Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SIT42-P01 Room:Convention Hall Time:May 22 17:15-18:30

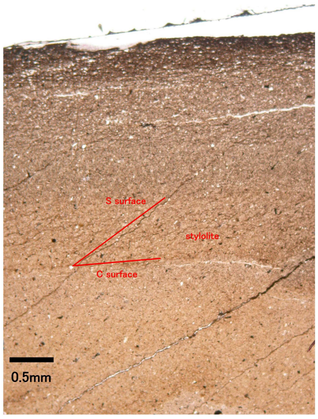
Deformation mechanism of spherical/elliptical sandstone bodies

GOTO, Shigetoshi[1*]

[1]Kyushu Civil Engineering Co.,Ltd.

Spherical blocks (10 cm to 10 m in diameter) and lenticular sandstone bodies (several centimeters to several tens of centimeters) with S-C structure are observed in Shimanto supergroup, Miyazaki Prefecture, southwest Japan. Those are emplaced under rheological conditions with frictional heat caused earthquake on fault.

Keywords: S-C structure, friction solution, rheology transition



Spherical tectonic block 12cm in diameter
(pelagic clay)

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SIT42-P02 Room:Convention Hall Time:May 22 17:15-18:30

Factors controlling entablature formation in columnar joints: Suggestions from the analogue experiments

HAMADA, Ai[1*], TORAMARU, Atsushi[2]

[1]Earth and Planet. Sci., Kyushu Univ., [2]Earth and Planet. Sci., Kyushu Univ.

Columnar joints of lava and ignimbrite have two types of structure within one flow unit: colonnade and entablature. Colonnade have relatively wide, straight and directionally ordered columns, on the other hand, entablature have relatively narrow, curved and disordered columns in different directions. Columnar joints are formed by volume contraction due to temperature decrease during cooling. The fractures in colonnade are thought to develop perpendicular to the isotherm. In entablature, however, how the complex structure is related to the isotherm and what causes such a complex structure is still unclear. It has been well known that in desiccation experiments using starch-water mixtures, structures similar to colonnade form, but structures similar to entablature have not been reproduced so far. Therefore, this study aims at reproducing the entablature structure with additional conditions different from experiments before. We conducted consisting of three experiments: Experiment 1: To reproduce the typical threefold structure: upper colonnade, entablature and lower colonnade, we designed an experimental setup in which water can evaporate from upper and lower surface of mixture by attaching a membrane. The drying rate is controlled by changing the distance between the lamp to the starch surface. For a monotonic drying rate with a constant distance being 10cm, the colonnade structure developed from upper and lower surface. Experiment 2: Under the same condition of Experiment 1, after the colonnade structure developed partially, we suddenly increased the drying rate by shortening the distance between the lamp and the mixture surface from 10cm to 1.5cm. As a result, the colonnade structure developed discontinuously correlating with the sudden change of the drying rate. A curved structure to the rim of the container developed after changing the drying rate. To observe the whole structure by Experiment 2 in detail, we took images by Micro-focus X-ray CT (manufactured by Tesco at 119 micro meter resolution, at Fukuoka Industrial Technology Center). From analysis of images, we found following three facts: 1) the number of fractures suddenly increase after changing the drying rate, 2) the widths of columns, which developed before changing the drying rate, become smaller and 3) the new columns form at the triple or quadruple junctions of cracks constructing columns which developed before changing the drying rate. Experiment 3: To examine the cause that forms a curved structure, we conducted the experiment under the constant drying rate with the distance being 1.5cm. From the images which we took before the mixture dried perfectly, the curved cracks develop perpendicular to an iso-surface of water concentration. From these results, we concluded that a sudden increase in contraction rate forms new columns at the triple or quadruple junctions to release accumulated tensile stress, which remains after the growth of pre-existing cracks. The inhomogeneous concentration distribution with a curved iso-surface results in the formation of curved cracks. We could substantiate the possibility that the entablature structure in columnar joints is caused for the inhomogeneous temperature distribution of rocks. As formation processes of new columns, two cases are expected 1) the case that one column was divided into multiple columns by forming new cracks inside the columns and 2) the case that new columns nucleate at triple and quadruple junction of cracks, although it was difficult to distinguish these two cases with conventional X-ray CTs. In order to closely observe the columns nucleation at triple and quadruple junctions, we use High Resolution 3D X-Ray Microscope VersaXRM-500 (manufactured by Xradia (U.S) at 3.7 micro meter resolution). As a result, it was confirmed that columns nucleations take place at triple and quadruple junction of cracks.

Keywords: columnar joint, analogue experiment, crack, formation process, Micro-focus X-ray CT, 3D X-ray Microscope

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SIT42-P03 Room:Convention Hall Time:May 22 17:15-18:30

Rheological Characteristics Leading to Magma Flow Instability

KUROKAWA, Aika[1*], KURITA, Kei[1]

[1]Earthquake Research Institute, University of Tokyo

During volcanic eruptions alternate transitions between two contrasting states are known to generate oscillatory phenomena. Switching between tremor stage and non-tremor stage and periodic transition between eruption stage and quiescent doom growth stage are typical examples. These should reflect dynamics of magma inside volcanoes, which gives us indispensable information about physics of volcanic eruption. One of the main causes for this transition is instability due to double-valued relation between flow rate and driving pressure. It indicates that two flow rates exist at one pressure and jump between two states causes transition. The origin of this double-valued nature of magma flow has not been clarified yet though volatile-dependent viscosity is suggested. To figure out the dynamics of this transition and physical origin of the double-valued relation, rheology of magma should be a key. ?Similar phenomenon is known as spurt in the fields of polymer science. It is controlled by a jump of flow rate due to the wall friction controlled by the double-valued relation of stress and strain rate. In this phenomenon an abrupt increase in flow rate under certain range of driving pressure is observed.

