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TOMO XXXVIII

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Gruta da Figueira Brava (Arrábida):
Geological Setting

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Resumo

Palavras-chave: Miocénico; Plistocénico; Portinho da Arrábida; Gruta da Figueira Brava; Portugal.

A serra da Arrábida é o melhor exemplo de actuação da Orogenia Alpina em Portugal. Foram caracterizadas pelo menos duas fases tectónicas: uma cerca de 17 Ma e outra mais recente do que 16 Ma.

Os depósitos miocénicos, essencialmente biocalcarenitos, datam do Burdigaliano médio e do Langhiano.

No Plistocénico, o mar escavou no sopé de arribas constituídas (no que aqui interessa) pelos biocalcarenitos miocénicos e talhou terraços. Existem conglomerados correspondentes a terraços marinhos de 12 a 15 e 5 a 8 metros, atribuíveis ao último interglaciário e ao início da glaciação de Würm (≈100000 anos, Tirreniano II e III).

O terraço de 5-8 metros, com particular interesse, depositou-se em estreita plataforma de abrasão marinha; tende a preencher a entrada das cavidades abertas nas arribas litorais, como a Lapa de Santa Margarida e a Gruta da Figueira Brava.

Com o avanço da glaciação do Würm, o nível do mar foi descendo. Há cerca de 30000 anos, a plataforma de 5-8 metros e as cavidades aí escavadas ficaram elevadas sobre extensa planície litoral. O mar situava-se cerca de 60 metros abaixo do nível actual. As comunidades humanas encontraram nesses territórios óptimos locais de caça. Cavidades como a Lapa de Santa Margarida e a Gruta da Figueira Brava, constituiam bons abrigos naturais. Aí ficaram preservados vestígios da ocupação – ossos de animais, restos de neandertalianos, indústrias líticas e de osso.

Abstract

Key-words: Miocene; Pleistocene; Portinho da Arrábida; Figueira Brava cave; Portugal.

The Arrábida Mountain Range is the best example in Portugal of alpine movements. During Miocene times the Arrábida chain acquired the present structural set up: overthrusting accidents striking ENE-WSW and N-S or NNE-SSW sinistral lateral ramps. The main tectonic phases occurred about 17 Ma and somewhat less than 16 Ma.

The Miocene deposits, mainly biocalcarenites, are middle Burdigalian and Langhian in age.

During the Pleistocene the sea erosion cut several terrasse levels. Scattered remnants of conglomerates corresponding to the 12-15 and to 5-8 meters marine terrasses are ascribed to the last interglacial and to the beginning of the Würm glaciation (≈ 100000 years, Tyrrhenian II and III). The 5-8 meters terrasse, which is of particular interest, was deposited in a narrow marine erosion platform; the corresponding deposits tend to fill the entry of the caves excavated in the sea cliffs during the Upper Pleistocene such as Lapa de Stª Margarida and Figueira Brava Cave. These holes, protected by overhanging parts of the cliffs as a sort of ceiling, were good shelters for man.

With the advance of the Würm glaciation the sea level was progressively going down. About 30000 years ago, the 5-8 meters platform and the caves dug in the cliffs were elevated as related to an extensive coastal plain. The sea level was *ca.* 60 meters below the present level (Miskovski, 1987). The human communities found in these territories an excellent hunting ground. The Santa Margarida and Figueira Brava caves were thus natural shelters. A large number of remnants of their occupation are preserved such as shells, animal bones, a few Neanderthal remnants as well as lithic and bone implements. ^{14}C (and U series) dating indicate an age about 30000 years for level 2 where archaeologic remnants were exploited.

Introduction

The Figueira Brava cave is located in the Southern limb of the Arrábida Mountain Range, between Alpertuche and Fortaleza (Portinho da Arrábida) (Fig. 1, 2). It corresponds to the enlargement of a fault by marine erosion over miocene biocalcarenites during the Upper Pleistocene (Tyrrhenian III).

The Arrábida Mountain Range is the best example in Portugal resulting from the alpine movements. During Miocene times it acquired the present structural set up: overthrusting accidents striking ENE-WSW and N-S or NNE-SSW sinistral lateral ramps.

