

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

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

The value of the stress exponent,  $n$ , decreases with increasing strain,  $\gamma$ , with the rate of decrease depending on  $f_{\text{px}}$ . In samples with larger amounts of pyroxene,  $f_{\text{px}} = 0.3$  and  $0.4$ ,  $n$  the stress exponent decreases from  $n = 3.5$  at lower strains of  $1 \leq \gamma \leq 3$  to  $n = 1.7$  at higher strains of  $24 \leq \gamma \leq 25$ . In contrast, for the samples with  $f_{\text{px}} = 0.1$ , the stress exponent decreases from  $n = 3.5$  at lower strain decreases only to only  $n = 3.0$  at higher strains. In samples with larger  $f_{\text{px}}$ , the value of  $p$  grain size exponent changes from  $p = 1$  at lower strains to  $p = 3$  at higher strains. Furthermore, Hansen *et al.* (2012) observed that  $n = 4.1$  and  $p = 0.7$  in samples without pyroxene ( $f_{\text{px}} = 0$ ) regardless of strain. For samples with larger  $f_{\text{px}}$ , these values of  $n$  and  $p$  indicate that the deformation mechanism changes with strain, whereas for samples with smaller  $f_{\text{px}}$  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. First, elongated olivine and pyroxene grains align sub-parallel to the shear direction with a strong crystallographic preferred orientation (CPO) in samples deformed to lower strains for which  $n = 3.5$ . Second, mixtures of small, rounded grains of both phases, with a nearly random CPO develop in samples deformed to higher strains that exhibited a smaller stress exponent and strain weakening. The microstructural development forming well-mixed, fine-grained olivine-pyroxene aggregates can be explained by the diffusivity difference between Si, Me (= Fe or Mg), and O, such that transport of MeO is significantly faster than that of  $\text{SiO}_2$ . These mechanical and associated microstructural properties provide important constraints for understanding rheological weakening and strain localization in upper mantle rocks.

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