We focus on rheology of suspension and explore the possibility of the rheology, which has the double-valued nature. In this study PNIPAM aqueous suspension was used as an analogue material of multiphase magma. Since the volume fraction of PNIPAM systematically changes with the concentration of gel powder and temperature, it is possible to measure change of rheology continuously associated with change of the fraction of solid phase. By experiments with controlled shear rate, we revealed the double-valued relation in shear stress and shear rate at certain range of volume fraction of the solid phase. We would like to remark magma has a similar characteristic rheology, which can explain volcanic oscillatory phenomena. This work was collaborated with E.D Giuseppe and A. Davaille.

Keywords: Magma, Rheology, PNIPAN, Instability, Complex fluid

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SIT42-P04 Room:Convention Hall Time:May 22 17:15-18:30

Why the black fault rocks appear black color? -Enrichment and alteration processes of minerals in the fault zones-

OOHASHI, Kiyokazu[1*]

[1]Graduate School of Science, Chiba University

Color of rock including fault rocks is one of the important material properties, which is affected by its condition, mineralogy, elements and so on. Black-colored fault rocks frequently found from the intensely-comminuted fault core in different faults (e.g., the Median Tectonic Line, the Tanakura Tectonic Line, the Atotsugawa fault system and the Chelungpu fault). However, origin for black color is still unknown since the coloring agent for each black fault rocks is not examined up to now. I thus performed detailed material analyses and color measurement with spectrophotometer to determine the coloring agent for the black fault rocks.

Keywords: Graphite, Carbon, Black fault rock, Elemental mobilization

SIT42-P05 Room:Convention Hall Time:May 22 17:15-18:30

Rheological crossover within the framework of rate- and state-dependent friction

HATANO, Takahiro[1*]

[1]ERI, University of Tokyo

We derive the rate- and state-dependent friction law starting from creep constitutive laws for a true contact patch. Consequently, the microscopic expressions for phenomenological parameters are obtained that govern the velocity dependence of steady-state dynamic friction. We show that positive velocity dependence is unlikely if the sliding and frictional healing (due to uniaxial compression) are accommodated by the same creep mechanism. We also show that friction may exhibit positive velocity dependence if the frictional healing is dominated by pressure solution.

Keywords: rate- and state-dependent friction, creep, pressure solution

SIT42-P06 Room:Convention Hall Time:May 22 17:15-18:30

LPO development of single crsytals of wet synthetic quartz sheared at low temperature

KANEKO, Hideaki[1*], MUTO, Jun[1], NAGAHAMA, Hiroyuki[1]

[1]Inst. Geol. Paleontol., Tohoku Univ.

Shear zone develops through strain softening of rocks during progressive deformation. One of the strain softening mechanisms is geometrical softening caused by crystal changes its orientations for easier slip system. Geometrical softening causes development of lattice preferred orientation (LPO) closely related to dynamic recrystallization.

The mechanism of dynamic recrystallization of quartz which is a common crustal mineral is separated into regimes 1-3 by increasing the temperature and decreasing the strain rate. The c axis LPO of quartz changes from a crossed-girdle LPO to Ymax LPO with increasing the temperature and strain (Hirth and Tullis, 1992JSG).

Heilbronner and Tullis (2002Geol. Soc. Spec. Publ.) conducted general shear experiment in each of the three dislocation creep regimes of Hirth and Tullis (1992JSG) and examined the LPOs in each regime. Heilbronner and Tullis (2006JGR) sheared quarzite samples experimentally at regime 3 conditions of Hirth and Tullis (1992JSG) where grain boundary migration is the dominant recrystallization mechanism, and examined the changes in c axis LPO with increasing shear strain and degree of recrystallization. Muto et al. (2011JGR) have undertaken an experimental study using single crystals of wet synthetic quartz to investigate the development of LPO in dynamically recrystallized grains and its effect on the flow strength of quartz aggregates. They observed that domains of recrystallized grains with a Y max LPO developed at moderate to high shear strain in all cases by grain boundary migration.

Although Heilbronner and Tullis (2006JGR) and Muto et al. (2011JGR) clarified that the effect of dynamic recrystallization on LPO development in regime 3 conditions, the effect of dynamic recrystallization in lower temperature where sugrain rotation is the dominant recrystallization mechanism is not clear yet because Heilbronner and Tullis (2002) have used the natural quartzites. The use of single crystals of known initial crystallographic orientations makes it possible to determine relationships between the initial crystallographic orientation and those of recrystallized grains.