In the Southern limb of Arrábida the Miocene constitute a narrow discontinuous band striking E-W stretching from Alpertuche to the Fortress

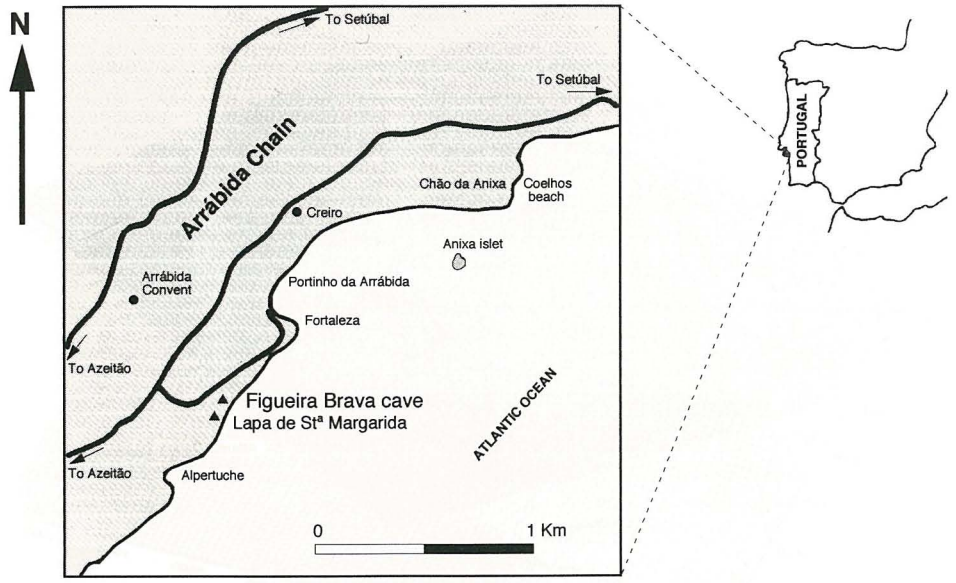

FIG. 1 - Location of Gruta da Figueira Brava and Lapa de Santa Margarida.

reappearing in the eastern end of Portinho da Arrábida beach and from there to the Figueirinha beach.

The Arrábida chain was referred to by Eschwege (1831). However the first important studies are those by Choffat (1906, 1908, 1950), who showed the existance of an angular unconformity between what he ascribed to the M1 (Burdigalian) and M2 (Helvetian) units defined by him. Zbyszewski (1967) described equivalent geological sections, reporting the deposits to the Helvetian VI and the Burdigalian and Aquitanian as Helvetian V due to their mollusc associations.

Ribeiro (in Ribeiro *et al.*, 1979, p. 24, Fig. 2.12) reinterpreted the tectonic sketch of Choffat. He confirmed the existence of an angular unconformity and showed a complex syncline-anticline fold which would connect the continent to the Anixa islet.

Pais *et al.* (1991), in the follow up of the revision of the Setúbal geological map by G. Manuppella (Instituto Geológico e Mineiro, formerly Serviços Geológicos de Portugal) studied the lithostratigraphy of the Neogene deposits from the southern limb of Arrábida Mountain Range and the structural evolution.

In 1995, Antunes *et al.* published the first $^{86}Sr/^{87}Sr$ dating of mollusc shells from several lithological units which enabled the dating of two tectonic phases; the oldest occurring about 17 Ma (Burdigalian), a later one younger than 16 Ma.

