Geophysical Research Abstracts
Vol. 20, EGU2018-3677, 2018
EGU General Assembly 2018

Importance of fault dynamics in controlling the operation of plate tectonics on terrestrial planets

Shun-ichiro Karato (1) and Sylvain Barbot (2)

(1) Yale University, Geology and Geophysics, New Haven, CT, United States (shun-ichiro.karato@yale.edu), (2) Earth Observatory of Singapore, Nanyang Technological University, Singapore

The frontier of rock deformation studies lies not only in the plastic deformation at high pressures but also in the low-pressure behavior of rock friction. This becomes obvious when one wants to understand why plate tectonics occurs on Earth but not on other terrestrial planets like Venus from the geodynamic point of view. According to large-scale geodynamic modeling, plate tectonics style of mantle convection occurs only when the lithosphere is not so strong (∼100 MPa or less strength). This requirement is in contradiction to a canonical model of the lithosphere strength based on rock deformation studies showing the strength exceeding several 100s MPa. Models to solve this puzzle include (i) water effects, or (ii) grain-size effects, or (iii) weak low-temperature plasticity. However, water model is hard to explain why deep (∼20-40 km) faults are so weak, and grain-size model cannot explain why lithosphere is so weak in the shallow cold region unless unusually small grain-size is assumed (∼10 nm or less), and weak low-temperature plasticity model has weak experimental/theoretical basis. In addition, the third model predicts weaker lithosphere at higher temperatures that is in contradiction to the observed contrast between Earth and Venus.

We propose that thermal weakening of friction has a key to solve this puzzle. Laboratory studies on friction show that although the friction coefficient assumes a nearly universal value (∼0.6), the friction coefficient is reduced to ∼0.1 or less when fault motion is accelerated. The accelerated fast fault motion occurs at relatively low temperatures (<600 C for peridotite), but the friction coefficient remains high at high temperatures where fault motion is slow. Consequently, in the hot lithosphere on Venus, the friction coefficient is high and plate tectonics cannot occur, whereas in the cold lithosphere on Earth, friction coefficient becomes low once fault motion is accelerated allowing plate tectonics to occur. This model predicts that there are a certain number of normal fault earthquakes at the trench to accommodate deformation. The results agree well with the seismological observations on the frequency of earthquakes related to plate bending near trenches by Chapple and Forsyth (1979).