The character and propagation of Miocene compression in the Tagus Abyssal Plain

Carácter e propagação da compressão Miocénica na Planície Abissal do Tejo

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Abstract

The effects of the Miocene through Present compression in the Tagus Abyssal Plain are mapped using multi-channel seismic reflection and refraction data. Four distinct structural domains are recognized along seismic line IAM5. The Miocene tectonic inversion is mainly accommodated in Domain 3 by oceanwards directed thrusting at the ocean-continent transition and continentwards on the continental slope. Rheological numerical modelling indicates that the frictional strength in the ocean-continent transition zone is reduced in 30% relative to the surrounding regions.

Keywords: *Tectonic inversion, passive margin, seismostratigraphy, deep structure, FEM modelling.*

Resumo

O efeito da compressão Miocénica na Planície Abissal do Tejo é descrito com base em dados de reflexão e refracção sísmica. São reconhecidos quatro domínios estruturais distintos ao longo do perfil IAM5. A inversão Miocénica é acomodada principalmente no domínio 3 em cavalgamentos vergentes para o oceano na zona de transição continente-oceano e vergentes para o continente no talude continental. Modelação numérica do comportamento reológico indica que a resistência ao atrito na transição continente-oceano é 30% inferior à normal.

Palavras-chave: *Inversão tectónica, margem passiva, sismoestratigrafia, estrutura profunda, modelação numérica.*

Introduction

It is now widely recognized that many non-volcanic rifted continental margins are characterized by the presence of a transitional zone between the thinned continental crust and oceanic crust. However, the nature of this zone is still a matter of debate. The interpretation and modelling of wide angle and near vertical seismic data along IAM-5 multi-channel (MCS) profile (Afilhado et al., 2008) indicates that nearly the entire Tagus Abyssal Plain (TAP) is underlain by oceanic crust (Domains 1 and 2 in figure 1B), and that the transitional zone is a region ~ 40 km wide, called the OCT, similar to the zone of exhumed serpentinized mantle recognized in the Iberia Abyssal Plain to the north. However, the OCT in the TAP is rather narrower than the exhumed serpentinized mantle zone in the Iberia Abyssal Plain. Furthermore, along IAM-5 line, reverse faulting in the Miocene seems to be concentrated at the limits of the main crustal domains (Afilhado et al., 2008). Zones displaying compressional deformation of Eocene and Miocene age were also identified in the Iberia Abyssal Plain, coincident with the ocean-continent transition (Masson et al., 1994). The concentration of deformation was postulated to occur due to a rheological contrast, but no modelling supported this conclusion (ibid.). In this study, described in more detail in Neves et al. (2008), our aims are to address the following questions: (1) how do the tectonic structures observed within the sediments and shallow acoustic basement correlate with the deep structure computed from wide angle by Afilhado et al. (2008); (2) how did the Miocene compression propagate across the various rheological domains of the TAP, and (3) what is the role of rheology in the concentration of the Miocene compression, or in other words, what constraints on the rheology of the OCT can we infer from the Miocene compression. These goals were pursued by thoroughly studying the

tectonostratigraphy of the region that encompasses the TAP, giving special emphasis to the IAM5 multi-channel seismic profile (Figure 1B).