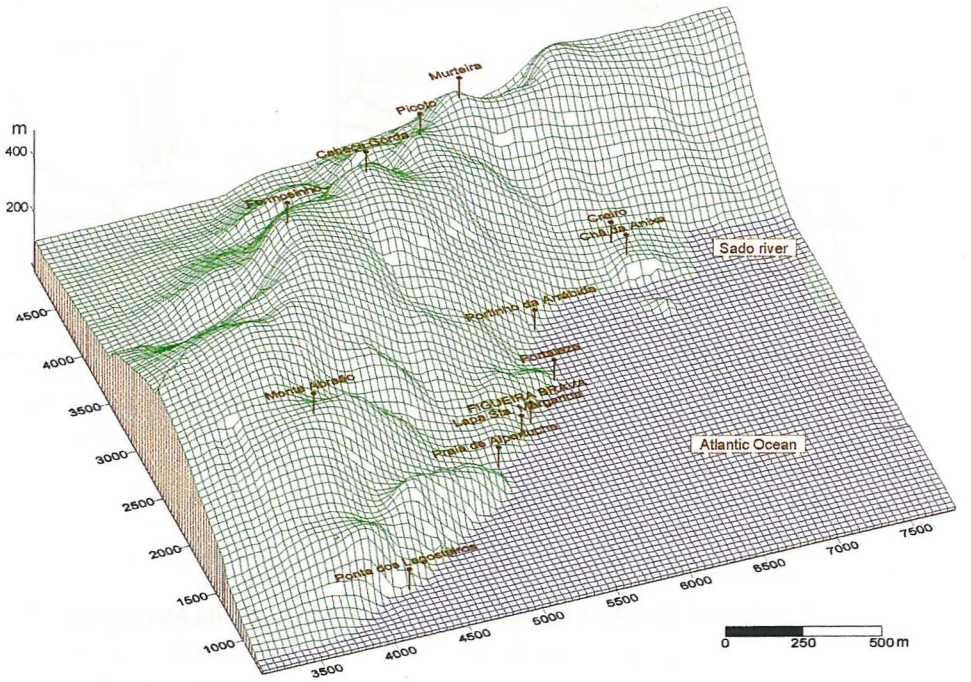

FIG. 2 - Block diagram of the area around Alpertuche. The location of Gruta da Figueira Brava is shown.

The Arrábida Chain has been an island for several times in the Miocene, namely during the transgressive events of Burdigalian and Serravallian (Antunes *et al.*, 1999). The insularity of this region could have led to some faunal endemisms and to the preservation of some archaic forms (Fig. 3).

The Southern limb of Arrábida is also interesting in what concerns the Quaternary. At Forte da Baralha region, in the western part of Arrábida chain, marine terrasses are well characterized by morphology. Deposits yielded mollusca studied by Dollfus (in Choffat & Dollfus, 1904-07) later reviewed by Zbyszewski (1943, 1958). Level 5-8 meters was referred by Zbyszewski & Teixeira (1949). This is quite distinct of the 15 m level, that was ascribed to Tyrrhenian II. They state that the 5-8 m terrasse deposits of Forte da Baralha are composed of a calcareous conglomerate with abundant shells. It yielded two languedocian implements *in situ*, one at Forte da Baralha, another one at Lapa de Santa Margarida (Breuil & Zbyszewski, 1945). Daveau & Azevedo (1980-81) published on the geomorphology of southwestern Arrábida. Cardoso (1994) produced a synthesis of the coastal

