# MORPHOSTRUCTURE OF THE TORE SEAMOUNT AND EVIDENCES OF RECENT TECTONIC ACTIVITY (WEST IBERIA MARGIN)

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**Abstract:** The Tore Seamount, whose origin is still a matter of debate, is located in the northern end of the Tore-Madeira Rise off the West Iberia Margin, a geological setting characterized, from east to west, by thinned continental crust, exhumed continental mantle and oceanic crust related to the Mesozoic opening of Atlantic Ocean. New multibeam bathymetry and multichannel seismic lines data allowed a detailed morphological, seismostratigraphic and structural analysis of the Tore Seamount and of its connection with the Estremadura Spur. The morphology displayed by the Tore Seamount and by the Egas Moniz ridges, which connect it with the Estremadura Spur, are controlled by E-W thrust-faults and back-thrusts showing evidences of activity during the Late Pliocene-Pleistocene.

***Key words:*** *Tore Seamount, morphology, West Iberia Margin, Late Pliocene-Pleistocene, recent tectonics*

## 1. INTRODUCTION

The Tore Seamount is an enigmatic feature of unknown origin located in the West Iberia Margin, in the northern end of Tore-Madeira Rise that together with the Estremadura Spur separates the Iberia Abyssal Plain from the Tagus Abyssal Plain (Figure 1). In this sector of the West Iberia margin the Tore-Madeira Rise is cross cut from north to south by the J magnetic anomaly of Barremian-Aptian age that separates the oceanic crust domain in the west, from the zone of exhumed continental mantle in the east (Withmarsh and Wallace, 2001).

The Tore Seamount was described and mapped by Laughton *et al.* (1975) and surveyed with more detail by Cornen *et al.* (2001). It shows a NE-SW elongated shape formed by coalescent seamounts that surround a central elliptic depression. Three hypothesis were proposed by Laughton *et al.* (1975) to explain the origin of this submarine relief: a giant caldera, a crater of meteorite impact, or it could be due to a chance mixture of tectonic trends.

The caldera hypothesis was refuted by these authors considering the huge dimensions that the magmatic chamber must had to account for the seamount size. Monteiro *et al.* (1998) and Ribeiro (2002) proposed a meteorite impact origin for Tore related to possible ejecta deposits found at the Cenomanian-Turonian boundary in the coast of Portugal at about 300 km west of this seamount. Samples from dredges collected on the Tore Seamount correspond to alkali basalts and more differentiated rocks (Cornen *et al.*, 2001) as trachyte and thachy-andesite, respectively, 82.1±2.4 Ma and 88.3±3.3 Ma old (Merle *et al.*, 2006).

A magnetic dipoles alignment trending WNW-ESE to NW-SE is recorded from the Tore Seamount through the alkaline subvolcanic complexes of Sintra, Sines and Monchique emplaced in the West Portuguese Margin and onshore (Ribeiro, 2002). Badagola (2008) correlates this lineament with vertical faults that cross the Estremadura Spur and along which outcrop igneous plugs. One of these was dredge and consists of ankaramite dated of 74 Ma (Mougenot, 1988).

Historical and instrumental earthquakes have been recorded in the area between the western end of the Estremadura Spur and the Tore Seamount with magnitudes of Ms=3.0-4.5 (Martins and Mendes-Víctor, 2001). However, great magnitude earthquakes were felt in historical times, reaching Ms=7.0 in 1724 and Ms=6.5 in 1867 (Martins and Mendes-Víctor, 2001).

New data acquired by the Estrutura de Missão para a Extensão da Plataforma Continental (EMEPC) in the scope of the project of extension of the Portuguese continental shelf allowed better understanding of the Tore Seamount morphostructure and its genesis, its morphostructural connection with the Estremadura Spur located eastwards, and the identification of several structures that show evidences of past and recent tectonic activity.

## 2. DATA AND METHODS

The data used in this work (Figure 1) were acquired during several geophysical surveys made from 2004 to 2006 by the EMEPC. These data consist of multibeam bathymetry and multichannel seismic lines. The multibeam bathymetry was acquired onboard the research vessel NRP Gago Coutinho using the echosonder Simrad EM-120. The four multichannel seismic lines used in this work (IB-03, IB-04, IB-05 and IB-06) were acquired onboard the R/V Akademik Shatsky using a source of 5720 cubic inches bold gun array, a 7950 m length cable and a shot interval of 50 m. These seismic lines were calibrated using the stratigraphic data from ODP drills made in the West Iberian Margin, namely, Legs 149 and 173 (Sawyer *et a*l., 1994; Withmarsh *et al*., 1998).

