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Miocene marine mammals from Portugal
Paleogeographical and paleoecological significance

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ABSTRACT

Key words: Marine mammals; Miocene; Portugal; geographic and stratigraphic distribution; correlation with environmental changes; paleogeographical and paleoecological significance.

Neogene marine mammals are still incompletely known in Portugal. However, a general overview of the geographic and stratigraphic distribution of marine mammal localities in the Miocene of Portugal is already possible. An attempt of correlation between the trends shown by these distributions and the horizontal and vertical environmental shifts is presented. In general, sirenians occur in deposits representing shallow, warm, low energy aquatic environments; while cetaceans are more frequent in more open, deep and temperate marine environments.

RESUMO

Palavras-chave: Mamíferos marinhos; Miocénico; Portugal; distribuição geográfica e estratigráfica; correlação com variações ambientais, significado paleogeográfico e paleoecológico.

O conhecimento dos mamíferos marinhos neogénicos é ainda incompleto em Portugal. Contudo, é possível delinear a distribuição geográfica e estratigráfica das jazidas de mamíferos marinhos do Miocénico de Portugal. Tentou-se, igualmente, relacionar as tendências exibidas por estas distribuições com variações horizontais e verticais das condições paleoambientais. De modo geral, os Sirenia ocorrem em ambientes pouco profundos, de águas quentes e fraca energia; enquanto que os Cetacea são mais frequentes em ambientes marinhos abertos, de maior profundidade e águas mais temperadas.

INTRODUCTION

This paper is an updated version of a preliminary report on the same subject (Estevens, 1998a). It includes new data on the collections of the "Museu Nacional de História Natural da Universidade de Lisboa" (National Museum of Natural History of the University of Lisbon). The collections of the "Instituto Geológico e Mineiro" (Geological and Mining Institute) were reevaluated, and some new specimens were added to the collections deposited at the "Departamento de Ciências da Terra da Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa" (Department of Earth Sciences of the Faculty of Sciences and Technology of the New University of Lisbon).

Although long known in Portugal (Eschwege, 1831), Miocene marine mammals have not been much studied in this country (Antunes, 1984). Only a few short descriptive notes have been published (Vandelli, 1831; Kellogg, 1938-40; Zbyszewski, 1944, 1953, 1954; Antunes, 1959, 1979; Mata, 1963; Jonet, 1980-81). A considerable number of undescribed specimens can be found in Portuguese collections.

The systematic study of the Neogene marine mammals of Portugal was resumed by the author at the "Centro de Estudos Geológicos da Faculdade de Ciências e Tecnologia", under the supervision of Prof. Miguel Telles Antunes. The first results about a small assemblage of odontocetes from the Lower Tagus Basin Miocene will soon be presented. Meanwhile, based on published data

and on the inventory of specimens from collections, it is already possible to present a list of Portuguese Miocene localities where marine mammal remains were registered. Pliocene records are scarce and somewhat dubious (see below). At this point, only the presence of Cetacea, Sirenia or "Pinnipedia" will be acknowledged for each locality, with no indication of subordinal assignment. Such a list allows to outline the geographic and stratigraphic distribution of each group, focusing on the main differences between them. The paleogeographical and paleoecological significance of such differences was evaluated by correlating the detected trends with horizontal and vertical changes of the paleoenvironmental conditions.

The conclusions herein presented were hampered by some difficulties concerning both the published data and the inventoried collections.

Published records of marine mammals are not always reliable in what concerns systematics, even at an ordinal level. Many older references of cetaceans for the Early Miocene of Lisbon probably concern sirenians (particularly those in Cotter, 1956 and Choffat, 1950a). Another example is a record for the Burdigalian of Foz da Fonte (48), originally reported to Cetacea (Zbyszewski *et al.*, 1965) and later reassigned to Sirenia (Zbyszewski, 1967). As most of these records correspond to fragmentary material not always collected, it is difficult to determine their true taxonomic nature. Nevertheless, the scarce bibliographic references for which a positive correspondence could be established with material deposited in the studied collections indicate that most (if not all) Early Miocene published records of marine mammals correspond in fact to sirenians (as noted by Antunes, 1959, 1969-70, 1984). The systematic nature of some references, however, could not be definitely ascertained. In these cases, the taxonomic uncertainty will be indicated either by a broken outline of the symbols representing each marine mammal order (in Figs. 2 and 5), either by hatched areas (in Fig. 6).

The inverse problem was found when proceeding to the inventory of fossil marine mammals in Portuguese collections. In this case it was not the systematic assignment of the specimens that constituted a problem (at least for the majority of them), but rather the definition of their provenance. A large part of the collections of the "Instituto Geológico e Mineiro" raised too many problems in this respect. Many undescribed specimens are not labeled, and even for those sitting in labeled trays there is a strong possibility of having been misplaced. If for some it is still possible to deduce their original locality of provenance (through the adhering matrix or their relation to other well-known specimens), for others this was impossible.