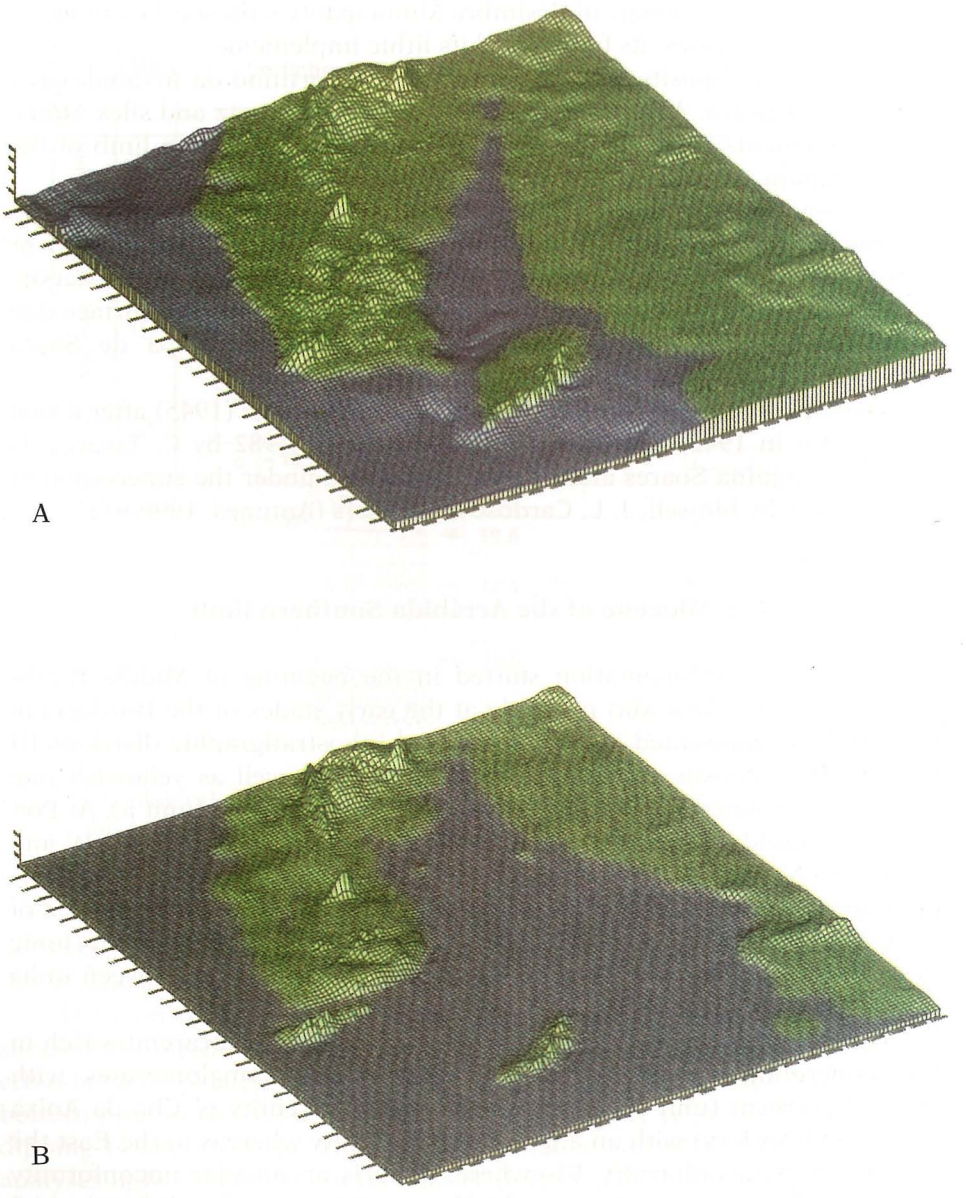

FIG. 3 - Paleogeographic model of the terminal part of the lower Tagus basin. A - During Burdigalian (after Arrábida Chain uplift), B – During Serravallian (Antunes *et al.*, 1999).

geology and geomorphology of Sesimbra Municipality with special emphasis on the marine terrasses, its faunas and its lithic implements.

Quaternary deposits are also known at the Portinho da Arrábida area near Figueira Brava. Antunes *et al.* (1992) described quartz and silex Mousterian implements collected "in situ" at Creiro in the southern limb of the Arrábida Chain.

The source rocks of the lithic material are slope deposits with quartz and miocene biocalcarenite elements up to 50 cm in size, in a fine sandy or reddish silty matrix. Particularly important are the infillings of the karstic surfaces as well as the coastal deposits over the marine abrasion surface dug in the miocene calcarenites and related caves as the Lapa de Santa Margarida and the Gruta da Figueira Brava.

These caves were mentioned by Breuil & Zbyszewski (1945) after a visit to both sites in 1942. The latter was prospected in 1982 by C. Tavares da Silva and Joaquina Soares and properly excavated under the supervision of M. T. Antunes by himself, J. L. Cardoso and others (Antunes, 1990-91).

The Miocene of the Arrábida Southern limb

The marine sedimentation started in the begining of Middle Burdigalian (Sr dating ≈18.8 Ma) probably at the early stades of the Burdigalian transgression represented in Lisbon by local lithostratigraphic divisions III and IVa. The deposits consist of biocalcarenites as well as yellowish fine grained sandstones poor in fossils overlaying the Paleogene (unit a). At Portinho da Arrábida its average thickness is 30 meters striking N 75° W and dipping 40° N. At the top of this unit (a), it seems that there is a gap possibly contemporaneous with the one shown in the Cristo Rei section by the end of division IVb (Antunes *et al.*, 1996). This matches with an important tectonic phase around 17 Ma giving rise to an angular unconformity between units (a) and (b).

The unit a) is followed by whitish and yellowish biocalcarenites rich in algal concretions, coarse-grained sandstones, and conglomerates with carbonate cement (unit b). In the westernmost extremity of Chã da Anixa they overlain unit (a) with an angular unconformity whereas to the East the contact is a paraconformity. Elsewhere, there is an angular unconformity over the Middle Jurassic. Average thickness is 35 meters. Sr dating (≈ 16.5 Ma) still points to the Burdigalian.

