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Early Miocene compressional structuring of the Tyrrhenian margin of the Northern Apennines: New perspectives from the direct dating of the Zuccale Fault, eastern Island of Elba (Italy)

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The northern Tyrrhenian Sea and the inner northern Apennines (NA) are classically regarded as a late Miocene–Pleistocene back-arc system characterized by crustal extension and acidic magmatism coeval with shortening farther east at the front of the belt. The easternmost Island of Elba is well suited to study the complexities of the Neogene tectonic framework of the inner NA because it exposes a well-preserved section of the orogenic wedge. There, the nappe pile formed by eastward thrusting, stacking and folding of oceanic and continental units from the Eocene down to the late Miocene, with good constraints on deformation timing and conditions during the late Miocene provided by well-dated magmatism and contact metamorphism.

On Elba, the famous low-angle Zuccale fault (ZF) is generally interpreted as a major low-angle normal fault (LANF), whose late Miocene activity would have greatly facilitated regional E-W extension in the geodynamic framework of the opening of the northern Tyrrhenian Sea. The ZF is an east-dipping low-angle fault that displaces the nappe pile by up to 6 km. The fault architecture is complex although it can be approximated by an exclusively brittle, flat-lying component dated to < c. 5 Ma cutting through steeper, brittle-ductile and earlier top-to-the E thrust related fabrics (Viola et al., 2018). Based on geochronological, kinematic and regional considerations, Viola et al. (2018) constrained a Late Miocene-Early Pliocene compressive stress state on Elba, with the cataclastic brittle ZF likely being its latest expression.

We present new illite K-Ar ages obtained from the flat-lying foliated phyllonite of the ductile ZF, that is, the precursor to the brittle component. Two top-to-the E foliated gouge and phyllonite samples document illite synkinematic authigenesis at the Aquitanian-Burdigalian transition, constraining E-vergent shear localization along a flat already in the earliest Miocene. This excludes any significant contribution of the ZF to the regional extensional history and suggests that the exposed ZF represents a flat segment of a large thrust zone that contributed to the structuring of the orogenic wedge by nappe imbrication. Pliocene brittle compressional faulting only selectively reactivated portions of this Early Miocene compressional structure.

Our new results, when integrated with existing structural and geological considerations, require the critical analysis of existing geodynamic models and call for alternative scenarios excluding an important contribution by the ZF to the regional extension and, additionally, contemplating crustal shortening in the late Miocene-early Pliocene. Moreover, they outline the complexity and non-linearity of the Apennines in the central Mediterranean region. Whereas the NA might be regarded as broadly belonging to the Western Alps domain, where compression prevailed with only minor extension in recent times, the Southern Apennines represent a distinct scenario with significant Pliocene slab roll-back triggering upper mantle-scale convection leading to the incipient oceanization of the southern Tyrrhenian back-arc basin. Due to a varying geodynamic configuration in the Miocene-Pliocene, the dynamic interplay between (i) Adria plate motion, (ii) overall framework of subducting Adria and (iii) upper mantle convection caused a significantly different geodynamic evolution along the Apennine belt.