



Late Pliocene to Pleistocene tectonic activity in SW Portugal: the S. Teotónio-Aljezur-Sinceira fault system – a review

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Abstract: The São Teotónio-Aljezur-Sinceira fault system extends NNE-SSW for 50 km, parallel and close to the southwest Portuguese coast, presenting several small Cenozoic tectonic basins. Although several studies were carried out to recognize and evaluate the recent tectonic activity, estimated as slow rate with 0.017-0.032 mm a⁻¹, a detailed seismotectonic study was never conducted. A thorough geomorphologic and tectonic study is necessary to understand the relationship between this fault system (on-shore faulting) and off-shore structures related to the nearby Azores-Gibraltar plate boundary zone, which generate important seismic activity, such as the 1755 Lisbon earthquake.

Keywords: neotectonics, strike-slip, fault basins, Pleistocene, Portugal.

The southwest region of mainland Portugal is located close to the Eurasia-Nubia plate boundary, the Azores-Gibraltar fracture zone (Fig. 1). East of the Gloria transform fault, this boundary becomes complex, particularly as it approaches the Goringe Bank, the Horseshoe Plain and the Gulf of Cadiz (Fig. 1), where deformation related to the NW-SE convergence of Iberia and Nubia, at a rate of ca. 4-5 mm a⁻¹, becomes distributed across a zone a few hundred kilometres wide (Ribeiro *et al.*, 2006). The comparison between geological and geodetic models shows that the convergence between Nubia and stable Europe is slower (30 to 60%) and rotated 10° to 30° counterclockwise for the geodetic models compared to the geological model values, evidencing that the collision between the two plates is oblique and is increasing the dextral strike-slip component (Nocquet and Calais, 2004).

Since 1992, Zitellini and others (Zitellini *et al.*, 1999), in several marine campaigns using multi-channel seismic reflection (MCS), high resolution bathymetry, and other techniques, have recognized several active structures (folds and faults) in this region, showing that this is a tectonically complex area with distributed deformation.

The Marquês de Pombal fault is a NNE-SSW trending major thrust located ca. 100 km SW of cape São Vicente, presenting a ca. 1 km high, 60 km long scarp in the sea floor, and extending at least 30 km in depth (Fig. 1). When it was first recognized (Zitellini *et al.*, 1999), this structure was considered the most likely source for the 1755 earthquake, in spite of the estimated Mw 8.7. However, later campaigns (Zitellini *et al.*, 2001, 2004; Gracia *et al.*, 2003; Terrinha *et al.*,

