PPS21-P03 Room:Convention Hall Time:May 20 18:15-19:30

Rheological structure in Venus and implication to its surface tectonics

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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. However, the Magellan mission revealed that plate tectonics is unlikely to work on the Venus [1][2]. 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 [3]. 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 [4]. In this study, we conduct two-phase deformation experiments to directly investigate rheological contrast between plagioclase (crust) and olivine (mantle) and discuss the difference between these planets in terms of rheological behaviors. Moreover, one-dimensional numerical calculation is performed to evaluate the influence of strength contrast to the decoupling of deformation rate at the Moho.Our experiments using solid-medium deformation apparatus directly determine the relative strength between plagioclase (crust) and olivine (mantle) without any extrapolating of flow law. The experimental conditions were ranging 2GPa and 600-1000 degrees under dry conditions. In one-dimensional numerical calculation, three models were prepared; each model is distinguished in rheological structure. First model has no strength contrast at Moho, second and third models have double-digit difference and four-digit difference in viscosity each at Moho. And we observed difference of the surface velocity at each model when it is assumed that the velocity at the bottom (100km depth) is 20 cm/year and stress value is constant (=100MPa) at each depth in calculations.

The experimental results show that olivine is expected to always be stronger than plagioclase. This result contradicts to that inferred from power-law creep of olivine and plagioclase, suggesting that Peierls mechanism could be dominant deformation mechanism in both olivine and plagioclase at relatively low temperatures. In the case of the Earth, rheological structure of oceanic lithosphere is constrained well by Byerlee's law and power-law type flow law [5]. The oceanic crust and mantle lithosphere are strongly coupled mechanically because the Moho has no strength contrast, so that they could move and subduct together into the deep. In contrast, our experimental results imply that large strength contrast exists at Moho in Venus, resulting decouple of the motion between the crust and mantle lithospheres because the weak lower crust acts as a lubricant. Also one-dimensional numerical calculations show us that the surface velocity becomes more sluggish in the model which has larger strength contrast (from two-digit to four-digit difference in viscosity) at Moho. Therefore the crustal part is less likely to be involved to mantle convection when strength contrast gets larger and larger. [1] Kaula, W. M. & Phillips, R. J., Geophys. Res. Lett. 8, 1187 (1981). [2]Turcotte D. L., Morein G., Roberts D., & Malamud B. D., Icarus 139, 49?54 (1999). [3]Mackwell, S. J., Zimmerman, M.E. & Kohlstedt, D.L., J. Geophys. Res. 103, 975-984 (1998). [4]Tsenn, M. C. & Carter, N. L., Tectonophys. 136, 1-26 (1987). [5]Kohlstedt, D. L., Evans, B. & Mackwell, S. J., J. Geophys. Res. 100, 17,587-17,602 (1995).

Keywords: plagioclase, olivine, venus, relative strength, deformation experiment, tectonics