THE IONIAN BATTLEFIELD: 
THE (TOO) MANY FAULTS OF A “LAZY” SUBDUCTION ZONE

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1. Rationale. The Ionian sea and its margins have attracted a great deal of interest from various research groups in the last ten years or so. In spite of this effort, the tectonic complexity of this vast region, and the difficulty to acquire good quality data, still hamper a full understanding of the tectonic evolution, and of the active tectonics in particular.

The progressive south-eastward migration of the Calabrian Arc during the opening of the Tyrrhenian basin was likely related to large-scale tears in the subducted lithosphere (e.g., Wortel and Spakman, 2000; Argnani, 2009; Argnani et al., 2016), making this area a relevant case study for this kind of tectonic process (STEP Fault; Govers and Wortel, 2005). Following up from this idea, a school of thought has emphasized the role of lithospheric tears in shaping the present Calabrian Arc accretionary wedge, with the aim of characterizing its active tectonics and seismicity (Fig. 1). I argue that in this approach the role of lithospheric tears has been sometimes overemphasized, and in some instances, data and literature have been used in a selective way. Whereas hypothesis-driven interpretations can be acceptable when data are scanty, the selective use of data and literature have led to contrasting interpretations, often driven by pre-defined conclusions, which in many instances are little or not supported by evidence.

Fig. 1 - Simplified tectonic map of the western Ionian region, showing the main structural features that are encountered in the literature. The structures in red are from Argnani (2014), those in black are from Gutscher et al. (2017). The inferred location of the continent-ocean boundary in the southern Ionian Sea (light orange), the region supposed to undergo transtension (gray pattern), and a large field of serpentinite diapirs (orange spots) are also indicated (after Polonia et al., 2017). The gray line is one of the refraction profiles in Dellong et al. (2108), with the segment of thinned continental crust indicated in bold. The bluish bands in NE Sicily indicate inferred locations of lithospheric tears. The structures are superimposed on the morpho-bathymetry of Gutscher et al. (2017).
2. Contended Issues. The majority of the contended issues is related to the occurrence, number and extent of lithospheric tears along the western Ionian region.

2.1. How many lithospheric tears? At least three belts where lithospheric tearing is supposed to occur have been proposed on the western Ionian region, and their occurrence is considered not exclusive by some authors (Fig. 1). These fault zones can be named Malta Escarpment (Argnani and Bonazzi, 2005), Alfeo Fault System (Gutscher et al., 2016) and Ionian Fault (Polonia et al., 2012); they all occur within a distance of 100-150 km, that is the expected thickness of the old Ionian lithosphere (Argnani, 2005). The extent and magnitude of the supposed lithospheric tear on each of these fault zones vary according to the authors, going from a minimalist approach, with incipient tear mostly north of Siracusa (Argnani and Bonazzi 2005; Argnani, 2012), to a ca. 50 km-wide transtensional zone located between the Alfeo and Ionian faults (Polonia et al., 2017).

The occurrence of multiple, and narrowly-spaced, lithospheric tear faults in the old and thick Ionian lithosphere is unsound in many respects, and it has not been observed elsewhere in similar settings (e.g., Govers and Wortel, 2005).

2.2. Constraints on lithospheric tears. Tomographic evidence of slab tears are based on seismic tomography (e.g., Neri et al., 2009), that suggests the occurrence of tears to the north and south of the Calabrian slab; these tears are intended as perpendicular to the strike of the subducted slab, and propagating into the foreland region. The data show that seismicity and high velocity anomaly fade out laterally along strike; as an alternative interpretation the lithospheric tear can have propagated along the strike of slab from the north and from the south (Argnani et al., 2016). The efficient wave propagation along the slab waveguide from deep slab earthquakes and recorded on the stations in the foreland (Mele, 1998; Monna and Dahm, 2009) suggest that this interpretation is viable and that lithospheric tears may be mostly limited to the Tyrrenhian region.

It is worth noting that the distribution of instrumental seismicity does not show major lineaments in the Ionian basin, whereas the sparse focal mechanisms show mostly strike-slip solutions with roughly NW-SE P axes; improved hypocentral locations, however, are desirable in the Ionian Sea.

