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Strength contrast between plagioclase and olivine: implication for rheological layering in the terrestrial planets

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It is thought that plate tectonics is a product of the localized brittle failure in the lithosphere and viscous flow in the asthenosphere, and rheological layering (strength profile) is a key to understand terrestrial planet tectonics (Burgmann and Dresen 2008). Physical properties, such as temperature and pressure and stress, and the chemical compositional layering between crust and mantle result in a strong rheological layering in the planet interior. It has estimated by previous deformation experiments that the brittle-ductile transition occurs in the planet interior and deformation mechanisms can be changed with increasing depth. In the present study, we investigate rheological variation in the crust-mantle transition and discuss the reason why plate tectonics doesn't exist in the other terrestrial planets except the Earth.
Two different models about the strength profile have been proposed. The first is the "jelly sandwich" model that had been embraced for the past two decades. This model is that a weak middle and lower crust are sandwiched between strong upper crust and strong mantle lithosphere just like a jelly sandwich (Chen and Molnar 1983). The other one is the "creme brullee" model, in which the upper mantle is significantly weak, and consequently region for viscous deformation continues into the mantle depth (Burov and Watts 2006).
These two models of strength profile are given by extrapolating frictional strength and viscous flow law of each material to temperature and pressure corresponding to the Earth interior. In this study, we perform experiment to directly determine the relative strength between plagioclase and olivine without any extrapolating of flow law. Plagioclase and olivine samples are together sandwiched between alumina pistons in a simple shear geometry. The experiment conditions are ranging 0.5-1GPa and 373-873K, corresponding conditions approximately to Moho of each terrestrial planet.
It is possible that parameter which has the most effect on the relative strength is temperature and water. Based on the previous deformation experiments, the effect of water on strength is nearly identical between plagioclase and olivine. However, temperature can change the inversion of strength of plagioclase and olivine at 1GPa and around 773K due to different activation energy between these two minerals. If the surface materials are weaker than those of below, it could be never subducted into the deeper, resulting constant viscosity type tectonics. It is thought that this potential is important to discuss why plate tectonics doesn't exist or why it was stopped in Venus (interior temperature is 873-973K at 30km depth) and in Mars (interior temperature is about 373 K at 30km depth).
Crustal materials consist predominantly of plagioclase that largely control deformation of the crust, whereas deformation of the upper mantle is largely controlled by olivine. At this time, we prepared sintered polycrystalline aggregates of plagioclase and olivine by HIP in Institute for Study of the Earth's interior, Okayama University. Average grain size of hot-pressed plagioclase is 15-16.5 micron and a that of olivine is 17.5-21.0 micron. In the future, we will use the hot-pressed samples and perform deformation experiments using solid-medium deformation apparatus at both dry and wet conditions.

Keywords: strength profile, olivine, plate tectonics, plagioclase, strength contrast