Over this assemblage there are fossil poor whitish and/or yellowish siltites (unit c). The thickness is approximately 8-9 meters. They may date from late Burdigalian.

More recent Miocene deposits consist of about 76 meters thick whitish fossiliferous biocalcarenites, striking N30°E, dipping 25° SE; the latter

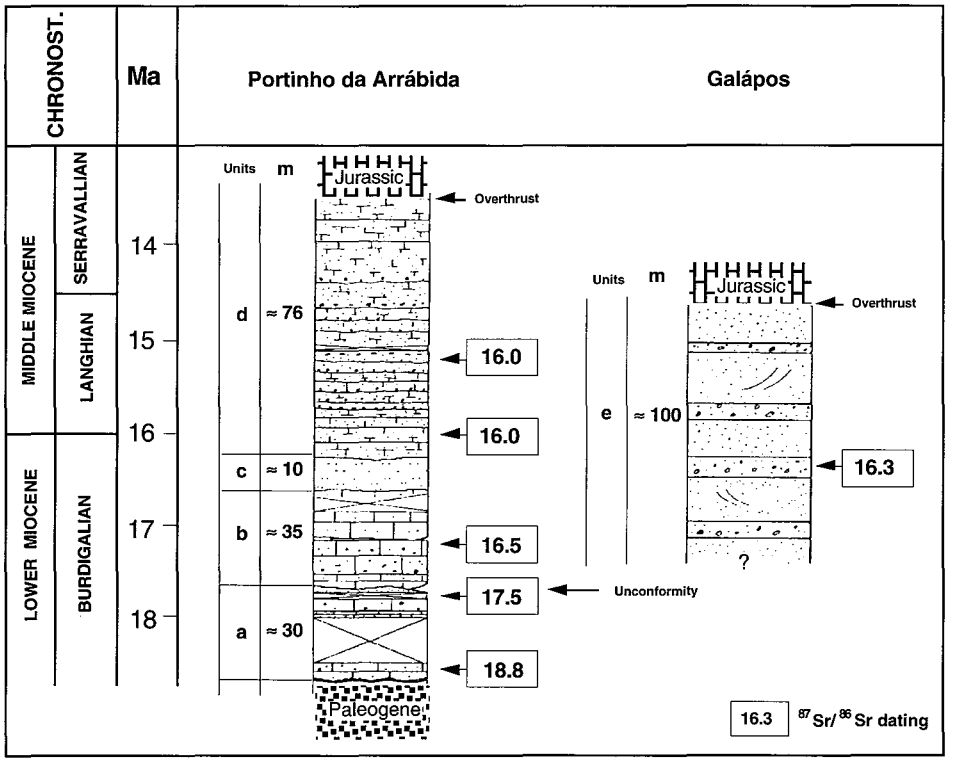

FIG. 4 - Lithological columns and datation for the Miocene of the Southern limb of the Arrábida Chain (Antunes *et al.*, 1995).

increase to the East up to 50° SE. Sr dating indicates 16 Ma (beginning of the Middle Miocene).

Between Galapos and the Figueirinha beaches outcrops coarse grained sandstones interlayered with conglomerates with fossiliferous beds (unit e); cross-bedding structures indicate currents oriented to the East at the bottom and to the West at the top. The thickness is around 100 meters; dipping is about 25° N. They are overthrusted by the Lower Jurassic. Sr analyses indicate 16.3 Ma in the middle part (end of Burdigalian). They may be a lateral equivalent of units (b) and/or (c) (Fig. 4).

Unit (b) is folded, locally overthrusting units (c) and (d) and laying unconformably over (a). Unit (d) contacts unit (c) through an irregular surface. It was not possible to correlate in the field the unit (e) with the other units, their atitude and lithology being completely different (Antunes *et al.*, 1995).

Unit (a) of the Portinho da Arrábida Neogene, locally folded as a closed syncline with vergence to SE, is in sequence with the Paleogene, the Cretaceous and the Upper Jurassic. These inverted units are part of the overturned limb of the Formosinho anticline. The latter is limited to the South in the continental shelf (Ribeiro, in Ribeiro *et al.*, 1990) by the main overthrust of the Arrábida Chain; and to the North by another overthrust which connects the Dogger to the Miocene. This assemblage forms a duplex structure probably extending for several kilometers. The tectonic phase which gave rise to the folding of the lower unit is dated around 17 Ma. The units (a) to (d) were folded in a sequence of anticline, syncline and anticline. The axis trend approximately ENE-WSW, dip to ENE and pass respectively between Pedra da Anixa and Chã da Anixa, at Coelhos beach, and to the North of this beach (Fig. 4) (Pais *et al.*, 1991; Antunes *et al.*, 1995). Folding occurred less than 16 Ma ago and is compatible with the Neocastillian phase well known in Iberia during the Langhian.

