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1 Active inversion tectonics from Algiers to Sicily

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

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

28 1 Introduction

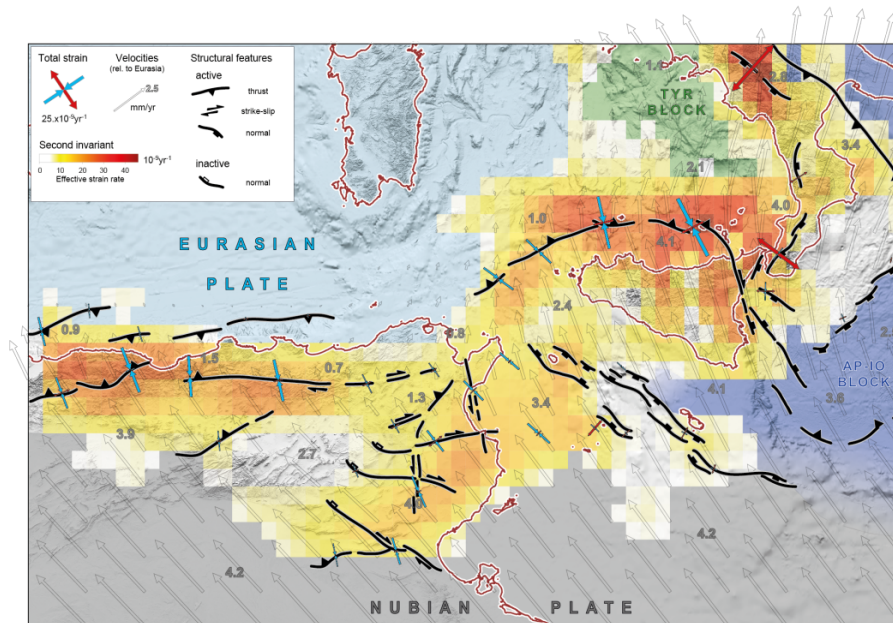
29 Slow motion between Africa and Eurasia in the easternmost western Mediterranean is
30 accommodated within belts of variable widths, from relatively narrow in central Alge-
31 ria (50-100 km), to wide in Tunisia (>100 km). From western Algeria to Sicily the
32 style of active deformation gradually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

38 [1], we discuss the compatibility of the active tectonics with the known present-day
 39 regional plate kinematics and the recent geodynamics of the region.

40 2 Active faults and seismicity

41 The core of the work is the identification of active faults, with special attention to
 42 offshore areas, in particular Algerian Basin, Tyrrhenian Basin, Pelagian Sea and Ioni-
 43 an Sea. The mapping process includes the analysis of seismicity, both instrumental
 44 and historical, using epicenter locations and focal mechanisms [2]–[4]. Various
 45 sources were homogenized to obtain a comprehensive catalogue of earthquakes in the
 46 0-50 km depth range. Satellite images on land and seismic profiles offshore further
 47 helped in discriminating active faults. The Geographic Information System (GIS)
 48 database includes 94 fault segments with parameters and related bibliography.

49 3 Strain modelling using earthquakes and geodetic constraints



50
 51 **Fig. 1.** Strain model based on the style of deformation documented by earthquakes together
 52 with GPS constraints. Modelled velocities are shown with respect to Eurasia, together with the
 53 effective strain rate (second invariant). Strain-rate axes are shown only in strategic locations.
 54 Areas not deforming are colored in green (Tyrrhenian block) and blue (Ionian plain). Structural
 55 features are simplified from mapped faults.
 56

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

59 (Figure 1). Haines & Holt methodology is used to derive a continuous crustal velocity
60 field [5]. The model consists of a finite-element grid, with ~400 grid cells (0.5° by
61 0.5° in dimension) covering the Nubia-Eurasia plate boundary zone between longi-
62 tudes 3°E (Algiers) and 18°E (Calabria). To avoid any a priori assumption on the
63 location of the main deformation zones, all cells are allowed to deform, with the ex-
64 ception of bottom rows (Nubia) and top rows (Eurasia).

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

72 **4 Results**

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

84 The width of the inverted domain increases eastward with increasing thin-skinned
85 vs thick-skinned deformation [9]. In northeastern Algeria strain is partitioned into
86 strike-slip and reverse faults on land [10], and N80° en-échelon reverse faults offshore
87 [11]. In Tunisia, convergence is accommodated within an area three to four times
88 larger, from the Gafsa fault zone in the south to the northern coast. Obliquity of Afri-
89 ca-Eurasia motion is accommodated through a series of E-W trending right-lateral
90 strike-slip faults (Gafsa, Kasserine, Sbiba-Cherichira faults). Conjugate left-lateral
91 strike-slip faults are also active in eastern Tunisia, both onland and offshore (North-
92 South axis, Hammamet-Monastir, Sidi Ali Ben Aoun faults).

93 Further east, the Pelagian grabens (Malta, Pantelleria and Linosa) that initiated in
94 the upper Miocene [12] are presently transtensive. Focal mechanisms for the entire
95 Pelagian platform indicate strike-slip [13], while GPS shows that the Pantelleria rift
96 system still accommodates a small extensive component of motion between the Nubia
97 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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