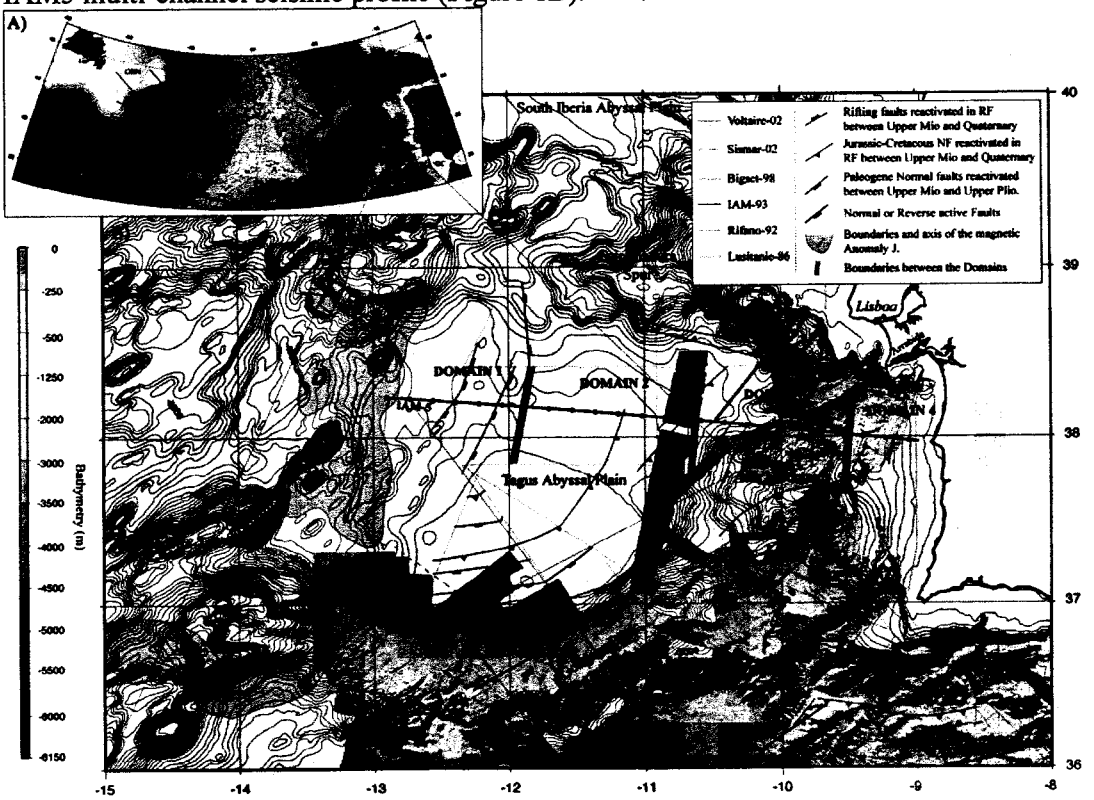

Figure 1. A) Bathymetric Map of the North Atlantic Ocean (data from Gebco97) with location of the study area including the main MCS lines (see Neves et al. (2008) for details **B)** – Tectonic - bathymetric map of the study area showing the location of the analyzed MSC profiles. The faults have been mapped during the present work, the black ones come from Terrinha et al. (submitted). The boundaries and axis of the J Anomaly are based on the interpretation of the magnetic grid of Verhoef et al., 1996 (Fidalgo, pers. comm.). MPF: Marques Pombal Fault; SVC: Sao Vicente Canyon; SC: Setubal Canyon; HSF: Horseshoe Fault.

Tectonics of line IAM5 and the propagation of the Miocene deformation in the TAP

The MSC IAM-5 profile was analyzed in terms of its deep crustal structure and of the Meso-Cenozoic tectonic deformation. This joint analysis led to the recognition of four main structural domains (DOMAINS 1, 2, 3 and 4) and three sub-domains (Sub-domain 3A, 3B and 3C) as shown in Figure 2 and 3. The main observations regarding the propagation of the Miocene deformation in the TAP can be summarized as follows: a) the folding of sediments is associated to faulting and the best developed folds are located on the hanging-wall of reverse faults; b) only minor deformation structures formed to the west of the abyssal basin, west of km80 in Domain; c) FD, FE1 and FE2 (Figure 3) are the only existent westwards directed reverse faults of Miocene age and they are located west of the mid-crust continental wedge; c) to the east of the pinch out of the mid-crust continental wedge (km245) thrusting is only eastwards directed; d) shortening initiated in the continental slope (east of km245) in Early to Middle Miocene times and propagated to the west when FD, FE1 and FE2 formed; e) at the end of the Miocene FD, FE1 and FE2 ceased their activity and deformation has been accommodated since then to recent times on the continental slope, i.e. east of the middle continental crust pinch out, by means of eastwards directed thrusting; f) the thick-skinned half-graben faults HG1 (Miocene through Present) and HG2 (Figure 2) (Miocene only) accommodated the eastwards directed thrusting.