The Miocene of Alpertuche

At Alpertuche, the Miocene forms a higher than 100 meters, nearly 1000 meters long by 350 meters wide hill stretching to the Fortress. The outcrop consists of biocalcarenites in angular unconformity over the 55° dipping Jurassic. Strongly karstified biocalcarenites are rich in large pectinids and *Gryphaea gryphoides*. The terra-rossa filled depressions contain large amounts of rounded quartz pebbles which are the biocalcarenites residual material (Pl. 1, Fig. 2).

Thick (several meters) coarse biocalcarenites outcrop around Figueira Brava Cave. They show several joints and are locally faulted. Karstic holes, such as Figueira Brava Cave and Lapa de Santa Margarida, are developed where they criss-cross. Both were used as shelters by pre-historic man and Figueira Brava Cave supplied important archaeological materials.

The Pleistocene of the Portinho da Arrábida

Scattered remnants of conglomerate outcrops corresponding to the 12-15 and to 5-8 meters marine terrasse levels have been ascribed to the last interglacial and to the beginning of the Würm glaciation (≈ 100000 years, Tyrrhenian II and III).

The 5-8 meters terrasse is of particular interest. It was deposited in a narrow marine erosion platform and fills the bottom of the entry of the holes opened up in the sea cliffs such as Lapa de Santa Margarida and Figueira Brava Cave. Zbyszewski (1965) described the following sucession (top to bottom) close by Lapa de Santa Margarida.

3 - reddish to brownish, well cemented breccia, with terrestrial vertebrates bones, mousterian splinters and stalagmitic layers;
2 - reddish cement conglomerate with fragments of *Patella safiana*, *Chamelea*, *Venerupis*, *Ostrea*, etc.;
1 - conglomerates of large pebbles with palaeolithic industries.

Zbyszewski & Teixeira (1949) classified the following fossils from the 5-8 meters terrasse (updated nomenclature according to J. Angel González-Delgado, Salamanca University):

Former designation	**Present designation**
Bivalvia	
Mactra solida	*Spisula solida*
Tapes pullastra	*Venerupis pullastra*
Venus gallina striatula	*Chamelea gallina striatula*
Cardium echinatum	*Acanthocardia echinata*
Cardium edule umbonata	*Cerastoderma glaucum umbonatum*
Cardium norvegicum ponderosa	*Laevicardium crassum*
Mytilus edulis	*Mytilus edulis*
Glycymeris (Pectunculus) bimaculata	*Glycymeris (G.) bimaculata*
Pecten maximus	*Pecten maximus*
Murex erinaceus	*Ocenebra erinacea*
Purpura haemastoma	*Thais haemastoma*
Patella coerulea subplana	*Patella coerulea subplana*
Patella safiana	*Patella safiana*
Patella vulgata	*Patella vulgata*
Cirripedia	
Pollicipes cornucopiae	*Pollicipes cornucopiae*
Echinoidea	
Echinus milliaris	*Echinus milliaris*
Strongilocentrotus lividus	*Paracentrotus lividus*

According to Zbyszewski & Teixeira (1949) the 5-8 meters terrasse is about the same age as the one at the bottom of Devil's Tower in Gibraltar, an important Neanderthal site.

Patella safiana is typical of relatively warm waters (in present times, its Northernmost distribution limit are the Moroccan shores). *Glycymeris bimaculata* lives at 25 to 35 meters depth. *Chamelea gallina* is a plantless fine sands environment bottom dweller. The *Patella*, *Mytilus*, echinoderms and

cirripeds live on sea floor rocks. However, the majority of this animals inhabits sandy or pelitic sea floors.

The conglomerates of Figueira Brava Cave yielded lithic implements among them a redeposited abevillian biface, mousterian denticulates and other types as well as languedocian splinters. At the inner part of the cave the deposits are not consolidated by carbonate.

