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Experimental Deformation of Antigorite at Mantle Wedge Conditions

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The rheology of antigorite can control intraslab seismicity, the strength of the oceanic lithosphere and mantle wedge, and the slip stability of creeping continental faults. We have conducted high pressure and temperature axial compression experiments on antigorite serpentinite within the antigorite stability field and where dehydration to forsterite and talc is expected to investigate how dehydration affects rheology. Samples were deformed in a Griggs-type apparatus at P = 0.5 - 1.5 GPa, T = 300 - 700°C and at strain rates of 10^{-5} s^{-1} and 10^{-6} s^{-1}. As detailed in Chernak and Hirth (in review), samples experienced localized deformation at temperatures from 300 to 625°C when deformed to high enough strain. Surprisingly, sample ductility decreases with increasing temperature. Samples deformed at 300°C strain harden until $\sim$20% strain when faulting initiates; there is no evidence for localization at lower strain. At 400°C, strain hardening ceases at $\sim$10-15% strain and samples are characterized by a broad zone of deformation surrounding one or more fractures. Samples deformed at 550°C and 625°C strain weaken abruptly after $\sim$5-10% strain and contain one distinct fault. Strain rate stepping experiments indicate that antigorite has velocity strengthening behavior from 300 - 700°C.

Our results have important implications for interpreting laboratory stress measurements obtained in situ using the deformation-DIA (D-DIA) apparatus, where strength is estimated by averaging stress measured by X-ray diffraction on three different lattice planes. At low strain, our results are in good agreement with the results of Hilairet et al. (2007), who conducted D-DIA experiments on antigorite at the same conditions as in our study. However, at higher strain, our samples experienced localized deformation whereas Hilairet et al. (2007) concluded that antigorite deformed by ductile processes. Despite differences in deformation behavior, we find that our stress measurements are in close agreement with stresses measured on the ‘hardest’ lattice plane, suggesting that direct comparisons between the apparatuses may be possible.

Samples deformed above the thermal stability of antigorite at high pressure (1.5 GPa) are extremely weak and show evidence for dehydration along grain boundaries. However, microstructural observations indicate the weakness is not associated with localization; samples are homogeneously deformed to $\sim$25% strain. Thus, in contrast to conventional wisdom, our results suggest that antigorite dehydration at high pressure causes a transition from localized to distributed deformation and that antigorite dehydration may not be directly responsible for intermediate depth seismicity. As hypothesized by Rutter et al. (2008) it is possible that earthquakes are generated when water that is released during dehydration is expelled into surrounding – less ductile – rock.