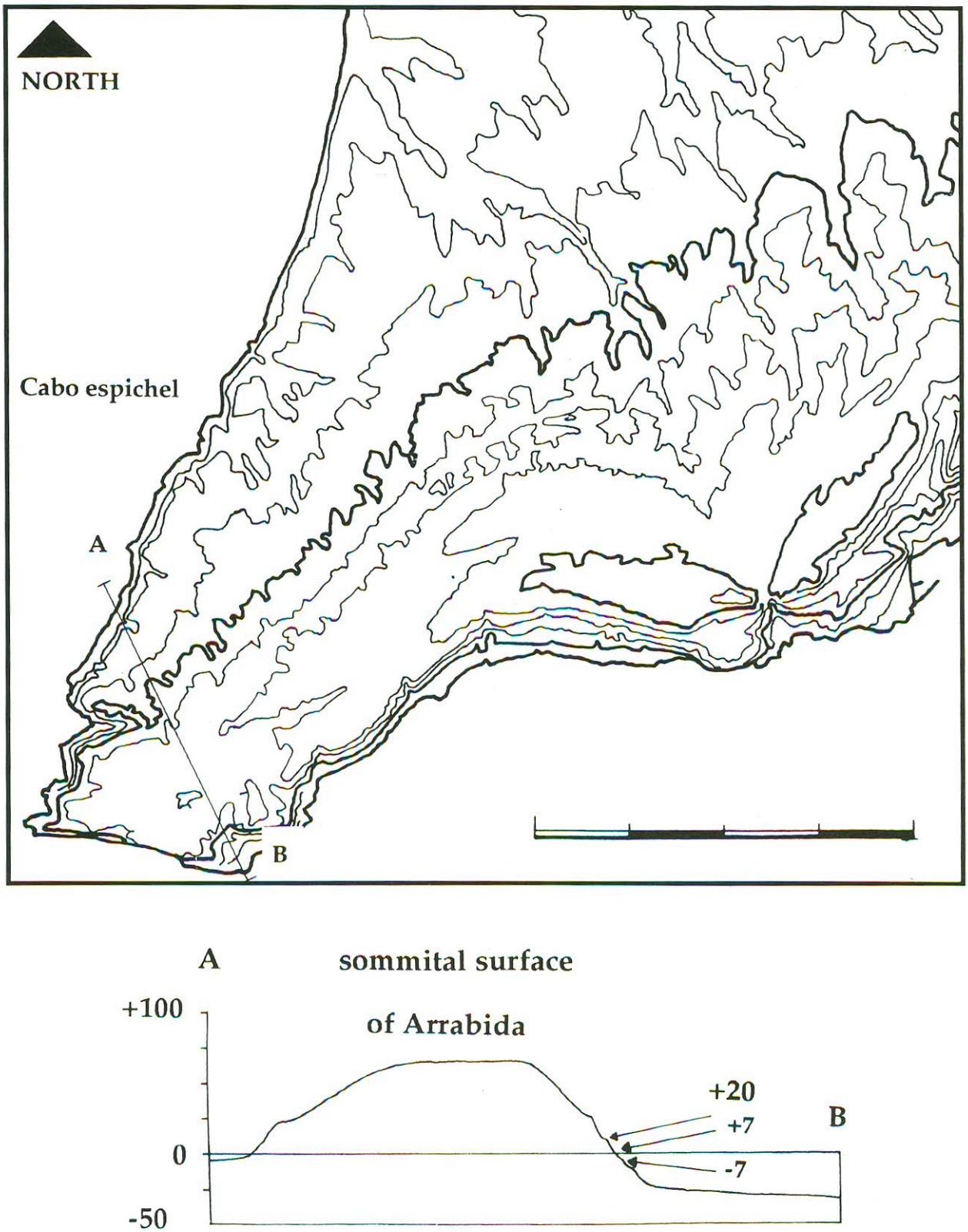

Fig. 2 – The sea levels on the southern slope of Arrabida Mountain.
I diversi livelli del mare lungo il versante meridionale del Monte Arrabida.