Therefore, the list of localities presented and the conclusions therefrom derived are based only on those records for which the geographic and stratigraphic occurrence could be safely determined.

GEOGRAPHIC DISTRIBUTION

Marine mammal localities are unevenly distributed throughout the Miocene of Portugal (Fig. 1).

The great majority (85,7%) of the 56 localities are located in the distal region of the Lower Tagus Basin (LTB). This includes Lisbon region (LR) and Setúbal Peninsula (SP), located respectively north and south of Tagus River (Fig. 2). Few localities can be found southwards of this area: only 5 in the vast region encompassing Alcácer do Sal, the littoral of Alentejo and Alvalade Basin (Fig. 3), and a mere 3 in Algarve (Fig. 4). A single additional record (not discussed here), concerns the Santa Maria Island, in the Azores Archipelago (Cotter, 1888-92).

The predominance of marine mammal localities in the LTB results largely from the fact that this basin contains the most complete Miocene marine series in Portugal (Antunes *et al.*, 1996). As a consequence, the LTB has been both the most studied and the one from where more fossils were collected. Barnes (1976: 338) noted that for the eastern North Pacific fossil cetacean assemblages a biased collecting might be partly on the origin of such diversity or abundance trends. A more detailed prospection of the other Tertiary Portuguese basins may lead to the discovery of new localities. However, this would just attenuate the observed geographic trend without producing any dramatic changes. The LTB will certainly remain the most important area in Portugal in what concerns Miocene fauna in general, and marine mammals in particular.

A significant geographic segregation can be observed between Sirenia and Cetacea localities within the distal region of the LTB (Fig. 2).

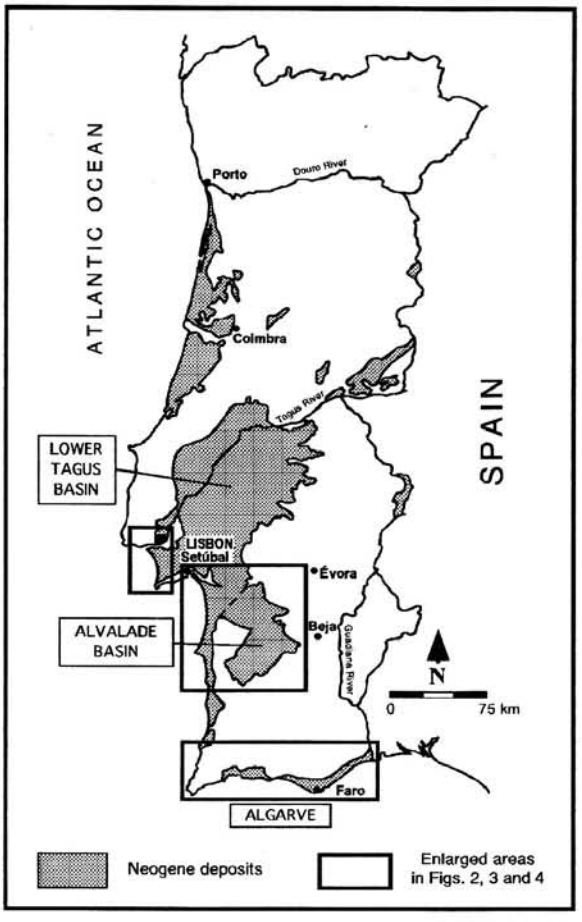

Fig. 1 - Miocene basins of Portugal dealt with in this paper.

