The viscosity of the mantle wedge

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The thermal structure of the mantle wedge, and the processes that accommodatemelt migration to the arc volcanoes are controlled by the viscosity of themantle. Some parts of the mantle wedge may have a lower viscosity than anyother region of the upper mantle. Estimates for the viscosity of theasthenosphere based on geophysical observations and experimental data on therheology of peridotite range from 1018 to 1019 Pas [e.g., Melosh, 1977, Craigand McKenzie, 1986; Hager, 1991; Karato and Wu, 1993; Hirth and Kohlstedt, 1996].These estimates are all determined for the oceanic asthenosphere. There areseveral reasons why the viscosity of the mantle wedge could be even lower thanthat in the oceanic asthenosphere. First, the water content in parts of themantle wedge could be higher than that in the asthenosphere due to the flux offluids from the subducted slab. Experimental observations indicate that theviscosity of olivine aggregates decreases approximately linearly withincreasing water content [e.g., Mei and Kohlstedt, 2000; Karato, 2002).Olivine in the oceanic asthenosphere contains »1000H/106Si, which for a depthof 120 km is approximately 20% of the solubility [Hirth and Kohlstedt, 1996].

Thus, at similar depths the mantle wedge may contain as much as 5 times more water. Second, because of the high water content, partial melting of the wedge will not result in as significant of an increase in viscosity as proposed for the melting region of mid-ocean ridges [e.g., Hirth and Kohlstedt, 1996; Phipps Morgan, 1998]. In fact, depending on the degree of melting and the flux of volatiles from the subducting slab, the presence of melt may even decrease the viscosity of the wedge. For a constant water content, analyses of experimental data on the influence of melt on the rheology of olivine aggregates indicates that the viscosity of the mantle decreases exponentially with increasing melt content [Kelemen et al., 1997; Kohlstedt et al., 2000; Mei et al., 2002]. Finally, based on the petrologic and geophysical data discussed by Kelemen et al. [2002], the temperature in the mantle wedge may beapproximately the same as that in the oceanic asthenosphere. Taken together, these observations suggest that in some regions of the mantle wedge the viscosity may be up to an order of magnitude lower than that in the oceanic asthenosphere.