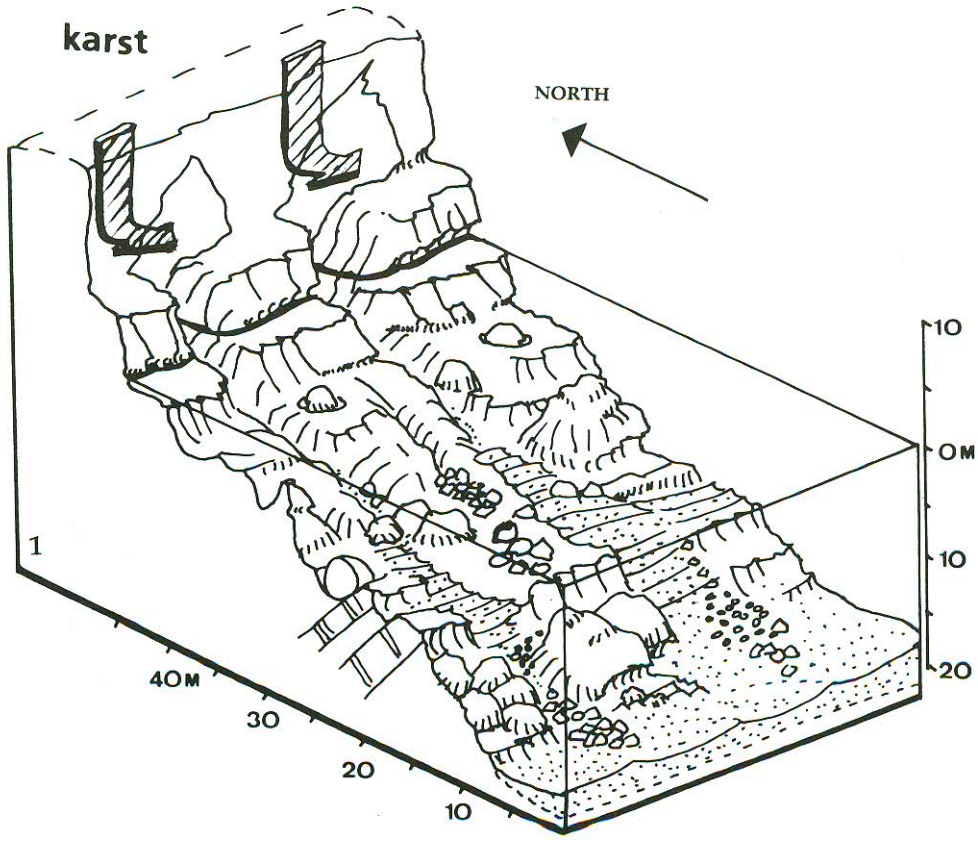

Fig. 3 – Diagrammatic block of diving site of Cabo Espichel, nº 1 on figure 9. The + 7 m level is deformed by the local tilting to the West and is incised by paleo streams, themselves deviated to the West. The – 7 m level was carved later, after the incision of these streams. Some isolated evidences of coast line are found at – 12 and – 20 m, but they are not continuous and have not been recognized on other sites.
Blocco diagramma del luogo di immersione di Cabo Espichel, nº 1 di fig. 9. Il livello + 7 m è deformato da un basculamento locale verso Ovest ed è inciso da paleocorrenti anch'esse deviate verso Est. Il livello – 7 m è stato scavato in un secondo momento, dopo l'incisione operata da queste correnti. Alcune isolate evidenze della linea di costa sono state trovate a – 12 m e a – 20 m, ma non sono continue e non sono state riconosciute in altri luoghi.

incisions and gelifracts, during a sea level rise. Many of the karstic caves have not been explored yet. The ravines are evolving today as submarine forms, with rockfalls, sand flows going up, bio erosion.

2.1.2. – *Site 2 (figure 4) Cha Os Navegantes, Baralha, maximum depth: 21 m.*

The + 20 m level is a wide abrasional platform, broken by faults, eroded by karstic lapiaz and locally buried under slope deposits. The +7 m level is a wide abrasion form, looking like the abrasion surface that usually develops under a mobile shingle ridge. Many boulders, some of sandstone and other of granite may be found in the notch. Most of them are of local limestone. The – 7 m level is a narrow platform, with potholes and a deep notch (over 0.6 m). The submarine ravines are active, with many blocks falling down and recovering the sand sheet with coarse debris cones at 20 to 22 m depth.

2.1.3. – *Site 3 (figure 5), Vale do Cavalo, maximum depth: 13 m.*

This site is the submarine continuation of a subaerial fault. The submarine continuation is clearly visible and is not polished by waves, suggesting a very recent activity. The – 7 m level is sligthly tilted to the West (by 0.1 m) and this is the only possible sign of late Holocene neotectonics in this region. Two sea stacks are situated in the eastern part of the site with a – 7 m notch and an abrasion platform at + 7 m. No evidence of any other level is found.

2.1.4. – *Site 4 (Figure 6) Cabo de Ares, eastern side, maximum depth: 19 m.*

This site is affected by two faults. The older one is NE/SW and determines the coast line. The second is NW/SE and is buried beneath mylonites, breccia and slope deposits, forming different superimposed layers. They are excavated by the present

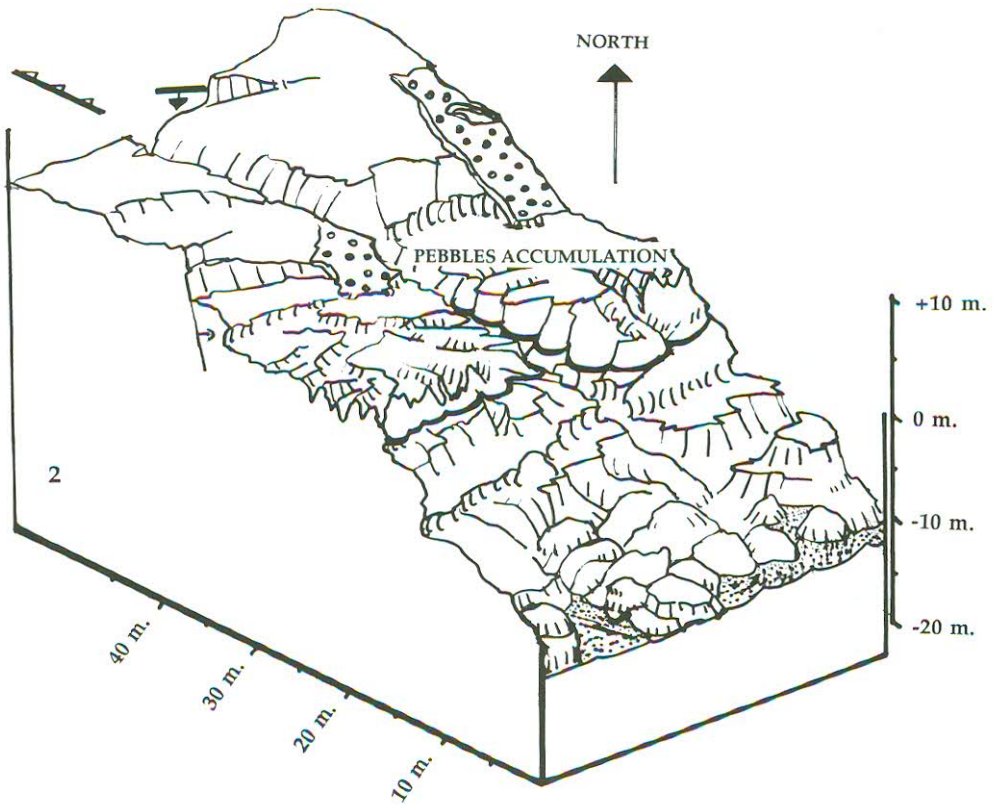

Fig. 4 – Diagrammatic block of diving site of Baralha, at the foot of Cha Os Navegantes, number 2 on figure 9. The + 20 m level is a wide abrasion platform, covered by later slope deposits. The + 7 m level is an abrasion platform, polished by a spit-like accumulation of pebbles. A notch is filled by later littoral deposits, with some shells (26000 BP). The – 7 m level is not very wide, but is very continuous. *Blocco-diagramma del luogo di immersione di Baralha, al piede di Cha Os Navegantes, n° 2 di fig. 9. Il livello + 20 m è un'ampia piattaforma di abrasione, coperta da successivi depositi di scarpata. Il livello + 7 m è una piattaforma di abrasione elaborata da ciottoli accumulati con energia. Una cavità è riempita da depositi litorali depostisi successivamente, contenenti alcune conchiglie (26000 dal presente). Il livello – 7 m non ha grande estensione, ma è continuo.*

sea level but they bury the – 7 m level, which is not deformed. It is a 2 m large abrasion bench with a 0.5 to 0.7 m notch and two big potholes are present. The foot of this fault scarp is eroded by the moving body of sands which feeds a beach, some two hundred meters to the East.

