Com os melhores cumprimentos,
Carlos Marques da Silva

Bioerosional evidence of rocky palaeoshores in the Neogene of Portugal: environmental and stratigraphical significance

CARLOS MARQUES DA SILVA, MÁRIO CACHÃO, JORDI MARTINELL & ROSA DOMÈNECH

Silva, C. M. da, Cachão, M., Martinell, J. & Domènech, R.: Bioerosional evidence of rocky palaeoshores in the Neogene of Portugal: environmental and stratigraphical significance. *Bulletin of the Geological Society of Denmark*, Vol. 45, pp. 156–160. Copenhagen 1999–01–30.

Occurrences of Neogene rocky shores in Portugal have been identified by help of bioerosion trace fossils. Ichnogenera *Gastrochaenolites, Entobia, Caulostrepsis, Maeandropolydora* and *Trypanites* are generally present. The importance of bioeroded surfaces for field recognition of wave-cut platforms, hard substrate marine-flooding surfaces (transgressive surfaces), and of major interruptions (hiatuses) in the stratigraphic record is stressed.

Key words: Bioerosion, rocky palaeoshores, Neogene, Miocene, Pliocene, Portugal.

C. M. da Silva & M. Cachão, Departamento de Geologia, Universidade de Lisboa. Rua da Escola Politécnica, 58. P-1294 Lisboa Codex. Portugal. Museu Nacional de História Natural - Grupo Paleo, Centro de Geologia da Universidade de Lisboa. J. Martinell & R. Domènech, Departament d'Estratigrafia i Paleontologia, Facultat de Geologia, Universitat de Barcelona, E-08071 Barcelona. Spain. 15 September 1998.

As exposed rock surfaces associated with a low or zero rate of sedimentation, rocky shores provide a very favorable environment for bioeroding organisms. Rocky shores are also remarkable from a geological point of view. They represent a unique marine sedimentary environment, one in which erosional processes dominate (rather than depositional processes) and where wave-cut platforms are being formed.

Therefore the identification of rocky shores in the geological record is very important, for they represent major flooding surfaces and provide us with crucial information about palaeoshorelines and ancient sea levels. Bioerosion structures play a major role in their recognition.

Bioerosional evidence allows us to reconstruct the evolution of the marine hard substrate biota, which is far less well known than that of soft bottom communities. Rocky-shore communities, which are known in strata as old as the Lower Ordovician, are composed of three main types of organisms: borers, encrusters and clingers (Johnson 1988, Bromley 1994), all of them recognised in the fossil record almost exclusively by their trace fossils.

This contribution briefly describes and comments on the Portuguese occurrences of bioerosion structures associated with rocky shores – mineralised, lithified surfaces – that were active during Neogene times. An overview of the same kind of Neogene substrates located on the Mediterranean side of the Iberian peninsula and southeastern France may be found in Gibert, Martinell & Domènech (1998).

Bioerosion studies in Portugal

The oldest reference to Portuguese Neogene trace fossils in lithified substrates goes back to Choffat who, in 1903-4, in the Nossa Senhora da Vitória site, recognised the occurrence of "...cailloux calcaires, arrondis [of Hetangian age], ayant de nombreux trous de coquilles perforantes [of Pliocene age]" (Choffat, 1903-4: 112). Much later, other authors referred to the existence of perforations (identified as the work of the bivalve genus *Pholas*) in the contact surfaces of Jurassic/Neogene formations in Algarve, southern Portugal (Pais 1982, Antunes 1984).

