Seismotectonics of the Algarve Region (onshore area)

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The Algarve is the southernmost area of Portugal mainland, corresponding to the region in the Portuguese territory closest to the Azores-Gibraltar plate boundary zone, between the Nubian and the Eurasian plates. At this longitude, this plate boundary corresponds to a wide, ~E-W trending, dextral transpressive deformation zone associated with oblique convergence of the plates (Rosas et al., 2008; Zitellini et al., 2009) at approximately 4mm/yr in the NW-SE direction. This tectonic setting is responsible for significant seismicity and regional tectonic activity which are evidenced by numerous earthquakes and by Pliocene to Pleistocene deformation, presenting a scenario of important seismogenic potential (Dias & Cabral, 2000; Dias, 2001; Terrinha *et al.*, 1998).

The seismic activity is expressed by important historical and instrumental events, being located at the northern edge of a broad belt of seismicity that extends approximately from the Straits of Gibraltar to the Gorringe submarine ridge (1755 Lisbon earthquake, M = 8.5; 1969 Horseshoe Abyssal Plain earthquake, M_S = 8) and also near the littoral and onshore (1719 Portimão earthquake, IMM max. IX; 1722 Tavira earthquake, IMM max. X; 1856 Loulé earthquake, IMM max. VIII and a scattered low magnitude instrumental seismicity) (Carrilho et al., 1997, Carrilho, 2005). However, the earthquake activity does not propagate significantly inland, suggesting the presence of submarine geologic structures that absorb an important part of the Iberia-Nubia interplate deformation (Dias, 2001; Dias & Cabral, 2002; Dias et al., 2004).

The particular location of Algarve in the plate tectonics framework explains the significant neotectonic activity, intended as the tectonic activity from the Upper Pliocene to the Present. The occurrence of Pliocene to Quaternary deformation is mainly testified by structures at the outcrop scale, consisting of a large number of fractures (faults and joints), some soft sediment deformation structures (such as collapse structures and convolute bedding) and a few folds, affecting the younger sedimentary units, mostly the Plio-Pleistocene “Faro-Quarteira Sands”. However, the recognition and characterisation of the neotectonic structures was often difficult due to the absence of reference horizons and/or to the deficient characterisation of the deformed sediments. In fact, there are several problems like similar colour and lithology of the Plio-Pleistocene sediments that difficult the establishment of the criteria for their separation and differentiation, and consequently do not allow to differentiate the various tectonic events. Also, the presence of monotonous series of sands, without reference levels, difficult or do not allow a kinematic analysis and characterization of the fractures dynamics.

The meso-scale structures affecting Plio-Pleistocene sediments are often scattered through large areas and are not easily related to major tectonic features in the underlying rocks. The scattered fracturing observed in the Faro-Quarteira Sands and conglomerates probably results, in most cases, from the underground evolution of a paleokarst developed in Jurassic and Miocene rocks that the cover sediments fill up. The continuing growth of the buried karst wells induces jointing and faulting in the cover sediments, as testified in several outcrops along the coastal cliffs, where the fractures in the detrital sediments were seen rooted at karst pit walls lined by a thick dissolution residual clayey layer (Dias, 2001; Dias and Cabral, 2002).

The regional morphology, although apparently affected by relatively young (Plio-Pleistocene) vertical movements of the crust, looks mainly conditioned by erosional processes, showing poor evidences of direct, fault related, neotectonic geomorphic expression. Also, the recognition of main active macrostructures at the outcrop scale is not easy. Nevertheless, several active macro-scale structures were identified in the study region, on the basis of geomorphological and/or stratigraphical criteria, namely the recognition of some geomorphic expression of ground deformation such as related fault scarps, and the presence of structures displacing young sediments at outcrops located nearby or along the trace of the mapped regional fault. The active faults that were so recognized in various areas of the Algarve present distinct trends and kinematics, although many show some reverse movement component (Fig. 1).

