

allow us to study the effect of pressure on fabric and texture development in the mantle.

Goetze had an eye for expeditious measurement and high-quality, high-impact data, a sure recipe for advancement of science when it can be achieved. His are probably the best standards for gauging the success of the new machines. Both the D-DIA and RDA have been developed in a relatively short amount of time (sizeable groups of motivated investigators are involved in both projects), and mostly without unexpected technological complications. Both have strained samples at conditions approaching design limits, but neither has yet produced what Goetze would consider a meaningful measurement of the state of deviatoric stress. The new machines are solid-medium deformation apparatuses and as such bring the concern that since the medium has significant shear strength, stress measurements may be poorly resolved. There is a difference here, however: the state of stress can be measured directly in the samples themselves, thus mitigating (or even exploiting) the effects of the shear strength of the medium. Even in gas deformation rigs, the opportunity for directly viewing samples is rare; in the solid-medium rig it is unprecedented. X-ray transparent anvils may soon bring stress measurement resolution down to 10 MPa, still a huge error bar in Goetze's world. Time and experience will make the error bars smaller, hopefully to a level where the measurements will have a real impact on our picture of Earth's mantle, and the new high-pressure deformation machines will not end up consigned to the dusty basements of experimental geophysics laboratories.

#### MR51A-11 1145h

##### An Experimental Study of the Rheology of Jadeite

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Understanding the rheology of eclogite, probably governed by the behaviour of sodic pyroxenes of the diopside-jadeite solid solution series (omphacite), is essential for predictions on interplate coupling and shear heating in subduction zones and the simulation of subduction processes. We first investigated the mechanical behaviour of the end member jadeite (NaAlSi<sub>3</sub>O<sub>6</sub>). Deformation experiments were carried out on synthetic and natural jadeite aggregates. The synthetic samples were crystallized in the stability field of jadeite from a synthetic glass precursor. A standard procedure yields uniform microstructures with an average grain size of approximately 12 μm. In contrast, the natural jadeite samples from Myanmar reveal a coarse grain size and a heterogeneous microstructure. Deformation experiments were carried out at a confining pressure of 2.5 GPa in a modified Griggs apparatus using a molten eutectic CsCl/NaCl mixture. For the synthetic samples, the microstructures indicate deformation in the dislocation creep regime, with a grain shape and crystallographic preferred orientation. The mechanical data for synthetic jadeite were fit by a power law using a global inversion method. An activation energy for dislocation creep of  $Q = 326 \pm 27 \text{ kJ/mol}$  and a stress exponent  $n = 3.7 \pm 0.4$  and a preexponential factor of  $\ln A = -3.3 \pm 2.0$  are found for synthetic jadeite. The microstructure of the deformed coarse-grained natural jadeite samples reveals inhomogeneous crystal plastic deformation and mechanical twinning. The orientation distribution of twinned and untwinned crystals yields a critical resolved shear stress of  $150 \pm 25 \text{ MPa}$  for the (100)[001] twinning of jadeite. Extrapolation of the flow law for synthetic jadeite to a geological strain rate of  $10^{-14} \text{ s}^{-1}$  reveals that end-member jadeite is significantly weaker than diopside in the dislocation creep regime. The flow strength of pyroxenes of the omphacite solid solution series as a function of composition awaits a systematic study.

#### MR51A-12 1200h

##### Plastic Deformation and Strain-Hardening of Forsterite: a Mesoscopic Simulation

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The determination of the rheological properties of deep-Earth's minerals is one of the most challenging issues of Earth Sciences for two reasons. From the experimental point of view, it requires deformation experiments under extreme P, T conditions to be performed. On the theoretical point of view, the experimental data have to be extrapolated over several orders of magnitude in time (strain-rate) and space in order to be applied to the Earth's mantle. The latter aspect can now be addressed through the development of multi-scale modelling of plastic deformation.

Significant progress have been achieved in the recent years to simulate plastic deformation of crystals at the mesoscopic scale. One can now compute the collective properties of large numbers of dislocations (e.g. several hundreds of lines) in sufficiently large model crystals, with typical linear dimensions of about 15 μm. The most important achievement in this domain is certainly the development of three-dimensional simulations accounting for crystallographic effects and slip geometry initiated by Kubin and Canova.

The mesoscopic approach combines a simplified description of the core properties with the more rigorous elastic theory of dislocations, in order to understand the formation and dynamics of the microstructures of deformed specimens. Dislocation segments (edge, screw and mixed) are displaced on a discrete lattice which has the same symmetry as olivine. The dislocation segments move in response to the local effective stresses applied to them. The mobilities can vary for each slip system or dislocation character. They have been fitted to mechanical data obtained on single crystals.

In this study, we aim to simulate the strain hardening behaviour resulting from the interaction of dislocations from different slip systems. It is thus necessary to describe the interactions between dislocations from intersecting slip planes, including the formation and destruction of dislocation junctions. The stability of dislocation junctions has been investigated from the point of view of elasticity and with the simulation.

#### MR52A MCC: Hall C Friday 1330h

##### Applications of Measurements of Physical Properties of Rocks to Large-Scale Tectonic Processes II Posters

**Presiding:** R J El-Khozondar,  
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#### MR52A-0991 1330h POSTER

##### Numerical Simulations of Coarsening of Lamellar Structures: Applications to Pervoskite and Magnesio-wüstite

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Understanding the microstructural evolution in rocks is essential to theories of the dynamics of the solid interior of the Earth. The eutectoid transformation at 660 km depth produces alternating thin lamellae of pervoskite and magnesio-wüstite. We performed numerical simulations of coarsening of lamellar structures using Monte Carlo Potts model.