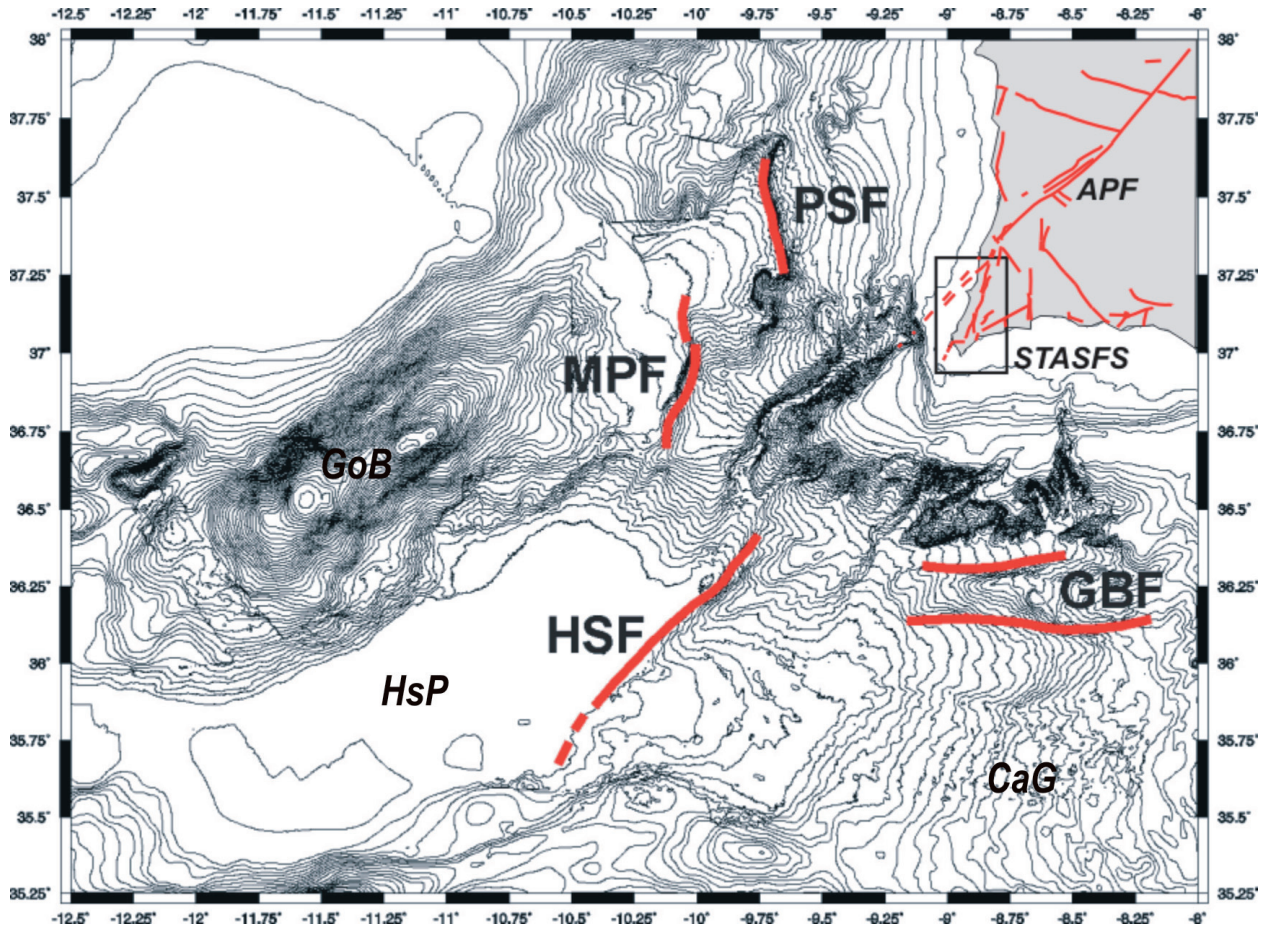


Figure 1. Main Neotectonic structures located, SW Portugal. Onshore structures: APF: Alentejo Placencia Fault; STASFS: São Teotónio Aljezur Sinceira Fault System (marked by the box). Offshore Structures: PSF: Pereira de Sousa Fault; MPF: Marques de Pombal Fault; HSF: Horseshoe Fault; GBF: Guadalquivir Bank Faults; GoB: Gorringer Bank; HsP: Horseshoe Plain; CaG: Cadiz Gulf. Adapted from Terrinha *et al.* (*in press*).

2003), revealed another important thrust located further to the south, the Horseshoe fault, which trends NE-SW along ca. 175 km, parallel to the São Vicente canyon. This canyon probably also coincides with a fault, the offshore SW prolongation of the Alentejo-Placencia fault (Fig. 1). All these structures are related with the Iberia-Nubia convergence and are the source not only of the 1755 earthquake, but also of the Mw 7.9 1969 event, and of other significant historical seismicity (Borges *et al.*, 2001).

The São Teotónio-Aljezur-Sinceira fault system consists of a 50 km long, NNE-SSW trending set of faults located close to and parallel to the SW coast of the Portuguese territory (Figs. 1, 2 and 3). It comprises onshore faults which are located closest to the complex Iberia-Nubia plate boundary and may be correlated with the ongoing plate boundary deformation. This coastal area, where the fault system is located, is therefore particularly appropriate for establishing the

offshore-onshore link through a detailed neotectonic study concerning faulting and vertical deformation, using references such as marine terraces, and including exploration with paleoseismological techniques.

Regional geologic framework

The study region is located in the SW area of the Iberian Hesperian Massif, in the South Portuguese geotectonic zone of the Iberian Variscides, and comprises mainly flysch type metasedimentary rocks of Carboniferous age (Oliveira *et al.*, 1984). In its southern area it also includes sedimentary rocks and a few volcanics of the Mesozoic Algarve Basin, related with the opening of the Atlantic, and a hypabyssal syenitic intrusion of Late Cretaceous age, the Monchique Massif. This Paleozoic and Mesozoic basement presents remnants of a sedimentary cover of Miocene to Quaternary age, preserved in a culminant position at plateaus, or inside several tectonic troughs along the

São Teotónio-Aljezur-Sinceira fault system.