2.1.5. – *Site 5 (figure 7) Figueira Brava, maximum depth: 6 m.*

This part of the coast is almost entirely dominated by the input of alluviums from the Sado river. The + 7 m is represented by archeological remains inside of the grottos. The – 7 m level is fossilized and appears only through one sea stack.

2.2. – Paleo hydrodynamics

These observations may be used to reconstruct the paleo hydrodynamics which have shaped the geomorphological features during the successive sea stands.

The diagrammatic blocks of figure 8 represent a synthetic view of two submarine sites just E and W of Cha Os Navegantes. On 6a the + 7 m level is a narrow form whereas the – 7 m level is wide (+ 3 m). On 6b the + 7 m is very wide and the – 7 m is narrow. This assymetry is propably linked to a difference in exposure to waves during the shaping of the forms.

Observations about littoral drift may confirm this idea. The pebbles found inside of the + 7 m notch are not all of local origin. Some of them are coming from the region of Albufeira and only littoral drift from the West could explain such a transfert. This means that waves, from the West were attacking the cliffs of Cabo Espichel and moving eroded material to the East, to the Cha. There, in a more sheltered location the pebbles might accumulate and built a shingle ridge, moving with the storms and polishing the rocks beneath. They have carved the notch during the same time, exactly

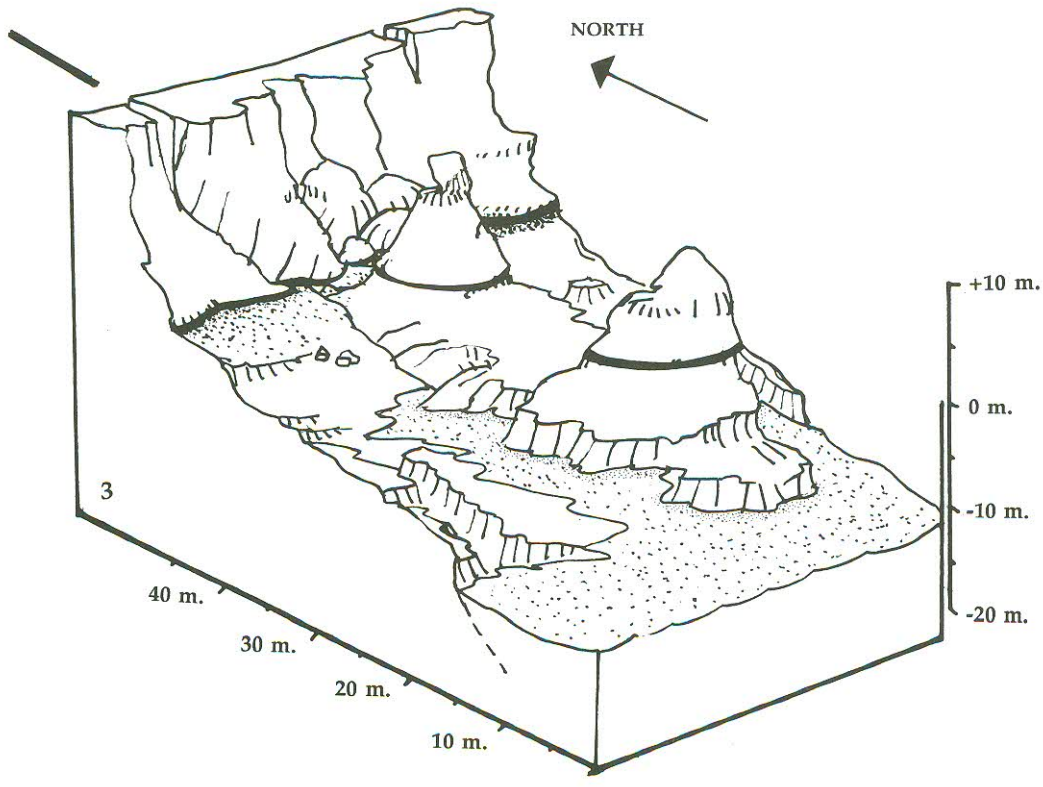

Fig. 5 – Diagrammatic block of diving site of Vale do Cavalo, number 3 on figure 9. Two sea stacks are separated by a −7 m abrasion platform and an active fault runs throught this form. Th +7 m level may be observed landward of the stacks and on their sheltered face also. It may have been destroyed on the exposed face.

Blocco-diagramma del sito di immersione di Vale do Cavalo, n° 3 di fig. 9. Due zone di accumulo sono separate da una piattaforma di abrasione marina a −7 m e una faglia, attiva, corre tra questi due accumuli. Il livello +7 m può essere osservato sulla parte verso costa degli accumuli e sulla loro parte riparata. Può essere stato distrutto sulla parte esposta.

as we can observe today in the cliffs of Normandy (Dieppe or Etretat) where the same combination of processes occurs.

The −7 m level is interesting as it displays the exact opposite distribution of large and narrow platforms, as if the drift was eroding in the East and building a shingle abrasive ridge in the West. Though the narrow bench in the West (at −7 m) may also be the result of a greater retreat under today exposed conditions. In other sites (Cabo de Ares especially) we can find the same difference between two parts of the −7 m level, suggesting also a drift to the West. Figure 9 proposes an hypothesis for the paleo directions of littoral drift.

3. – PROPOSAL FOR A CHRONOLOGY.