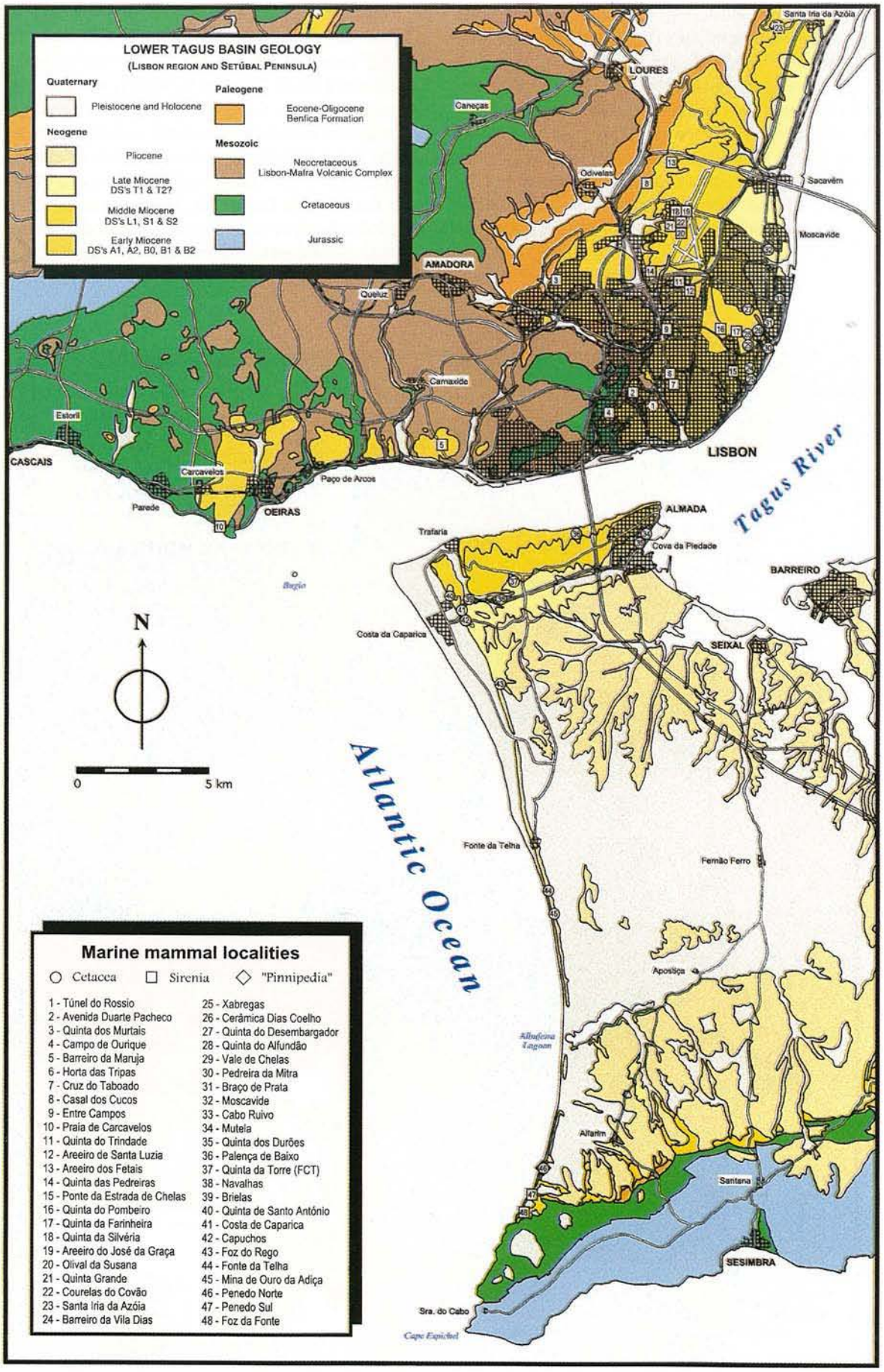

Fig. 2 – Geographic distribution of Miocene marine mammal localities in the Lower Tagus Basin (Lisbon region and Setúbal Peninsula). Geology adapted from Almeida (1980), Choffat (1950b, 1960), Manuppella (1994) and Zbyszewski *et al.* (1981).

Sirenia localities are almost exclusively located in LR, many of them within the limits of Lisbon. There are only two localities to the west (5 - Barreiro da Maruja and 10 - Praia de Carcavelos) and another two near the northern outskirts (8 - Casal dos Cucos and 13 - Areeiro dos Fetais). Santa Iria da Azóia (23) could constitute the northernmost record of Sirenia for the Portuguese Miocene, but see below discussion on uncertain taxonomic assignment of remains therein found. Sirenians are scant south of Tagus River, occurring only at Penedo Sul (47) and Foz da Fonte (48).

Cetaceans, on the other hand, predominate in SP (86,7% of marine mammal localities in this area). Those located north of Tagus River are concentrated in easternmost Lisbon. Túnel do Rossio (1) would constitute the exception, but the reader is again referred to the discussion on uncertain taxonomic assignments below.

The single "pinniped" record consists of phocid remains from Penedo Norte (46) (Antunes *et al.*, 1995).

In the Alvalade Basin (Fig. 3), marine mammals were recorded at the three localities that have produced the richest fossil assemblages of this region (Antunes *et al.*, 1986).