In Portugal, the palaeoecological and palaeoenvironmental significance of bioerosion structures, namely as indicators of rocky shores, has only lately been recognised and utilised (Silva, Cachão, Martinell

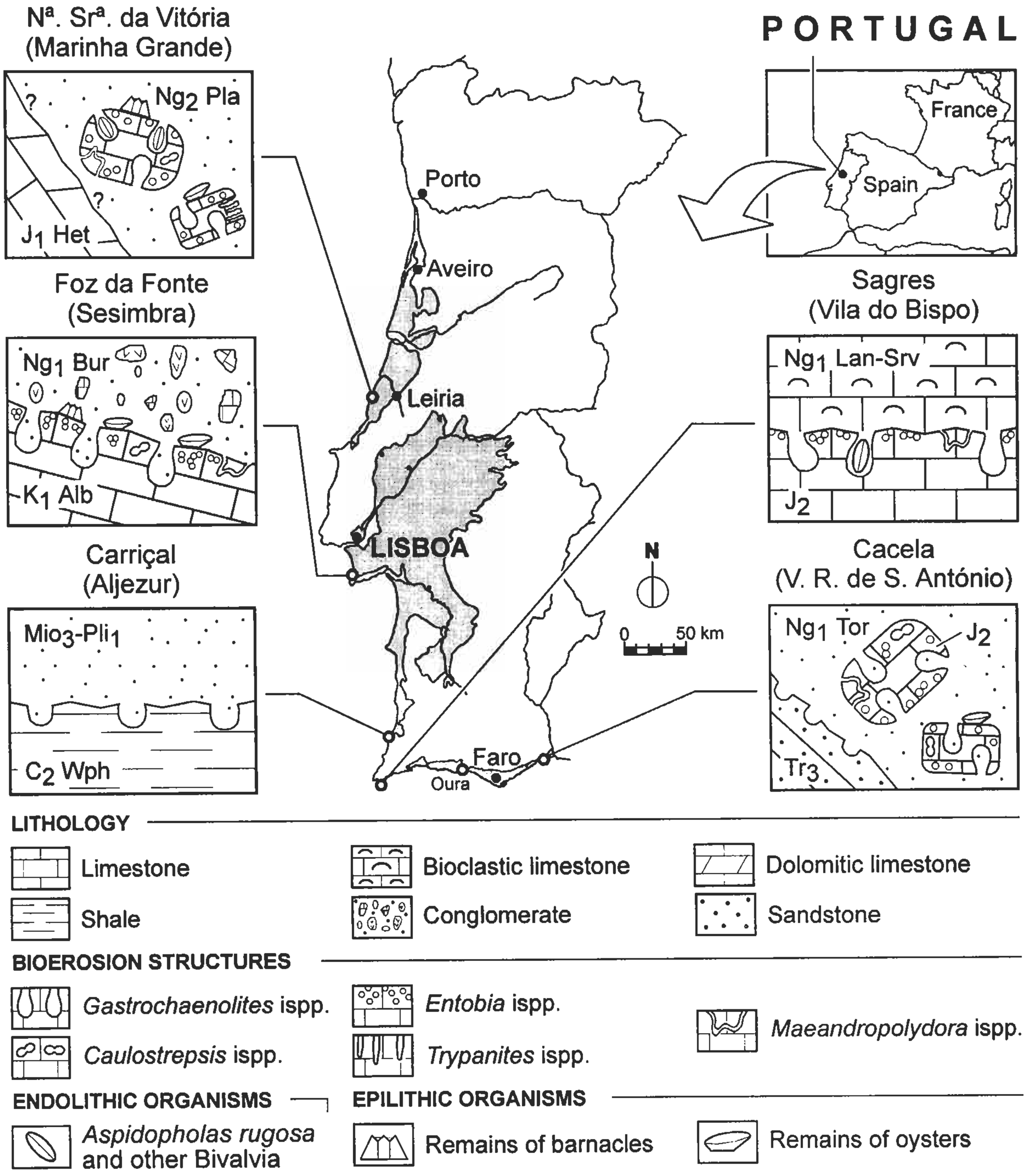

Fig. 1 Geographical location of the Portuguese outcrops featuring Neogene bioerosion structures associated with rocky palaeoshores (modified after Silva et al. 1995). Dotted surface: geographical distribution of the main Neogene outcrops.