Submarine sea levels are not dated. The +7 m sea stand is dated on two sites. To the East, close to Portinho de Arrabida, in the grotto of Figueira Bravo prehistoric remains have been investigated by TELLES ANTUNES (1991) and dated of 30 000 B.P.. They include bears and rhinocerontes and give a testimony of a cold climate. To the West, close to Cha Os Navegantes some shells collected inside of the +7 m notch were dated by ourselves: the shells are 26500 600 B.P. ^{14}C (Pa 1206) whereas the carbonate cement is 25100720 B.P. ^{14}C (Pa 1197).

These dates may seem in contradiction with some reconstitution which have been proposed by ERLIDES (1992) and RAMOS& REGNAULD (1993). The +7 m level was then attributed to the latest interglacial, the Eemien.

3.1. – COAST LINE AT 26000 B.P.

At 30000 B.P. the sea level was some 30 to 45 m below today 0, (GRANJA & SOARES DE CARVAL-

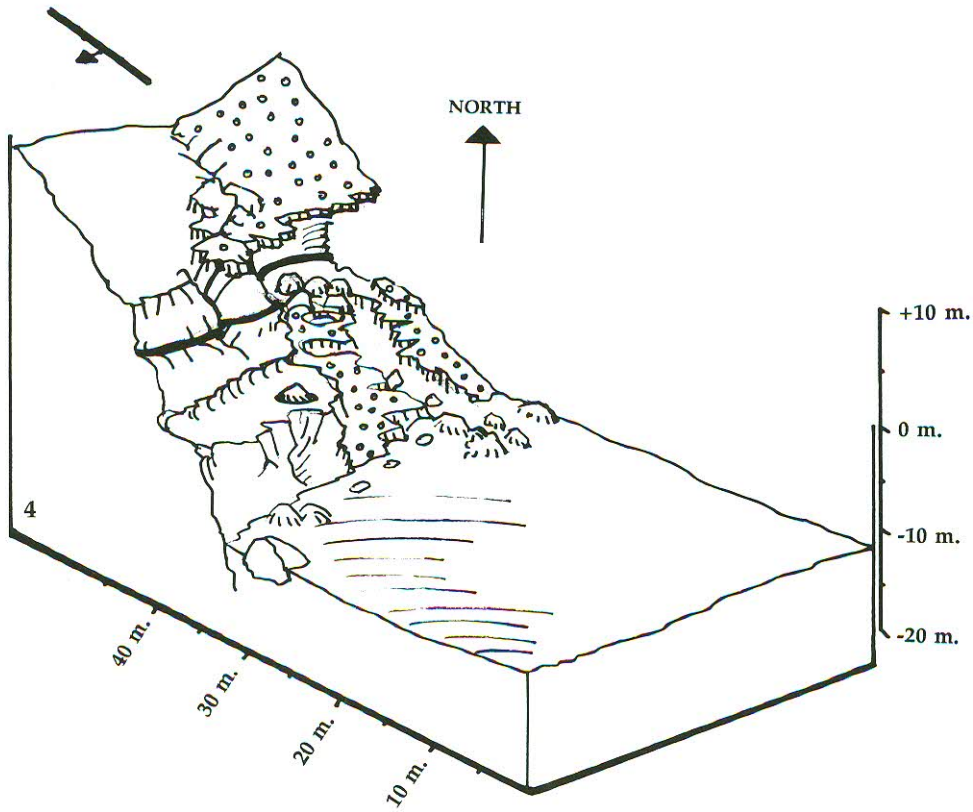

Fig. 6 – Diagrammatic block of the Cabo de Ares diving site, number 4 on figure 9. The fault line is filled with breccia and slope deposits going downn into the submarine region. They are eroded by the – 7 m level which is also represented by an abrasion platform and a notch. + 7 m and + 20 m level are not visible on this precise site, but just 20 m to the West.

Blocco diagramma del punto di immersione di Cabo de Ares, nº 4 di fig. 9. La faglia è riempita con brecce e depositi di scarpata che arrivano fino alla regione sottomarina. Essi sono erosi dal liv – 7 m, che è anche rappresentato da una piattaforma di abrasione e da una cavità di erosione. I livelli + 7 m e + 20 m non sono ben visibili in questo sito, ma appena 20 m verso Ovest.

HO, 1993) a figure that fits well into different sea level curves (SHACKELTON, 1987; PIRAZZOLI, 1992). In Portugal recent works (RODRIGUES *et alii*, 1992) have demonstrated that the sea was 140 m below zero at 18.000 B.P. If the + 7 m level was a coast line 25.000 years ago, and if it is, today, 7 m above sea level, we have an uplift of more than 7,5 meters every 1000 years. This uplift rate, though not totally unknown (such as on active faults in Sumatra, DETOURBET *et alii*, 1993) is very uncommun on passive margins and absolutely unknown in Portugal. On active portuguese faults such as Villarica (CABRAL, 1988) the uplift is 0,25 m/1000 years, as an average during the two last million years. BRUM FEREIRA proposed similar values in 1980. On figure 10 a standart sea level curve, corrected after RODRIGUES *et al.*, 1989.is drawn. The dark stripe beginning at 26000 BP represents, graphically, the uplift rate that should have existed if the + 7 m sea level were a 26000 BP coast line.

For three reasons this uplift rate is difficult to accept. First of all a sea level at + 7 m at 26000 B.P. would mean that Figueira Brava grotto (+ 7 m also) was submerged at 30000 B.P. as the sea level was even higher. How could hunters have cooked inside of a marine cave ? The second reason questions how such a rapid deformation has not been noticed elsewhere than on the shore. From a third point of view it is difficult to correlate this uplift with the observed deformation of the + 7 m level in the vicinity of Cabo Espichel (one to three meters for the same length of time) and with the almost total absence of deformation for the – 7 m sea level. So the sand and shell deposit dated from 25000 B.P. cannot be a proof of a sea level at this time, in this place.

