VISCOSITY OF A MOLTEN MANTLE: INSIGHTS FROM A COMBINATION OF EXPERIMENTAL TECHNIQUES ON LIQUID PERIDOTITE

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Existence of molten peridotite in the early history of the Earth has long been the subject of debate and conjecture. Interest in the physical properties stems from a number of sources but was re-focussed in the wake of the proposal for the existence of a Smagma oceanT in the evolution of the moon, the Earth and other terrestrial planets. The application of phase equilibrium, buoyancy, thermodynamic and fluid dynamic constraints on the behaviour of molten mantle all rely on adequate characterisation of the properties of molten peridotite, largely lacking to date. The viscosity in particular, has received too little attention. A big experimental effort has been provided to obtain the dependence on temperature (T) of viscosity at ambient pressure (P) for the natural peridotite collected at Balmuccia, Italy. High-T measurements were performed by using concentric cylinder (CC). The high-T viscometry was started at 1600°C and proceeded at 10°C intervals, separated by cooling stages at 5°C/min, each one held for 1 hour. No measurements were possible below 1570°C, because crystallization had occurred. All standard attempts to obtain a homogeneous glass failed. A new technique was therefore used. Small 1-2 mm chips were hung in Pt loops suspended from a long Pt wire and the loops lowered by hand into the high-T viscosity furnace until the chips fused into a bead of liquid held in the loop by surface tension. These samples were then left to quench and placed aside to be used in the splat-quenching device (SQD) (which allows quench rates on the order of 10exp4 °C/s) to finally obtain a supercooled liquids by squeezing and rapidly quenching a falling liquid drop, through a joint action of a complex photoelectric-driven electromagnetic device. Electron microprobe analysis revealed that only a few vol% of the obtained glasses
crystallized in isochemical crystals, whereas the homogeneity of the glassy matrix composition was found to be excellent. As the amount of glass obtained was too small to be used in the micropenetration technique we used differential scanning calorimetry (DSC) to derive the viscosity at low-T. DSC allowed us to unequivocally determine glass transition temperatures (Tg) for cooling/heating rates of 20, 15, 10, 8 and 5 K/min, as the peak of the Cp curves. At this point we used a recent method developed by [1] that, on the basis of the equivalence of the shear stress and the enthalpic relaxation time, allow to predict the low-T viscosity. The combined results obtained by using the different techniques above mentioned were fit by VFT equation with the high-T limiting value (viscosity value at infinite temperature) being fixed at a value of 10exp-4.31 Pas [2]. A comparison between the data obtained here with the recent model from [3] (calibrated with melts as basic as basanite), have shown that in the range 900 to 1600 °C, the viscosity calculated according to [3] is very similar to those measured or calculated by the VFT fit, if A = -4.31; the discrepancy becoming significant at T<900 °C.

The very low T dependence of viscosity at superliquidus conditions obtained from the fitting here, indicates that at putative temperatures of the core-mantle boundary, near 5000 °C, the viscosity will decrease up to 10exp-3.5 Pa s.