At the Southern end of Praia dos Coelhos there is a more than 2 meters thick conglomerate with well rounded cobbles up to 50 cm in diameter.

With the advance of Würm glaciation the sea level went down. About 30000 years ago, the 5-8 meters platform and the dug in the cliffs holes were elevated above a new and extensive coastal plain. The sea level was *ca.* 60 meters below the present level (Miskovski, 1987). The human communities found excellent hunting grounds in these territories. The caves Santa Margarida and Figueira Brava were natural shelters. Several remnants of their occupation are preserved such as animal bones, a few Neanderthal remnants as well as lithic and bone implements. ^{14}C and U series dating indicate an age around 30000 years for level 2 where archaeologic material has been collected (Antunes, 1990-91 Antunes & Cardoso, 1999).

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References

ANTUNES, M. T. (1990-91) – O Homem da Gruta da Figueira Brava (*ca.* 30000 BP). Contexto ecológico, alimentação, canibalismo. *Memórias da Academia das Ciências de Lisboa, Classe de Ciências*, XXXI: 487-536.

ANTUNES, M. T. & CARDOSO, J. L. (2000) – Gruta Nova da Columbeira, Gruta das Salemas and Gruta da Figueira Brava. Stratigraphy, and Chronology of the Pleistocene deposits. *Memórias da Academia das Ciências de Lisboa, Classe de Ciências*, XXXVIII: 23-67, 40 fig., 2 tab..

ANTUNES, M. T.; CARDOSO, J. L.; KULLBERG, J. C. & LEGOINHA, P. (1992) – Paleolítico médio em Galapos (Arrábida). *Ciências da Terra (UNL)*, 11: 7-16.

ANTUNES, M. T.; ELDERFIELD, H.; Legoinha, P. & Pais, J. (1995) – Datações isotópicas de Sr do Miocénico do flanco Sul da Serra da Arrábida. *Com. Inst. Geol. e Mineiro*, Lisboa, 81: 73-78.

ANTUNES, M. T.; ELDERFIELD, H.; LEGOINHA, P.; NASCIMENTO, A. & J. Pais (1999) – A Stratigraphic framework for the Miocene from the Lower Tagus Basin (Lisbon, Setúbal Peninsula, Portugal). Depositional sequences, biostratigraphy and isotopic ages. *Rev. Soc. Geol. España*, Madrid, 12 (1): 3-15.

ANTUNES, M. T; LEGOINHA, P.; NASCIMENTO, A & PAIS, J. (1996) – The evolution of the Lower Tagus basin (Lisbon and Setúbal Peninsula, Portugal) from Lower to Earlier Middle Miocene. RCANS Interim-Colloquium, Tours. *Géologie de la France*, 6: 59-77.

BREUIL, H. & ZBYSZEWSKI, G. (1945) – Contribution à l'étude des industries paléolithiques du Portugal et leurs rapports avec la géologie du Quaternaire. Les principaux gisements des plages quaternaires du littoral d'Estremadura et des terrasses fluviales de la basse vallée du Tage. *Com Serv. Geol. Portugal*, XXVI, 678 p.

CARDOSO, J. L. (1994) – O litoral sesimbrense da Arrábida. Resenha dos conhecimentos da sua evolução quaternária e das ocupações humanas correlativas. *Sesimbra Cultural*, 4: 5-12.

CHOFFAT, P. (1906) – Sur la tectonique de la chaîne de l'Arrábida entre les embouchures du Tage et du Sado. *Bull. Soc. Géol. France*, 4e série, VI: 237.

CHOFFAT, P. (1908) – Essai sur la tectonique de la Chaîne de l'Arrábida. *Comm. Serv. Geol. Portugal*, Lisboa, 89 p.

CHOFFAT, P. (1950) – Géologie du Cenozoïque du Portugal. *Comunicações dos Serviços Geológicos de Portugal*, XXX (suplemento): 183 p.

CHOFFAT, P. & DOLLFUS, G. F. (1904-07) – Quelques cordons littoraux marins du Pléistocène du Portugal. *Bol. Soc. Géol. France*, Paris, IV: 739-753, & *Comunicações dos Serviços Geológicos de Portugal*, VI: 158-173.

