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Active inversion tectonics from Algiers to Sicily

Alain Rabaute^{1,2} and Nicolas Chamot-Rooke³

¹ Geosubsight, 119 Avenue de Stalingrad, 91120 Palaiseau, France

² Sorbonne Université, CNRS-INSU, Institut des Sciences de la Terre Paris, IStEP UMR 7193, F-75005 Paris, France.

³ Laboratoire de Géologie, Ecole normale supérieure, PSL Research University, CNRS UMR8538, Paris 75005, France
 alain.rabaute@geosubsight.com

Abstract. Using an updated active faults map in the easternmost Western Mediterranean (Algeria to Calabria), plus constraints from geodesy (GPS horizontal motion) and seismology (focal mechanisms) input in a strain model, we discuss how the slow Africa-Eurasia motion (4 mm/yr) is accommodated along this segment of the Mediterranean. The width of the inverted domains is variable, strain being concentrated into narrow belts in northern Algeria and north Sicily while it is distributed in Tunisia and over the Pelagian platform. The style of deformation further evolves from west to east, from pure thrusting in Algeria to distributed strike-slip in Tunisia to transtension in the Pelagian grabens. We suggest that the present-day deformation is best explained in terms of (1) accommodation of the obliquity following a strain partitioning process with dextral shear onland and en-échelon thrusts offshore northeastern Algeria, along the past trace of the STEP fault that opened the Miocene Algerian Basin, (2) thrusting offshore northern Sicily along the same STEP fault that opened the Tyrrhenian Basin in the Pliocene, (3) increasing thin-skin versus thick-skin in Tunisia as a result of inherited structures, (4) far field Ionian slab pull, strongly active at the Mio-Pliocene initiation of the Pelagian grabens and still remnant today.

Keywords: Africa/Eurasia Kinematics, Active Tectonics, Strain Partitioning, Inverted Margin, Slab Pull

1 Introduction

Slow motion between Africa and Eurasia in the easternmost western Mediterranean is accommodated within belts of variable widths, from relatively narrow in central Algeria (50–100 km), to wide in Tunisia (>100 km). From western Algeria to Sicily the style of active deformation gradually evolves from pure thrust to a combination of strike-slip and thrust (eastern Algeria and Tunisia), and finally to extension in the Siculo-Tunisian Strait. Both width and style of deformation thus evolve from west to east, in relation with the complex geological history of the African margin, a patchwork of mountain building (Tell, Atlas), continental block collages (Kabyllia), subduction, back-arc opening and closing. Based on a recent seismotectonic map of the area

[1], we discuss the compatibility of the active tectonics with the known present-day regional plate kinematics and the recent geodynamics of the region.

2 Active faults and seismicity

The core of the work is the identification of active faults, with special attention to offshore areas, in particular Algerian Basin, Tyrrhenian Basin, Pelagian Sea and Ionian Sea. The mapping process includes the analysis of seismicity, both instrumental and historical, using epicenter locations and focal mechanisms [2]–[4]. Various sources were homogenized to obtain a comprehensive catalogue of earthquakes in the 0–50 km depth range. Satellite images on land and seismic profiles offshore further helped in discriminating active faults. The Geographic Information System (GIS) database includes 94 fault segments with parameters and related bibliography.

3 Strain modelling using earthquakes and geodetic constraints

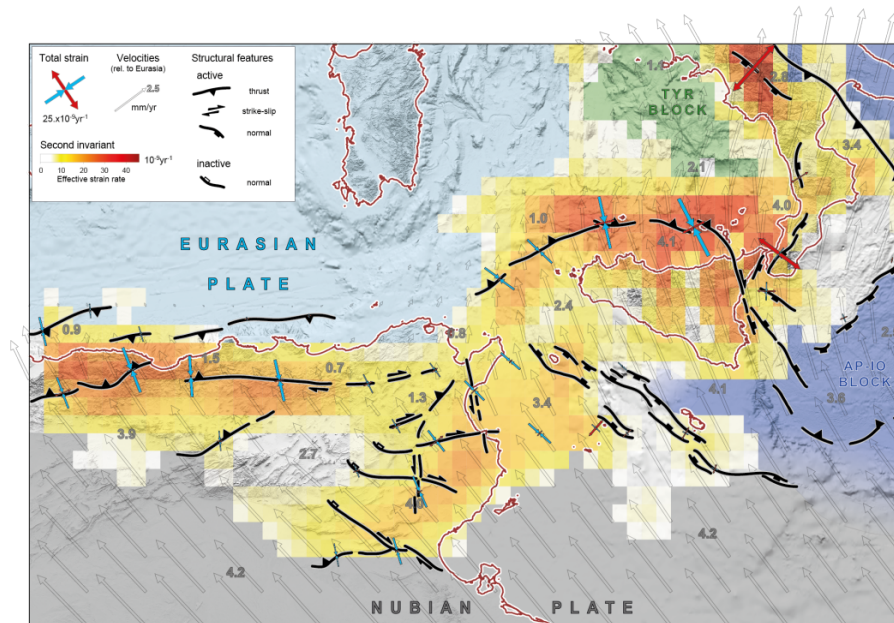


Fig. 1. Strain model based on the style of deformation documented by earthquakes together with GPS constraints. Modelled velocities are shown with respect to Eurasia, together with the effective strain rate (second invariant). Strain-rate axes are shown only in strategic locations. Areas not deforming are colored in green (Tyrrhenian block) and blue (Ionian plain). Structural features are simplified from mapped faults.

