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Pliocene Atlantic molluscan assemblages from the Mondego Basin (Portugal): Age and palaeoceanographic implications

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ABSTRACT

The Pliocene molluscan assemblage from the Mondego Basin (Portugal, Western Iberia) plays a particularly important role in the understanding of the palaeobiogeography of Neogene–Quaternary molluscs of the Atlantic Frontage of Europe and the western Mediterranean. The importance of these Portuguese molluscan deposits is stressed, as it is the only assemblage representative of the southern portion of the Pliocene French–Iberian biogeographical Province.

The Pliocene marine fossiliferous deposits of the Mondego Basin (central-west Portugal) are dated using their nannofossil and molluscan assemblages, as well as Strontium dating. The results suggest a late Zanclean to early Piacenzian age. Chronologically they are equivalent to the Mediterranean Pliocene Molluscan Unit 1 (MPMU1). However, due to the more northern geographical location of the Mondego Basin assemblages, their molluscan content is closer to that of MPMU2 than to that of MPMU1 in the Mediterranean.

The presence of a stock of thermophilic taxa in the Mondego assemblage, no longer existent in European waters, enabled us to suggest a palaeoenvironmental reconstruction for mid-Pliocene SSTs in the region. We put forward the hypothesis that the SSTs at the latitude of Mondego, during late Zanclean to early Piacenzian, would be characterized by a yearly SST pattern analogous to that of present-day Cape Blanc (West Africa). Consequently, whilst subtropical conditions existed in the Atlantic Zanclean to mid-Piacenzian at Mondego latitude in the Mediterranean fully tropical conditions prevailed at that time. The Mondego SST estimates correlate with those estimated for MPMU2 in the Mediterranean.

The global palaeoenvironmental reconstruction of mid-Pliocene SSTs in the PRISM2 Project suggests, for western Iberia, at Mondego latitude, an August SST of about 23 °C, and a February temperature of about 17 to 18 °C. Our hypothesis suggests similar August SST differing in only half a degree Celsius (23.5 vs. 23 °C) and February SSTs slightly higher (19 vs. 17–18 °C).

1. Introduction

Many factors constrain the geographical dispersal of shallow marine benthic molluscs such as nutrients, substrate, predation, competition, ocean circulation, natural barriers. However, it is now generally accepted that the main factor controlling their latitudinal distribution is water temperature. Not simply maximum and minimum sea-surface temperature (SST), but the duration of the time interval in which water temperature reaches critical levels required for successful reproduction (Hall, 1964; Davoli, 1976; Raffi et al., 1985, 1989; Monegatti and Raffi, 2001).

Along Eastern Atlantic coasts there is a southwards latitudinal increase in molluscan diversity. This pattern is attributed, mainly, to an increase in sea surface temperature. Therefore, biogeographical boundaries reflecting these latitudinal changes are determined by major changes in thermal gradients (Monegatti and Raffi, 2001).

Moreover, on a global scale, sea-surface water temperature fluctuations, namely cooling periods, are singled out as the primary agent of extinction, local disappearance and major equatorward faunal latitudinal shifts (Stanley, 1986; Stanley and Ruddiman, 1995).

Hence, molluscan assemblages, and thermophilic benthic molluscs in particular, are important proxies for the determination of palaeobiogeographical boundaries and the estimation of ancient shallow marine thermal conditions, as well as excellent ecostratigraphic tools.

The Pliocene molluscan assemblage from the Mondego Basin (Portugal, central west Iberia) plays a particularly important role in the understanding of the palaeobiogeography of Neogene–Quaternary molluscs of the Atlantic Frontage of Europe and the western Mediterranean (Fig. 1).

Miocene Atlantic molluscan assemblages are well documented, being present in several Neogene basins from southern Iberia to

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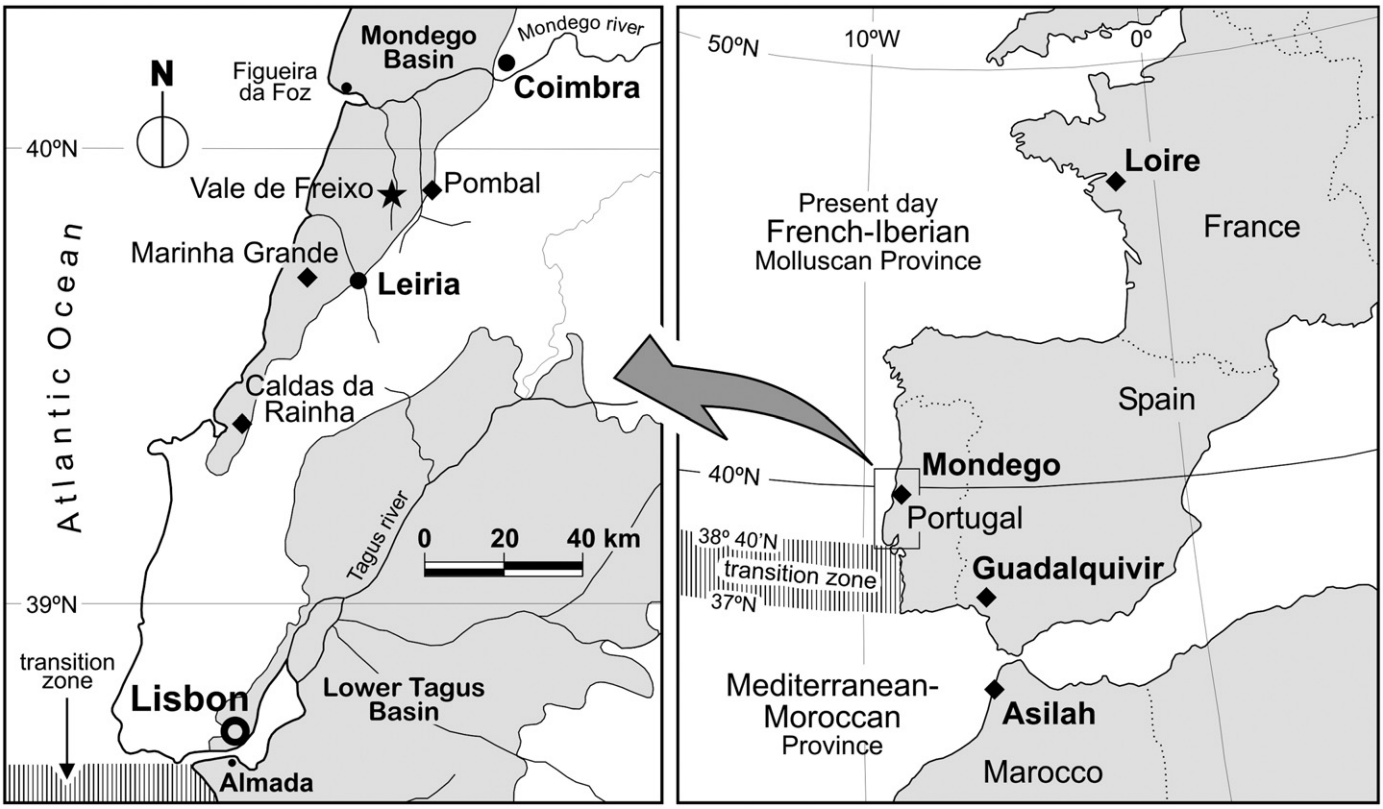

