ACTIVE FAULTS AND GEOMORPHOLOGY IN THE SEAFLOOR BETWEEN THE GIBRALTAR STRAITS AND THE TORE-MADEIRA RISE

Falhas Activas e Geomorfologia do fundo Oceânico entre o Estreito de Gibraltar e A Crista Tore-Madeira

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Resumo: Apresenta-se um mapa tectónico das falhas activas e um mapa geomorfológico entre a Crista Tore-Madeira e o Estreito de Gibraltar. Classificam-se as falhas do ponto de vista geométrico, cinemático e cronológico. Apresentam-se resultados de modelação numérica e análoga para a interferência de falhas de desligamento dextrógiro (próximas de WNW-ESE/90º) e cavalgamento (NE-SW/SE) e ainda para a interferência destas falhas de desligamento com o prisma acrecionário do Golfo de Cádis. Os resultados experimentais sugerem que no primeiro caso de interferência simulado se formam falhas de coalescência entre os desligamentos e os cavalgamentos, locais onde e concentra a sismicidade registada durante 12 meses por 25 OBS (2006-07). As experiências sugerem ainda que o prisma acrecionário e os desligamentos são ambos activos no presente. Discute-se a partição da deformação e a migração da frente de deformação ao longo da Margem Ocidental Ibérica.

Palavras chave: Partição da deformação, migração da deformação, padrões de interferência de falhas, mapa tectónico do SW da Ibéria.

Abstract: *A tectonic map of the active faults together with a geomorphologic map of the area comprehended between the Tore-Madeira Rise and the Straits of Gibraltar is presented. The geometry, kinematics and chronology of the faults are discussed. Results from numerical modelling relative to slip rate on the faults are presented, as well as the results of analogue modeling regarding the interference of the SWIM dextral strike-slip faults (WNW-ESE/90º) with the NE-SW/SE thrust faults. In the first case of experiments, heterogeneous slip faults linking the two main fault systems form. The location of these faults coincide with the location of epicenters recorded during 12 months by OBSs deployed in the study area (2006-07). The second set of experiments suggests that both the SWIM Faults and the Accretionary Wedge are active at Present. The partitioning of the deformation and the deformation front migration along the West Iberia Margin is discussed.*

Key words: *strain partitioning, deformation migration, fault interference patterns, tectonic map of southwest Iberia.*

INTRODUCTION

The offshore area of southwest Iberia located between the Gloria Fault / Tore-Madeira Rise straddles the SW Iberia - NW Africa plate boundary. These two plates now converge at a velocity of approximately 4 mm/y (e.g. Fernandes et al 2003, figure 1). The area was studied using multibeam bathymetry and multichannel seismic profiles shown in figure 2.

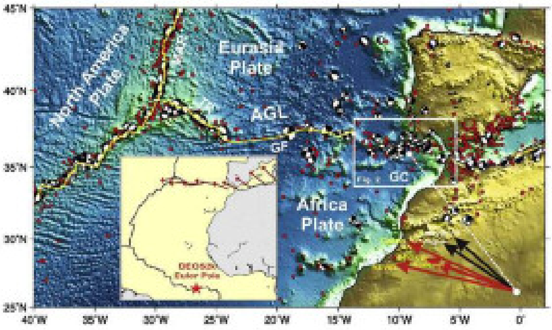

Figure 1- Geotectonic location of the study area. The White rectangle depicts the area shown in figure 2.

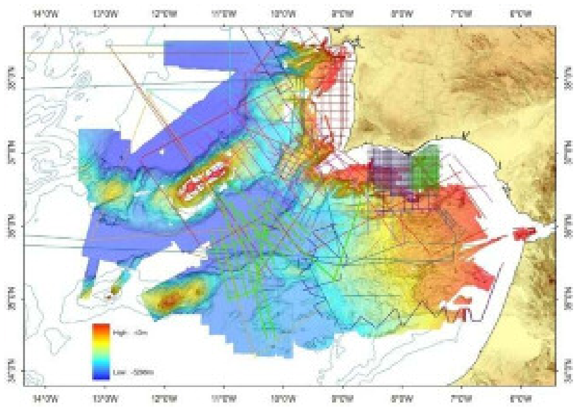

Figure 2- Multibeam bathymetry (Zitellini et al., 2009) and multichannel seismic lines used in this study.