We find that an isotropic lamellar structure degenerates via edge spheroidization and termination migration into nearly equiaxed grains with a diameter which is 2 to 3 times larger than the original lamellar spacing. The duration of this process is comparable with the time it would take Ostwald ripening to produce grains of the same size. After degeneration of lamellar structure, grain growth quickly reaches the asymptotic regime of coarsening described by a power-law function of time. Lamellae with anisotropic grain boundaries coarsen more slowly and via discontinuous coarsening mechanism. This produces larger grains upon degeneration of lamellae.

#### MR52A-0992 1330h POSTER

##### Mechanical Behaviour and Fabric Development in Experimentally Deformed Magnesio-wüstite (Mg,Fe)O as a Function of Fe-content

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In a series of tests in a HT-HP deformation apparatus ('Paterson rig') we investigated the deformation behaviour of magnesio-wüstite (Mg,Fe)O in torsion at 1400 K, 300 MPa confining pressure and a strain rate of  $2 \times 10^{-3} \text{ s}^{-1}$ . The Fe-content was varied from 10 to 50 at. % in steps of 10 at. %. The samples were deformed to shear strains ( $\gamma$ ) up to 15 in order to achieve steady state microstructures and textures. The shear stress - shear strain curves showed little to no weakening after the initial yield and the strength of the samples decreased slightly with increasing Fe.

Analysis with electron backscattering diffraction (EBSD) in the SEM revealed that a crystallographic preferred orientation (texture) developed in all the samples indicating that dislocation creep contributes significantly to the deformation. Deformation is accompanied in all samples by grain size reduction. At low Fe-content (low homologous temperature) the recrystallization mechanism is progressive subgrain rotation; with higher Fe content (and increasing homologous temperatures) grain boundary mobility increases resulting in a larger recrystallized grain size at comparable shear strains.

The development of the crystallographic preferred orientation is characterized by the transition from a deformation texture ( $\gamma = 1-6$ ) to a recrystallization texture at  $\gamma > 6$ . The recrystallization texture remains constant to the highest strains. The deformation texture at lower strains is consistent with dislocation glide predominant on the  $\{111\}\langle 110 \rangle$  and  $\{100\}\langle 110 \rangle$  slip systems, whereas the recrystallization texture cannot be modelled by dislocation glide alone. This texture evolution was observed in all the samples except those with 50 at. % Fe, where a deformation texture develops only at high shear strains and a recrystallization texture was not found. Preliminary results suggest that the slow formation of a crystallographic preferred orientation in these samples is possibly due to increased grain boundary mobility and grain growth.

#### MR52A-0993 1330h POSTER

##### Rheology and Microstructure of (Ca,Sr)TiO<sub>3</sub> Perovskite Deformed in Compression and Torsion

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(Mg,Fe)SiO<sub>3</sub> perovskite is considered to be the most abundant phase in the Earth's lower mantle, along with magnesio-wüstite and other minor high pressure phases. Therefore knowledge of the rheological properties of (Mg,Fe)SiO<sub>3</sub> is crucial to the understanding of the rheology of the lower mantle. Presently, deformation experiments, yielding reliable rheological data, cannot be performed within the stability field of (Mg,Fe)SiO<sub>3</sub> perovskite. Fortunately, many elements can combine to form the perovskite structure and hence an analog for (Mg,Fe)SiO<sub>3</sub> perovskite that is stable at experimentally tractable conditions can be found. (Ca,Sr)TiO<sub>3</sub> is one such material, which is stable at atmospheric pressure, and undergoes two structural phase transitions between 100 and 1600 K depending on the Ca:Sr ratio. By studying the deformation behavior of (Ca,Sr)TiO<sub>3</sub> some insight can be gained in to the rheological properties of (Mg,Fe)SiO<sub>3</sub> perovskite.

Polycrystalline samples of (Ca<sub>0.9</sub>Sr<sub>0.1</sub>)TiO<sub>3</sub> have been synthesized from high purity oxides yielding samples with <3% porosity and a grain size of ca. 100 μm. These samples have been used to study the rheological properties of the tetragonal and cubic phases. Data from compression experiments performed over a temperature range spanning the orthorhombic to cubic phase transition show a power-law rheology with a stress exponent of ~4 and an activation energy of ~600 kJmol<sup>-1</sup>. A crystallographic preferred orientation develops in the compression experiments that is consistent with [110] slip. (Ca<sub>0.9</sub>Sr<sub>0.1</sub>)TiO<sub>3</sub> samples deformed in the cubic stability field to high strain in torsion show a comparable strength to compression tests under the same conditions. In these high-strain torsion

experiments there is no shape preferred orientation of the grains consistent with the shear strain. Despite this lack of a shape fabric a crystallographic preferred orientation develops that is consistent with [100] slip. Lattice rotations towards the rims of grains are observed to be about an axis perpendicular to the shear direction. It is thought that these samples are deforming by grain boundary sliding, probably accommodated by components of both diffusion and dislocation creep.