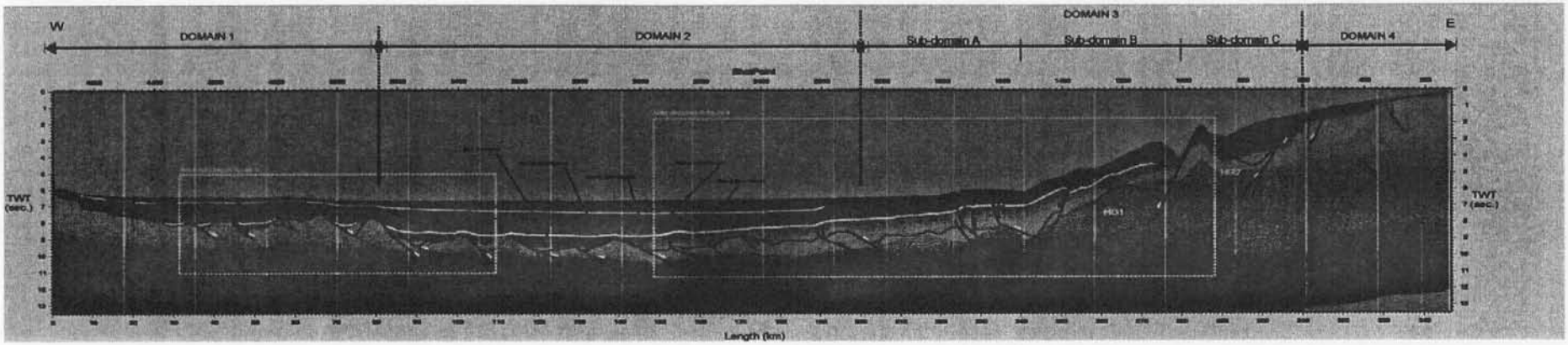

Figure 2. General tectonic and seismostratigraphic interpretation of the IAM-5 MCS profile. Seismostratigraphic calibration based on Roque (2007). White arrows, normal fault kinematics (Late Mesozoic/Paleogene); Black arrows, reverse fault reactivation (ranging from Late Paleogene/Early Miocene through Present). Domain 1 and Domain 2 correspond to oceanic crust. In Domain 3 we distinguish three sub-domains: **Sub-domain 3A** which coincides with the **OCT**, Sub-domain 3B which is a highly deformed adjacent continental segment, and Sub-domain 3C. Domain 4 corresponds to the non-rifted continental margin.

