Geophysical Research Abstracts
Vol. 13, EGU2011-3300, 2011
EGU General Assembly 2011

An experimental study of the brittle-ductile transition of basalt under oceanic crust conditions

Marie Violay (1), Benoit Gibert (1), David Mainprice (1), Brian Evans (2), Philippe Adrien Pezard (1), and Jean-Marie Dautria (1)

(1) University Montpellier 2, Géosciences Montpellier, Montpellier, France (marie.violay@gm.univ-montp2.fr), (2) Dept. of Earth, Atmospheric, and Planetary Sciences Massachusetts Institute of Technology 77 Massachusetts Ave.Cambridge, MA 02139-4307. USA

One of the primary ways of the solid earth interacts with the ocean system is hydrothermal circulation. Mechanical properties of rocks at depth control the transport behaviour of very high temperature hydrothermal reservoirs. In particular, the brittle to ductile transition in rocks may strongly influence their permeability and the maximum depth and temperature where hydrothermal fluids may circulate. In order to characterize these properties in the context of Icelandic crust, we conducted triaxial compression experiments to investigate the effects of pressure, temperature and strain rate on the rheology of basaltic rocks. The tests were carried out at temperature from 400 to 950 °C, confining pressure from 100 to 300 MPa, pore pressure from 0 to 50 MPa and strain rate from 10-6 to 10-4 s^{-1}. Two basalts were selected for their variation in glassy component. Mechanical and micro-structural observations at a constant strain rate of 1 × 10-5 s^{-1} and at confining pressure of 100 MPa and 300 MPa indicate that the rocks are brittle and dilatant up to 700 to 800 °C. At higher temperatures and effective pressures the deformation mode becomes ductile in the sense that the deformation is distributed and that no shear rupture plane develops. Experiments of glassy and non-glassy basalts (GB, GFB) of similar chemical compositions show that glass plays a key role on the sample strength. It lowers the temperature of the brittle to ductile transitions. After defining the physical conditions which cover the ductile and brittle field, the mechanical behavior of the samples were assumed to be characterized by a Mohr-Coulomb criterion in the brittle field and by a steady-state, power law in the ductile field. In the brittle field, the glassy and non-glassy basalts behave similarly, a friction coefficient of 0.42 have been determined. In the ductile domain the GB and GFB were characterized by the same stress exponent $3<n<4.2$ indicative of deformation dominated by dislocation creep processes but by very different activation energy $QGB = 59 \pm 15$ KJ/mol and $QGFB = 456 \pm 4$ KJ/mol. The strength of the oceanic crust has been estimated on the basis of these assumptions. Such extrapolation suggests that the brittle to ductile transition will strongly depends on the nature of starting material. In a basaltic crust displaying a thermal gradient of ∼ 100-150 °C/km, as in Iceland, glassy basalts may undergo the transition at about 50-100 °C, whereas the same transition might occur in non glassy basalts at deeper conditions, i.e. temperatures higher than 550 ±100 °C. The effect the transition on the permeability of basaltic rocks has not been measured, but the brittle-ductile transition might be considered as a limit for the depth at which supercritical hydrothermal fluids may circulate. For basaltic crust with a geotherm similar to that under Iceland, an estimate of depth of the brittle-ductile transition is about 5 to 7 km. This result is consistent with the lower limit of the Icelandic seismogenic zone which seems to be associated with a 600 ± 100 °C isothermal surface (Fridleifsson and Elders, 2005).

Fridleifsson G.O., Elders W.A. The Iceland Deep Drilling Project: a search for deep unconventional geothermal resources. Geothermics 34 269–285. 2005.