#### MR52A-0994 1330h POSTER

##### Different Piezometer Relations for Different Recrystallization Mechanisms in Quartz?

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Three different mechanisms of dynamic recrystallization observed in both experimentally (Hirth & Tullis 1992) and naturally (e. g. Stipp et al. 2002) deformed quartz aggregates raise the question of whether each mechanism has a different piezometer relation. In order to address this question, axial compression experiments on Black Hills quartzite (BHQ,  $d = 100\text{--}150\ \mu\text{m}$ ) have been carried out using a molten salt assembly in a Griggs type apparatus. BHQ samples were deformed 'as-is' ( $\sim 0.15\ \text{wt}\%$  water) to axial strains of 22 to 45% at temperatures of 800<sup>o</sup> to 1100<sup>o</sup> C and strain rates between  $1.6 \times 10^{-6}\ \text{sec}^{-1}$  and  $1.7 \times 10^{-5}\ \text{sec}^{-1}$ . These deformation conditions include dislocation creep regimes 2 (dominantly subgrain rotation recrystallization, SGR) and 3 (dominantly grain boundary migration recrystallization, GBM) of Hirth & Tullis (1992) and the deformation microstructures of the samples confirm this interpretation.

Recrystallized grain sizes were measured optically using c-axis orientation images and range from  $4.4 \pm 1.1\ \mu\text{m}$  to  $18.0 \pm 5.5\ \mu\text{m}$  for flow stresses ranging from 200 to 50 MPa to 60 to 20 MPa. Unpublished data from Bishop cover regime 1 (dominantly bulging recrystallization, BLG) dislocation creep. 'As-is' samples of novaculite ( $d = 5\ \mu\text{m}$ ) were deformed in a solid salt assembly at temperatures of 700<sup>o</sup> to 850<sup>o</sup> C and strain rates of  $1.9 \times 10^{-6}\ \text{sec}^{-1}$  and  $1.9 \times 10^{-5}\ \text{sec}^{-1}$ . Recrystallized grain sizes measured on SEM images of etched sections range from  $1.1\ \mu\text{m}$  to  $2.2\ \mu\text{m}$  for flow stresses ranging from 1050 to 150 MPa to 470 to 100 MPa.

Plotting both data sets on a logarithmic diagram of flow stress and grain size indicates a sharp change in slope at the transition from BLG to SGR. The slope above the transition to SGR is close to the Twiss (1977) piezometer whereas the slope for BLG is steeper, similar to what has recently been published for BLG in feldspar aggregates (Post & Tullis 1999). We propose that the change in the piezometer relation is related to a change in the dominant recrystallization mechanism. Such a change has been reported for the transition from SGR to GBM in halite (Guillopé and Poirier 1979) and calcite (Rutter 1995). The lack of a measurable slope change within the higher temperature part of the sample set might indicate that the given deformation conditions are still transitional to dominant GBM.

Guillopé, M. & Poirier, J. P. 1979, JGR 84, 5557-5567. Hirth, G. & Tullis, J. 1992, JSG 14, 145-159. Post, A. & Tullis, J. 1999, Tectonophysics 303, 159-173. Rutter, E. H. 1995, JGR 100, 24651-24663. Stipp, M., Stünitz, H., Heilbronner, R. and Schmid, S. M. 2002, Geol. Soc. London, Spec. Publ. 200, 171-190. Twiss, R. J. 1977, Pure Appl. Geoph. 115, 227-244.

#### MR52A-0995 1330h POSTER

##### Grain Growth in Quartz: Effect of Temperature, Pressure, Composition and Water

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The microstructure of rocks exposed to elevated temperatures in the Earth may be altered significantly as a result of grain growth. Quantification of changes in grain size distributions of rocks due to grain growth is of key importance in modeling geodynamic processes. Many recent models incorporate a combination of grain growth and dynamic recrystallization, which determines the evolution of grain size and hence the relative contribution of grain size sensitive versus grain size insensitive deformation. Furthermore, grain growth may occur during periods of static annealing prior to or during the exhumation of rocks. Therefore, grain growth need to be accounted for if the grain size (distribution) of exhumed rocks is used as a piezometer to constrain stresses associated with geodynamic processes.

As quartz is one of the most abundant minerals in the Earth's crust, detailed knowledge of grain growth in quartz is highly relevant to geodynamic processes and paleostress estimates involving crustal rocks.

In this study, we investigated grain growth in natural and synthetic polycrystalline quartz aggregates in the  $\alpha$ -quartz stability field. Synthetic samples produced from high-purity quartz glass powder and four types of Arkansas novaculite with average starting grain size between 2 and 50  $\mu\text{m}$ , different impurity contents and hydrogen contents of 200-5000  $\text{H}/\text{Si}$  were used. The samples were annealed at 2 GPa pressure and temperatures between 800 and 1000<sup>o</sup> C in a piston cylinder apparatus with NaCl as a pressure medium. Annealing times varied between 2 and 24 hours. Microstructural investigation is performed using optical and electron microscopy, with emphasis on the determination of grain size distribution, coordination number and misorientation distribution.

Under the investigated conditions, all samples showed thermally activated grain growth with varying grain growth kinetics for the different types of novaculites. In general, microstructures consist of polygonal grains with gently curved grain boundaries after annealing. Typically, the average grain size increased by a factor of 25-40 after 24 hours at 1000<sup>o</sup> C and 2 GPa. For an annealing time of 24 hours, an increase in annealing temperature by 200<sup>o</sup> C roughly corresponds to a fivefold increase in average grain size. The results allow the effect of temperature, pressure, water content and composition on grain growth kinetics in quartz aggregates to be quantified. With the grain size distribution data grain growth laws could be calibrated that constrain grain growth in natural quartz bearing rocks.