In this study, we conduct general shear experiments in a Griggs apparatus using single crystals of synthetic quartz in order to investigate the development of LPO in dynamically recrystallized grains at a low temperature where subgrain rotation is a dominant recrystallization mechanism.

Experiments are conducted at Pc=1.5 GPa, P=600-700oC at a constant strain rate of 10-5 /s. Starting materials oriented to activate three main slip systems are sandwiched by alumina pistons that cut at 45o from the maximum compression direction. Before experiment, water content of samples are measured by FTIR analysis. After deformation experiments, crystallographic orientations were measured using EBSD analysis. We investigate the development of LPO of recrystallized quartz aggregates in three different initial orientations with increasing shear strain and degree of recrystallization.

The basal<a> sample (gamma ˜ 0.7, no recrystallization) show the c axis LPO of a symmetric single broad peripheral maximum, rotated 35o with the sense of shear. Other basal<a> sample deformed to gamma ˜2.5 shows strain hardening after yielding at gamma ˜1. Its c axis LPO has a symmetric single broad peripheral maximum, rotated 90o with the sense of shear from initial Z axis to X axis. This indicates that the shear deformation and thinning rotates crystal that causes the activation of hard prism[c] slip system. The prism<a> sample deformed to gamma ˜2.5 becomes steady state with a flow stress of 300MPa after yielding at gamma˜0.5. In the presentation, we will show the experimental results on the LPO development in three different initial orientations as a function of strains and degree of dynamic recrystallizations.

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SIT42-P07 Room:Convention Hall Time:May 22 17:15-18:30

Deformation experiment on synthetic polycrystalline anorthite: effect of water

FUKUDA, Jun-ichi[1*], MUTO, Jun[1], NAGAHAMA, Hiroyuki[1]

[1]Department of Earth Sciences, Graduate School of Science, Tohoku University

Feldspar is a major constituent of the crust as well as quartz. The rheology of the middle-lower crust is mainly governed by that of feldspar. Therefore, the deformation mechanisms of feldspar have been investigated from analyses of natural samples and by deformation experiments. Plastic deformation of materials including feldspar is broadly classified into two main mechanisms; grain-size-sensitive creep (dislocation creep) and grain-size-insensitive creep (diffusion creep and grain boundary sliding). The former mechanism exhibits lattice preferred orientation (LPO) and the latter does not.

It is well known that increasing water contents in polycrystalline feldspar promote plastic deformation, as reported in Dimanov et al. (1999, JGR) and Rybacki et al. (2006, JGR). However, capability of a pressure range by a gas a gas (Paterson-type) deformation apparatus used in their studies is limited up to 400 MPa. Therefore, a solid-medium deformation apparatus should be used to investigate the middle-lower crustal condition, where water circulation is important as suggested in recent tomographic studies. Also, H2O fluid easily diffuses into a polycrystal through grain boundaries as fast mass paths. Then, the subsequent solution-precipitation process may occur, as inferred from grain morphologies and development of LPO controlled by the solution-precipitation process (Vernooij et al., 2006 Tectonophysics for quartz; Heidelbach et al., 2000, JSG for feldspar). Therefore, the effects of water on e.g., transition from brittle deformation to plastic deformation, and relationship between stress/strain and deformation mechanisms should be quantitatively determined.

In this study, we focus on the middle-lower crustal conditions, external influx of water, and polycrystalline feldspar, and performed following deformation experiments. Shear and axial deformation experiments were conducted for initially dry feldspar samples with water added using a Griggs-type deformation apparatus. The temperature and confining pressure are up to 950 C and 1 GPa. As a starting material, fine-grained (<5 um) glass powders with the composition of anorthite 100 were sintered in vacuum at 1400 C during 4 hours. Then, polycrystalline anorthite with a grain size less than 5 um were prepared. Electron backscattered diffraction (EBSD) measurements revealed that crystallographic orientations of the synthesized polycrystalline anorthite were random, although elongated grains with the aspect ratio of up to 2 were observed in a band contrast image. Observation of sample morphology shows that pores up to 1 um are present at grain junctions. Infrared (IR) spectroscopy revealed that the sample is dry without water absorption bands. Using these samples, 0.1-0.5 wt % water was introduced into the sample by adding distilled water or by dehydration of pyrophyllite powders at high pressure and temperature. After the deformation experiments, concentration of interference color at 300 um from the sample edges were observed under a polarized optical microscope with a gypsum plate, indicating development of LPO. Pores were not recognized in these regions. These observations indicate that plastic deformation occurred due to introduction of water into the sample. In the IR spectra for this region, water absorption bands due to zoisite, which must be produced as a reaction product under differential stress, were recognized. The creep mechanisms of feldspar, which are dominated during deformation due to water distribution will be determined from electron backscattered diffraction (EBSD) analyses and observations of grain morphologies. We will discuss changes in stress/strain due to introduction of water into the sample, and relationship between water distribution and deformation mechanisms.