We propose to make a difference between the carving of the form and the filling of the notch by sediments. Obviously the notch of the + 7 m level was created by a very aggressive system of waves,

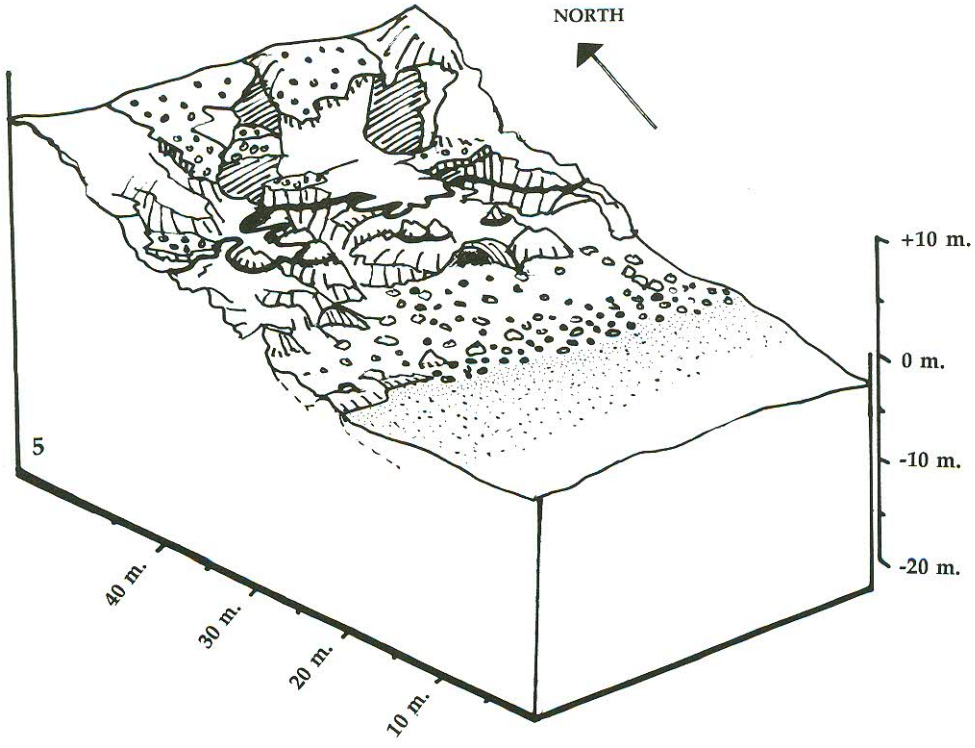

Fig. 7 – Diagrammatic block of Figueira Brava diving site, nº 5 on figure 9.
The + 7 m level is found inside of the grottos, with datable material (human bones and cooking relicts at 300000 BP).
The Sado alluviums recover the – 7 m level which appears only throught sea stacks.
Blocco diagramma del punto di immersione di Figueira Brava, nº 5 in fig. 9.
Il livello + 7 m è stato trovato all'interno di grotte con materiale databile (ossa umane, tracce di cottura di 30 000 anni dal presente).
Le alluvione del Sado ricoprono il livello – 7 m che si riconosce solo attraverso i depositi marini.

rolling pebbles against the foot of the cliff: the sand can not accumulate at the same moment inside of an exposed notch. So the filling is posterior and may be related to any sea level that could bring marine sand close enough and allow the wind to blow it and fill the notch.

Today marine sand and shells may be found up to 15 metres above sea level in the vicinity of Cha Os Navegantes. Some shells are left by birds, ressembling false "*knoekkenmodding*" up to 105 meters. In the Cha the sand is thrown by waves that break along the cliff, which is 10 m high. Close to Cabo de Ares, the costline has no cliff but a steep slope and the marine sand, shells may be found up to 25 metres. If we transfer these observations 25000 years ago, we may explain marine sand in the + 7 m notch with a sea level that would be located some 10 to 25 meters below. The uplift rate would then be reduced to 0,30 m/1000 years, and still be hardly compatible with the data of the neotectonic studies. But if we take into account the possibility for birds to leave many shells around their nest, then the sea level may be any where below.

These consideration do not allow to draw any conclusion for uplift rate during the last glacial period (between the Eemien and the Holocene). The high hypothesis implies an uplift rate which is higly debatable. The low hypothesis (based on the deformation of the + 7 m level) implies a 3 m downward relative tilting to the West that is to say a differential uplift of 0,03 m/10 000 years. Any figure between these two may be correct.

3.2. – Possible dates for the + 7 m and the + 20 m sea levels.

The + 7 sea level was carved during a long sea stand: it is a 10 to 18 m wide abrasion platform cut in hard limestones. Today waves have cut a 10 to 50 cm abrasion bench in these limestones, during two (more or less) thousand years. This a very low