One issue that should be considered is that wrench faults are not uncommon in accretionary werges, remaining however confined within the wedge and above the basal decollement (e.g., Breen et al., 1986); therefore, it may not always be obvious to image the surface expression of a lithospheric faults. Moreover, the lithospheric STEP is not a plain strike-slip fault, as some vertical displacement, increasing along the fault towards the hinterland, is expected.

The pieces of geological evidence that support the occurrence of lithospheric tear are based on crustal-scale or shallower geophysical data, mostly seismic data.

Fault activity along the Malta Escarpment have been documented by seismic data that show extensional basins filled by ca. 1000 m thick sediments (Argnani and Bonazzi, 2005). The activity of this fault system is likely responsible for the 1693 earthquake that affected eastern Sicily (Argnani et al., 2012).

The Alfeo fault system runs about 40 km from the Malta Escarpment offshore southeast Sicily and gets closer northward. This feature has some morphologic expression and in places it is documented by seismic data of variable quality (Gutscher et al., 2016). A dominant right-lateral strike-slip motion is inferred, based on morphology and on the occurrence of small releasing-bend basins. Interestingly, the connection between the faults bounding the basins at shallow depth and the discontinuity observed at depth in the oceanic basement is not always obvious (e.g., Maesano et al., 2016). The Alfeo fault system is supposed to connect to Mt. Etna, but there is little data supporting this interpretation in the northern segment of the fault system, where some structural complexity has been observed offshore Mt. Etna (Argnani et al., 2013).

The Ionian Fault system has been initially interpreted as a right-lateral lithospheric strike-slip fault separating the two lobes of the outer Calabrian Arc accretionary wedge (Polonia et
al., 2012), and subsequently it has been continued into the Messina Strait. This fault system, however, still lacks a convincing documentation. Detailed morphobathymetry shows no surface expression, and in its southernmost stretch, the morphology clearly displays a left-lateral motion (Gutscher et al., 2017). Seismic profiles show features that can represent the deformation within the accretionary wedge, without the need to have a lithospheric tear.

2.3. Issues related to lithospheric tears - Lower plate Quaternary rifting below the Calabrian accretionary wedge. A ca. 50 km-wide belt of transtension is inferred to be present between the Alfeo and Ionian Faults (Fig. 1; Polonia et al., 2017). This transtension is considered to be responsible for a crustal thinning from 35 to 20 km (beta factor 1.75). A Pleistocene extension of that amount, comparable to the stretching in the North Sea Central Graben but achieved in a shorter time interval, would have left a clear trace in the upper crustal section, and this is not the case.

Recent refraction data have been acquired in the western Ionian Sea (Dellong et al., 2018). A crustal profile crossing the Malta Escarpment and continuing NE-ward, off the coast of Calabria, shows a crustal thinning between the Malta Escarpment and Calabria. According to the authors this refraction data support that the Alfeo Fault acted as a lithospheric tear, along which a sedimentary basin formed by rifting during the Plio-Pleistocene.

In both these interpretations emphasis is given to the role of sub-vertical strike-slip faults, whereas the role of displacement of the Calabrian Arc along the subduction interface is possibly underestimated.

2.4. Seismicity and tsunamigenic potential of lithospheric tears. The northern stretch of the Ionian Fault is interpreted to be responsible of the 1908 Messina earthquake and tsunami (Polonia et al., 2012). The NW-strike of the Ionian Fault, however, is not compatible with the seismological data of the 1908 earthquake. Moreover, there is no evidence of such a fault in the seismic data acquired in the Messina Strait (Argnani et al., 2009). The 1169 earthquake and the 1693 eastern Sicily earthquake and tsunami have also been related to a lithospheric tear, the Alfeo Fault (Polonia et al., 2012). The strike slip motion of this fault, and its subdued morphology suggest that its tsunamigenic potential is limited. Even assuming a vertical throw, a large magnitude is required in order to reproduce the 1693 tsunami, and its effect would be felt along the Calabrian coast (Armigliato, 2018; p.c.); but there is no mention of such an event in the chronicles. So far the most promising tectonic structure that can explain the 1693 earthquake and tsunami is the fault located offshore Augusta (Argnani et al., 2012), whether or not it is related to a lithospheric tear.

References

Argnani, A.; 2014: Comment on the article “Propagation of a lithospheric tear fault (STEP) through the western boundary of the Calabrian accretionary wedge offshore eastern Sicily (Southern Italy)” by Gallais et al., 2013 Tectonophysics. Tectonoph. 610, 195–199.