Keywords: anorthite, water introduction, Griggs deformation apparatus, EBSD analysis, infrared spectroscopy

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SIT42-P08 Room:Convention Hall Time:May 22 17:15-18:30

FABRICATION OF HIGHLY DENSE AND FINE-GRAINED POLYCRYSTALLINE ANORTHITE BY VACUUM SINTERING

KOIZUMI, Sanae[1*], HIRAGA, Takehiko[1]

[1]Earthquake Research Institute, University of Tokyo

Introduction: In laboratory measurements of physical and chemical properties of the earth's lower crust, highly dense polycrystalline aggregates of major constituent minerals such as anorthite ($CaAl_2Si_2O_8$) are required. For precise measurements of these properties, the aggregates should have (1) high density, (2) fine grain size (to escape from cracking during quenching), (3) homogeneous microstructure, (4) controlled sample shape and size, and (5) controlled chemistry. We have developed a technique to synthesize anorthite aggregates which meet the above conditions.

Experimental: We used nano-sized powders of SiO_2, Al_2O_3, $CaCO_3$ and $Mg(OH)_2$ as starting material to synthesize single phase aggregates of anorthite and, two phase composite of anorthite + diopside and anorthite + quartz. Those powders were mixed to provide a resulting mole ratio of CaO, Al_2O_3, SiO_2, and MgO to obtain desired mineral assemblies. Densified aggregates were obtained through the following stages: calcination, forming and sintering. The final materials were characterized with X-ray powder diffraction (XRD) and secondary electron microscopy (SEM).

Results and Discussion:

Anorthite: Calcineation was conducted under temperature of 670-970oC with fixed duration of 30-180 min. Coalescence of the powder was observed $>$ 820oC, which was revealed by SEM. XRD result indicates that decarboxylation of anorthite solid state reaction completes at $>$ 770oC for 90 min. For sintering, a temperature of 1210-1260oC with controlled time can provide essentially full dense aggregates of anorthite with an average grain size of 1.7 micro m and porosity of 0.2 vol%.

Two-phase materials (anorthite + diopside): Diopside grains of 10 vol% was introduced to anorthite aggregates. Calcination at 770oC for 30 min and sintering at 1200oC for 50h were found to be the best conditions so far to synthesize highly dense aggregates. Average grain sizes of 1.6 micro m and 0.8 micro m were detected for anorthite and diopside grains, respectively. Density of 99.6% was achieved.

References: S. Koizumi et al., Phys. Chem. Miner. 37, 505-518 (2010)

Keywords: lower crust, anorthite, grain size, sintering

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SIT42-P09 Room:Convention Hall Time:May 22 17:15-18:30

Anisotropic strength and deformation behavior of antigorite serpentinite

URATA, Yoshito[1*], ANDO, Jun-ichi[1], SODA, yusuke[2]

[1]Department of Earth and Planetary Systems Science, Graduate School of Science, Hiroshima University, [2]Frontier Science Organization, Kanazawa University

Introduction: Resent seismic wave analysis suggest that serpentinite exists along the subducting plate. Serpentinite is important to understand about subducting oceanic plate and high-pressure metamorphic rocks. Most Antigorite serpentinite which exist on the ground show lattice preferred orientation and they have foliation. Maximum strength of the rock with foliation varies with the angle between maximum compressional axis and foliation. This angle is said to be Azimuth. Deformation experiment using the metamorphic rock, peak of the maximum strength is when Azimuth is 0 degrees and 90 degrees, and least at 30˜45 degrees.(Nasseri et al., 2003) The value of strength decrease from peak to least differ from metamorphic rocks. The biggest strength decrease seen in the experiment is 75% at phyllite and the smallest is 11% at biotite schist. In this study, we have conducted axial compression deformation experiment using the solid state pressure deformation experiment apparatus to investigate the strength decrease and azimuthal anisotropy of serpentinite with foliation and lattice preferred orientation. And observed about the recovered samples to clarify the characteristics of plastic deformation of Antigorite.

Experimental: We have conducted constant strain rate experiment of Antigorite serpentinite, in order to understand the effect of microstructural anisotropy on deformation behavior. The sample is naturally deformed foliated Antigorite serpentinite which is characterized by preferential arrangement of (001) of Antigorites parallel to the foliation. We prepared three types of oriented starting samples, whose foliations were set at 0 degrees, 30 degrees and 90 degrees with respect to the axial stress. Experimental conditions were 500 C temperature at 1 GPa confining pressure with 500 um/h displacement rate of piston.

Results and Discussion: Maximum strength of the sample 30 degrees is lower than that of 0 degrees and 90 degrees.(Strength decrease is seen.) The experimental data indicate that the maximum strength of 0 degrees is 40 % bigger than that of 90 degrees, and 90 degrees is 35 % bigger than that of 30 degrees. Suggested from the micro-structure observation, sliding occurs along the foliation at sample 30 degrees and begin to fold since it cannot slide any more bound by upper and lower pistons. There is small plastic deformation area at sample 0 degrees that stress drop is suggested to be occur by brittle fracture. Those of 90 degrees were due to plastic deformation of antigorite itself and extensional breakage of antigorite grains, respectively. These experimental result show that serpentinite has very strong azimuthal dependence. Noticeable stress drop could occur at subducting plate in case serpentinite has lattice preferred orientation by shear stress.