The occurrence of variably trending active faults showing reverse movement component suggests the action of a compressive stress field that produced a regional constrictive finite strain roughly in the last 2 Ma. Present stress indicators for Southern Portugal also show some dispersion of the $S_{Hmax.}$ azimuth, attested by earthquake focal mechanism solutions, which include strike-slip (predominant), and thrust faulting, although a NW-SE direction prevails.

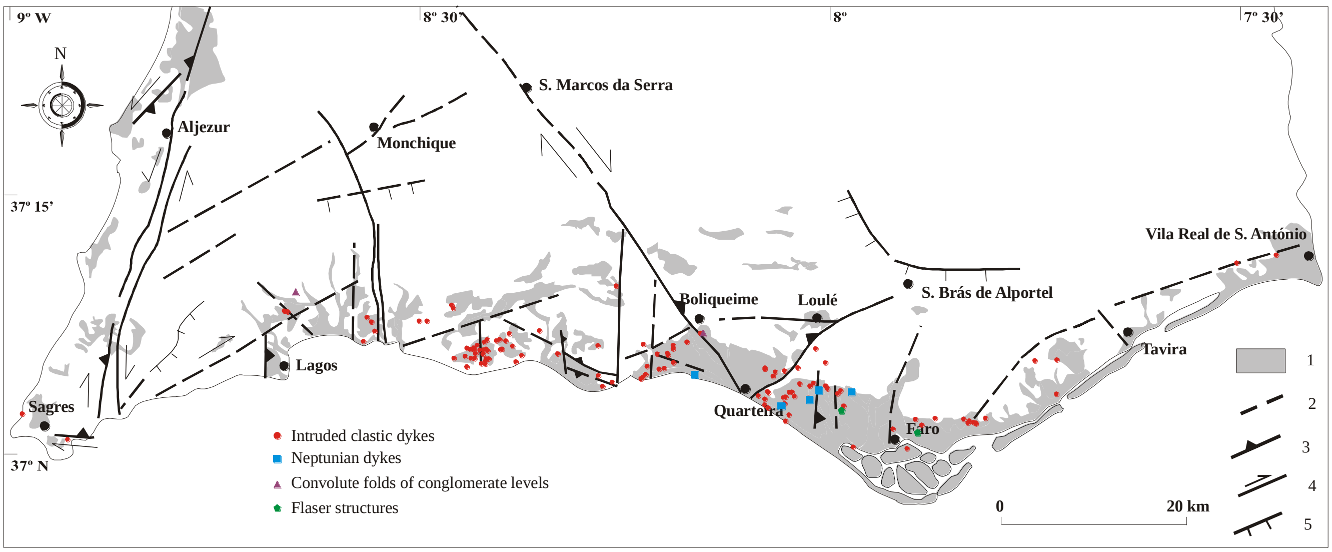

Figure 1 - Map of the main active faults and seismites sites identified in the Algarve Region. 1, Pliocene to Quaternary sediments; 2, probable active fault; 3, reverse fault (teeth on hanging wall); 4, strike-slip fault; 5, fault with unknown dip (ticks on downthrown side (Dias, 2001; Dias and Cabral, 2002).

The significant instrumental seismicity in the Algarve region suggests that at least part of the regional faults recognized in outcrops and identified as active from geological and geomorphological criteria, are responsible for this seismic activity. From the neotectonic data, it is estimated that these active structures have or may generate M 5.8 to 7.1 maximum earthquakes (Dias, 2001, Dias et al., 2009). This is consistent with the presence of soft sediment deformation structures identified in the Algarve region affecting the Pliocene to Quaternary cover sediments, which have been interpreted as due to liquefaction resulting from strong ground motion (neptunian dykes, intruded clastic dykes, convolute folds and flaser structures) (Dias & Cabral, 2002; Dias 2001; Ressurreição, 2009). Theses soft sediment deformation structures (seismites) may result from ground motions related to strong distant earthquakes, but the proximity of many of the seismites to known active faults (Fig.1) suggests a relationship to moderate to high magnitude ($M \geq 5.5$) events generated by these faults (Rodríguez Pascua, 1998), although some of these seismites point to a higher level of local magnitudes (Dias & Cabral, 2000, Dias, 2001, Dias et al., 2009).