The present tectonic framework is controlled not only by Variscan heritage, such as NE-SW and NW-SE

faulting, but also by faulting related with the opening of the Atlantic and the Thetys during the very beginning of the Alpine orogenic cycle, in the Mesozoic: the Atlantic related fracturing generally trends N-S,

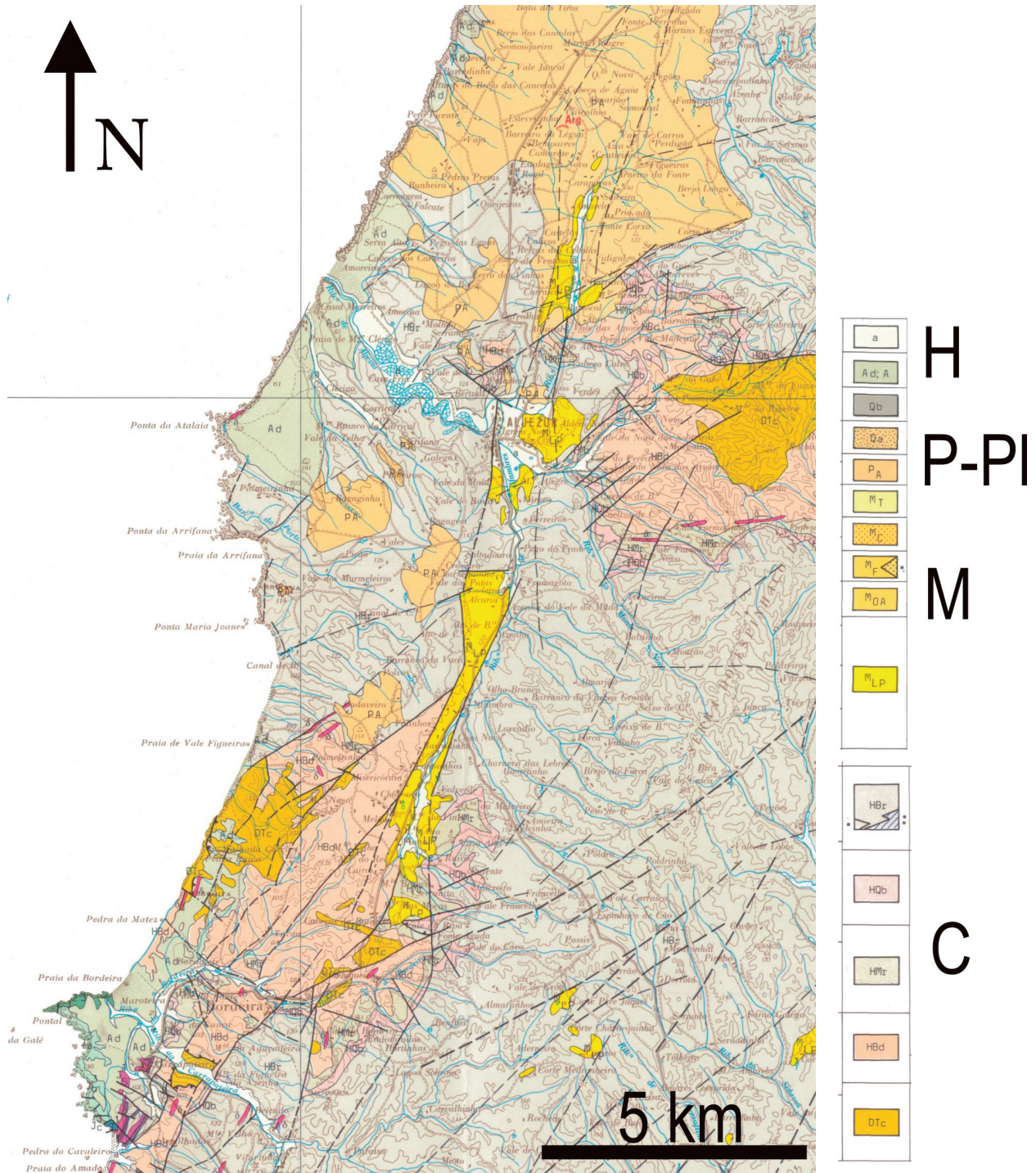


Figure 2. Detail from the northern and central STASFS south of the area of Aljezur; Aljezur and Ribeira de Alfambras basins are mapped in this figure. C: Carbonic meta-sediments sequence; M: Miocene sediments; P-Pl: Pliocene to Pleistocene sediments; H: Holocene sediments. Adapted from the Geological Map of Portugal, 1:200 000 scale, sheet 7 (Oliveira *et al.*, 1984).

