Pressure and grain size dependence of the strength of magnesite aggregates

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Intermediate depth (170-400 km) deep focus earthquakes are observed in subducting slabs, but unlike shallow (50-170 km) and deep (400-660 km) deep focus earthquakes, the mechanism(s) responsible for these earthquakes are not clear. One common alteration product observed in peridotites, magnesite ($MgCO_3$), is stable along the pressure-temperature path of a subducting slab. Low pressure experiments indicate that magnesite is weaker than olivine, but there are no data to constrain the pressure or grain size dependence of magnesite strength when deforming by low temperature plasticity mechanisms.

We performed two series of experiments using the D-DIA at beamline 6-BMB at the Advanced Photon Source at Argonne National Laboratory in order to determine the pressure and grain size dependence of magnesite deforming by low temperature plasticity mechanisms (dislocation glide and twinning). In order to determine the pressure dependence of magnesite strength, we deformed fine-grained magnesite cylinders to strains of 25-30% at T=500^{o}C, strain rate of $2*10^{-5}$/s and a range of pressures (3-6 GPa). In order to determine the grain size dependence of magnesite strength, we deformed stacked cylinders (1mm X 1mm) of magnesite with different grain sizes (1 and 17 μm or 1 and 100 μm) in series to strains of 25-30% at T=500^{o}C, strain rate of $2*10^{-5}$/s and a range of pressures (3-6 GPa). Stacked samples allow direct observation of the materials' relative strengths via differences in strain rates of the two materials.

The strength of fine-grained magnesite deforming by low temperature plasticity mechanisms increases as a function of increasing pressure. Unlike previous low pressure magnesite experiments performed to low strains (10-15%), the magnesite deformed to high strain strain weakened at strains greater than 15%. The pressure dependence (V*) of magnesite after this strain weakening is 19 (+/- 3) $*10^{-6}$ m^3/mol, which is slightly higher than observed for other mantle phases, such as olivine and orthopyroxene. The strength of magnesite aggregates also decreases as a function of increasing grain size, which is consistent with previous observations of the grain size dependence of calcite strength. Although the pressure dependence is higher than olivine, the strength of magnesite in subducting slabs is considerably lower than olivine and may cause strain localization and intermediate depth deep focus earthquakes.