Dynamics of the fault motion and the origin of the contrasting tectonic style on Earth and Venus

*Shun-ichiro Karato[1], Sylvain Barbot[2]

1. Yale University, Department of Geology and Geophysics, 2. Earth Observatory of Singapore, Nanyang Technology University

Earth is a unique terrestrial planet on which plate tectonics operates. On a similar terrestrial planet like Venus (~95 % size of Earth), there is no evidence for plate tectonics at least in the recent ~500 Myrs. Various models have been proposed to explain this enigmatic observation including the difference in the water content and/or in the surface temperature. However, none of the previous models provide satisfactory explanation because they invoke processes that have not been quantitatively explored in any detail. For instance, models invoking different water content are difficult to explain weakening of the deep portions of the Earth's oceanic lithosphere. Similarly, proposed mechanism of grain-size reduction cannot explain weak shallow lithosphere without requiring unreasonably small grain-size. Here we propose an alternative model to explain the Earth-Venus contrast based on the well-established experimental observations on the dynamics of fault motion. Unstable, accelerated fault motion, which occurs only below ~400°C in the crust and ~600°C in the mantle that leads to the reduction of friction coefficient by melting. Based on the laboratory data on high-velocity friction, we show that thermal weakening makes Earth's lithosphere weak enough to make plate tectonics possible. In contrast, this weakening process is prohibited by the high surface temperature (~470°C) on Venus keeping the Venusian lithosphere strong. In this model, the difference in the surface temperature leads to the different tectonic style between Earth and Venus through the difference in the degree of dynamic weakening of fault motion.

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