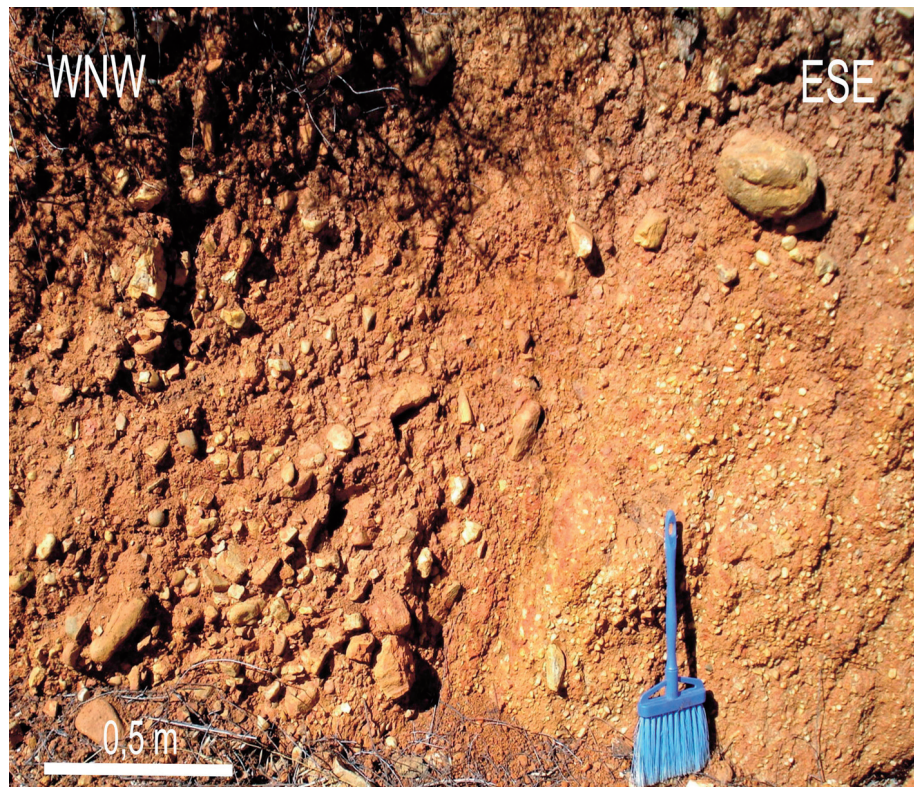


Figure 3. Alfambras Fault, at Alfambras basin, south Aljezur, on the central sector of STASFS. This fault is a NNE-SSW sinistral (?) strike-slip; on the western side are coarser colluvium deposits than on the eastern side, which appear to be finer ones. Ages still unknown but likely to be Pliocene-Pleistocene.

while the Thetys related fracturing is oriented approximately E-W. During the Alpine cycle and right up until the present, the stress field has suffered changes and, therefore, pre-existent fractures behaved differently.

A remarkable structure in the study area is the NE-SW trending Messejana or Alentejo-Plasencia fault, which can be followed for ca. 600 km in the Iberian Peninsula, from the Central System Ranges in Spain to the SW offshore of Portugal. It causes left-lateral strike-slip offsets of up to 3 km in the Palaeozoic basement rocks, and is considered by several authors as a Late Variscan fault which was successively reactivated during the Alpine orogenic cycle, as documented by intrusions of Jurassic dolerite rocks along the fault zone (known as the “Messejana Dyke”) and by displacements affecting Cenozoic cover sediments (Arthaud and Matte, 1975; Martins, 1991; Cabral, 1995; Marques *et al.*, 2002). Villamor (2002) considers the Alentejo-Plasencia fault as a Tertiary strike-slip fault that runs near, and sub-parallel to the Messejana Dyke.