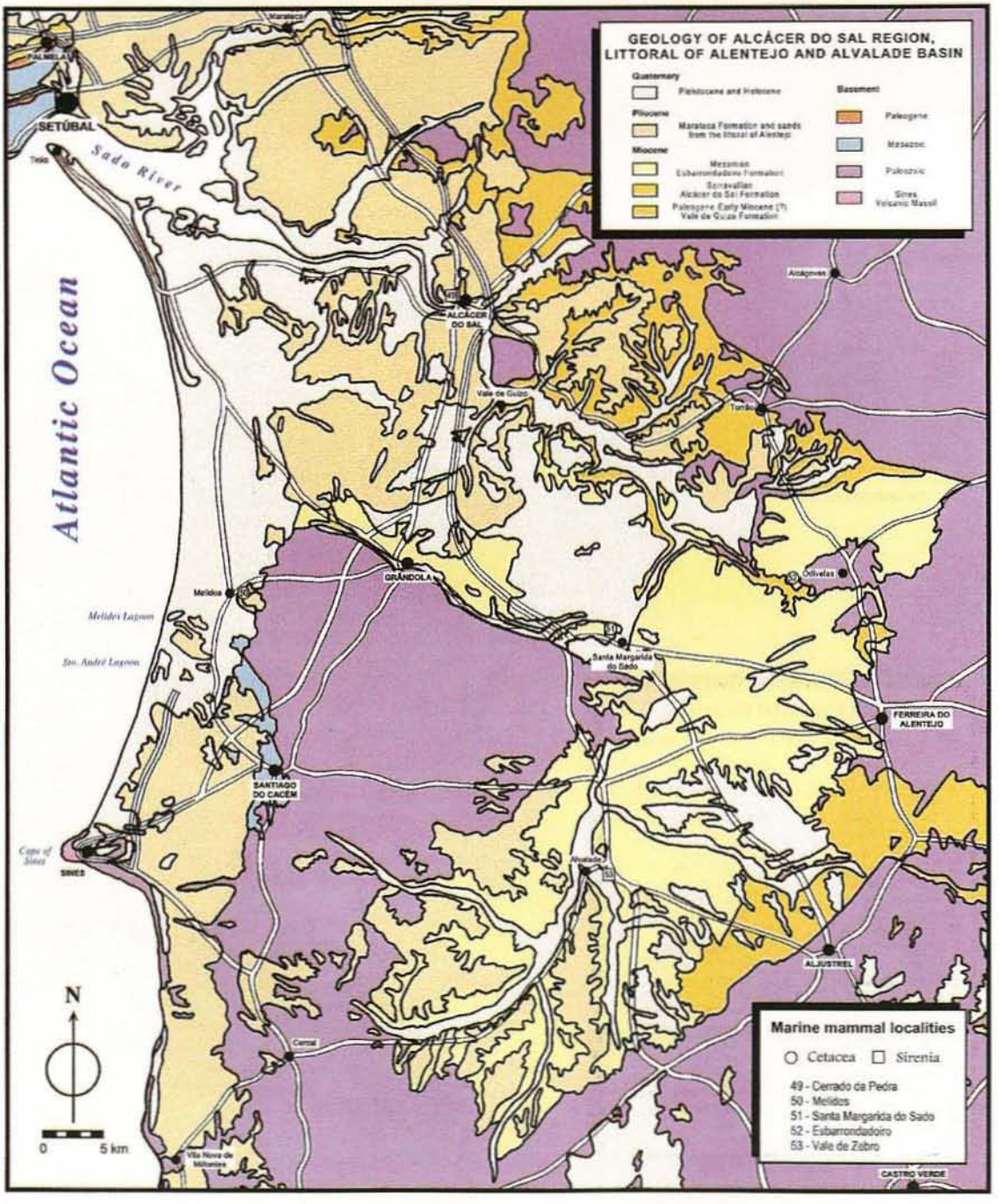

Fig. 3 - Geographic distribution of Miocene marine mammal localities in Alcácer do Sal region, littoral of Alentejo and Alvalade Basin. Geology adapted from Oliveira *et al.* (1992).

Only cetaceans were found at Esbarrondadoiro (52), whilst there were only sirenians at Vale de Zebro (53). According to a personal communication from J. Pais, sirenian rib fragments are to be added to Santa Margarida do Sado (51), from where only cetacean remains were known (Estevens, 1998a). The latter thus becomes one of the few Portuguese localities where fossils of these two groups occur simultaneously.

Marine mammals were also recorded at Cerrado da Pedra (49) (Sirenia *in* Antunes & Mein, 1983), located in the southeastern extension of the LTB (Alcácer do Sal region), and in Melides (50) (Cetacea *in* Zbyszewski, 1954).

Only one locality in Algarve (Fig. 4) had so far been referred in the literature as yielding marine mammal remains: Olhos de Água (55), from where both Sirenia and Cetacea were described (Antunes, 1979). This and Santa Margarida do Sado are the only Portuguese localities where sirenians and cetaceans were simultaneously recorded. The inventory of the Portuguese collections revealed further undescribed specimens of cetaceans from the Miocene of Algarve, collected at Cerro das Mós (54) and Cacela (56).

STRATIGRAPHIC DISTRIBUTION

The stratigraphic distribution of the 56 Neogene localities where marine mammals were recorded is summarized in Fig. 5.