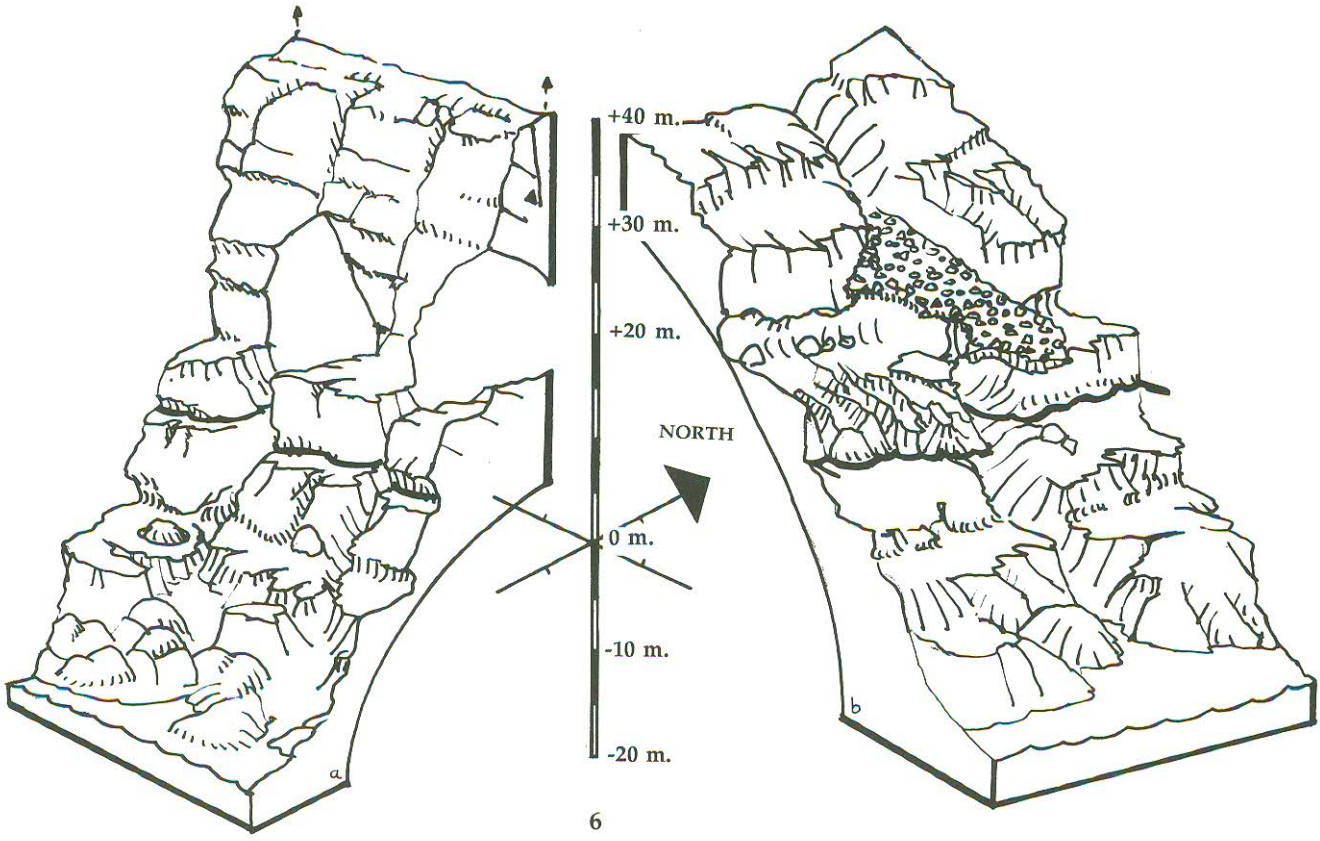

Fig. 8 – Two synthetic diagrammatic blocks, drawn out of different dives, all located on n° 6 in figure 9.The orientation of these two littorals is shown by the arrows in the middle. Evidences for palaeo littoral drifts are from the West for the + 7 m level, from the East for the – 7 m level. The – 7 m drift was a very secondary morphological agent and most of the eroded material was evacuated down ward in the ravines and a very small amount of pebbles only was deplaced laterally.

Due blocco-diagrammi sintetici ripresi da differenti immersioni, tutti localizzati nel n° 6 di fig. 9. L'orientamento delle due linee di costa è indicata dalle frecce al centro. Le tracce delle paleo-correnti litorali sono da Ovest per il livello + 7 m, da Est per il livello – 7 m La corrente dei – 7 m era un elemento morfologico secondario e la maggior parte del materiale eroso è stato trascinato in basso in solchi e solo una piccola quantità di ciottoli è stata spostata lateralmente.

rate of retreat, probably due to the fact that the sea ward side of the platform is also receeding. The measured form is only a part of the total form. With the same waves pattern a 40 000 years duration is needed for the shaping of the + 7 m platform. As the waves were more efficient (palaeo drift was more from the West) it is reasonable to assume that this period was shorter.

The + 20 m sea level is much wider. The land ward limit of this palaeo abrasion platform is not known with accuracy, because of the slope deposits which lay upon. In some places (Western Cha) this + 20 m platform exceeds 25 m, and is probably larger in the center of the Cha. So, a long period of time has to be taken in consideration for its shaping.

A model may then be proposed with figures taken in the bibliography. SUNAMURA (1992) gives a wide review of erosion rates in limestones and shows that it varies between 1 mm and 1 cm per year. Uplift rate in Portugal is 0,25 mm/year as an average on an active fault. With the lowest recession rate and the average uplift rate we obtain, on figure (10) some very interesting hypothesis.

The + 20 m level would date of the Eemien (120000 B.P.), with a long lasting high stand (2 to 5 m above today zero). The + 7 m level could be associated with the first manifestations of the regression or with an interstadial high stand, at 85000 B.P. and 20 m below zero. At 6000 B.P. it was, then, some 10 m above sea level, and at 30000 B.P., 40 m above, giving many opportunities for storms to fill the notch with sand and pebbles. The 26 000 B.P. shells would have been deposited 60 m above sea level and are more probably bird food, though anthropic origin cannot be formally rejected. The