Keywords: Antigorite Serpentinite, Deformation Experiment, SEM, Deformation Mechanism

SIT42-P10 Room:Convention Hall Time:May 22 17:15-18:30

Coalescence and Zener pinning of mineral grains in mylonite

HIRAGA, Takehiko[1*], MIYAZAKI, Tomonori[1], TASAKA, Miki[1], YOSHIDA, Hidehiro[2]

[1]Earthquake Research Institute, University of Tokyo, [2]National Institute of Material Science

Recently, we have succeeded in demonstrating true superplasticity in geological materials (Hiraga et al. 2010). Superplastic deformation is commonly considered to proceed via grain boundary sliding (GBS) which results in grain switching in the samples. As a result, initial equigranular shape of grains can be remained even after severe deformation of the sample, which is one of the characteristic microstructure of superplastically deformed materials. Further, due to large contribution of intergranular deformation on total strain, development of crystallographic preferred orientation in the materials is not expected either. Thus, it is very difficult to recognize the operation of GBS in microstructure of the deformed rocks. Hiraga et al. (2010) showed coalescence of periclase grains almost perpendicular to the tensile direction after superplastic deformation in forsterie + periclase aggregates, although the paper focused on the deformation enhanced grain growth during superplastic deformation. Here we present more details of the coalescence microstructure and compare it with that of ultramylonite, often considerd to have deformed by GBS creep. We show the microstructures of coalascence of similar mineral phases and Zener controlled grain sizes. Such observations indicate pervasive operation of GBS in the earth's mantle and crust.

Keywords: Mylonite, Grain size, Coaelescence, Zener relation, Superplasticity

SIT42-P11 Room:Convention Hall Time:May 22 17:15-18:30

Exploration of microstructure induced by ultra low strain rate in mantle derived olivine

YAMAMOTO, Takafumi[1*], ANDO, Jun-ichi[1], OHFUJI, Hiroaki[2], MORISHITA, Tomoaki[3], TOMIOKA, Naotaka[4], WATANABE, Katsuaki[5]

[1]Department of Earth and Planetary Systems Science, Hiroshima University, [2]Geodynamics Research Center, Ehime University, [3]Frontier Science Organization, Kanazawa University, [4]Institute for Study of the Earth's Interior, Okayama University, [5]Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

Kitamura et al. (1986) and Ando et al. (2001) found Fe concentration on dislocation core created in olivine grains of deformed alpine type peridotite. They believe that the Fe concentration occurs during dislocation creep at very low strain rate condition in the upper mantle. This phenomenon is known as Cottrell atmosphere in the material science. On the basis of this detection phenomenon, they demonstrate that the study of ultra low strain rate effect on olivine plasticity is a very important to understand the dynamics of the upper mantle.

We try to confirm whether Fe concentration on dislocation core is a common phenomenon in deformed olivine grains of mantle derived peridotite. We are now observing microstructures of three types of peridotite, namely xenoliths from basalt and kimberlite and alpine, by using optical microscopy, EPMA, EBSD, TEM, ATEM, and STEM technique.

We obtained presently the following results. The Fe concentration is detected in the alpine type peridotites collected from Uenzaru, Horoman and Oman, but not in the xenoliths of basalt collected from Takashima, Megata, Kurose and Salt Lake. Microstructural observations can explain the later result by three different possibilities: Fe concentration on dislocation core is not occurred in olivine grains 1) in whole upper mantle, 2) only in the high stress (namely high strain rate) region of the upper mantle, and 3) it diffused away due to static recovery in basaltic magma.

Reference : Ando et al. (2001) Nature, 414, 893. Jung et al. (2006) Tectonophysics, 421, 1. Kitamura et al. (1986) Proc. Japan Acad., 62, 149.

Keywords: Olivine, Cottrell Atmosphere, Dislocation Creep, Lattice Preferred Orientation

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SIT42-P12 Room:Convention Hall Time:May 22 17:15-18:30

The compression experiments on forsterite-melt system

SUEYOSHI, Kenta[1*], HIRAGA, Takehiko[1], MIYAZAKI, Tomonori[1]

[1]Earthquake Research Institute,The University of Tokyo

It is known that the earth mantle has anisotropy in seismic wave velocity (Tanimoto and Anderson, 1984). Fast direction of the wave propagation corresponds approximately to the direction of the plate motion, indicating that the mantle anisotropy is originated from the mantle flow. As the mantle flow, olivine crystallographic axes might align to the specific direction resulting in the formation of anisotropy in the wave velocity. Partial melt can be present where the olivine deforms significantly in the mantle so that it is required to know how olivine grains acquire lattice preferred orientation (LPO) under the presence of melt experimentally.

We conducted compression creep experiments on forsterite + anorthitic melt samples with a dimension of ph10*10mm. We used an Instron type deformation testing machine equipped with a vertical furnace. Temperature condition of 1270 degrees(Celsius) and strain rate of 10^(-6~-8)/s were used. During the experiment, most of the samples exhibited the strain hardening. Microstructure observations after the tests revealed the occurrence of the significant grain growth during the tests. We attribute the hardening to the increase of the grain size. The samples demonstrated strain weakening after the hardening stage. Such weakening is possibly due to the crack formation in samples. After the deformation, well polished sample sections were prepared for SEM/EBSD analysis. We found b-axis alignment of forsterite parallel to the compression direction. Since creep strength of the sample is grain size sensitive, the samples are estimated to have deformed via diffusion creep mechanism. LPO development under the deformation mechanism should be explored.

