ESRF	**Experiment title:** In situ deformation of eclogite at high pressure and temperature	**Experiment number**: ES260
Beamline: ID06-LVP	**Date of experiment**: from: 22/04/2015 to: 28/04/2015	**Date of report**: *Received at ESRF:*
Shifts: 18	**Local contact(s)**: Dr. J. Guignard, Dr. W. Crichton	

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Report:

This exploratory study investigates the strength and microstructural evolution of a bimineralic (garnet-clinopyroxene) eclogite at high pressure and temperature to obtain a better understanding of material transport and flow of former subducted crust in the Earth's upper peridotite-dominated mantle. To date, only few studies have investigated the polyphase rheology of eclogite, at limited pressure (< 3 GPa) using the Griggs deformation apparatus [1,2,3]. At those uppermost mantle conditions, weak quartz (< 10%) as well as friction in the press substantially contribute to the uncertainty in the stress measurement. The previous result that eclogite has similar strength as a harzburgite (olivine+orthopyroxene mixture) [1], is therefore questionable. We expand upon previous studies by using the large volume press (LVP) installed at ID06 to achieve higher pressures than before (5 GPa) preserving a bimineralic eclogite composition. The 18 allocated shifts were used to precisely measure, *in situ*, the macro-strain and lattice d-spacing changes (for stress estimation) in eclogite in series with an olivine or orthopyroxene sample deformed under a range of temperatures (1100 – 1470 K) and strain rates (3×10^{-6} – 1×10^{-4} s^{-1}).

Preliminary results

We have caried out a series of olivine/eclogite and orthopyroxene/eclogite layered deformation experiments at 4-5 GPa. The bimineralic eclogite is a melting residue of a model altered MORB [4], composed of approx. 50:50 garnet and clinopyroxene. The samples have all been pre-sintered at 1473 K and 5 GPa up to 5 days to achieve thermochemical equilibration and stable grain size prior to deformation experiments at the same or lower tempertures. The grain sizes of olivine, orthopyroxene and eclogitic garnet and clinopyroxene range from 10 to 60 µm, except where we used a fine-grained orthopyroxene sample (1-5 µm). A garnet fraction in the eclogites remained at 1-5 µm grain size due to sluggish grain growth (**Fig. 1A**).

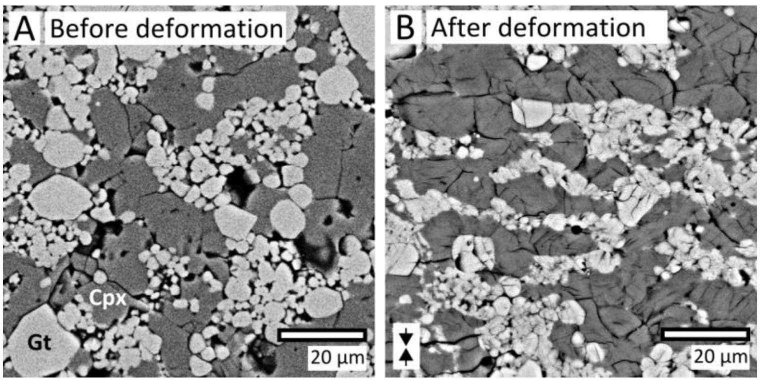
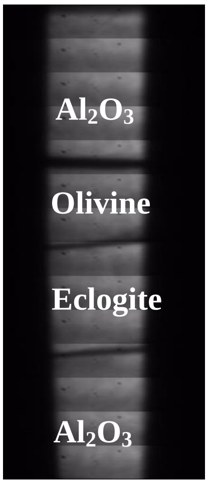


Figure 1. Eclogite microstructure before (A) and after (B) deformation. Note the striking formation of alternating garnet-cpx layers after compressive deformation. Some grains were plucked out from polishing.

Scanning electron microscope images of the deformed samples show the following general features (**Fig. 1B**); 1) some grain size reduction occurred, although it is not clear which grains are dynamically recrystallized grains, 2) the fine-grained garnet fraction in the eclogites appears more distributed in layers than before, and 3) the clinopyroxene grains appear more flattened and layered than before.