São Teotónio-Aljezur-Sinceira fault system

The São Teotónio-Aljezur-Sinceira fault system (STASFS), already mentioned in this work, is likely to

be related in its northern sector with the Alentejo-Plasencia fault (APF) (Fig. 2). Along the STASFS, several Cenozoic tectonic basins, parallel to the main trend, reflect a strike-slip component and neotectonic behaviour. This fault system has been considered as a Late Variscan structure (Ribeiro *et al.*, 1987, Dias, 2001), as a southern branch of the APF. However it is not clear whether this fracturing is mainly related with the Atlantic opening, and therefore more recent.

The STASFS Cenozoic kinematics is mainly sinistral strike-slip, with a minor (?) reverse component, compatible with a NW-SE maximum horizontal compressive stress (Fig. 3). The reverse component increases northwards approaching the APF, due to an eastward restraining bend where both structures merge. However, stress fluctuations are expected in this fault system, due to the vicinity of major tectonic structures related with the boundary referred to above, which may be in a transient state due to the increase in the Iberia-Nubia dextral transcurrent component (Ribeiro, 2002).

Four Cenozoic strike-slip basins occur along the STASFS, from north to south, the S. Miguel (Odeceixe), Aljezur, Ribeira de Alfambras and Pedralva-Sinceira troughs, whose sedimentary content helps understand the latest evolution of this fault sys-

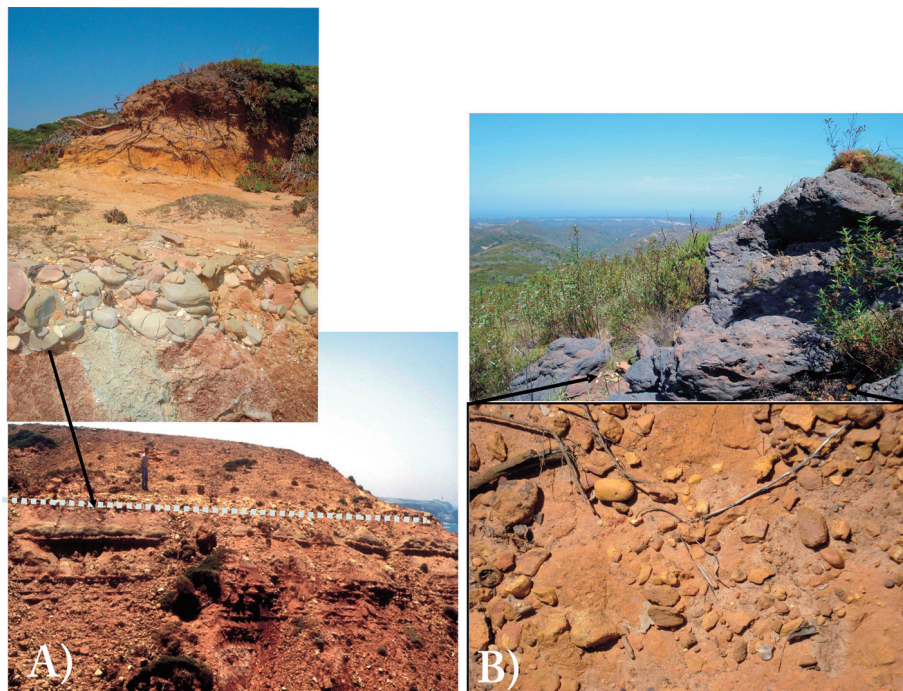


Figure 4. A) Pleistocene Uplifted Beach deposits (80-85m), with schist and greywacke clasts at Telheiro. The dotted line indicates the paleo-beach level, on Triassic bedrock (Dias, 2001); it is possible to observe the beach deposit above the bedrock and below the aelionites, B) uplifted Pliocene, strongly cemented aelionites at Fonte Santa (350 m altitude) and beach deposits, poorly preserved but above the Paleozoic bedrock and below the cemented aelionites.

tem (Fig. 2). The basins generally have lengths of less than 5 km and a maximum width of 1.5 km, and are filled with Miocene to Pleistocene sediments. In some places, fault-related post-Pliocene vertical displacements of up to 100 m may have occurred (Pereira, 1990; Cabral, 1995), but generally they only reach a few tens of metres. Although small, the basins show a complex structure with minor sub-basins, as in Aljezur (Amaro, 2001), evidencing distinct episodes of the STASFS tectonic evolution.