#### MR52A-0996 1330h POSTER

##### Grain Growth Kinetics in Wadsleyite

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Grain-size evolution associated with the olivine to wadsleyite (or ringwoodite) transformation plays an important role in controlling the rheological properties of subducting slabs. We have investigated the kinetics of evolution of grain-size associated with the olivine to wadsleyite transformation using a Kawai-type multi-anvil apparatus. The starting material is a fine-grained polycrystalline wadsleyite synthesized by transforming a powder sample at  $\sim 16\ \text{GPa}$ , 1173 K for 1 hour. The samples have uniform grain-size of 1-2  $\mu\text{m}$ . Small pieces of samples were cut from a single starting material, and subsequently annealed at  $\sim 16\ \text{GPa}$ , 1373-1773K for 1-8 hours. Samples were surrounded by fine-grained dry olivine powders (in dry experiments) or surrounded by a mixture of talc and brucite (in wet experiments). A rhenium capsule was used in dry experiments whereas a Au-Pd capsule was used in wet experiments. Annealed samples show nearly homogeneous grain-size distribution indicating a normal grain-growth. The results are fitted to a grain-growth equation,  $GS^n - (GS_0)^n = k \exp(-H^*/RT)t$  where GS is grain-size at time t,  $GS_0$  is the initial grain-size, n is a constant,  $H^*$  is activation enthalpy and T is temperature. Our results under dry conditions show  $n \sim 2$  and  $H^* = 130\text{--}140\ \text{kJ/mol}$ . We also noted a significant influence of chemical environment on grain-growth: grains near a rhenium capsule show much larger grain-size than grains far from the capsule. Effects of different chemical environment including different capsule materials and water content are under investigation which will provide useful constraints on the defect chemistry in wadsleyite.

#### MR52A-0997 1330h POSTER

##### Development of a Rotation Drickamer Apparatus for Deformation Studies Under High Pressure and High Temperature: Applications to magnesio-wustite and Wadsleyite

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Well-controlled high-pressure deformation experiments are critical for understanding the dynamics of Earth's interior. Most of the previous works on ultrahigh-pressure ( $P > 10\ \text{GPa}$ ) deformation experiments have two limitations. (1) The mode of deformation is "stress-relaxation", in which stress changes with time in a given experiment, and (2) the magnitude of stress is limited ( $< 1$ ). To overcome these limitations and to perform large-strain plastic deformation

under the upper mantle and top of lower mantle conditions, we have constructed a new apparatus by modifying the Drickamer-type high-pressure press combined with a rotation actuator involving an ac servo-motor. After the desired pressure and temperature are reached, torsional stress can be applied to a sample with a constant rotation rate. The advantage of this design is that the direction of shear deformation is normal to that of compression and therefore compression and deformation can be separated. A sample (typically  $\sim 1.8\ \text{mm}$  diameter and  $\sim 0.2\ \text{mm}$  thickness) is sandwiched between two zirconia plates and two heater plates made of TiC + diamond. Thin foils of W3%Re and W25%Re are inserted between two halves of samples which act as a thermocouple as well as strain markers. We have conducted a preliminary test on MgO at  $\sim 12\ \text{GPa}$  and  $\sim 1470\ \text{K}$  to the strain up to  $\sim 3$ . Deformation experiments on wadsleyite are underway to investigate the fabric development and rheology in this mineral.

#### MR52A-0998 1330h POSTER

##### Preliminary deformation results to 12 GPa pressure using the Deformation-DIA

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High-pressure studies of the rheological behavior of Earth materials under high pressures are essential for understanding the dynamics of Earth's interior. However, outside of shock experiments and those in the diamond anvil cell, the highest working pressure for conventional deformation rigs (e.g., triaxial gas-medium apparatus, Griggs solid-medium apparatus) has been about 4 GPa. We report here first results from a new deformation apparatus called the deformation-DIA (D-DIA), a cubic-anvil, solid-medium apparatus specifically designed for constant-pressure deformation and capable of deforming samples at high temperatures (up to 2000 K) to pressures up to 15 GPa. Based on the cubic DIA apparatus, the D-DIA allows independent motion of the two vertical anvils to impose deformation on samples, and at the same time allows reverse motion on the four side anvils, thus preventing pressure from rising during deformation.

Preliminary tests have been conducted on samples of NaCl, MgO, and olivine. The cold-pressed samples (1-2 mm in length and 1.2 mm in diameter), hard alumina pistons, and thermocouples form a 6-mm-long deformation column that is inserted into a graphite resistance heater within a 6-mm edge length cubic pressure medium, either pyrophyllite or boron epoxy. The cell is first squeezed hydrostatically to reach desired pressures and then deformed in compression at constant pressure. Experiments are carried out using synchrotron radiation, which makes it possible to measure sample length change and pressure in-situ to levels of  $< 1\ \text{mm}$  and 10 MPa, respectively. To date we have carried out several constant displacement rate experiments at sample shortening rates of  $1 \times 10^{-5}$  to  $4 \times 10^{-4}\ \text{s}^{-1}$  over shortening strains of 10-30% at temperatures of 500-1200<sup>o</sup> C and pressures of 5-12 GPa. Pressure is monitored by the location of diffraction peaks of a small amount of well-characterized proxy material (often MgO) in the deformation column. Pressure is controlled manually by metering hydraulic fluid from the main ram (which drives the side anvils) at a rate such that diffraction pattern holds constant as the deformation proceeds. In our first tests, we have been able to hold pressure to within  $< 1\ \text{GPa}$  of the desired value. With experience, better use of proxy materials, and eventual use of x-ray transparent anvils, we expect to achieve much finer control of pressure.