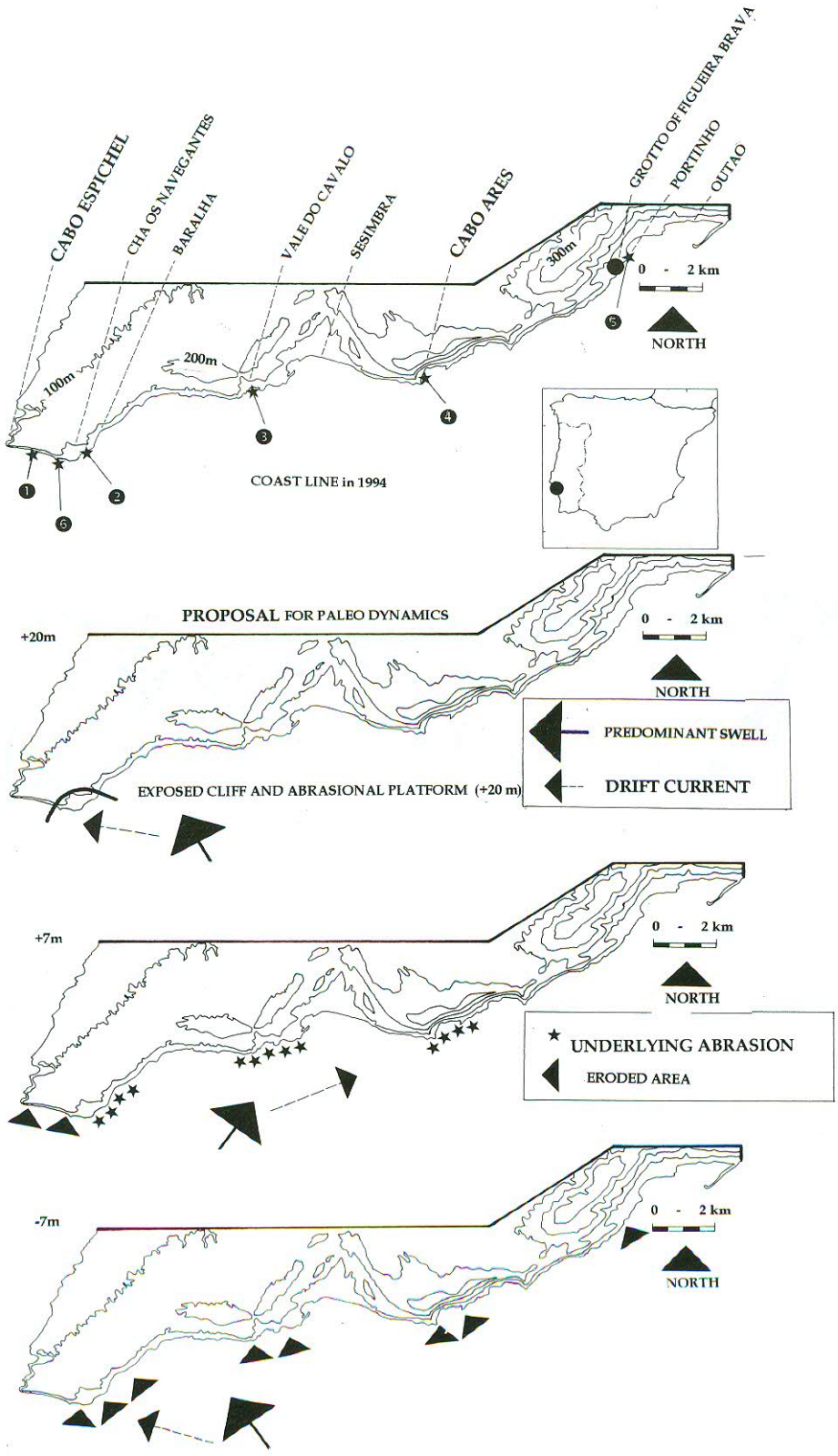

Fig. 9 – Location of some peculiar sites, represented in the diagrammatic blocs (numbers from 1 to 6). and proposal for palaeo hydrodynamics. The + 20 m sea level was carved by a South East swell; the + 7 m by a South West swell, producing an eastward drift; the – 7 m sea level by a South to South East swell, with a local and very low Westward drift.

Ubicazione di alcuni siti particolari rappresentati nei blocco-diagrammi (da nº 1 a nº 6) e proposti per la paleo-idrodinamica. Il livello + 20 m è stato scavato da onde di tempesta da Sud-Est; il livello + 7 m da onde provenienti da Sud-Ovest, che hanno prodotto una corrente verso Est; il livello – 7 m da onde di tempesta da Sud Sud-Est, con una corrente locale molto poco intensa verso Ovest.

Figueira Brava grotto, standing some 50 m above the sea would have been a perfect observation post for hunter watching the Sado coastal plain. The −7 m sea level is an Holocene step during the transgression, as the sea level rise is becoming slower, probably at 5 000 B.P.

4. – CONCLUSIONS

The southern slope of the Arrabida mountain displays sea levels between + 20 and −7 m. The whole region is undergoing an uplift, the exact rate of which is unknown. A proposal for a 0,25 mm/year uplift, which the average calculated value for the Quaternary in Portugal allows to reconstruct the evolution of the coast line and gives the best solution for the succession of morphologies observed on the different sea levels. The + 20 m level was shaped during the latest interglacial and the + 7 m level is a short stand during the first phases of regressions that follows the Eemian. During the glacial low stand subaerial agents have incised ravi-

