Deciphering orogenic and post-orogenic fluid-assisted deformations by coupling structural, mineralogical, geochemical, and geochronological investigation methods. An example from Zannone Island, Italy

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Zannone is a very important island, located in the Neogene-Quaternary extensional domain of the Tyrrenian back-arc basin, as it is the unique spot where the Paleozoic (?) crystalline basement is hypothesized to be exposed in central Apennines. The exposure of such hypothetical basement in the Zannone Island is very problematic as it implies very large normal displacements (> 3 km) along surrounding faults. No such displacements are known along faults close to Zannone Island.

In this work, we study the hypothetical Paleozoic crystalline basement exposed in the Zannone Island with the main aim of understanding its geological nature and relationships with the surrounding rocks. We use a multidisciplinary approach including 1) interpretation of seismic reflection profile; 2) field survey; 3) petro-textural observations; 4) microthermometry on fluid inclusions; 5) geochemical analyses of stable and clumped isotopes; 6) illite crystallinity and mineralogical analyses of clays and host rocks; 7) analyses of minor gaseous species (He, Ne, and Ar concentrations and isotope ratios) in fluid inclusions; 8) U-Pb geochronology of syn-tectonic calcite, and 9) K-Ar dating of syn-kinematic clay minerals.

Our results show that the hypothetical Paleozoic (?) crystalline basement exposed on the Zannone
Island is, instead, represented by siliciclastic rocks of very low metamorphic grade. This is testified by the quartzarenites nature of the rocks, the presence of chloritoid and by the observed incipient foliation marked by fine-grained white micas and disposed parallel to the bedding. The contact between such siliciclastic rocks and the overlapping Triassic Dolostone is represented by a low-angle thrust cut by sets of high-angle normal faults with associated calcite mineralizations. K-Ar dating on clay minerals in fault gouge reveals that at least one event of authigenesis (i.e. fluid-assisted tectonic activity) occurred in Zannone Island <22 Ma ago. U-Pb dating on sin-tectonic calcite mineralizations allowed to constrain the compressional deformation and subsequent normal faulting in the study area at around 7 Ma. This result is consistent with the 1) described emplacement of imbricate thrust sheets onshore close to Zannone Island and 2) syn-tectonic sediments-filling basins observed by seismic reflection studies. Microthermometry on fluid inclusions and stable isotopes analyses on syn-tectonic mineralizations highlighted the involvement of two different fluids during tectonic processes. One characterized by low salinity (as NaCl equivalent; i.e. meteoric-derived fluids) and one by high salinity (as NaCl equivalent; i.e. deep crustal-derived fluids). Microthermometry on fluid inclusions allowed to constrain a wide range of P-T entrapment conditions. For this reason, we highlighted a transition from lithostatic toward hydrostatic pressure during precipitation of syn-tectonic mineralizations.