Cyclicity of paleofluid infiltration in the active Mount Morrone Fault System (central Apennines, Italy) constrained by carbonate concretions

Gianluca Vignaroli1, Valentina Argante2, Federico Rossetti2, Lorenzo Petracchini3, Michele Soligo2, Mauro Brilli3, Tsai-Luen Yu4,5, and Chuan-Chou Shen4,5,6

1Dipartimento di Scienze Biologiche, Geologiche e Ambientali - Università degli Studi di Bologna, Bologna, Italy (gianluca.vignaroli@unibo.it)
2Dipartimento di Scienze - Università Roma Tre, Roma, Italy
3Istituto di Geologia Ambientale e Geingegneria - Consiglio Nazionale delle Ricerche, Roma, Italy
4High-Precision Mass Spectrometry and Environment Change Laboratory (HISPEC), Department of Geosciences, National Taiwan University, Taipei, Taiwan (ROC)
5Research Center for Future Earth, National Taiwan University, Taipei, Taiwan (ROC)
6Global Change Research Center, National Taiwan University, Taipei, Taiwan (ROC)

Active faults are characterized by creation/destruction of secondary (tectonic) permeability in response to a continuous interplay between deformation and fluid pressure fluctuations during the seismic cycle. The study of the paleofluid circulation in fault rocks can thus provide insights into the hydraulic and mechanical behavior of the seismogenic crust.

This work integrates data from field geology with geochemical and geochronological constraints to understand the spatio-temporal evolution of the paleofluid circulation in the Mount Morrone Fault System (MMFS), a ~25 km-long tectonic structure activated during the extensional Quaternary phase of the central Apennines (Italy). The MMFS cuts through a Mesozoic-Cenozoic multilayer carbonate succession for a cumulative stratigraphic offset of about 2 km. Fluvio-lacustrine and slope deposits (Middle-Late Pleistocene) occur at its hanging wall and are variably involved by faulting. The MMFS is currently classified as a silent seismic fault, with an estimated Mw= 6.5-7.0 potential magnitude and recurrence time at 2.4 ka for an expected earthquake.

The structural survey focused on the western strand of the MMFS cutting through a succession of Sinemurian dolomitized limestones. A composite network of NW-SE-striking, SW-dipping fault surfaces defines the structural architecture of the MMFS in the study outcrops, with high angle (dip > 55°) faults that systematically cut and displace medium-to-low angle (dip in the order of 30°-50°) faults. Both fault systems are characterized by dominant dip-slip movement and normal kinematics. Lenses of cm-thick cataclasites often occur along the slip surfaces. Cataclasites are made by sub-angular to sub-rounded carbonate clasts (up to 1 cm-wide) dispersed in a very fine-grained matrix. Layers of cm-thick carbonate concretions occur associated with the cataclasites, testifying for pulses of fluid discharge along the fault surface during the tectonic activity of the MMFS. Microstructural investigations document that: (i) carbonate concretions show an internal
texture of fibrous vein having fiber growth direction roughly perpendicular to the vein wall, and (ii) the basal portions of the carbonate concretions are fractured and incorporated within the underlying cataclasites through the deposition of a new calcite cement. The geochemical (δ¹³C and δ¹⁸O stable isotope) analyses on selected samples attest for a progressive chemical shift of the mineralizing fluid from marine (in host rock and in cataclasites) to meteoric waters (in carbonate concretions). The U-Th dating of carbonate concretions and calcite slickenfibers constrains the fault-controlled fluid circulation to the Middle Pleistocene, with ages spanning from 270 to 180 ka. Significantly, the dating of carbonate concretions documents a 12-kyr cyclicity of the fluid infiltration in the fault zone.

The development of the secondary permeability in the MMFS thus corresponds to a combination of faulting and tensile fracturing, in response to a cyclic increasing of the shear stress and the pore pressure during the seismic cycle. The polyphasic deformation system of the MMFS constitutes a record of fault activation and reactivation episodes that could contribute to define the recurrence model of seismic events on regional-scale faults.