Keywords: forsterite-melt system, EBSD, creep, LPO

SIT42-P13 Room:Convention Hall Time:May 22 17:15-18:30

Superplasticity in hydrous melt-bearing dunite: Implications for shear localization in Earth's upper mantle

OHUCHI, Tomohiro[1*], NISHIHARA, Yu[2], KAWAZOE, Takaaki[1], SPENGLER, Dirk[3], SHIRAISHI, Rei[4], SUZUKI, Akio[4], KIKEGAWA, Takumi[5], OHTANI Eiji[4]

[1]Geodynamics Research Center, Ehime University, [2]Senior Research Center, Ehime University, [3]Institute of Earth and Environmental Sciences, Potsdam University, [4]Department of Earth and Planetary Materials Science, Graduate School of Science, Tohoku University, [5]Photon Factory, High Energy Accelerator Research Organization

The rheological properties of olivine, the major constituent mineral in Earth's upper mantle, control the dynamics of the upper mantle. Many experimental studies have been performed on the plastic flow behaviors of olivine at high temperatures (i.e., temperatures at the upper mantle) and low pressures (< 0.5 GPa) (e.g., Durham and Goetze, 1977). Previous studies showed that the plastic flow of olivine at high temperatures (T > 1500 K) is controlled by two creep mechanisms, power-law dislocation creep and diffusion creep (e.g., Karato et al., 1986). Some authors argued that other creep mechanisms such as dislocation-accommodated grain boundary sliding and diffusion-accommodated grain boundary sliding also play an important role in the upper mantle (e.g., Hirth and Kohlstedt, 1995). Both of them (dislocation- and diffusion-accommodated grain boundary sliding) are often termed as superplasticity. It has been reported that superplasticity may dominate the plastic flow of minerals in some parts of the Earth (glaciers: Goldsby and Kohlstedt, 2001; shear zones in the lower crust: e.g., Behrmann and Mainprice, 1987; shear zones in the upper mantle: Hiraga et al., 2010; lower mantle: Karato et al., 1995).

It has been reported that intergranular melt/fluid phases decrease the creep strength of olivine. In the olivine-basalt system, power-law dislocation creep and diffusion creep are enhanced by the presence of a melt phase (Mei et al., 2002). Moreover, it has been reported that grain boundary sliding (GBS) dominates the deformation of olivine in the olivine-basalt system with a high volume fraction of melt (> 4 vol.%) (Hirth and Kohlstedt, 1995). Similar observations have been reported in aqueous fluid-bearing peridotites (McDonnell et al., 2000). It is known that the dihedral angle between olivine and fluid decreases with pressure (Mibe et al., 1999; Yoshino et al., 2007), which shows a reduction in the solid-solid grain boundary area with increase in pressure. Thus, a significant weakening of olivine aggregates by addition of fluids is expected at high pressures. However, the effects of intergranular fluids on the creep strength of olivine aggregates have not been evaluated at high pressures (pressure range in previous studies: 0.3-0.6 GPa).

In order to explore the rheological properties of fluid-bearing dunite (i.e., olivine aggregate) under the conditions of Earth's upper mantle, we conducted deformation experiments on hydrous melt-bearing dunite (olivine + 4 vol.% orthopyroxene + 4 vol.% clinopyroxene with less than 2.5 vol.% of the melt phase) were conducted at pressures of 1.3-5.7 GPa and temperatures of 1270?1490 K. The strain rate was proportional to steady-state creep strength to the 2.1 power, and the creep strength markedly increased with increase in grain size. Developments of the crystallographic preferred orientation of olivine and flattening of olivine grains were hardly observed even after 33?55 % shortening of the samples. These observations show that grain boundary sliding (GBS) dominated the deformation of olivine (i.e., superplasticity). The creep strength of hydrous melt-bearing dunite was 2?5 times lower than that of melt-free dunite. Superplasticity is the dominant creep mechanism of olivine in fluid-bearing fine-grained peridotites under low-temperature and high-stress conditions (i.e., peridotite shear zones in the upper mantle). Superplasticity induced by geological fluids would play an important role in the shear localization (and thus initiation of subduction) in the upper mantle.

Keywords: olivine, hydrous melt, grain boundary sliding, superplasticity, shear localization, subduction

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SIT42-P14 Room:Convention Hall Time:May 22 17:15-18:30

Simultaneous analysis of strain and texture of polycrystalline materials using two-dimensional X-ray diffraction pattern

SETO, Yusuke[1]*

[1]Kobe Univ. Sci.

Angle dispersive powder X-ray diffraction experiments using a two-dimensional area detector are one of the most powerful methods for Earth material sciences, particularly under high pressure conditions. A two-dimensional intensity distribution on Debye rings immediately involves information of the number of crystallites, lattice preferred orientation (LPO) and lattice strains under stress; i.e. the number of crystallites is directly related with the spottiness on the Debye rings. When a LPO is developed, diffracted intensities along the Debye rings show circumferential oscillations unique to a manner of the three-dimensional orientation distribution. The effect of lattice strain appears in elliptic distortions of the each ring or a deviation of the original crystallographic geometry between rings. These are substantial factors of the bulk physical properties of a polycrystalline material, including seismic velocity, thermal/electric conductivity and so on, but in many cases the quantitative treatments have not yet been developed into a standard technique.