Marine mammals occur in almost every Portuguese Miocene marine unit, from the earliest ones at the distal region of the LTB (Aquitanian DS A1), to the latest ones at the Alvalade Basin (late Messinian, Esbarrondadoiro Formation). Inversely, only the littoral marine sands at Olhos de Água (55), in Algarve, could be referred to the Pliocene, according to a recent $^{87}Sr/^{86}Sr$ isotopic datation of a mollusk bed located just above the sands (Antunes *et al.*, 2000b). The vertebrates found in a lower stratigraphic level (among which the marine mammals), seem however to indicate a Middle to Late Miocene age (Antunes, 1979). These may thus constitute a redeposited association (Antunes, personal communication).

Fig. 5 also shows significant differences between the groups of marine mammals in what concerns their stratigraphic distribution.

Within the distal region of the LTB, sirenians are frequent in LR from the Aquitanian to the Langhian, nearly disappearing afterwards (Antunes, 1984). The few middle Serravallian records (Estevens, 1998a) are now considered too doubtful and were consequently disregarded. Only two sirenian records are known for SP, both of them Burdigalian (localities 47 – Penedo Sul and 48 – Foz da Fonte). A rib fragment collected at Santa Iria da Azóia (23) was questionably ascribed to Cetacea (Choffat, 1950a: 120). The fragment seems to indicate a sirenian instead, and in that case it would constitute the latest record of the group (early Serravallian) for the distal region of the LTB. Conversely, in the southeastern extension of this same basin (Alcácer do Sal region), sirenians occur later (late Serravallian) at Cerrado da Pedra (49) (Antunes & Mein, 1983). Further to the south, in the Alvalade Basin, they

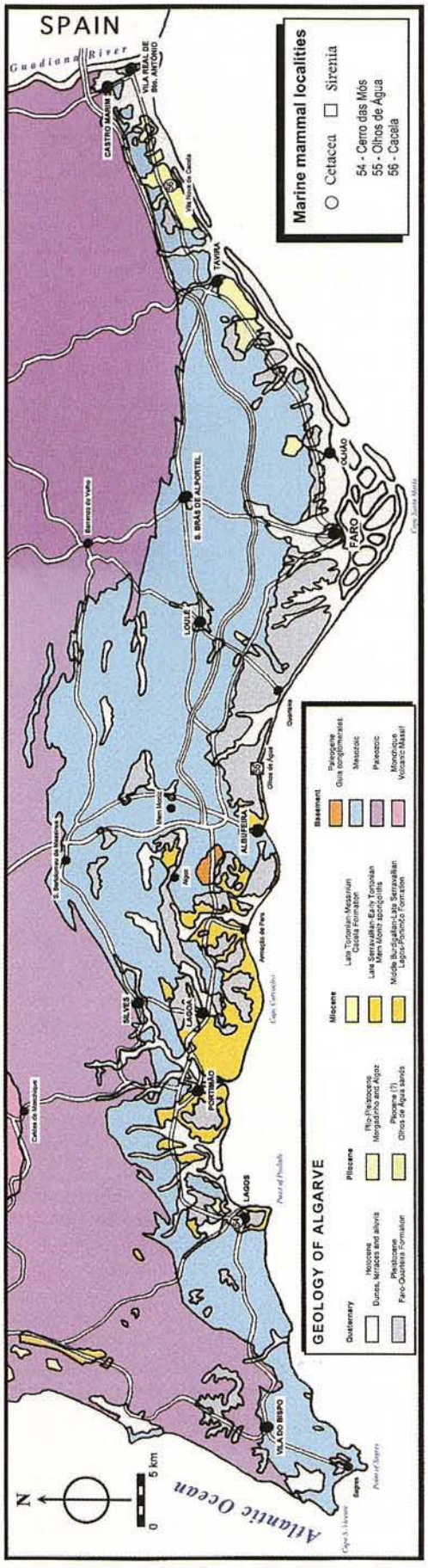

Fig. 4 - Geographic distribution of Miocene marine mammal localities in the Algarve. Geology adapted from Oliveira *et al.* (1992), revised by J. Pais.

