



	Experiment title: In situ deformation of eclogite compositions at high pressure	Experiment number: ES379
Beamline: ID06-LVP	Date of experiment: from: 04/05/2016 to: 10/05/2016	Date of report: 09/09/2016
Shifts: 18	Local contact(s): Dr. K. Spektor, Dr. W. Crichton	<i>Received at ESRF:</i>
Dr. R.J.M. Farla^{1*}, Dr. A. Rosenthal^{2*}, Dr. C. Bollinger^{1*}, Dr. S. Petitgirard^{1*}, Dr. J. Guignard^{3*}, Dr. W. A. Crichton⁴, Dr. T. Kawazoe^{1*}, Prof. D. J. Frost¹ ¹ Bayerisches Geoinstitut (BGI), Universität Bayreuth, 95440 Bayreuth, Germany ² Laboratoire Magmas et Volcans, Université Blaise Pascal, 63178 Clermont-Ferrand, France ³ Laboratoire Geosciences Environnement Toulouse (GET), 31400 Toulouse, France ⁴ European Synchrotron Radiation Facility (ESRF), Grenoble 38000, France		

Report:

This exploratory study investigates the strength and microstructural evolution of bimineralic eclogite (garnet-clinopyroxene) compositions at high pressures (4-7 GPa) and temperatures (1000-1500K). The main aim is to assess the importance of subducted oceanic crust (eclogite) on mantle convection in the Earth's peridotite-dominated mantle. To date, only few studies have investigated the polyphase rheology of eclogite at low pressures (< 3 GPa) using the Griggs deformation apparatus [1,2,3]. At those uppermost mantle conditions, weaker 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) [1], is therefore questionable. We expand upon previous studies by using synchrotron X-rays to probe the stress-strain evolution during deformation in the large volume press (LVP) installed at ID06. We deformed bimineralic eclogite, garnetite and clinopyroxenite aggregates at pressures up to 6.7 GPa during the 18 allocated shifts. In several experiments, San Carlos olivine was deformed with eclogite for a direct viscosity comparison.

Preliminary results

In preparation for our visit to ESRF, the bimineralic eclogite aggregates were synthesized at 5 GPa and 1470 K up to 4 days in a multianvil apparatus at BGI. We used a composition representative of a melt residue of a model-altered MORB [4], producing a ratio of approx. 50:50 garnet to clinopyroxene. The garnetite and clinopyroxenite aggregates were

synthesised corresponding to a composition based on the melt residue of the aforementioned bimineralic eclogite. Therefore, the solid solution compositions of garnet and clinopyroxene are expected to be very similar in all experimentally deformed samples. The small amounts of relict kyanite in the garnetites and garnet in the clinopyroxenites are not resolved in the X-ray diffraction patterns. Scanning electron microscope images of the deformed bimineralic eclogite samples were reported previously (ES260). Here we show the deformation assembly and a microstructural comparison of the undeformed and deformed garnetite and

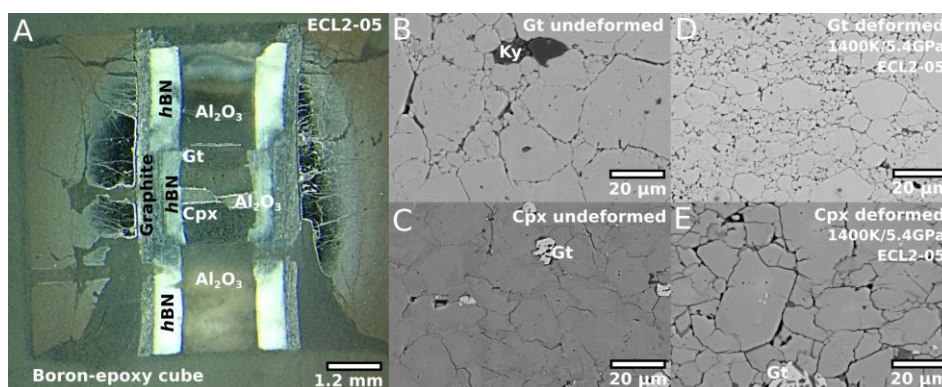


Figure 1. High-pressure assembly (A) and microstructure of undeformed (B,C) and deformed (D,E) garnetite (Gt) and clinopyroxenite (Cpx). Crack in (A) is due to blow out during decompression.

clinopyroxenite samples (Fig. 1). Grain size distribution of olivine and eclogitic clinopyroxene shows a peak at 10-30 μm , whereas the distribution of eclogitic garnet shows an additional peak at 1-5 μm grain size due to sluggish grain growth kinetics.