In the present study, the author developed a software code, which simulates a two-dimensional diffraction pattern based on given experimental parameters (e.g. wave length, beam convergence, camera length, pixel size of a detector, and so on) and (poly)crystalline properties (crystal structure, crystallite number, size, orientation distribution, lattice strain and so on). Through the simulation, the effect of the parameters on the diffraction pattern can be quantitatively and visually estimated. Furthermore, to find the orientation distribution and the lattice strain from the observed diffraction pattern, a fitting procedure is incorporated into the code as follows: The software initially generates a large number (10^6-10^7) of crystallites with random orientation under a strain-free condition, evaluates the residual of the simulated/observed patterns, and then iteratively modifies the orientation distribution and stress condition. In each iterative step, randomly selected crystallites (0.1-1.0 %) are roughly orientated toward a randomly generated direction, and the modified distribution are (or not) adopted if the residual becomes small (or large). Components of stress tensor are also modified at several intervals. By repeating the iteration step many times ($>10^5$), the simulation seems to converge to a certain condition. A pole figure (density map of a crystallographic axis or plane direction) can be calculated from the obtained orientation distribution. The fitting procedure was applied for several actual diffraction patterns from in-situ uniaxial compression experiments, and its validity was confirmed.

Keywords: X-ray powder diffraction, lattice preferred orientation, lattice strain, two-dimensional detector, polycrystalline material

SIT42-P15 Room:Convention Hall Time:May 22 17:15-18:30

Brine distribution in halite rocks - Inference from measured electrical conductivity

KITANO, Motoki[1*], WATANABE, Tohru[1]

[1]Department of Earth Sciences, Faculty of Science, University of Toyama

Intercrystalline fluid can significantly affect rheological and transport properties of rocks. Its influences are strongly dependent on its distribution. The dihedral angle between solid and liquid phases has been widely accepted as a key parameter that controls solid-liquid textures. The liquid phase is not expected to be interconnected if the dihedral angle is larger than 60 degrees. However, observations contradictory to dihedral angle values have been reported. The grain boundary fluid coexists with a positive dihedral angle. Similar thin fluid films might exist in grain boundaries of crustal materials, and play important roles in crustal processes. In order to understand the nature of grain boundary fluid, we measured electrical conductivity of synthetic wet halite rocks at various temperature and pressure conditions.

Halite-water system is used as an analog for crustal rocks. The dihedral angle has been studied systematically at various pressure and temperature conditions. The dihedral angle is larger than 60 degrees at lower pressure and temperature. It decreases to be less than 60 degrees with increasing pressure and temperature. A sample is prepared by cold-pressing (140MPa for 20 minutes) and annealing (T=160C and P=180MPa for 20 hours) of wet NaCl powder. Grains are polygonal and equidimensional with diameters of 50-100 micrometers.

Experiments are performed using a conventional cold-seal vessel with an external heater. The pressure medium is silicon oil (viscosity=0.1 Pa s). Dimensions of a sample are 9 mm in diameter and 7 mm in length. Viton is used as a jacketing material. Platinum electrodes are placed at both ends of the sample. The confining pressure of 30 MPa is first applied to a sample, and then the temperature is increased to 120C and kept for 5days. The temperature is then changed to 180C (162C@sample) and 140C (126C@sample). Electrical impedance of the sample is measured at different pressures. Impedance measurements are made with an LCR meter (NF ZM2353) (40Hz to 200kHz), and a lock-in amplifier (SRS SR830) and a current amplifier (SRS SR570) (40mHz to 400Hz). Debye-type impedance spectra are observed, to which a parallel array of a capacitor and a resistor can be applied as an equivalent circuit. Measured resistance is converted to conductivity.

Measured conductivity is higher than the conductivity of NaCl by 2-3 orders of magnitude, implying that the electrical conduction is dominated by that through brine. Quasi-stationary conductivity observed at T=180C is almost independent of the pressure. This is consistent with a slight change in the dihedral angle with the pressure. The connectivity of brine should mainly be governed by the triple junction tubes, which are difficult to deform. If the interconnection is governed by grain boundary fluid films, the conductivity should be very sensitive to the pressure increase.

The progressive decrease in conductivity at 140C and $P<50$MPa reflects the increase in the dihedral angle, while the increase in conductivity at 100MPa the decrease in the dihedral angle.

Even at conditions of the dihedral angle larger than 60 degrees (e.g., T=140C, P=30MPa), brine is interconnected. However, we cannot say that connected paths are stable or not. No stationary value is observed. Longer runs should be done to study the connectivity of brine at lower temperature and pressure conditions.

Keywords: electrical conductivity, halite rocks, dihedral angle, grain boundary fluid, fluid distribution

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SIT42-P16 Room:Convention Hall Time:May 22 17:15-18:30

Experimental study of seismic attenuation by using a rock analogue

KARASAWA, Fumiya[1*], TAKEI, Yasuko[1]

[1]Earthquake Research Institute, University of Tokyo.