We are as yet unable to determine the state of deviatoric stress within samples because the tungsten carbide (WC) anvils we now use limit x-ray diffraction to the vertical plane (At this stage, stresses within samples are estimated from quenched dislocation density within deformed samples). Modifications to the D-DIA are being undertaken that will allow us to replace x-ray opaque WC anvils with transparent cubic boron nitride anvils, which will not only to make multi-plane diffraction possible but may increase our pressure limit above 15 GPa. Our goal is to conduct quantitative deformation experiments under high pressures and temperatures at P-T conditions corresponding to or near those of Earth's transition zone.

## MR52A-0999 1330h POSTER

## Mid-Infrared Radiation, Electric Charges, and Acoustic Emission During Rock Deformation

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Satellite infrared imaging data indicate slightly elevated temperatures along large fault systems. Often, before major earthquakes, transient thermal anomalies occur with a positive  $\Delta T$  of 2-4 degrees C. The apparent increase in ground temperature is not understood. Rocks contain positive holes, h (defect electrons in the oxygen sublattice). Normally dormant in form of positive hole pairs (PHP), mechanical stress can activate the h. Being highly mobile charge carriers, the h spread outward from the source volume. We conducted rock deformation experiments to test the hypothesis that, when h arrive at the rock surface, they recombine and emit photons in the mid-IR. Using a 1500 t press at the Geophysical Laboratory, Carnegie Institution, we loaded the central area, 13.5 cm diameter, of 25 x 25 x 9 cm blocks of dry granite (Imperial Red, supplied by Gem Granites) at a rate of 35 MPa/min until failure between 750-800 t. We measured the IR emission spectrum (3.3-14.5 microns) from a 6 cm diameter surface area at 4 cm-1 resolution with liquid N<sub>2</sub>-cooled InSb/MCT detectors, using a custom-improved MIDAC spectrometer from ICES, UC Santa Barbara, and recorded the IR emission of the whole block at 8.3 micron, using a 256 x 256 array QWIP (Quantum Well Infrared Photodetector) camera from NASA Goddard Space Flight Center, with 0.025K resolution. For acoustic emission we used three SONY Lavalier microphones and a mixer MACKIE 1402 VLY with a time resolution of 20 microsec. We also measured surface potentials and electric currents flowing from ground into the rock, using a KETHLEY 617 Electrometer. We observe diffuse mid-IR emission and an increase in IR spectral signals, equivalent to a radiative temperature increase of 0.3 degree C. We observe positive surface potentials and electric currents flowing into the rock, increasing with stress and reaching 100-150 pA close to failure. These observations support our hypothesis that h charge carriers are set free in granite undergoing massive deformation, spread into the surrounding undeformed rock, and recombine radiatively at the surface.

## MR52A-1000 1330h POSTER

## High Temperature Deformation-Mechanism Maps for Synthetic Plagioclase Rocks

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Estimation of crustal stresses and viscosities are based on extrapolations of laboratory experiments to natural strain rates, temperatures, and pressures. We present deformation-mechanism maps for feldspathic rocks in stress-grain size space. The data are from creep tests on fine-grained synthetic aggregates of anorthite, labradorite, and albite, deformed at 300 MPa confining pressure and temperatures between  $\approx 0.6$ - $0.9 T_m$ . Samples were nominally dry (0.005-0.01 wt% H<sub>2</sub>O) or contained 0.1-0.3 wt% H<sub>2</sub>O (wet). Some specimens contained  $<5$  wt% Si-rich melt.

The deformation mechanism maps show a transition from grain boundary diffusion-controlled creep to dislocation creep as a function of grain size, temperature and water content. The critical grain size at the transition between regimes increases with increasing water content.

When extrapolated to strain rates of  $10^{-14}$ s<sup>-1</sup> our data indicates that dislocation creep of wet plagioclase rocks depends on composition and requires minimum temperatures of  $\approx 350$ - $450^\circ\text{C}$  at stresses of  $\approx 100$ - $300$  MPa. This is in good agreement with field estimates. At similar conditions in the diffusion creep regime stresses are between  $\approx 1$ - $10$  MPa for ultramylonite-type rocks with  $\approx 10$ - $30$   $\mu\text{m}$  grain size. However, nominally dry plagioclase rocks are drastically stronger and require temperatures  $\approx 200^\circ\text{C}$  higher to initiate dislocation creep.

At temperatures between  $400$ - $600^\circ\text{C}$  and depending on trace content of H<sub>2</sub>O and deformation mechanism the viscosity of feldspar-dominated crustal rocks is estimated to range from  $\approx 10^{22}$  Pa-s -  $10^{19}$  Pa-s. Significantly lower viscosities of rocks containing  $> 0.1$  wt% water require a fine grain size  $<50$   $\mu\text{m}$  at higher temperatures.