The seismic stratigraphy interpretation was made using the Kingdom Suite software. The bathymetry analysis was made using ArcGis and Fledermaus software.

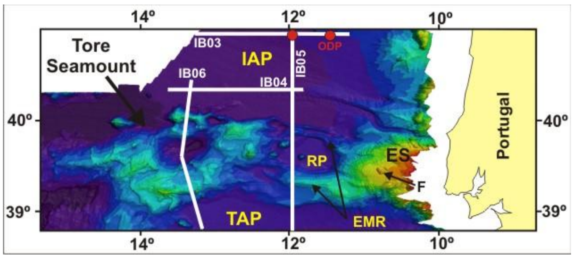


*Fig. 1. The data set used in this work: multibeam bathymetry of Tore Seamount area; multichannel seismic lines (IB03, IB04, IB05, IB06); ODP data. IAP: Iberia Abyssal Plain; RP: Rincão da Pomba; ES: Estremadura Spur; EMR: Egas Moniz Ridges; TAP: Tagus Abyssal Plain; F: Fontanelas volcano.*

## 3. RESULTS

The analysis of the multibeam bathymetry data shows that the Tore Seamount is made up of a central elliptic depression elongated parallel to the NE-SW direction, surrounded by a ring of irregular reliefs. The Tore Seamount is connected towards east with the Estremadura Spur by E-W ridges (Egas Moniz ridges) (Figure 1).

The Tore Seamount is about 239 km long and 130 km wide, formed by coalescent E-W and ENE-WSW ridges and small seamounts defining an elongated feature that surrounds the central asymmetric depression of about 85 km long and 50 km wide. Inside of the main depression, a minor elliptic one, of about 25 km long and 12 km wide, is recognized, reaching the maximum depth of 5536 m, greater than the depth values of the adjacent abyssal plains of Iberia (about -5200 m) and Tagus (about -4800 m). The top of the ridges and small seamounts are located between a depth range of 2300 m and 3000 m. The connection with the Estremadura Spur is made by four E-W asymmetric ridges from about 46 to 96 km long, whose crests are located, from north to south, from -4540 m to -3050 m. These ridges and the eastern flank of Tore Seamount enclose a small basin about 4900 m depth, named Rincão da Pomba (Figure 1).

The seismic stratigraphy interpretation of multichannel seismic lines IB-03, IB-04, IB-05 and IB-06, calibrated with the stratigraphic data from ODP Legs 149 (Sawyer *et a*l., 1994) and 173 (Withmarsh *et al*., 1998) made in the Iberia Abyssal Plain, allowed the identification of five seismic units. Seismic unit U1 is correlated laterally with Late Berriasian-earlyValanginian breccias drilled by ODP legs 149 and 173. This seismic unit is overlain by seismic unit U2 that corresponds to Late Cretaceous sediments. Above it rests the seismic unit U3 that corresponds to Maastrichtian to early Eocene sediments. This unit is cover by seismic unit U4 that consists of middle Eocene-middle Miocene sediments showing evidences of bottom-currents activity. Contourite deposits of this age were drilled during ODP Leg 173 (Withmarsh *et al*., 1998). The youngest seismic unit is unit U5 that consists of Late Pliocene-Pleistocene sediments.

The seismic line IB-06 (Figures 1 and 2) shows that the minor depression of the Tore Seamount is filled up by over than 1.0 second twt of faulted sediments cover by about 0.1 seconds twt of younger undeformed sediments. The basement underlying this minor depression is characterized by the presence of parallel high-amplitude reflections alternating with chaotic seismic facies. The nature of the basement is difficult to determinate.