The purpose of this study is to investigate the high-temperature anelasticity of rocks in the seismic frequency range. In order to estimate temperature anomaly and melt distribution in the upper mantle quantitatively by inversion analyses of three dimensional seismic velocity structures, it is absolutely necessary to understand the anelasticity of mantle rocks in detail. Anelasticity is the transitional property between elasticity and viscosity. Change of seismic velocity is caused both by the anharmonic effect and the anelastic effect. The former can be evaluated quantitatively but the latter can not. To better understand the anelastic effect, it is important to measure anelasticity as functions of frequency, temperature, grain size and melt fraction. By using custom fabricated forced oscillation apparatus[Takei et al., 2011], we have measured the viscoelastic properties of polycrystalline organic borneol as an analogue to mantle rock.

In previous studies[McCarthy et al., 2011; McCarthy and Takei, 2011], dispersion of Young's Modulus E and spectrum of attenuation Q^{-1} were measured as functions of temperature, grain size and melt fraction over abroad frequency range ($10^{-4} < f$ (Hz) < 2.15). Using viscosity n measured at each temperature, grain size and melt fraction, the Maxwell frequency $f_M = E_U/n$ was calculated, where E_U represents the unrelaxed Young's modulus measured at ultrasonic frequency. When Q^{-1} spectrum was plotted as a function of normalized frequency f/f_M, all Q^{-1} spectra collapsed onto a single master curve. The Q^{-1} spectra obtained from olivine aggregates[Gribb and Cooper, 1998; Jackson et al, 2002] also collapsed onto the same master curve, when plotted as a function of f/f_M. This efficiency of the Maxwell frequency scaling strongly suggests that the dominant mechanism of anelasticity in the experimental frequency range is "diffusionally accommodated grain boundary sliding". However, the seismic frequencies normalized by the Maxwell frequency in the mantle are considerably higher than the experimentally measured frequencies. Therefore, experiments at higher frequencies, lower temperatures and larger grain size would be needed.

In this study, in order to measure anelasticity at higher normalized frequency, we have modified the apparatus by using high-speed displacement maters that handle higher sampling rate, and low temperature incubator. At higher frequency, lower temperature and/or larger grain size, Q^{-1} of the sample is low. In order to measure low Q^{-1} accurately, we found it important to improve the rigidity of the apparatus. Also, small time delay of load and displacement maters comes to the issue. So we have to measure the delay accurately. The effect of the delay on attenuation is nonnegligible at high frequency. Based on the result of this calibration, we will check the validity of the high frequency part of the Q^{-1} spectrum in our previous study.

References:

Takei, Y., K. Fujisawa, and C. McCarthy, 2011, JGR, 116, doi:10.1029/2011JB008382
McCarthy, C., Y. Takei, and T. Hiraga, 2011, JGR, 116, doi:10.1029/2011JB008384
McCarthy, C., and Y. Takei, 2011, GRL, 38, doi:10.1029/2011GL048776
Gribb, T. T., and R. F. Cooper, 1998, JGR, 103
Jackson, I., J. D. Fitz Gerald, U. H. Faul, and B. H. Tan, 2002, JGR, 107, doi:10.1029/2001JB001225

Keywords: anelasticity, seismic attenuation

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SIT42-P17 Room:Convention Hall Time:May 22 17:15-18:30

Estimates of internal friction by Sompi spectral analysis for resonant sphere spectroscopy

YAMAMOTO, Megumi[1*], YAMAMOTO, Akihiko[1], OHNO, Ichiro[1]

[1]Ehime University

The Reasonant Sphere Technique (RST) is a powerful tool to measure elastic and anelastic properties of a solid sample. In RST, free oscillations of the sample are excited by impulsive input, and the output waveform data are acquired as a function of time(FT method). Generally, the resonant spectrum has been obtained by spectral analysis using Fast Fourier Transform (FFT) in which the degree of dissipation of the vibration energy (internal friction) is measured by the broadening of the resonance peaks. As reported in the previous conference of the Japan Geosience Union Meeting (Yamamoto et al., 2011), we applied the Sompi method to RST data and determined elastic moduli and internal friction. Yamamoto et al. (2011) concluded that internal friction $Q_{12}{}^{-1}$ of a single crystal MgO by the Sompi spectral analysis demonstrates positive value although our FFT analysis as well as previous works (Sumino et al., 1976; Oda et al., 1994) showed negative values. This suggests that the Sompi analysis for RST may be more effective than FFT technique for estimates of internal friction values. However, we found the strong dependence of internal friction values on the number of modes used for the estimates of internal friction. We acquired the waveform data by changing the force holding the specimen in order to extrapolate to zero-force. The data were analysed by both FFT and Sompi methods, and frequencies and half-widths (FFT)/decaying rates (Sompi) at zero-force were estimated. The modes with enough amplitude and good reproducibility were selected, and the internal friction parameters were estimated according to Sumino et al.(1976). The results show that the errors in internal friction determined using both FFT and Sompi method become smaller than those reported by Yamamoto et al. (2011). The present study suggests that Sompi analysis may be more effective to estimate internal friction.

Keywords: Reasonant Sphere Technique, Sompi method, internal friction, elastic constant