This area and the adjacent onshore of South Portugal show clear examples of rift tectonics from Triassic through early Late Cretaceous times (Cenomanian), Late Cretaceous alkaline magmatism (onshore, the Sintra, Sines and Monchique alkaline complexes; offshore, the Ormonde intrusives in the Gorringe Bank), compressive tectonics due to Africa-Iberia collision from Late Cretaceous through Neogene times and Pliocene-Quaternary wrench and compressive tectonics.

GEOMORPHOLOGY

There are various examples of tectonomorphic features. It is shown in this work that they are generally associated to the reactivation of the Mesozoic syn-rift structures.

The produced geomorphologic map based on the interpretation of this dataset showed the existence of very well defined (discrete) 3D features that correspond to the uplifted blocks carried on top of thrusts. These blocks vary from the point of view of size, surface shape, slope, roughness, etc.

Flat plateaus bound by reverse faults with lengths larger than 70 km (Portimão Bank, Guadalquivir Bank, Marquês de Pombal block) are dissected by gullies or landslides. A large number of turbidite levees up to 20 km long are controlled by uplift of the southwest Portuguese Margin on the foot-wall of a rift fault, the 100 km long Pereira de Sousa fault scarp (Gràcia et al., 2003; Terrinha et al., 2003).

The accretionary wedge of the Gulf of Cadiz (after Gutscher et al., 2002) shows a corrugated surface due to thrust tectonics, mud volcanism and extensional gravity tectonics (Pinheiro et al., 2003; Somoza et al., 2003; Gutscher et al., 2008).

The Principe de Avis submarine mountains (approximately, 37º30'N; 10ºW) form a plateau with an undulated shape that corresponds to a sequence of thrust hanging-wall anticlines draped by Pliocene-Quaternary sediments.

The crescent shaped giant scours formed at depths around 4 km are a nice example of morphologic features that formed associated to tectonic and sedimentary-erosive processes (Duarte et al., 2010).

The valleys, gullies and canyons have different positions and orientations in the study area. The E-W trending broad valleys sit on top of old syn-rift faults that were subsequently reactivated as thrusts and more recently as wrench faults. The gullies and canyons are associated with recent uplift of the westernmost part of the southwest Iberian Margin (Terrinha et al., 2009).

The WNW-ESE trending lineaments that are visible in the multibeam bathymetry were interpreted as dextral strike-slip faults of recent activity (Rosas et al., 2009).

NEOTECTONICS

The map presented in this work (figure 3) depicts the active faults (i.e., faults that were active in the Pliocene through Present time interval). We also present an evolution of the main faults since their formation through Present.

The length of the faults is presented and a table (table 1) with maximum predictable earthquakes is discussed for the different kinematics, using the relevant empirical equations.

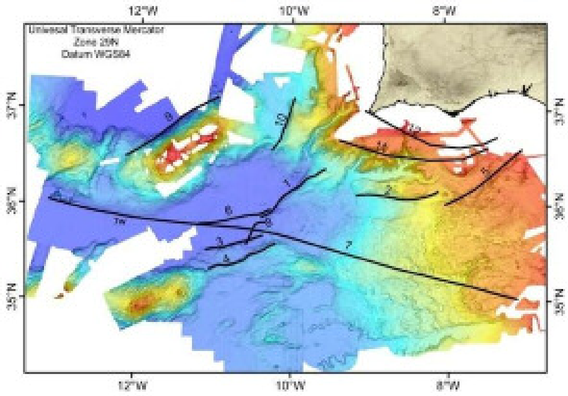

Figure 3- Schematic fault map of the active faults in the study area using multichannel seismic profiles and the SWIM swath bathymetry (Zitellini et al., 2009). Numbers on the faults refer to faults in table 1.

