

Effect of pyroxene on the rheological weakening of olivine + orthopyroxene due to phase mixing

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To understand the effects of secondary minerals on the rheological weakening due to phase mixing, we conducted torsion experiments on samples composed of iron-rich olivine + orthopyroxene. Olivine and pyroxene aggregates with volume fractions of pyroxene of $f_{\text{px}} = 0.1, 0.3$, and 0.4 were deformed in torsion at a temperature of 1200°C and a confining pressure of 300 MPa using a gas-medium apparatus.

The value of the stress exponent, n , decreases with increasing strain, γ , with the rate and magnitude decrease depending on f_{px} . In samples with larger amounts of pyroxene, $f_{\text{px}} = 0.3$ and 0.4 , $n = 3.5$ at lower strains ($1 \leq \gamma \leq 3$) decreasing to $n = 1.7$ at higher strains ($24 \leq \gamma \leq 25$). In contrast, for the sample with $f_{\text{px}} = 0.1$, again $n = 3.5$ at lower strains decreasing only to $n = 3.0$ at higher strains. Furthermore, Hansen *et al.* (2012) determined $n = 4.1$ with a grain size exponent of $p = 0.7$ in samples without pyroxene ($f_{\text{px}} = 0$) independent of strain. For samples with larger f_{px} , the observed values of n and p indicate that the deformation mechanism changes with increasing strain, whereas for samples with smaller f_{px} , no change in mechanism occurs.

The microstructures in our samples with larger amounts of pyroxene provide insight into the change in deformation mechanism identified from the experimental results. Elongated olivine and pyroxene grains align nearly parallel to the shear direction with a strong crystallographic preferred orientation (CPO) in samples deformed to lower strains for which $n = 3.5$. In contrast, mixtures of small, equant grains of both phases, with a nearly random CPO develop in samples deformed to higher strains that exhibit both a smaller stress exponent ($n \sim 2$) and strain weakening. The microstructural development forming well-mixed fine-grained olivine-pyroxene aggregates can be explained by the difference in diffusivity among Si, Me (= Fe or Mg), and O. These mechanical and associated microstructural properties provide important constraints for understanding rheological weakening and strain localization in upper mantle rocks.