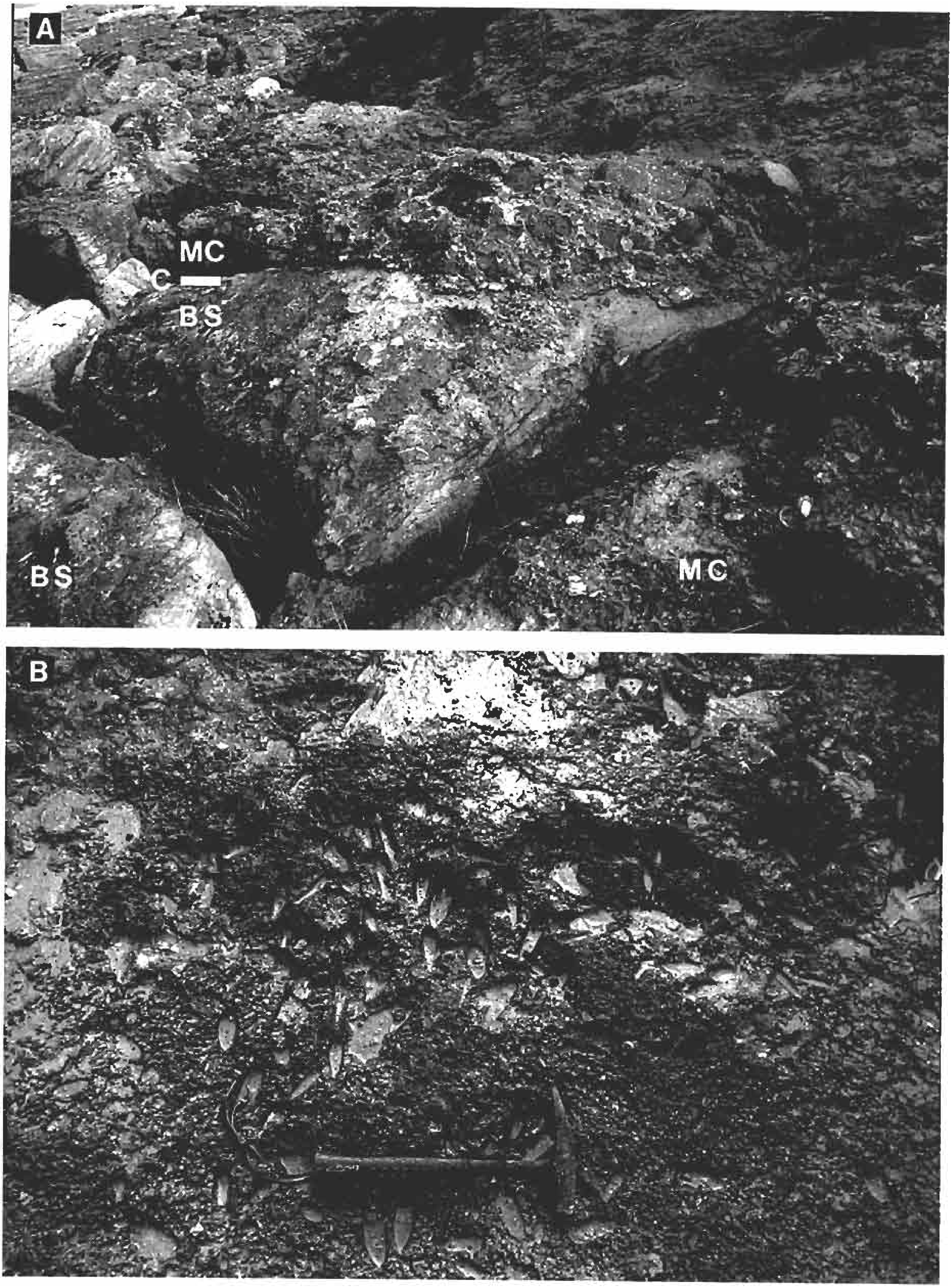

Fig. 2. The Foz da Fonte outcrop (Sesimbra). A, general view of the bioeroded marine-flooding surface and overlying sediments; BS: bioeroded surface (Cretaceous), C: contact, MC: Miocene (Burdigalian) basal conglomerate. B, detail of another sector of the same bioeroded surface. Note the clusters of large, mainly subhorizontal *Gastrochaenolites* isp. and the smaller, more evenly distributed *Gastrochaenolites* isp. perpendicular to the bioeroded surface.

