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Difference on tectonics and rheological structure of Venus and Earth inferred from deformation experiments

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Venus has been regarded as a twin planet to the Earth, because of density, mass, size and distance from the Sun (Taylor and McLennan, 2008). However, the Magellan mission revealed that plate tectonics is unlikely to work on the Venus (Turcotte et al., 1999). The plate tectonics is one of the most important mechanism of heat transport and material circulation of the Earth, consequently, its absence might cause the different tectonic evolution between Earth and Venus. Rheological structure is a key to inferring mantle structure and convection style of planet interiors because the rock rheology controls strength and deformation mechanism. In previous study, the behavior of Venusian lithosphere has been inferred from the power-law type flow law of dry diabase (Mackwell et al., 1998). They indicated that lower crust can be weaker than upper mantle, which might result decoupling at the crust-mantle boundary (Moho depth) and mantle convection without crustal entrainment. However, the power-law creep cannot be applicable to infer the rheological structure at Moho depths, because the dislocation-glide control creep (Peierls mechanism) is known to become dominant at relatively low temperatures in materials with a relatively strong chemical bonding such as silicates (Tsenn and Carter 1987). In this study, we conduct two-phase deformation experiments to directly investigate rheological contrast between plagioclase (crust) and olivine (mantle) using solid-medium deformation apparatus and discuss the difference between these planets in terms of rheological behaviors.

In this study, we performed experiment to directly determine the relative strength between plagioclase and olivine without any extrapolating of flow law; the crustal materials consist predominantly of plagioclase that largely control deformation of the crust, whereas deformation of the upper mantle is largely controlled by olivine. These samples are together sandwiched between alumina pistons in a simple shear geometry and we used the hot-pressed samples and performed deformation experiments using solid-medium deformation apparatus. The experimental conditions were ranging 1GPa and 600-1000 degrees, corresponding conditions approximately to Moho of the Venus under dry conditions.

The experimental results under dry conditions show that olivine is expected to always be stronger than plagioclase. The rheological structures of Venus are inferred from our experimental results and draw a comparison between Earth and Venus. In case of the Earth, rheological structure of oceanic lithosphere is constrained well by Byerlee's law and power-law type flow law (e.g., Kohlstedt et al., 1995). The moho of oceanic lithosphere is still brittle deformation range owing to the low temperature. The oceanic crust and mantle lithosphere are strongly coupled mechanically, so that they could move and subduct together into the deep. The temperature of moho, which strongly influences the coupling strength, depends on crustal thickness. The crustal thickness of Venus is, however, not constrained by the observation. In this study, crustal thickness of Venus is assumed to be 7km because of comparison with oceanic lithosphere of the Earth. Our experimental results imply that large strength contrast exists between lower crust and upper mantle in Venus. Decoupling of the motion between the crust and mantle lithospheres is expected to occur because the weak lower crust acts as a lubricant. Moreover, the soft crust cannot subduct into the hard mantle. The strength contrast between the crust and the mantle is supposed to prevent from recycling the crust into the mantle as Earth's plate tectonics. To quantitatively examine the effects of the soft lower crust on the Venusian tectonics, we are conducting numerical simulation using the rheology obtained from our experiments.

Keywords: plagioclase, olivine, strength contrast, venus, rheology, plate tectonics