Besides the evidence of Miocene to Plio-Pleistocene faulting, the study area also shows signs of significant vertical movements (Cabral, 1995; Dias, 2001). Effectively, the regional morphology shows a domed erosional surface cutting the Variscan basement and culminating inland at an altitude of around 400 m, above which rises the residual relief of the Monchique intrusive massif (903 m). This culminating piedmont surface, although strongly dissected by the present drainage network, may be traced from Monchique to the littoral, progressively declining in altitude to an elevation roughly fluctuating from 150 m to 60 m along the shoreline, which presents extremely abrupt cliffs and a few raised marine terraces (Figs. 4 and 5).

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As it descends to the coastal area the erosional surface becomes covered with siliciclastic sediments of probable (Late?) Pliocene age, evidencing fluvio-marine sedimentation on a vast littoral plane. These cover sediments reach a maximum altitude of 350 m on top of this marginal plateau. In the southwestern area, they are preserved near the coast, overlying an extremely flat erosional surface on the Variscan rocks at an altitude of 120-140 m, showing a slight bulge up to a height of 155 m near the shoreline, at Torre de Aspa (Fig. 4).

Although a detailed study is still missing, this suggests active lithosphere folding, with the inherent topographic expression, likely to be related with the Marquês de Pombal-Horseshoe Fault System. If so, the recent tectonic STASFS evolution, as well as of the surrounding morphology, have a close correlation with the major offshore structures of the intervening plate boundary zone.

Acknowledgements

This work is supported by Fundação da Ciência e Tecnologia, through a doctoral fellowship (SFRH/BD/36892/2007).

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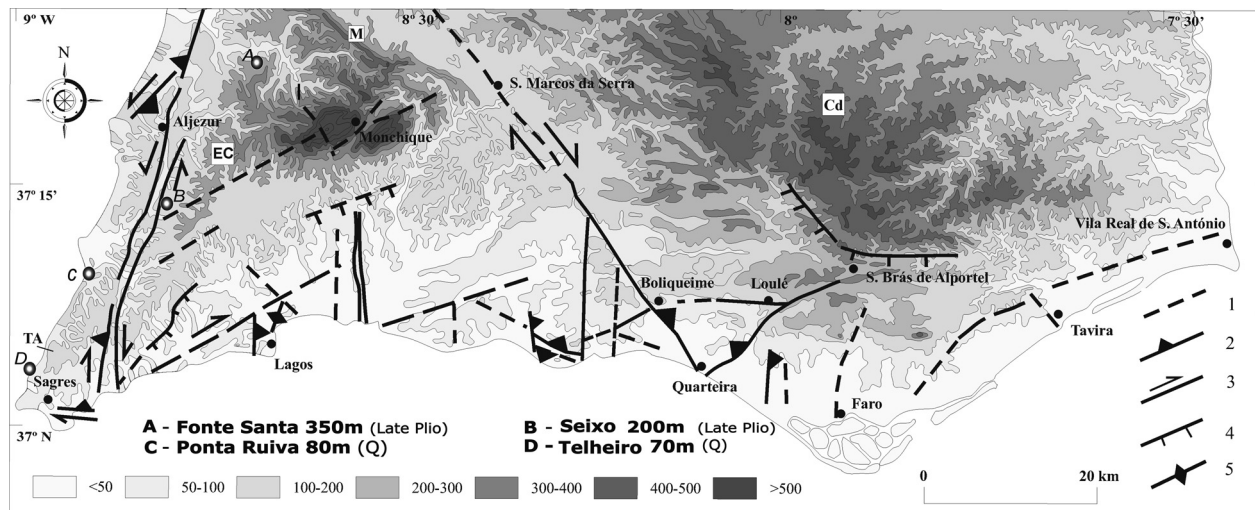


Figure 5. Hypsometric map from Algarve region and neotectonic structures according to Dias (2001). Several marine terraces (white dots) are indicated on the study area. Structures legend: 1: Probable fault; 2: Reverse fault; 3: Strike-slip fault; 4: Vertical fault (traces on downthrown side); 5: Active Folding. EC: Espinhaço-Cão Sierra; M: Monchique Sierra; Cd: Caldeirão Sierra; adapted from Dias (2001).

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