Table 1. Summary information on Portuguese Neogene sites displaying bioerosion structures in rocky substrate.

	SITES				
	N.S. da Vitória Ng_2 Pia (*)	Foz da Fonte Ng_1 Bur	Carriçal Mio_3-Pli_1	Sagres Ng_1 Lan-Srv	Cacela Ng_1 Tor
Subtrate attributes					
Age	J_1 Het (*)	K_1 Alb	C_2 Wph	J_2	Tr_3 and J_2
Lithology	Dolomitic limestone	Limestone	Shale	Limestone	(Tr_3) Sandstone (J_2) Limestone
Exposure type	Boulders: S, Cs	S	S	Cs	(Tr_3) S (J_2) Boulders: S,Cs
Surface preservation	Good	Regular	Very poor	Good	(Tr_3) Very poor (J_2) Good
Ichnogenera					
Gastrochaenolites	•	•	•	•	• (Tr_3, J_2)
Entobia	•	•		•	• (J_2)
Caulostrepsis	•	•			• (J_2)
Maeandropolydora	•	•		•	• (J_2)
Trypanites	•				
Epilithobionts					
Barnacles	•	•			
Oysters		•			• (J_2)
Bryozoans		•			

S - Surface exposure; Cs - Cross section exposure; * - Age symbols and stage abbreviations after Harland et al. (1989).

& Domènech 1995). This recent interest in bioerosion in general (see also Silva, Hindson & Andrade 1996), and in the bioerosion of fossil rocky shores in particular, based on data collected in earlier field work carried out for general palaeontological and stratigraphic studies of the Portuguese Neogene, led to the identification of several outcrops where bioerosion structures occur in mineralised, lithified substrates (Fig. 1).

Bioerosional evidence of Neogene rocky shores

Portuguese Neogene formations overlie a wide range of lithologies, spanning very different ages (Palaeozoic to Lower Cainozoic). Carbonate substrates feature the more diversified, abundant and well preserved ichnocenoses, but non-carbonate rocks (sandstones and shales) also bear bioerosion stuctures. The identification of bioerosion structures, and consequently the estimation of the real composition of the ichnocenoses, is affected by rock exposure attributes such as surface preservation and exposure characteristics (single bioeroded surface exposure, cross section exposure of bioerosion structures, or both). So far, six sites displaying bioerosion structures in rocky substrate have been identified: Nossa Senhora da Vitória, Foz da Fonte (Fig. 2A, B), Carriçal, Sagres and Cacela (information about these occurrences is summarised in Figure 1 and Table 1). In addition there is the recently discovered intra-Miocene (Tortonian) bioeroded megasurface of Oura, near Albufeira (Algarve), which is at present under study. All reported sites display assemblages of bioerosion structures (igenn. *Gastrochaenolites*, *Entobia*, *Caulostrepsis*, *Maeandropolydora*, *Trypanites*) and, commonly, features (e.g. crowded assemblages of ichnospecies of *Gastrochaenolites* and *Entobia*) interpreted as corresponding to very shallow marine environments with a low or null rate of sedimentation: rocky palaeoshores.

Comments and conclusions

Despite the distinct geographical location, substrate age, lithology, and different preservational conditions of the sites, the studied ichnocenoses present some common features: a *Gastrochaenolites*/*Entobia* assemblage dominates the ichnocenoses, and structures assigned to igenn. *Caulostrepsis*, *Trypanites* and *Maeandropolydora* occur commonly. In most of the sites, *in situ* remains of epilithic organisms, i.e., barnacles, bryozoans and oysters, are also present on the bioeroded rock surface. In the Carriçal site, as well as in the Triassic substrate of Cacela, only poorly preserved *Gastrochaenolites* isp. structures were found, certainly due (1) to the noncarbonate substrate material (respectively, shale and sandstone), (2) to the restricted exposed area and (3) to poor rock surface pres-

ervation. The mega-bioeroded surface of Oura, with an estimated length of several hundred metres, although installed on carbonate substrate material, has a poorly preserved surface, thus displaying only scattered patches of *Gastrochaenolites* individuals.

