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Brittle versus ductile deformation as the main control of the deep fluid circulation in continental crust

Marie Violay (1), Claudio Madonna (2), and Jean-Pierre Burg (2)

(1) EPFL ENAC, LEMR, Station 18, CH-1015 Lausanne, Switzerland (marie.violay@epfl.ch), (2) Geologisches Institut, ETH Zurich, Sonneggstrasse CH-8092 Zurich, Switzerland

The Japan Beyond-Brittle Project (JBBP) and the Taupo Volcanic Zone-Deep geothermal drilling project in New Zealand (TVZ-DGDP) proposed a new concept of engineered geothermal development where reservoirs are created in ductile rocks. This system has several advantages including (1) a simpler design and control of the reservoir due to homogeneous rock properties and stress states in the ductile domain ,(2) possible extraction of supercritical fluids (3) less probability for induced earthquakes. However, it is at present unknwon what and how porosity and permeability can be engineered in such environments.

It has been proposed that the magmatic chamber is surrounded by a hot and ductile carapace through which heat transfer is conductive because the plastic behaviour of the rock will close possible fluid pathways. Further outward, as temperature declines, the rock will encounter the brittle-ductile transition with a concomitant increase in porosity and permeability. The thickness of the conduction-dominated, ductile boundary zone between the magmatic chamber and the convecting geothermal fluid directly determines the rate of heat transfer.

To examine the brittle to ductile transition in the context of the Japanese crust, we conducted deformation experiments on very-fine-grain granite in conventional servocontrolled, gas-medium triaxial apparatus (from Paterson instrument). Temperature ranged from 600˚C to 1100˚C and effective confining pressure from 100 to 150 MPa. Dilatancy was measured during deformation. The method consisted in monitoring the volume of pore fluid that flows into or out of the sample at constant pore pressure. Permeability was measured under static conditions by transient pressure pulse method. Mechanical and micro-structural observations at experimental constant strain rate of 10^{-5} s^{-1} indicated that the granite was brittle and dilatant up to 900 ˚C. At higher temperatures the deformation mode becomes macroscopically ductile, i.e., deformation is distributed throughout the sample and no localized shear rupture plane develops. These observations have important implications for deep geothermal power in Japan.