The map is complemented by a strain model based on the style of deformation documented by earthquakes together with GPS (Global Positioning System) constraints

(Figure 1). Haines & Holt methodology is used to derive a continuous crustal velocity field [5]. The model consists of a finite-element grid, with ~ 400 grid cells (0.5° by 0.5° in dimension) covering the Nubia-Eurasia plate boundary zone between longitudes 3°E (Algiers) and 18°E (Calabria). To avoid any a priori assumption on the location of the main deformation zones, all cells are allowed to deform, with the exception of bottom rows (Nubia) and top rows (Eurasia).

The model derives a continuous velocity field by fitting simultaneously observed geodetic velocities and style of deformation (i.e. principal strain axis direction). The continuous velocity gradient tensor field provides estimates of the strain rate tensor (second invariant, dilatational and shear components), rotation rate, interpolated velocities and rigid plate motions [5]. To put reliable constraints on the far-field velocity boundary condition, the motion of Nubia with respect to Eurasia was prescribed to a global geodetic solution [6].

4 Results

Faults map and strain modelling document various patterns of deformation, which are generally attributed to the complex geological history of this segment of the Mediterranean. The slow convergence (4 mm/yr) is presently accommodated close to the North African margin, at the boundary with the Oligocene to mid-Miocene Algerian Basin and Miocene to Pliocene Tyrrhenian Basin. From Algeria to eastern Sicily, inversion tends to locate close the present-day coastline, which is also the trace of the STEP fault that accompanied the eastward escape of the Ionian slab – resting nowadays below the Tyrrhenian and Calabria – and the successive Algerian and Tyrrhenian openings [7]. In both cases – i.e. northern Algeria and north Sicily – high strain is restricted to a rather narrow belt of thrusts, one of which being responsible for the Boumerdes-Zemmouri earthquake in 2003 [8].

The width of the inverted domain increases eastward with increasing thin-skinned vs thick-skinned deformation [9]. In northeastern Algeria strain is partitioned into strike-slip and reverse faults on land [10], and $\text{N}80^\circ$ en-échelon reverse faults offshore [11]. In Tunisia, convergence is accommodated within an area three to four times larger, from the Gafsa fault zone in the south to the northern coast. Obliquity of Africa-Eurasia motion is accommodated through a series of E-W trending right-lateral strike-slip faults (Gafsa, Kasserine, Sbiba-Cherichira faults). Conjugate left-lateral strike-slip faults are also active in eastern Tunisia, both onland and offshore (North-South axis, Hammamet-Monastir, Sidi Ali Ben Aoun faults).

Further east, the Pelagian grabens (Malta, Pantelleria and Linosa) that initiated in the upper Miocene [12] are presently transtensive. Focal mechanisms for the entire Pelagian platform indicate strike-slip [13], while GPS shows that the Pantelleria rift system still accommodates a small extensive component of motion between the Nubia plate and the Apulia-Ionian block [6].

98 5 Conclusions

99 The style of faulting observed from Algeria to Calabria is compatible with Africa-
 100 Eurasia kinematics but modulated by two effects: structural inheritance of the Atlasic
 101 and Alpine phases and a lateral slab pull imposed by the Ionian slab retreat. In north-
 102 eastern Algeria, the obliquity of convergence is accommodated through a strain parti-
 103 tioning process, with dextral strike-slip on-land and en-échelon thrusts offshore locat-
 104 ed at pre-existing sharp boundaries. Strain is accommodated over a larger inverted
 105 domain in Tunisia in relation with increased thin-skinned deformation above Triassic
 106 salt. Convergence is taken along conjugate strike-slip faults, so that offshore thrusts
 107 die out and material is escaping eastward towards the “free” Pelagian side. Pelagian
 108 pull was probably stronger in Mio-Pliocene time with the initiation of the Pelagian
 109 and Tunisian grabens, retreat of the Ionian slab and last pulse of opening of the Tyr-
 110 rhenian. Focal mechanisms indicate a progressive stress permutation, from pure
 111 thrusting in northern Algeria to strike-slip in Tunisia and finally transtension in the
 112 Pelagian grabens, compatible with a moderate but still active pull.

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