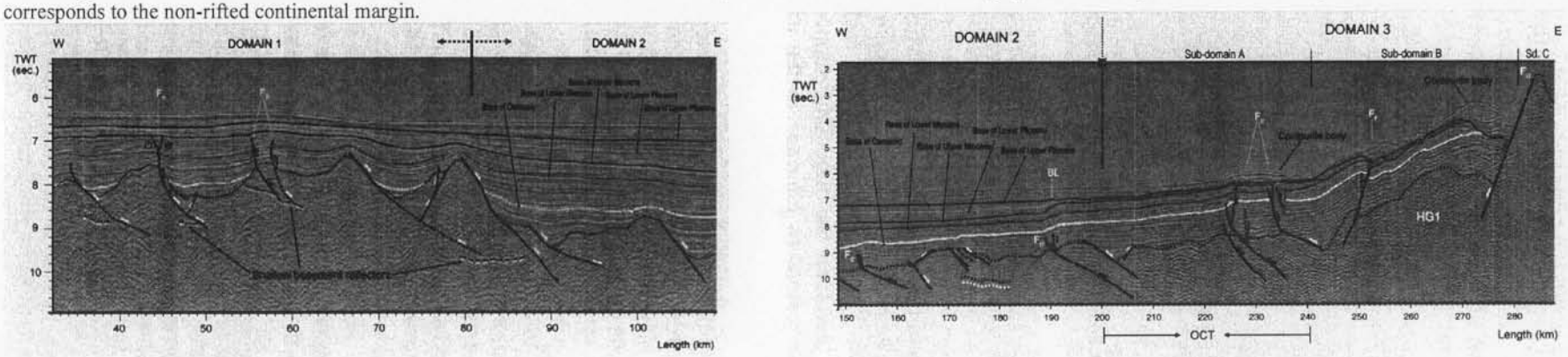

Figure 3. Detailed tectonic interpretation the western (left) and eastern (right) segment of IAM-5 MCS profile (zoomed from figure 2). $\mathbf{F_G}$ is a syn-rifting normal fault which underwent Miocene reverse fault reactivation, $\mathbf{F_C}$ is sealed by the Early Miocene, $\mathbf{F_D}$ is sealed by the reflector corresponding to the base of the Upper Pliocene and ,$\mathbf{F_F}$ affects the base of the Upper Pliocene and seemingly denotes a bathymetric expression suggesting active deformation at Present. Note that such age span denotes a diachronic migration pattern characterized by a progressively younger reverse fault reactivation towards the continental margin (i.e. towards the East). **Black and white double dashed lines** - Shallow basement reflectors. **OCT** – Ocean-continent transition. **B** - Westward migrated basin boundary.

Rheological Numerical modelling

Finite element numerical models address the response of the various domains to the Miocene compression, emphasizing the long-wavelength differential vertical movements and the role of possible rheologic contrasts. The concentration of the Miocene deformation in the transitional zone (TC), which is the addition of Sub-domain 3A and part of 3B, is a result of two main factors: (1) focusing of compression in an already stressed region due to plate curvature and sediment loading; and (2) rheological weakening.

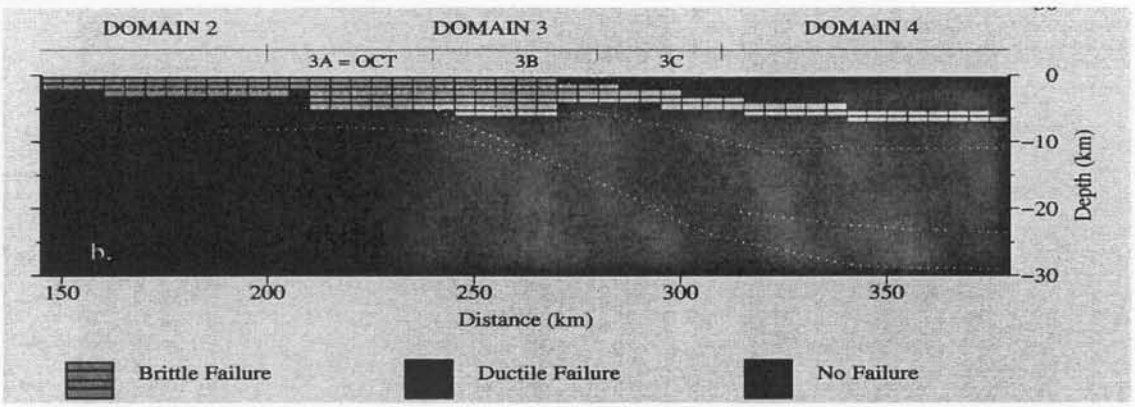

Figure 4. Predicted pattern of failure on a undeformed frame for 2000 m of shortening. Continental (wet quartzite) and transitional (wet diabase) rheologies have been tested in the transitional zone (TC) between km200-km270. In any case the brittle failure reaches the base of the upper crystalline crust in TC at ~5 km depth .

To explain the observed accommodation of Miocene shortening the frictional strength in the TC region needs to be reduced by ~30% when compared with surrounding regions. To the west of km240, in the OCT, the clear evidence of faults below 5km depth is not consistent with ductile flow and therefore the modeling supports a transitional or serpentinized mantle composition in this region. In contrast, to the east of km240 a continental composition is consistent with the existence of a decoupling zone at the base of the mid-continental crust. This supports the hypothesis of a mid continental crust-upper continental crust wedge that acted as an indenter controlling the location of the Miocene deformation in the TAP. According to this hypothesis oceanwards directed thrusting lies at the tip of this wedge and continentwards directed thrusting ramps up on top of a decollement at the basement-rift basin interface, probably the evaporites of Late Triassic-earliest Jurassic age.

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