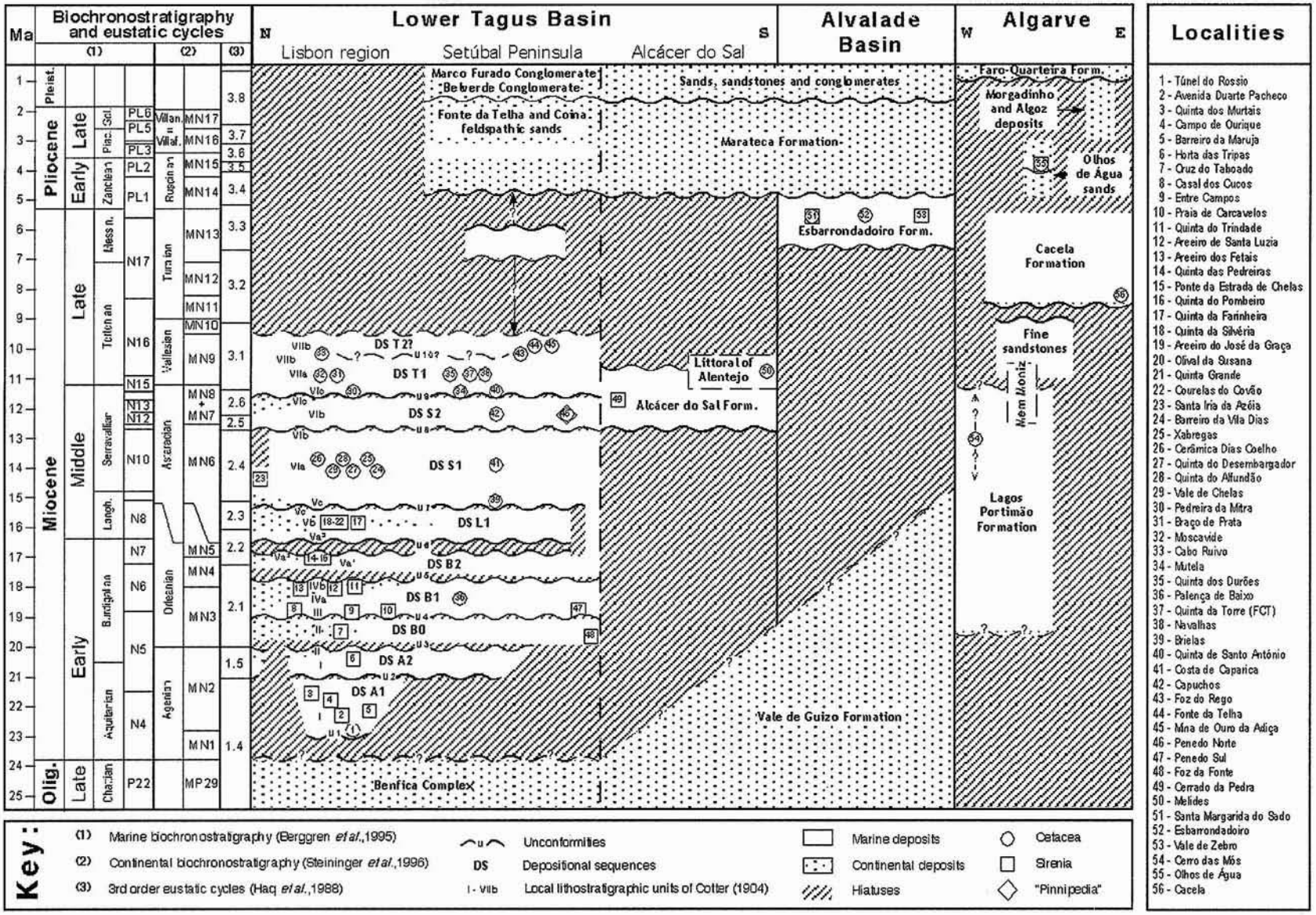

Fig. 5 - Stratigraphic distribution of marine mammal localities in the Neogene of Portugal. Continental biochronostratigraphy **(2)** and 3rd order eustatic cycles **(3)** correlated to marine biochronostratigraphy **(1)**. Stratigraphic frameworks adapted from Antunes *et al.* (2000a) and Manuppella (1994) for the Lower Tagus Basin (Lisbon region and Setúbal Peninsula); Oliveira *et al.* (1992) for the Lower Tagus Basin (Alcácer do Sal) and Alvalade Basin; and Antunes *et al.* (2000b) for the Algarve.

occur even later (Messinian) at Santa Margarida do Sado (51) and Vale de Zebro (53). The only sirenian record in Algarve is from Olhos de Água (55) (Antunes, 1979), supposedly of Pliocene age (see Antunes *et al.*, 2000b and above) but probably older (Middle to Late Miocene) and redeposited.

Inversely to sirenians, cetaceans only became common from the Langhian-Serravallian boundary upwards. At the LTB they occur mostly in the Serravallian and early Tortonian (Antunes, 1984). Outside this basin, there is one record for Melides (50) (Zbyszewski, 1954), correlative of the most modern well-dated levels of the LTB. On the other hand, cetaceans are known from latest Miocene beds at the Alvalade Basin (Messinian localities 51 – Santa Margarida do Sado and 52 – Esbarrondadoiro) (Antunes *et al.*, 1986), and Algarve (late Tortonian of Cacela - 56). Also in Algarve, cetaceans were found at Olhos de Água (55) (Antunes, 1979) and Cerro das Mós (54). The latter (on a small hill near Lagos) is now recognized to be Serravallian in age, according to recent isotopic datations of nearby correlative deposits (Antunes *et al.*, 2000b).

