Hematite (U-Th)/He constraints on Plio-Pleistocene deformation and hydrothermalism in the eastern Island of Elba, northern Apennines (Italy)

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The northern Tyrrenian 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 orogenic prism of the NA, which is well exposed in the easternmost Island of Elba, formed by eastward thrusting, stacking and folding of oceanic and continental units from the Eocene down to the late Miocene. Eastern Elba hosts the historically and economically most important Fe district of Italy, which, in the study area, consists of sulphide- and Fe-rich veins and breccias, in addition to minor massive Fe ore bodies of hydrothermal origin emplaced in actively deforming upper crustal conditions (Mazzarini et al., JSG, 2019). The Zuccale fault (ZF) on Elba is generally interpreted as a major normal fault, which would have greatly facilitated regional E-W extension during the late Miocene. It 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 by K-Ar on illite from fault gouge that cuts through steeper, brittle-ductile and earlier top-to-the E thrust related fabrics (Viola et al., Tectonics, 2018).

Aiming at directly constraining the syn- to post Pliocene evolution of the ZF and the age of the hydrothermal Fe deposits of the historic mining district, we performed hematite (U-Th)/He dating of the low-angle, hematite-decorated principal slip surface of the ZF at the famous Terra Nera section. Hematite samples examined in this study comprise platelet-shaped crystals (specularite), fine aggregates coating fault slip surfaces, massive veins, the fine matrix of breccias, and euhedral millimetric crystals from low strain domains. Ages from the ZF striated fault plane span the ~4.2±0.4 to 3.6±0.4 Ma time interval, fully consistent with available fault gouge illite K-Ar dates. Later NNE-SSW strike-slip faulting, associated with centimetric specularite veins, is constrained to between 2.1±0.2 and 1.7±0.2 Ma, roughly coeval with transient and local reactivation of the ZF as indicated by 1.9±0.2-1.5±0.2 Ma old euhedral, millimetric hematite infilling dilational jogs within the foliated ZF fault zone. Further north, in the Rio Albano area, mineralised hematite breccias
genetically associated with top-to-the E spectacular extensional faults are dated to between 1.6±0.2 and 0.9±0.1 Ma and postdate older ~2.7-2.6 Ma quartz-hematite veins associated with a discrete phase of top-to-the W shearing.

All obtained dates fit our independently built structural model of the investigated area, where clear crosscutting relationships and structural/metamorphic considerations have permitted establishing a sequence of kinematically constrained deformation events. For the first time we have defined the exact timing of deformation in the study area, contributing to the unravelling of the local, long and complex tectonic and mineralization history and to a better constrained regional picture.