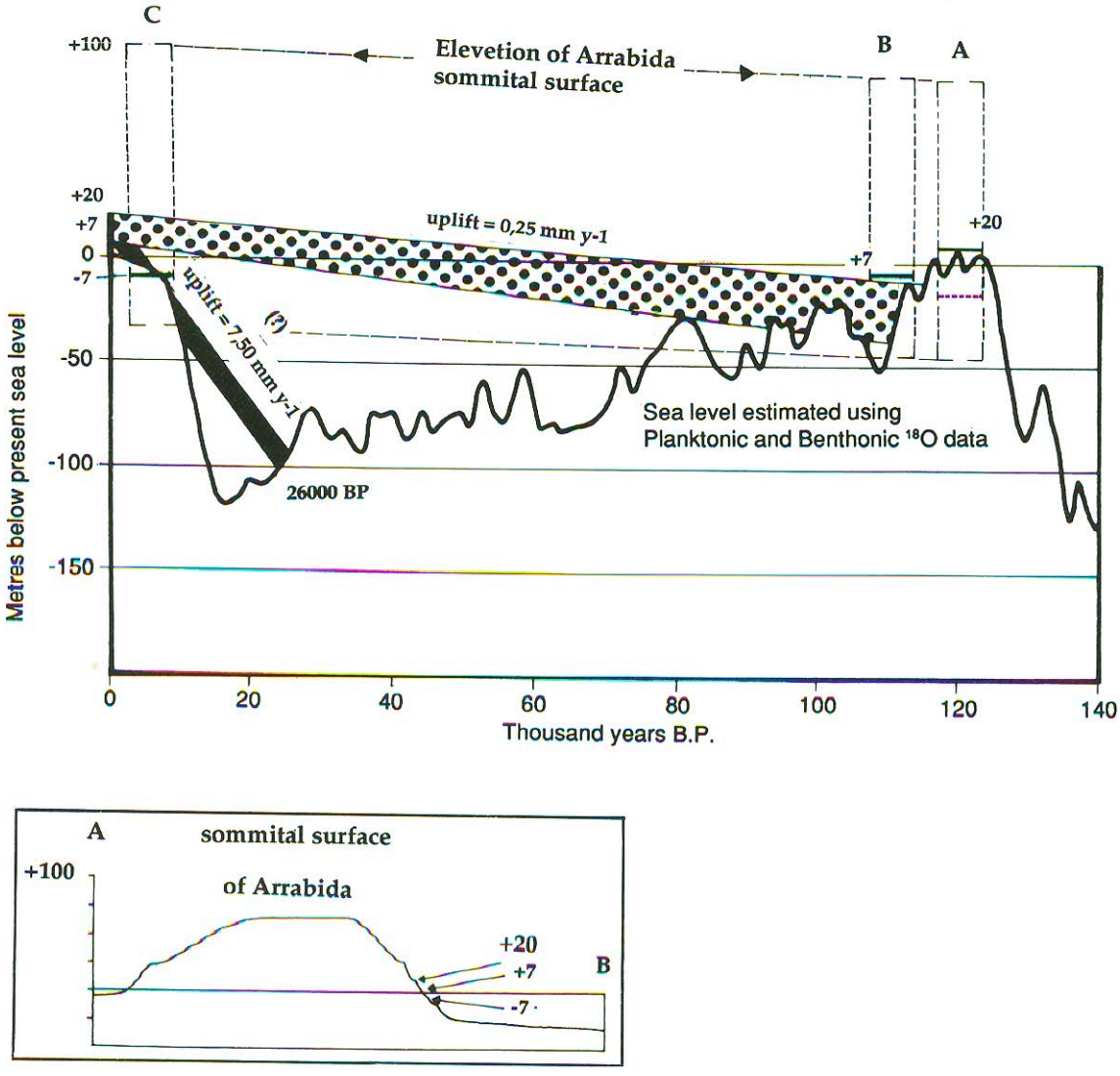

Fig. 10 – Different hypothesis for the chronology of the region. The sea level curve is adapted from Shackelton (1987) and from Rodrigues and Dias, (1989). A 26000 BP age for the + 7 m level implies a very high uplift rate which is totally unknown in the rest of the Portugal. We propose an age of 100000 BP for the carving of the notch and a later filling of it by storm waves moving sand from a lower sea level. Some birds or prehistoric gatherer may have left the shells dated of 26000 BP. The uplift rate is compatible with the average values for the two last millions years in Portugal.

Differenti ipotesi per la cronologia della regione. La curva del livello del mare è adattata da Shackelton (1987) e da Rodrigues e Dias, (1989). Un'età di 26000 anni dal presente per il livello + 7 m comporta una velocità di sollevamento molto alta che è del tutto sconosciuta nel resto del Portogallo. Noi proponiamo un'età di 100000 anni dal presente per lo scavo della cavità e un riempimento più tardo ad opera delle onde di tempesta che muovono la sabbia da un livello del mare più basso. Alcuni uccelli preistorici possono aver accumulato gusci datati 26000 anni. La velocità di sollevamento è compatibile con i valori medi per gli ultimi due milioni di anni in Portogallo.

nes, flowing down from these levels. The coldest periods produced coarse slope deposits which fossilize some areas. At the same time, according to the relative sea level fluctuations the + 20 and the + 7 m levels were never submerged but were, occasionally reached by storm deposits. The holocene sea level rise carved an abrasion platform at − 7 m and, perhaps also at − 12 m and − 20 m. These later levels respect the shape of the preexisting ravines which are now behaving as submarine forms, with debris flows and sand sheet moving up. Human occupation at 30000 B.P. gives a testimony of the landscape, as grottos were used as observation post above the Sado plain. Local geomorphic features give some indication about paleo littoral drift. These waves directions still have to be connected with a general circulation pattern.

REFERENCES

Brum Fereira (1980) - *Surface d'applanissement et tectonique récente dans le Nord de la Beira (Portugal).* Rev. Geol. Dyn. et Géogr. Phys., **22** (1): 51-62.

Daveau S., Azevedo T. Mira de (1981) - *Aspectos e evoluçao doo relevo da extremidade sudoeste da Arrabida (Portugal).* Boletim Soc. Geol. Portugal, **22**: 163-180.

Detourbet C., Bellier O., Sebrier M. (1993) - *La caldera volcanique de Toba et la grande faille de Sumatra (Indonésie) vues par l'imagerie SPOT.* C.R.A.S., **316**, 2, 10: 1439-1446.

Erlides (equipe: Regnauld *et alii* (1992) - *Découverte d'un niveau marin submergé le long de la chaine de l'Arrabida, Portugal.* Finisterra, **27**, 52/53: 165-168.

Granja H.M., Soares de Carvalho G. (1993) - *A synthesis of the reserches about the Pleistocene-Holocene evolution of the NW coastal zone of Portugal.* First International Conference on the Mediterranean coastal environnement, Med Coast, Antalya: 159-165.

Pirazzoli P.A.. (1992) - *Global sea level changes and their measurement.* Global and planetary change, **8**: 135-148.

Ramos Pereira A. (19889 - *Aspectos do relevo de Portugal. Litorais ocidental e meridional da peninsula de Setubal.* Finisterra, **23**, 46: 335-349.

Ramos Pereira A., Regnauld H., Gouery P., Dias J.A. (1993) - *Variations du niveau de la mer et systèmes morphogéniques associés dans l'ouuest de l'Arrabida (Portugal),* Third Inter. Conf. Geomorphology, Hamilton Canada, Abstracts, 227.

Ramos Pereira A., Regnauld H. (1993) - *Litorais quaternarios (emersos e submersos) na extremidade sudoeste da Arrabida (Portugal).* III Reuniao do Quaternario Iberico, Coimbra, L.A.G.F.: 55-73.

Rodrigues A., Dias J. Alveirhino (1989) - *Evolucao pos glaciaria da plataforma continental portuguesa a norte do Cabo Mondego.* Anais do Instituto Hidrografico, **10**: 39-49.

Shackelton N.J. (1987) - *Oxygen isotope, ice volume and sea level.* Quat. Science Rev., **6**: 183-190.

Sunamura T. (1992) - *Geomorphology of rocky coasts.* Wiley: 1-302.

Telles Antunes M. (1991) - *O homen da gruta da Figueira Brava (ca 30000BP), contexto ecologico, alimentacao, canibalismo.* Mem. Acad. Ci. Lisboa, **31**: 487-536.