So far, the only Early Miocene locality that unquestionably yielded cetacean remains is Palença de Baixo (36) (middle Burdigalian), in SP (LTB). There is a doubtful record for the Aquitanian of Túnel do Rossio (1) by Choffat (1889: 40): "os de grande taille, incomplet, paraissant appartenir à un crâne de Cétacé". As no specimens possibly related to this occurrence were found, it must be here held questionable.

The "pinniped" from Penedo Norte (46) is late Serravallian in age (Antunes *et al.*, 1995).

PALEOGEOGRAPHICAL AND PALEOECOLOGICAL SIGNIFICANCE

The geographic and stratigraphic trends summarized above can be correlated to environmental changes well documented in the literature.

The most striking case concerns the marine mammal record of the LTB Miocene, which was already the object of general considerations (Estevens, 1998b). Fig. 6 shows the close correlation between variations of the paleoecological conditions (namely sea temperature and depth) and the number of Sirenia and Cetacea localities for the distal region of the LTB.

Sirenia occur from the earliest Miocene (Aquitanian) to the early Middle Miocene (Langhian), when sea temperatures stayed over ≈24°C (ranging from tropical to subtropical environments according to Antunes & Pais, 1984). Sirenia are present whenever very shallow near-shore environments are concerned, and absent whenever environments became slightly deeper (never attaining the circalittoral stage). The maximum abundance of Sirenia occurred during the Langhian, when temperatures were highest in shallow, near-shore to fluvial tropical environments (Antunes & Pais, 1984, Antunes *et al.*, 1996). After the Langhian, a marked drop in temperature and increase in depth led to the disappearance of sirenians.

This change of environmental conditions turned the balance to the Cetacea favor. Cetaceans became frequent and reach maximum abundance at events of greater depth (circa or near-circalittoral stages) during the Serravallian and early Tortonian. It is noteworthy that the only Early Miocene Cetacea occurrence corresponds to the apogee of the Burdigalian transgression, another maximum depth event. The number of localities that yielded cetacean remains became much reduced at the late Serravallian.

The stratigraphic near-exclusion of sirenians and cetaceans in the distal region of the LTB is thus a result of important environmental changes that took place during the Langhian (Antunes & Pais, 1984). The subtropical to tropical climate and shallow, protected marine gulfs that prevailed from the Early to early Middle Miocene (Antunes *et al.*, 1996) were an ideal habitat for sirenians (Domning, 1976, 1978). The more temperate and deeper marine environments that followed (Antunes *et al.*, 1996, 2000a), were instead more favorable to the occurrence of cetaceans (Barnes, 1976; Fordyce *et al*, 1994).

The geographic distribution of marine mammals in the distal region of the LTB is also controlled by these paleoecological factors. The prevailing occurrence of sirenians in LR and cetaceans in SP is related to the predominance of essentially Early Miocene shallower deposits in the former, in contrast to the deeper marine Middle to Late Miocene sediments that cover most of the latter (Antunes *et al.*, 1996). The occurrence of a phocid in Penedo Norte (SP) agrees with these assumptions.

The scarce representation of Miocene marine mammals outside the distal region of the LTB is related to the lesser development of marine units.

The permanence of sirenians in the Alcácer do Sal region and Alvalade Basin (until the Late Miocene in the latter) is an indication of the persistence of shallow protected gulfs and moderately warm waters (Antunes, 1983; Antunes *et al.*, 1986). This took place well after the increase in depth and cooling verified by the end of the Langhian in the distal region of the LTB, that eventually led to the disappearance of sirenians from this area. The southwards withdrawal of Sirenia in the Portuguese Miocene is in agreement with the accentuation of the thermal latitudinal gradient recognized for the northwestern Atlantic during this epoch (Lauriat-Rage *et al.*, 1993).

The cetacean record of Melides (50) is compatible with the markedly open and littoral marine environment recognized for both these deposits (Prates & Carvalho, 1983-85) and their correlatives in the LTB.

In the Alvalade Basin, the contemporaneous occurrence of open marine environments (either shallower as in Santa Margarida do Sado, either relatively deeper as in Esbarrondadoiro) with the restricted inner gulf of Vale de Zebro (Antunes *et al.*, 1986), made possible for cetaceans and sirenians to occur simultaneously during the late Messinian.