## MR52A-1001 1330h POSTER

## The Olivine to Spinel Transformation Unmasked: A Direct Atomic View

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High-resolution transmission electron microscopy (HRTEM) of partially transformed samples of Mg<sub>2</sub>GeO<sub>4</sub> have revealed a clear picture of the atomic re-arrangements that take place when the olivine form of the compound transforms to the spinel type under the influence of high pressure and temperatures. This important transformation is an analog of the olivine-spinel transition in mantle silicates and has been the subject of much speculation. In this study it was found that when Mg<sub>2</sub>GeO<sub>4</sub> was subjected to 6GPa pressure at 600°C for 10 minutes, samples could be produced that contained both structure types with perfectly preserved interface regions. Examination of the atomic structure images of well-prepared specimens revealed a mechanism of transformation, which combines both, a shear component on the anion sub-lattice followed by the passage of a correcting dislocation which very effectively rearranges the cations. The shearing action transforms the hexagonal close packed array of anions in the olivine structure to a packing sequence that defines the face centred close packed structure of the spinel form. The dislocation associated with each shear has a Burgers vector perpendicular to the anion shear direction and the passage of these dislocations places the cations in the correct spinel sites. These effects are directly observed in atomic resolution images and uniquely define the process, which may have implications in the continuing search for the cause of deep earthquakes.

## MR52A-1002 1330h POSTER

## Effects of transformation kinetics on the mineralogy and the density of the subducting slab

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As the oceanic plate descends into the deep mantle, the major constituent minerals of olivine, pyroxene, and garnet cause high-pressure transformations. It

has been suggested that these transformations are kinetically inhibited due to low temperatures in the plate and metastable low-pressure phases exist beyond the equilibrium boundary. Because the density increase  $\sim 5$ - $10\%$  caused by these transformations is much larger than the thermal density difference between the plate and the surrounding mantle, kinetics possibly affects dynamics of the subducting slab. We examined kinetics of the olivine-spinel transformation, high-pressure transformations in enstatite, the post-spinel transformation, and the post-garnet transformation by in-situ X-ray observations. Taking kinetics of these transformations into account, we calculate the metastable mineralogy and the density both in the basaltic oceanic crust and underlying peridotite layer of the slab.

Pyrolyte model was used as mineral proportions in the peridotite layer. We assume that reactions between garnet and pyroxene can not occur due to the slow chemical diffusion at low temperatures of the cold slab. Therefore, it is expected that near iso-chemical transformations occur in olivine, pyroxene, and garnet. We used the thermal model proposed by Kirby et al. (1996) as the temperature in the peridotite layer of the cold slab. Transformed fractions were calculated as a function of depth based on the experimentally determined growth kinetics in these transformations. Olivine can survive metastably to more than 600 km depth, however the post-spinel transformation can complete near the equilibrium boundary even in the cold slab. On the other hand, metastable garnet exists more than 1000 km depths due to the slow growth rates. Consequently, the zero-pressure density of the peridotite layer becomes smaller than that of the surrounding pyrolyte mantle both in the transition zone and the lower mantle. These density differences are caused by the presence of metastable olivine in the transition zone, and negative slope of the post-spinel transformation boundary and the presence of the metastable garnet in the lower mantle. Although we have to consider the density differences at high pressure and temperature conditions and effects of latent heat production on transformation kinetics, these preliminary results may imply that the peridotite layer in the cold slab becomes neutral or buoyant at the transition zone and lower mantle.

In the basaltic oceanic crust, a major constituent mineral of garnet can survive metastably more than 1000 km depths when the temperature is less than 1600 K. The basaltic crust become buoyant in the lower mantle due to the presence of the metastable garnet, which possibly has an important role on the separation of the oceanic crust and the formation of the garnetite layer at the top of the lower mantle.

## MR52A-1003 1330h POSTER

## Symmetric Tilt Grain Boundaries of Synthetic Forsterite Bicrystals

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Structure and transport properties of grain boundaries in rocks are still poorly understood. For example, grain boundary diffusivity and mobility depend on orientation, and they are different for low and high angle grain boundaries. The transition from low to high angle grain boundaries in rock-forming minerals is not studied in detail, but a high angle grain boundary is commonly defined by a lattice misorientation of  $> 10^\circ - 15^\circ$ . To investigate the physical properties of olivine grain boundaries we produced a series of synthetic forsterite bicrystals with symmetric tilt grain boundaries by direct bonding [1,2]. For each bicrystal two oriented synthetic forsterite single crystals were joined at room temperature and annealed at  $400^\circ\text{C}$  for one week. All bicrystals were cut in two parts and one part was annealed further at  $1650^\circ\text{C}$  for 48h. The tilt axis of the boundary in the synthesized bicrystals is parallel to the a direction, and the tilt angles of the series range from  $9^\circ$  to  $21^\circ$ . Specimens were prepared for investigations in the transmission electron microscope (TEM) using focused ion beam (FIB) technique.

High-resolution TEM investigations of symmetric tilt grain boundaries reveal dislocation arrays between undisturbed crystal regions in samples annealed at  $400^\circ\text{C}$  and  $1650^\circ\text{C}$ . This suggests that bonding of bicrystals occurred already below or at  $400^\circ\text{C}$ .

The burgers vectors of the dislocations are parallel to c. Dislocation cores do not overlap up to a tilt angle of  $21^\circ$ . This indicates that for forsterite small angle grain boundaries exist up to tilt angles of  $21^\circ$ .

The dislocation model of small angle grain boundaries can be applied and the observed dislocation spacings d are related to tilt angle  $\theta$  and burgers vector length b by Franks formula [3]:  $d = b/(2\sin(2/\theta)) \sim b/\theta$ . With tilt angles increasing from  $9^\circ$  to  $21^\circ$  the dislocation spacing decreased.

Using Franks equation and the observation that dislocations do not overlap at a misorientation of  $21^\circ$  allows to estimate the maximum radius of the dislocation cores,  $r_0 < 1.4b$ .