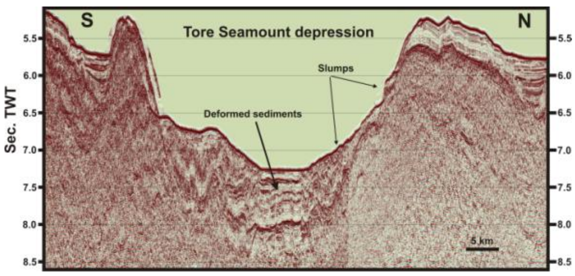


*Fig. 2. Seismic line IB-06 shows the central depression of the Tore Seamount filled up mainly by deformed sediments. The northern flank of this depression is affected by slumps.*

The joint interpretation of the multichannel seismic lines and multibeam bathymetry allowed the identification and mapping of several thrust-faults and flexures that deform the Late Pliocene-Pleistocene sediments. Some of these faults are blind-thrusts, while others show sea-floor expression, as for instance, the 55 km long E-W thrust-fault identified in the Iberia Abyssal Plain near the northern flank of Tore Seamount, forming a 188 m high scarp shown in the bathymetry data and in the seismic line IB-06 (Figures 1 and 3).

The Tore Seamount main depression is bounded at the north and the south by two major E-W north-dipping thrust-faults. The minor central depression is enclosed between two opposite-dipping thrust-faults trending ENE-WSW, and the infilling sediments are very deformed. This depression is located eastwards from the J magnetic anomaly (Withmarsh and Wallace, 2001).

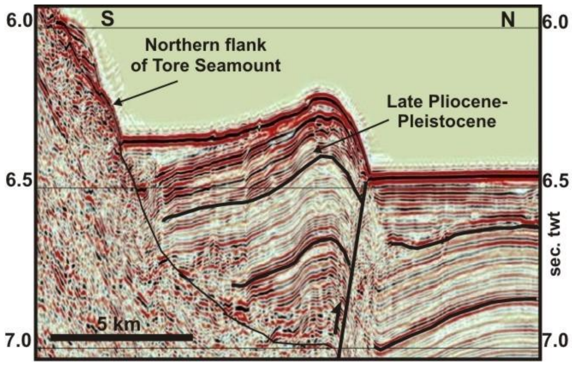


*Fig. 3. Thrust-fault in the Iberia Abyssal Plain close to the northern flank of the Tore Seamount (seismic line IB-06).*

The Egas Moniz ridges (Figure 1) are morphologically controlled by north-dipping E-W thrust-faults and back-thrusts. The Tore Seamount and the Rincão da Pomba basin are intruded by small volcanoes (Figure 1). An E-W alignment is identified between three of these volcanoes and the one located in the Estremadura Spur, named Fontanelas (Figure 1). These can possibly be related to the Late Cretaceous alkaline magmatic events also identified in the Portuguese mainland (Miranda *et al*., 2009).

## 4. DISCUSSION

The interpreted data show that the present-day morphology display by the Tore Seamount seems to be a conjugation of magmatic activity and tectonics. The magmatic morphogenesis of the Tore Seamount is associated with the Late Cretaceous alkaline events that originated the Madeira Rise as is shown by the morphological continuity between these two features and because they share similar petrology and geochemical signatures (Merle *et al*., 2006).

A possible genetic association with the Late Cretaceous alkaline magmatism recorded in the Portuguese mainland (Miranda *et al*., 2009) need be investigated in the future.

The compressive Plio-Quaternary tectonics accounted for the shape of the Tore Seamount and also the Egas Moniz Ridges that connect it with the Estremadura Spur. A Late Pliocene compressive phase is identified in these morphological domains and possible have a more regional character as is also recognized the Tagus Abyssal Plain (Batista, 2009). This Late Pliocene phase could be related to a general reorganization of the Iberia-Eurasia and Africa plate boundary.

The older Paleogene and Miocene compression phases that inverted many normal-rift-faults in Southwest and West Iberia Margins (e.g. Zitellini *et al*., 2004) probably were responsible by the shape of the Tore Seamount and Egas Moniz Ridges.

## 5. SYNTHESIS

The morphology of Tore Seamount is associated with the Late Cretaceous alkali magmatism and formation of the Tore-Madeira Rise and with the Late Pliocene-Pleistocene compressive tectonics.

The distribution of present-day and historical earthquakes epicenters in the Iberia Abyssal Plain near the northern flank of Tore Seamount could be related to the E-W trending south-dipping thrust-fault identified both in the multibeam bathymetry and seismic line IB-06.

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