References

Cabral, J. (1995), Neotectónica em Portugal Continental. *Mem. Inst. Geol. Mineiro*, Lisboa, 31, 265 p.

Cabral, J. e Ribeiro, A. (1989), Incipient subduction along the West-Iberia continental margin. In: *Abstracts, 28th International Geological Congress, Washington, D. C., USA*, 1/3, pp. 223.

Carrilho, F., (2005), *Estudo da Sismicidade da Zona Sudoeste de Portugal Continental*, Dissertação de Mestrado, Fac. Ciências da Univ. Lisboa, Portugal 147 p.

Carrilho, F., Senos, L., Fitas, A. & Borges, F. (1997), Estudo da Sismicidade do Algarve e Zona Atlântica Adjacente. *3º Encontro de Sismologia e Engenharia Sísmica, Sociedade Portuguesa de Engenharia Sísmica*, Lisboa, pp. 59-67.

Dias, R. P. (2001), *Neotectónica da Região do Algarve*. Dissertação de doutoramento, Fac. Ciências, Univ. Lisboa, 369 p., pol..

Dias R. P. e Cabral, J. (2002), Neotectónica da região do Algarve. *Comun. Inst. Geol. e Mineiro*, t. 89, pp. 193-208.

Dias, R. P.; Cabral, J. & Pena Reis, R. (2004), Paleoseismites and structures related to karst evolution in the Algarve region. In: Dinis, J. L. & Proença Cunha, P. (eds.): Cretaceous and Cenozoic Events in West Iberia Margins. 23rd Meeting of Sedimentology, Coimbra, 2004, Field Trip Guidebook, Volume 2, 73-91.

Dias, R. P.; Cabral, J. & Ressurreição, R., (2009), Perigosidade sísmica na região do Algarve. In Riscos Industriais e Imergentes, C. Guedes Soares, C. Jacinto, A. P. Teixeira, P. Antão (Eds), Edições Salamandra, Lisboa, pp, 201-215.

Ressurreição, R., (2009), *Estudos de Neotectónica na falha de Carcavai (Algarve): contribuição para a caracterização desta estrutura e de paleossismitos prováveis associados*. Dissertação de mestrado, Universidade de Lisboa, Portugal, 121 p.

Ribeiro, A., (2002), "Soft Plate and Impact Tectonics", Springer Verlag.

Ribeiro, A., Cabral, J., Batista, R. & Matias, L. (1996), Stress pattern in Portugal mainland and the adjacent Atlantic region, West Iberia. *Tectonics*, 15, (2), pp. 641-659.

Rodríguez Pascua, M. A. (1998), Paleosismicidad en emplazamientos nucleares (estúdio en relación con el cálculo de la peligrosidad sísmica). *Consejo de Seguridad Nuclear*, Madrid, 286 p.

Rosas, F.M., Duarte, J.C., Terrinha, P., Valadares, V. & Matias, L., (2008), "Morphotectonic characterization of major bathymetric lineaments in Gulf of Cadiz (Africa-Iberia plate boundary): Insights from analogue modeling experiments", Marine Geology, 15 p.

Terrinha, P. A. G. (1998), *Structural Geology and Tectonic Evolution of the Algarve Basin, South Portuga*l. PhD Thesis, Imperial College, London, 430 p.

Zitellini, N., Gràcia, E., Matias, L., Terrinha, P., Abreu, M.A., DeAlteriis, G., Henriet, J.P., Dañobeitia, J. J., Masson, D.G., Mulder, T., Ramella, R., Somoza, L., Diez, S., (2009), "The quest for the Africa-Eurasia plate boundary west of the Strait of Gibraltar", *Earth and Planetary Science Letters*, 28 p.