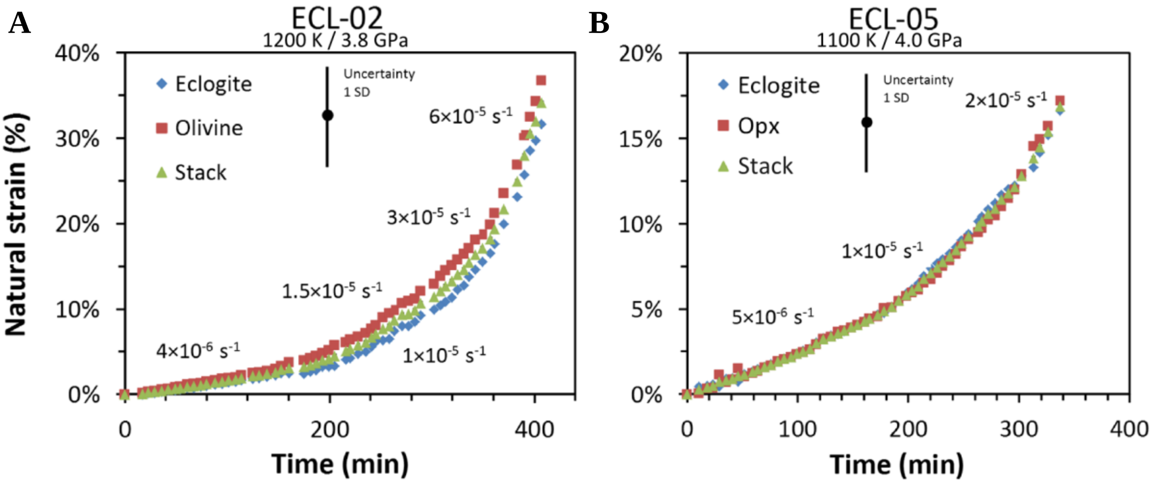


Figure 2. X-ray radiograph. Black lines are Re strain markers. Al_2O_3 parts are pistons.

Figure 3. Natural (true) strain plotted against time for two experiments. The kinks in the curves are due to an increase in anvil displacement rate, leading to an increase in sample strain rates, as labelled. On the left (A), eclogite was placed in series with olivine. On the right (B), eclogite was placed in series with orthopyroxene. Systematic uncertainty in strain (from marker positions) is shown with 1 standard deviation. Opx – orthopyroxene.

Furthermore, we recorded the strain evolution of the samples deformed up to 20 – 40% strain in near-real time based on the positions of the Re foil strain markers on the sample interfaces seen in the captured X-ray radiographs (**Fig. 2**). Estimation of strain (rate) in both samples in the stack is therefore very precise (within few percent uncertainty). Preliminary results indicate that olivine generally deforms faster (deformed to higher strain) than eclogite (**Fig. 3A**). However, at the highest temperature and strain rates, the strain accumulated in olivine is higher by a mere factor of 1.5 than eclogite, but only slightly higher than in eclogite at lower temperature/strain rates (**Fig. 3A**). Likewise, at various conditions orthopyroxene appears to deform at equal rates as eclogite (**Fig. 3B**). For stress estimation, we used radial X-ray diffraction. The d-spacing variation of the diffracted crystallographic planes as a function of azimuth and elasticity tensor of each phase were used to calculate stresses. Preliminary stress estimations in olivine suggests flow stresses of 1 to 2 GPa were reached. Given similar strain rates and assuming homogeneous stress (Reuss bound), the average stress in bi-mineralic eclogite is also 1-2 GPa. Therefore, we can expect one phase to be significantly stronger and another weaker with respect to olivine (to be confirmed). Olivine stress estimations so far agree with stresses calculated using olivine flow laws [5] at given experimental conditions. At these stresses, olivine mainly deforms by glide-dominated dislocation processes. However, orthopyroxene, eclogitic garnet and clinopyroxene may have deformed by other deformation mechanisms, such as power-law dislocation creep with or without grain boundary sliding.

Conclusions and further work

Deformation experiments on an important mantle component, eclogite were successfully performed at ID06-LVP. Preliminary work suggests bimineralic eclogite may indeed share similar strength variability as a harzbugite. However, in order to be confident in this interpretation, we will carry out detailed stress estimations. In addition, more on-line deformation experiments on eclogite mixtures and garnet /clinopyroxene end-members are desirable under a wider range of high temperatures.

References

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