Table 1 – Fault length, kinematics and maximum predicted magnitude earthquake.

Fault	kinematics	length (km)	Max. Magnitude (surface)
1	reverse fault	96	7.38
2	thrust + dextral strike slip	98	7.39
3	reverse fault	70	7.22
4	reverse fault	85	7.32
5	reverse fault	112	7.46
6	thrust + dextral strike slip	85	7.32
7	dextral strike slip	561	8.27
8	reverse fault	38	6.91
9	reverse fault	129	7.53
10	reverse fault	68	7.21
11	reverse fault	180	7.70
12	reverse fault	166	7.66
2+5		213	7.78
1+8		130	7.53
1+6		165	7.65
1+8+10		198	7.74
1+6+7w		350	8.03
Acc. Wedge	thrust (Gutscher et al 2002)		~8.5

The analogue model results (scaled sand box experiments) are compared to the natural analogue (figure 4) and the implications with respect to the relationship of the intersection of faults, their coincidence with clusters of seismicity and their geometry are discussed.

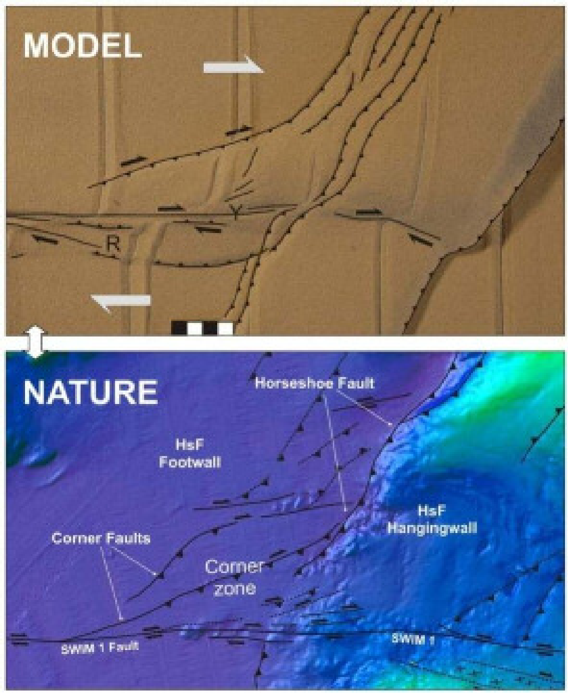

Figure 4- Comparison between natural prototype (below) and the sand box modeling results (top) on the thrust – wrench interference between the Horseshoe Fault and the SWIM 1 Fault in the study area.

CONCLUSIONS

The comparison of the results of numerical modelling and seismicity suggest that the shear zone proposed by Zitellini et al. (2009) as the present day plate boundary between Nubia and SW Iberia in the study area should not be taken as a single fault in what respects the generation of earthquakes.

The active SWIM WNW-ESE trending strike-slip faults and the NE-SW thrusts accommodate the partitioning of the deformation induced by the highly oblique movement of Africa with respect to Iberia.

The analogue experiments suggest that both the accretionary wedge of the Gulf of Cadiz and the SWIM faults are active at Present. However, these experiments only address the kinematics of the uppermost part of the crust, i.e. they were not performed with the boundary conditions or driving mechanisms in order to replicate subduction nor plate oblique convergence.

The data inspected indicate that Quaternary deformation is present along the southern part of the West Iberia Margin and eventually as far west as the Tore-Madeira Rise.

If the fault linkage observed at the surface exists at the hypocentral depths, and slip during earthquakes propagates laterally along linked faults, then there are other faults besides the accretionary wedge that might generate M~8 earthquakes.

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