In Portugal, bioerosion structures associated with mineralised, lithified substrates interpreted as being part of rocky palaeoshores generally occur in two different situations: (1) on relatively large sub-horizontal rocky surfaces and/or (2) on boulders somehow associated (both stratigraphically and geographically) with these surfaces. From a strictly palaeoenvironmental point of view, both of these types of occurrences are interpreted as being part of (or associated with) the rocky palaeoshore complex. Occurrences of the first type correspond to the bioeroded surfaces of wave-cut platforms resulting from cliff retreat, and occurrences of the second type correspond to boulders resulting from the breakdown of the retreating cliff.

From a stratigraphic point of view, all the above mentioned bioeroded rockground surfaces reflect hard substrate marine-flooding surfaces (transgressive surfaces). They are thus extremely important for the identification (for field recognition) and characterisation (the formalisation of formation boundaries) of major stratigraphic hiatuses.

Dansk sammendrag

Neogene klippekyster er blevet identificeret i Portugal ved hjælp af bioerosion. Ichnogenera *Gastrochaenolites*, *Entobia*, *Caulostrepsis*, *Maeandropolydora* og *Trypanites* er sædvanligvis til stede. Der er lagt vægt på bioeroderede overfladers betydning for identification i felten af bølge-eroderede platformer, hærdnede marine transgressive flader og længere afbrydelser (hiati) i stratigrafien.

Acknowledgements

This paper is a contribution of the "Acção Integrada Luso-Espanhola" and "Hispano-Portuguesa". Contribution of the PB94-0946 of the D.G.I.C.Y.T., Ministerio de Educación y Ciencia español. Contribution 7 of the "Grupo PALEO" (Palaeontology Group of the National Natural History Museum of the Lisbon University).

References

Antunes, M.T. 1984: Orla Algarvia. In Oliveira, J. T. (ed.) Carta Geológica de Portugal, 1/200000, Notícia Explicativa 7, 60–64. Lisbon: Serviços Geológicos de Portugal.

Bromley, R.G. 1994: The palaeoecology of bioerosion. In Donovan, S.K. (ed.) The Palaeobiology of Trace Fossils, 134–154. Chichester: John Wiley & Sons.

Choffat, P. 1903-4: L'Infralias et le Sinémurien du Portugal. Comunicações da Commissão do Serviço Geológico de Portugal 5, 49–114.

Gibert, J. M., Martinell, J. & Domènech, R. 1998: *Entobia* ichnofacies in fossil rocky shores, Lower Pliocene, northwestern Mediterranean. Palaios 13, 476–487.

Harland, W.B., Armstrong, R.L., Craig, L.E., Smith, A.G. & Smith, D.G. 1989: A Geologic time scale. Cambridge: Cambridge University Press.

Johnson, M. 1988: Why are ancient rocky shores so uncommon? Journal of Geology 96, 469–480.

Pais, J. 1982: O Miocénico do Litoral Sul Português. Ensaio de Síntese. Estudo complementar para a obtenção do grau de Doutor, Universidade Nova de Lisboa (unpublished).

Silva, C. M. da, Cachão, M. Martinell, J. & Domènech, R. 1995: Estruturas bioerosivas como indicadores de paleolitorais rochosos. O exemplo do Miocénico da Foz da Fonte (Sesimbra, Portugal). Dados Preliminares. Memórias do Museu e Laboratório Mineralógico e Geológico da Universidade do Porto 4, 133–137.

Silva, C.M. da, Hindson, R. & Andrade, C. 1996: Bioerosion evidence of extreme marine flooding of Algarve Region (southern Portugal) associated with the tsunami of the AD 1755 Lisbon earthquake: taphonomic and (palaeo)ecological analyses. In Meléndez Hevia, G., Blasco Sancho, M. F. & Pérez Urresti, I. (eds) 2nd Meeting on Taphonomy and Fossilisation, 371–378. Zaragoza: Instituición "Fernando el Católico".