Few paleogeographical or paleoecological inferences can be made from the scarce Miocene marine mammal occurrences in Algarve. The Lagos-Portimão Formation, where Cerro das Mós (54) is included, presents a "warm temperate" carbonate shelf facies according to Antunes *et*

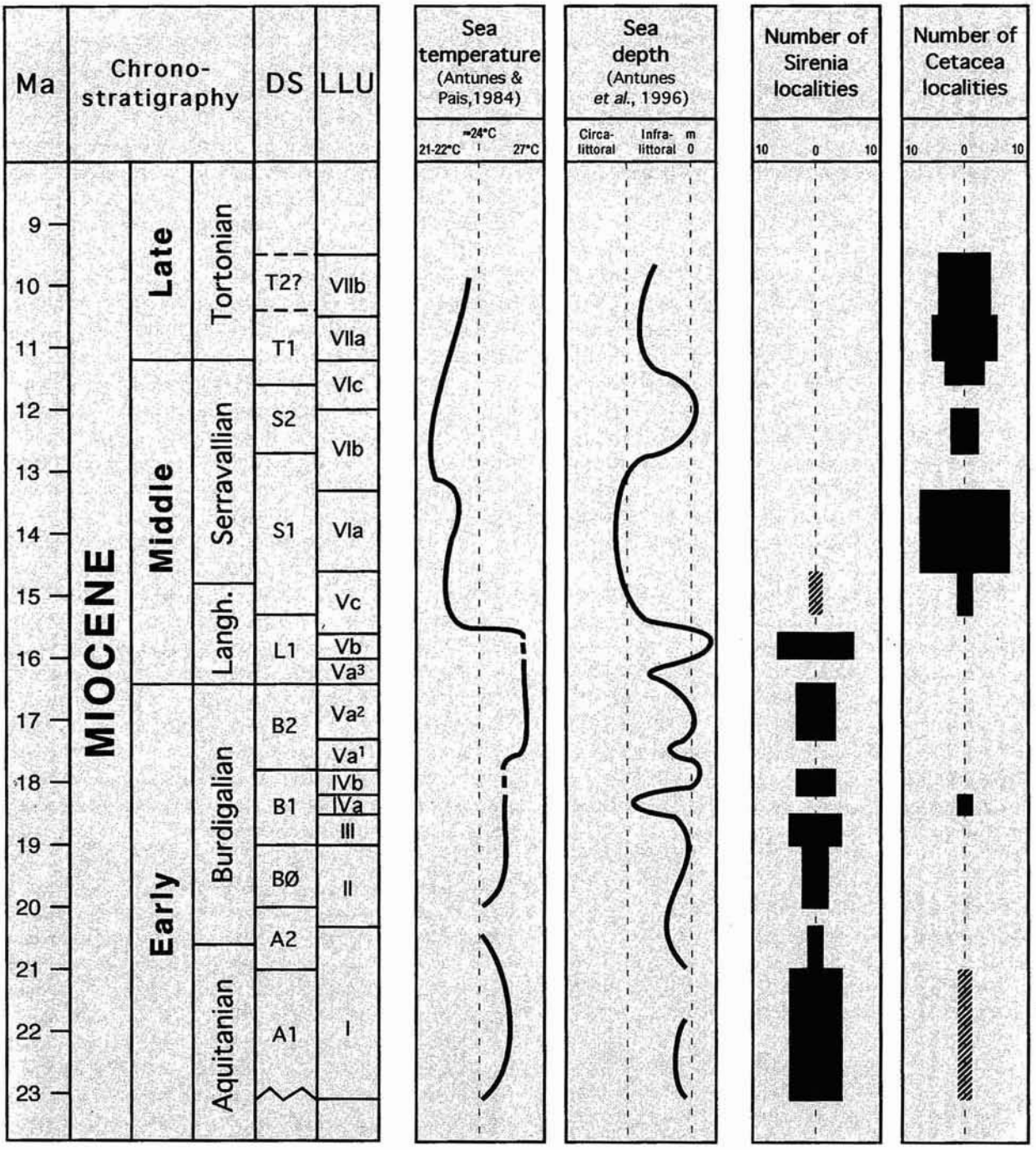

Fig. 6 - Correlation between the variation of sea temperature and depth and the number of Sirenia and Cetacea localities at the Lower Tagus Basin (Lisbon region and Setúbal Peninsula) during the Miocene. **DS** stands for depositional sequences (Antunes *et al.*, 2000a) and **LLU** for local lithostratigraphic units (Cotter, 1904).

al. (2000b). Vertebrates found in the same deposits point out, however, to near-tropical conditions (Antunes *et al.*, 1981). Cacela (56) corresponds to a littoral marine environment (Antunes *et al.*, 1981), and Olhos de Água (55) to a shallow coastal environment with a nearby estuary (Antunes *et al.*, 2000b).

In conclusion, the distribution of marine mammals in the Portuguese Miocene is closely controlled by ecological restrictions. Sirenia occur mostly in shallow, warm, low energy aquatic environments (as postulated by Domning, 1976, 1978), while cetaceans are more frequent in more open, deep and temperate marine environments (as recognized by Barnes, 1976 and Fordyce *et al.*, 1994). The paleogeographical and paleoecological significance of marine mammals, and their utility in the reconstitution of marine paleoenvironments, is thus reasserted by the present study.

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