DAVEAU, S. & AZEVEDO, M. T. (1980-81) – Aspectos e evolução do relevo da extremidade sudoeste da Arrábida (Portugal). *Bol. Soc. Geol. Portugal* (vol. Homenagem a Carlos Teixeira), Lisboa, 22: 163-179.

ESCHWEGE, G. Barão de (1831) – Memória geognostica ou Golpe de vista do Perfil das estratificações das differentes róchas, de que he composto o terreno desde a Serra de Cintra na linha Noroeste a Sodoeste até Lisboa, atravessando o Tejo até à Serra da Arrabida, e sobre a sua idade relativa. *Mem. Acad. R. Sci. Lisboa*, XI (I): 253-280, est. II e III.

MISKOVSKI, J. C. (sous la direction de) (1987) – Géologie de la Préhistoire: méthodes, techniques, applications. *Géopré*, Édition Association pour l'étude de environnement géologique de la préhistoire. Paris, 1297 p.

PAIS, J.; LEGOINHA, P. & KULLBERG, J. C. (1991) – Novos elementos acerca do Neogénico do Portinho da Arrábida (Serra da Arrábida). *III Congresso Nacional de Geologia*, Coimbra, p. 122.

RIBEIRO, A.; ANTUNES, M. T.; FERREIRA, M. P.; ROCHA, R., SOARES, A. F.; ZBYSZEWSKI, G., MOITINHO DE ALMEIDA, F.; CARVALHO, D. & Monteiro, J. H. (1979) – Introduction à la Géologie générale du Portugal. *Serv. Geol. de Portugal*, Lisboa, 114 p.

RIBEIRO, A.; KULLBERG, M. C.; KULLBERG, J. C.; MANUPPELLA, G. & PHIPPS, S. (1990) – A review of alpine tectonics in Portugal: foreland detachment in basement and cover rocks. *Tectonophysics*, Amsterdam, 184: 357-366.

ZBYSZEWSKI, G. (1943) – La classification du Paléolithique ancien et la chronologie du Quaternaire de Portugal en 1942. Instituto de Alta Cultura, 113 p., *Bol. Soc. Geol. Portugal*, Porto, 2 (1/2).

ZBYSZEWSKI, G. (1958) – Le Quaternaire du Portugal. *Bol. Soc. Geol. Portugal*, 13(1/2), 277 p.

ZBYSZEWSKI, G. (1967) – Contribution à l'étude du Miocène de la Serra da Arrábida. *Comunicações dos Serviços Geológicos de Portugal*, LI: 37-148, 12 pl.

ZBYSZEWSKI, G. & TEIXEIRA, C. (1949) – Le niveau quaternaire marin de 5-8 mètres au Portugal. *Bol. Soc. Geol. Portugal*, Lisboa, 8(1/2): 1-6.

PLATE 1

FIG. 1 – The Miocene (unit b, Burdigalian) overlying the Jurassic near Creiro.

FIG. 2 – Quaternary conglomerate overlying the Miocene at Coelhos beach.

FIG. 3 – General view of the Lapa de Santa Margarida (left) and Figueira Brava cave (right).

FIG. 4 – Figueira Brava cave. The entrance is at the left. The 5-8 m marine erosion platform is well marked.

FIG. 5 – Figueira Brava cave entrance with the 5-8m terrace over the narrow marine erosion platform.

PLATE 1

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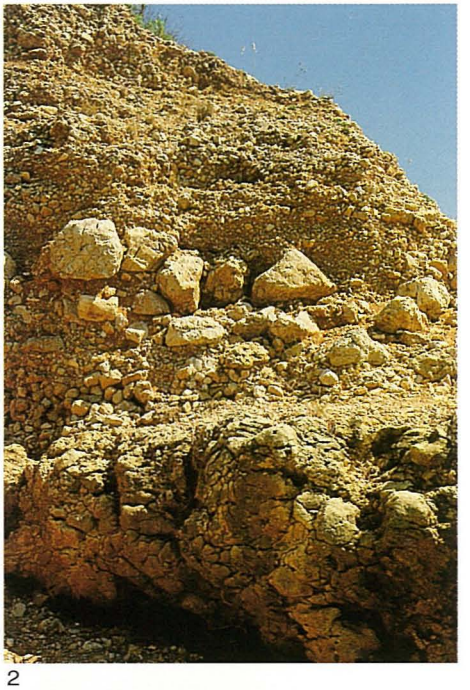

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