Combining the X-ray diffraction data and radiography images from this and previous beamtime (ES260), we obtained full stress-strain (rate) histories of the successfully deformed samples. The complete dataset offers a preliminary answer to the question what rock type and what mineral phase is stronger at mantle conditions, albeit at laboratory strain rates. The processed stress data is summarized in Figure 2, highlighting that the answer to the question strongly depends on the temperature-strain rate conditions, and thus what deformation mechanism is operating. Figure 2 shows the stress data normalised to 5 GPa and 10^{-5} s^{-1} . For the entire temperature range, olivine predominantly deforms by exponential creep (dislocation-glide) and can be fitted by the Goetze (1978) flow law. Whereas, both eclogitic garnet and clinopyroxene experience a transition from exponential creep to power-law creep at about $>1200 \text{ K}$. Above 1200 K, eclogite is increasingly weaker than olivine with increasing temperature. Furthermore, the small grain size fraction of garnet in the eclogitic

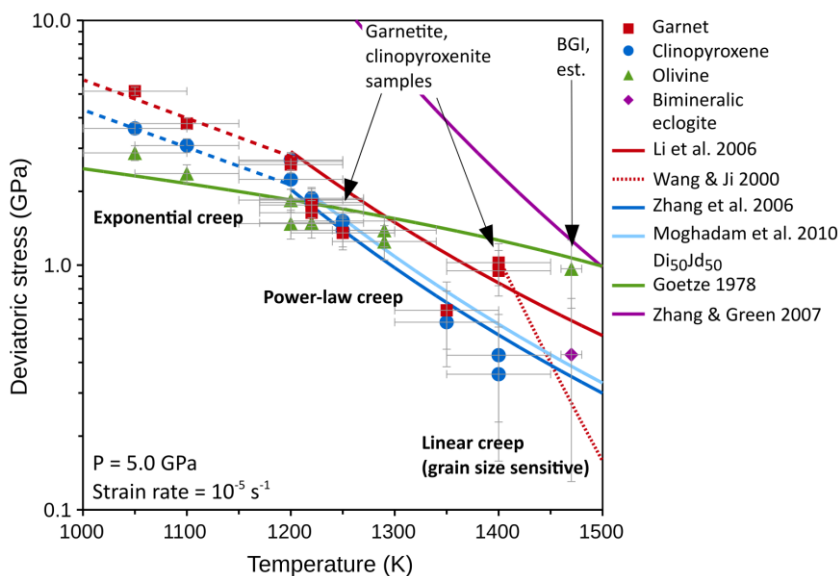


Figure 2. Normalized stress data plotted against temperature for all experiments. Red is garnet, blue is clinopyroxene, green is olivine. Garnet and clinopyroxene are part of a bimineralic eclogite mixture except where stated otherwise. A high temperature experiment at BGI is shown where the strength of eclogite (purple) is estimated indirectly by deforming olivine with eclogite, and assuming uniform stress in the cell assembly. The weaker sample shortens at a faster rate.

different compositions!) to the high-pressure experimental data, V^* appears to be 5 to $6 \times 10^{-6} \text{ m}^3 \text{ mol}^{-1}$, vastly different from the estimation made by Zhang and Green [3] of $V^* = 27.2 \times 10^{-6} \text{ m}^3 \text{ mol}^{-1}$. However, in order to confirm new flow law parameters for eclogite at high pressures, more data in the P,T range is needed to constrain the large experimental uncertainties.

Conclusions and further work

We show for the first time that eclogite rheology is likely characterised by the same deformation mechanisms that operate in olivine. However, at the same strain rate, the transitions between the mechanisms occur at lower temperatures in eclogitic garnet and clinopyroxene than in olivine. Hence, at laboratory timescales, at high temperatures and pressures, bimineralic eclogite can be weaker than olivine when clinopyroxene is the interconnected weak phase and/or when garnet dynamically recrystallizes to small grain size at high temperatures. For future work, a few experimental challenges need to be addressed. First, anvil failure may be caused by usage of hard alumina pistons that generate high stresses during cold compression, and may be replaced by crushable alumina. Second, the use of a graphite heater at high pressures $> 5 \text{ GPa}$ was found to be unstable at high temperatures ($> 1200 \text{ K}$). Therefore, Re foil heaters will be used in the future. At ID06, an upgrade from voltage-control to current- or power-control DC heating will further improve heating stability.

References

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samples may cause an additional transition to grain size sensitive creep (linear creep) at the highest temperatures ($> 1400 \text{ K}$), as shown by the red fine-dotted line. The strength of the eclogite appears to be dominated by the strength of clinopyroxene, whereas garnetite remains stronger than clinopyroxenite at 1400 K. Deformation of bimineralic eclogite is unfortunately not possible to temperatures higher than 1500 K as partial melting becomes significant. Further modeling and experimental work is required to extrapolate viscosities of all phases to mantle conditions and geological strain rates. The largest obstacle is the uncertainty of the pressure sensitive term (activation volume V^*) in the experimental flow laws. When attempting to fit the existing flow laws (of garnet and clinopyroxene with