- [1] Heinemann S et al. (2001) *Phys Chem Minerals* 28, 685  
 [2] Heinemann S et al. (2002) *Beih Eur Mineral* 14(1), 66  
 [3] Frank FC (1951) Pittsburgh Symposium on the Plastic Deformation of Solids. 150

## MR52A-1004 1330h POSTER

## The Effect of Fe Content on the Rheological Behavior of Olivine

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To investigate the influence of iron concentration on the rheological properties of olivine, triaxial compressive creep experiments were performed on fine-grained samples of Fo<sub>50</sub>. Samples were fabricated from a mixture of powders of San Carlos olivine, Fo<sub>90</sub>, and synthetic fayalite, Fo<sub>0</sub>. The fayalite powder was synthesized in a controlled atmosphere furnace from high-purity Fe<sub>2</sub>O<sub>3</sub> and SiO<sub>2</sub> in a molar ratio of 1:1.002. This non-stoichiometric ratio was used to ensure that the samples were buffered by enstatite rather than a binary oxide. The oxide powders (<10 μm) were reacted together in a Ni-covered alumina crucible at 1410 K for 22 h. The resulting fayalite aggregate was ground and again heated, this time at 1450 K for 44 h. This procedure yielded powders that were 99% fayalite. After combining the fayalite powder with San Carlos powder, the mixture was ground to a particle size of <10 μm and annealed at 1670 K for 16h. The resulting Fo<sub>50</sub> material was ground into powder of <10 μm, cold-pressed into a Ni capsule, and hot-pressed at 300 MPa and annealed at 1525 K for 2 h. The final grain size of the resultant sample was ~50 μm. Samples were then deformed in a gas-medium apparatus at a confining pressure of 300 MPa and a temperature of 1475 K. Differential stresses in the range 10 to 200 MPa resulted in strain rates between 10<sup>-7</sup> and 10<sup>-4</sup> s<sup>-1</sup>.

The samples were deformed in the dislocation creep regime, as indicated by the stress exponent of 3.3 ± 0.2. These Fo<sub>50</sub> samples creep at a rate over a factor of 10 faster than similar samples of Fo<sub>90</sub> deformed under the same conditions. As a result, an iron-rich mantle will be less viscous than Earth's mantle.

## MR52A-1005 1330h POSTER

## Plastic deformation of San Carlos olivine at high pressure

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Pressure dependence of the olivine rheology have profound influence on the dynamics of the Earth. Experimental studies of plastic deformation of San Carlos olivine (Mg, Fe)<sub>2</sub>SiO<sub>4</sub> with two grain sizes (5 micron and 0.5 micron) under upper mantle conditions are reported. Time resolved macroscopic differential stress and strain rates are measured in the large-volume high-pressure apparatus at mantle condition using synchrotron x-ray radiation. Grain size independent flow was observed, suggesting that dislocation creep is the dominant deformation process in the upper mantle. The microstructures of the run products quenched at different condition were investigated by TEM. This TEM investigation confirms that dislocation glide was an active mechanism during the high-pressure deformation experiments. It also identifies an increase of grain-size for fine samples and decrease for coarse samples. The measured differential stress are consistent with the activation volume of 0.5 cm<sup>3</sup>/mol. We also conclude that dynamic recrystallization may play a significant role in assisting olivine plastic deformation in the upper mantle.

## MR52A-1006 1330h POSTER

## Reaction Induced Weakening in Experimentally Deformed Plagioclase-Olivine Aggregates

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We investigated the deformation of plagioclase peridotite under chemical disequilibrium conditions by performing shear deformation experiments on plagioclase-olivine aggregates at 900°C and confining pressures of 1.0 and 1.5 GPa. In An<sub>92</sub>-Fo<sub>92</sub> aggregates the applied confining pressures result in different degrees of overstepping on the mineral equilibria Plg + Ol = Sp + Px and Plg + Ol = Gt + Px and cause chemical reactions. In contrast, An<sub>60</sub>-Fo<sub>92</sub> aggregates are in chemical equilibrium at both of these confining pressures and allow a comparison study of crystal plastic deformation of non-reacting samples.

Mixtures of olivine(2):plagioclase(1) were prepared from 4-10 μm powders of Fo<sub>92</sub>, An<sub>92</sub> and An<sub>60</sub>. The mixtures were placed between dunite pistons cut at 45° to the compression direction. Prior to deformation, the samples were dried at 1000°C for 6-12 hours in a CO<sub>2</sub> gas mixture and hotpressed for 24 hours at 0.75 GPa and 900°C-1050°C. Our experiments were carried out in a Griggs apparatus under a constant shear strain rate of 5 × 10<sup>-5</sup> sec<sup>-1</sup>. Comparison experiments were performed with pure Fo<sub>92</sub>, An<sub>92</sub> and An<sub>60</sub> at 900°C and 1.0 GPa.

In the absence of a reaction, flow stresses for An<sub>60</sub>-Fo<sub>92</sub> or Fo<sub>92</sub> samples could not be determined at 1.0 and 1.5 GPa confining pressure because these samples undergo strain hardening with no yield (up to stresses equal to the confining pressure), or result in crystal plastic deformation of the dunite pistons.

Significant reaction-induced weakening occurs in An<sub>92</sub>-Fo<sub>92</sub> samples and they deform at lower stresses than pure olivine and unreacted samples. These samples have an initial stress peak followed by approximate steady state flow or by strain weakening. The syndeformational reaction between An<sub>92</sub> and Fo<sub>92</sub> results in fine-grained (0.1-0.5 μm) Ol-Sp-Gt-Px reaction products forming along An<sub>92</sub>-Fo<sub>92</sub> phase boundaries. Hydrostatic An<sub>92</sub>-Fo<sub>92</sub> experiments at the same conditions and same total time result in < 5% reaction; thus the reaction appears to be enhanced by differential stress and/or crystal plastic strain energy.

