Introduction

As required for Plate Tectonics to occur, the deformation of the lithosphere needs to be localized across the stiff, viscous/ductile uppermost mantle.1,2 In this latter, strain localization originates from a restricted weakening that promotes stress rates to increase and grain size to reduce within a narrow zone, forming a so-called mantle shear zone. However, although many examples of mantle shear zone have been described in nature,3-5 the source of mantle weakening and subsequent strain localization remains elusive. Using a solid-medium Griggs-type deformation apparatus, here we explore the deformation of mantle rocks at temperature and pressure that involve high-temperature, viscous deformation. We moreover investigate the role of pyroxene for strain localization, which still remains poorly constrained. We thus deformed in direct shear at 900°C and 1.2 GPa a hot-pressed powder composed of 70% olivine (Fo90), 15% clino- pyroxene (diopside), and 15% of a selected grain size. Two sample types have been tested: a) olivine (CPx) and diopside (Pyx) or olivine (CPx) and a second one with the same size for both phases. For each experiment, we applied a bulk strain rate of 2.16 x 10^-5 s^-1, and we added 0.1 weight % of distilled water.

Precipitation into necks of boudined CPx

For both sample types (small vs. large CPx), we record a peak of differential stress (σ1-σ3) between 0.9 and 1.1 GPa, followed by a subduction weakening until a plateau is reached (strain - stress curves). The more the CPx size is small, the more the weakening is important. At the peak stress, no strain is discernible. In contrast, the weakening stage is coupled with the occurrence of major strain localization within the sample, giving rise to a well-developed shear zone (see Scanning Electron Microscopy - SEM images). While the presence of large CPx (30-60 μm) promotes intense strain localization through a shear zone of around 100 μm thick, the presence of small CPx (10-16 μm) gives rise to a shear zone of around 300 μm thick. In both cases, the grain size highly reduces within fine-grained layers that start from the CPx boundaries, and then extend through the olivine matrix. These layers are composed of well-crystallized olivine and clino-pyroxene grains (micrometer- to 0.1-0.2 mm grain size, as shown by TEM images). Transmission Electron Microscopy (TEM) and TEM microanalysis show that olivine and orthopyroxene are coexisting in several necks of boudined CPx. The olivine grains reveal very little change in composition, while the olivine matrix from a fluid phase, which is also mixed with melt (Fig. 1).

Strain - Stress curves

Discussion/Conclusion

Our results show that strain localization originates from intense grain size reduction because of stress-induced dissolution/precipitation. Indeed, both the nature of mineral phases that can precipitate and dissolve are quite different. Although CPx and olivine coexist in the experiments, the formation of Mg-rich diopside is observed in most experiments. The olivine matrix is enriched in Mg and Si, while the CPx shows a decrease in Mg and Si. The formation of Mg-rich diopside is accompanied by a decrease in the olivine matrix, which is consistent with the formation of a fluid phase. The decrease in Mg and Si content in the olivine matrix is consistent with the formation of a Mg-rich diopside.

Differential stress (MPa) vs. Grain size (μm)

These results are consistent with previous studies that have shown that the formation of Mg-rich diopside is accompanied by a decrease in the olivine matrix. The decrease in Mg and Si content in the olivine matrix is consistent with the formation of a Mg-rich diopside. The formation of Mg-rich diopside is accompanied by a decrease in the olivine matrix, which is consistent with the formation of a Mg-rich diopside. The decrease in Mg and Si content in the olivine matrix is consistent with the formation of a Mg-rich diopside. The formation of Mg-rich diopside is accompanied by a decrease in the olivine matrix, which is consistent with the formation of a Mg-rich diopside. The decrease in Mg and Si content in the olivine matrix is consistent with the formation of a Mg-rich diopside.