Concrete and Concrete-Like Rocks: The Role of Mineral Cementitious Fibers in Controlling Strength and Mode of Failure

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How does the Earth do chemistry? And how does Earth's chemistry do mechanics? These are fundamental questions to our understanding of failure and strength recovery of faults undergoing healing and cementation. The importance of these questions reside in the fact that the dynamics of slip along cemented faults can assume a wide range of slip modes — from fast earthquakes, to slow-slip events, to benign creep, whose origin remains unclear. This presentation starts from the example of an Italian caldera experiencing large deformation, low seismic efficiency, and slowslip events to show that such a rheology is consistent with the fibrous microstructure of the rocks from the seismogenic area. The rocks exhibit a cementitious matrix made of intertwined fibrous minerals, suggesting that the cementation of the volcanic ash in the caldera is the result from of a pozzolanic activity arising from the reaction of volcanic ash with lime and water — the basic recipe of Roman marine concrete. The same mineral fibers are in fact also found in cores of Roman-era concrete for which the region is known. Through the use of experiments and modeling, we find that fibers provide rocks and materials with strength, creep and ductility. In particular, parameters of the cementitious microstructure such as fiber length, orientation, and degree of entanglement control strength, mode of failure, and the mechanical transition from brittle to ductile. Thanks to the extraordinary progress in high-resolution imaging techniques, the presence of micro- and nanostructures of mineral fibers matrix is being found in rock cement from a range of natural environments. The study of chemical cementation and the rheology of fibrous microstructures is a first step to understand fault healing and damage resilience.

Biography: Tiziana Vanorio is Associate Professor in the Geophysics Department, and Sr. Associate Dean for Educational Affairs in the in the School of Earth, Energy, and Environmental Sciences at Stanford University. Tiziana leads the Stanford Rock Physics Laboratory (SRPL) where, together with her students, uses laboratory and imaging techniques to study the response of the physical and mechanical properties of rocks to Earth's conditions and processes. Particular emphasis is on understanding how rock-fluid interactions affect the physical and mechanical properties of rocks and geomaterials. Applications of her research include the characterization of reservoir rocks exposes to fluid injection, chemical processes in crustal rocks, and ancient materials. Tiziana is a Marie Skłodowska-Curie Fellow, the recipient of the 2018 Wegener Award by EAGE, 2015 NSF Career Award, and 2014 SPE Innovative Teaching Award.