Fig. 1. Geographical location of the Vale de Freixo site and of the Cainozoic Basins of Mondego and Lower Tagus (Western Portugal).

northwestern France. The Pliocene Mondego fauna, however, is the sole reference point between the Atlantic Zanclean molluscan assemblages of the Guadalquivir Basin (Spain, SW Iberia) and the Asilah Basin (NW Morocco), and the late Redonian assemblages of the Loire Basin (NW France). The Mondego fossiliferous localities are located immediately north of the transition zone between the present-day French–Iberian province, to the north, and the Mediterranean–Moroccan molluscan province, to the south (*sensu* Raffi et al., 1985; Monegatti and Raffi, 2001).

The aims of this paper are: 1) to date the Pliocene Atlantic molluscan assemblages from the Vale de Freixo fossiliferous site of the western Portuguese Mondego Basin as accurately as presently possible, in order to establish reliable correlations with coeval Atlantic and Mediterranean molluscan assemblages; 2) to correlate western Iberian Pliocene molluscan assemblages with Mediterranean Pliocene Molluscan Units (MPMU) of Monegatti and Raffi (2001); 3) to attempt a reconstruction of western Iberian Pliocene sea-surface temperatures; 4) to compare the SST data obtained with Pliocene global climatic models developed over the last decade.

2. The Portuguese Pliocene molluscan fauna

2.1. Previous works

The occurrence of fossils of Pliocene marine molluscs in the Mondego Basin, central-west Portugal, has been documented for over one hundred years, starting with Choffat (1889). A century later, little has been added to the knowledge of this interesting molluscan assemblage (Dollfus and Cotter, 1909; Cox, 1936, 1941; Zbyszewski, 1959; Brébion, 1971, 1974). The presence of Pliocene marine molluscs in the Lower Tagus Basin (Fig. 1), in the Almada region, has also been documented (Choffat, 1889; Dollfus and Cotter, 1909; Zbyszewski, 1943), but unfortunately these fossils are represented by poorly preserved casts.

The classic Portuguese Pliocene Mondego localities are situated in Caldas da Rainha, Marinha Grande and Pombal regions (Fig. 1). However, none of these localities has produced an assemblage as well preserved or diverse as that of Vale de Freixo, Pombal region, discovered in the early 1980s. Since then the study of Portuguese Pliocene molluscan faunas has received new vigour (Silva, 1990, 1992, 1996; Gili et al., 1995; Silva et al., 2000; La Perna et al., 2003; Silva et al., 2006; Landau et al., 2009b).

2.2. Geological setting

The Mesozoic sedimentary record of the Portuguese central-west Atlantic frontage, situated inwards of a marginal horst (the Berlenga Horst) constitutes the Lusitanian Basin (Carvalho et al., 2005). In Lutetian times (Middle Eocene) distensive faulting, related to the Pyrenean orogen, define two Tertiary sub-basins: the northern Mondego Tertiary Basin and the southern Lower Tagus Tertiary Basin (Cunha, 1992). The Pliocene sedimentary record of Caldas da Rainha, Marinha Grande and Pombal regions is part of the Mondego Tertiary Basin.

In the Mondego Basin, the Pliocene sequence is generally composed of shallow marine sediments (micaceous fine yellowish siliciclastic sandstones), nearshore sediments (mudstones and lignites with diatomites) and continental sediments (conglomerates and coarse sandstones) showing a regressive succession (Cunha, 1992). The marine fossililiferous outcrops correspond to the lowermost section of the sequence.

The Pliocene stratigraphic sequence in the Pombal–Marinha Grande region is composed of two members (Cachão, 1989): the Carnide Sandstone (Formação Arenito de Carnide) below, and, above, the Paredes/Roussa Sandstone (Formação Arenitos de Paredes/Roussa). The Paredes/Roussa Sandstone has not yet yielded any macro- or micro-body fossils. The Carnide Sandstone consists generally of fine yellowish silty micaceous sand, normally without evident macro- or micro-body fossils. Locally, the lowermost section of the Carnide Sandstone contains