The fine-grained products coalesce and accommodate most of the deformation by granular flow. Large plagioclase and olivine grains (4.0 - 10.0 μm) deform by dislocation creep, hence the reaction is associated with a switch in deformation mechanism from crystal plasticity to granular flow of reaction products.

Shear deformation is highly localized in regions of mineral reaction. Using the auto correlation function a quantitative analysis of the fabric and strain gradients was carried out. Such analysis indicates that the shear strain varies by at least a factor 5 within a single sample. Consequently, the strain rate also varies by at least this magnitude. The heterogeneous distribution of shear strain correlates directly with the reaction progress within the sample. From these observations it is concluded that mechanical weakening depends on reaction progress and increases with finite strain. Thus reaction and deformation appear to be interdependent processes.

## MR52A-1007 1330h POSTER

## Estimation of the timescale for textural equilibrium between liquid iron-sulfide and solid silicate under high pressure

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The determination of whether a liquid iron-alloy can segregate from a solid silicate matrix is a crucial factor in the investigation of terrestrial planet core formation. It is well known that the dihedral angle between liquid iron-alloy and solid silicate controls the connectivity of the liquid iron-alloy. The effects of physical and chemical properties, such as pressure and composition of the liquid, on the dihedral angle have been widely reported in recent years in a range of experimental studies. In such experiments textural equilibrium between the liquid iron-alloy and the solid sili-

cate has to be taken place within the duration of the experiment for the equilibrium dihedral angle to be measured. The timescale for textural equilibrium to occur is not well established, however, especially under high-pressure conditions. In this study, we have determined the dihedral angle between liquid iron-sulfide and olivine crystals as a function of time and estimated the time scale of textural equilibrium at certain P, T conditions. High pressure experiments were performed using Kawai-type and Walker-type multi-anvil apparatuses with LaCrO<sub>3</sub> stepped heaters and graphite capsules. Mixtures of powdered iron-sulfide and synthetic olivine (Mg # = 77) were used as starting materials. We have used two iron-sulfide compositions (Fe<sub>78</sub>S<sub>22</sub> and FeS). Experimental conditions were at 4.6 GPa and 1830 K for FeS and 1960 K for Fe<sub>78</sub>S<sub>22</sub>. Experimental durations were 0.5, 4, 8, 15, 24, 48 hours. Apparent dihedral angles were measured from backscattered electron images of the recovered samples with magnifications of x1200 and x2000. The true dihedral angle was taken to be the median value of the apparent dihedral angle distribution. The distribution of measured angles was close to the theoretical distribution reported by Harker and Parker (1945). The median dihedral angle for the olivine-FeS liquid experiments was observed to decrease with time from 81 (5) degrees after 0.5 hours to a minimum of approximately 65 (5) degrees after 8 hours. This behavior may reflect the time scale for textural equilibrium to be achieved but could also result in part from an increase in the carbon or oxygen content of the sulfide liquid with time.

## MR61A MCC: Hall C Saturday 0830h

## Advances in Mineral and Rock Physics Posters

Presiding: P N Sahay, Centro de Investigación Científica y Educación Superior de Ensenada (CICESE); S Japel, Johns Hopkins University

## MR61A-1021 0830h POSTER

## Synthesis, Characterization and Thermochemistry of K-Na-H3O Jarosites

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Jarosites, AFe<sub>3</sub>(SO<sub>4</sub>)<sub>2</sub>(OH)<sub>6</sub> where A commonly stands for K, Na or H<sub>3</sub>O, are frequently observed in sulfate-rich environments such as acid sulfate soils formed from sulfide sediments, acid mine drainage, and weathering of sulfide ore deposits. Accurate thermodynamic data are required to understand their energetics, determine their conditions of formation and establish precise stability fields. K-H<sub>3</sub>O, Na-H<sub>3</sub>O and K-Na-H<sub>3</sub>O jarosites were synthesized by coprecipitation or hydrothermally and characterized by XRD, FTIR, electron microprobe and thermal analyses. The resulting single phase solid solutions obey Vegard's law. Electron microprobe analyses indicated lower alkali and iron contents, in agreement with thermal analyses, revealing the presence of hydronium and "additional" water. Standard enthalpies of formation were determined by high temperature oxide melt solution calorimetry at 700°C with sodium molybdate 3Na<sub>2</sub>O.4MoO<sub>3</sub> solvent. These enthalpies vary linearly with the K/H<sub>3</sub>O, Na/H<sub>3</sub>O or K/Na ratio. The enthalpy of formation of pure hydronium jarosite was also determined experimentally, and used to evaluate that of the end-members KFe<sub>3</sub>(SO<sub>4</sub>)<sub>2</sub>(OH)<sub>6</sub> and NaFe<sub>3</sub>(SO<sub>4</sub>)<sub>2</sub>(OH)<sub>6</sub>. The enthalpy of dehydration, corresponding to the loss of the "additional" water, of some jarosites was determined to be close to the enthalpy of vaporization of water, suggesting that this "additional" water in jarosites is weakly bound to the rest of the structure. An updated set of "recommended" thermodynamic data for the end-member H<sub>3</sub>O-, K- and Na-jarosites is presented.