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

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Core Mantle Evolution

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, invoking different water content cannot easily explain weakening of the deep portions of the Earth's oceanic lithosphere. Similarly, grain-size reduction cannot explain a weak shallow lithosphere without requiring unreasonably small crystal grains. 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 ºC in the crust and ~600 ºC in the mantle leads to the reduction of friction coefficient by shear heating. 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, these weakening processes are prohibited by the high surface temperature (~470 ºC) 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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