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 [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.

## MR61A-1022 0830h POSTER

## Thermal Conductivity Measurement of Synthesized Mantle Minerals

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Direct thermal conductivity ( $k$ ) measurement of mantle minerals is crucial to constrain the thermal profile of the Earth as well as geodynamic studies of the mantle (e.g., to determine the Rayleigh number). We have embarked on systematic multi-anvil syntheses of dense polycrystalline specimens of mantle phases of adequate size and zero porosity for precise thermal conductivity measurements by the  $3\omega$  method (Cahill and Pohl, *Phys. Rev. B*, 1987) under elevated temperatures ( $T$ ). Coesite and stishovite (see Luo et al., *GRL*, 2002) as well as majorite and wadsleyite have been synthesized; ringwoodite and perovskite are scheduled. Preliminary thermal conductivity measurements at ambient pressure on coesite (120 - 300 K,  $9.53 \text{ Wm}^{-1}\text{K}^{-1}$  at 300 K) are consistent with prior room temperature data (Yukutake & Shimada, *PEPI*, 1978), while our stishovite data at 300 K appear to be low ( $1.96 \text{ Wm}^{-1}\text{K}^{-1}$ ). Efforts are being made to extend the measurement to higher temperatures (e.g., above Debye temperature  $\Theta_D$ ), thus allowing determination of  $k(T)$  relationship (say,  $k \propto T^{-n}$ ); success will depend on the decomposition kinetics of these metastable phases. The pressure dependence of  $k$  of these synthesized samples can also be measured (e.g., Osako et al., *HPMPS-6*, 2002; Xu et al., *EOS*, 2001). Recent thermal conductivity measurement on  $\text{LiF}$  and  $\text{Al}_2\text{O}_3$  from shock wave loading (Holland & Ahrens, 1998) is consistent with the modeling on  $\text{MgO}$  and  $\text{Al}_2\text{O}_3$  (Manga & Jeanloz, *JGR*, 1997) with classical theories. Thus,  $k$  values at modest pressures and  $T$  (say, above  $\Theta_D$ ) would allow extrapolation of  $k$  to appropriate mantle conditions.

URL: <http://www.gps.caltech.edu/~sluo>

## MR61A-1023 0830h POSTER

## Thermal Analyses of Magnesioferrite

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Magnesioferrite spinel (ideally  $\text{MgFe}_2\text{O}_4$ ) was synthesized at 900°C from equimolar amounts of reagent-grade oxides:  $\text{MgO}$  and  $\text{Fe}_2\text{O}_3$ . The cubic unit-cell parameter obtained at room pressure and temperature from an in-house Scintag PAD-X diffractometer is 8.3940(0) Å, space group  $Fd\bar{3}m$ , and  $Z = 8$ . Rietveld structure refinements indicate that the sample has a formula corresponding to  $\text{Mg}_{1.1654}\text{Fe}_{1.8346}\text{O}_4$  or  $(\text{Mg}_{0.2406}\text{Fe}_{0.7594})[\text{Mg}_{0.9248}\text{Fe}_{1.0752}]\text{O}_4$  (parentheses indicate tetrahedral cation sites and square brackets indicate octahedral cation sites).

The thermal expansion of magnesioferrite was determined by in-situ synchrotron X-ray diffraction ( $\lambda = 0.91997$  Å) at room pressure and temperatures ranging from 25 to 982°C on heating, and again on cooling from 982 to 25°C. Data were collected at a rate of about 9.5°C/min, both on heating as well as on cooling. The  $a$  unit-cell parameter increases linearly on heating, however, there is a discontinuity in the thermal-expansion curve at about 500°C. The variation

of the  $a$  cell parameter on cooling is linear and continuous. The  $a$  unit-cell parameters at 25°C obtained before heating [8.3869(5) Å] and after cooling [8.3819(9) Å] are different. Therefore, the above transition is irreversible. Simultaneous differential scanning calorimetry (DSC) and thermogravimetry (TG) data were also obtained on magnesioferrite using a Netzsch STA 449C simultaneous TG-DSC instrument. Data were collected at a heating rate of 10°C/min from 25 to 1400°C, and at the same rate on cooling down to 25°C. The DSC curve for magnesioferrite contains an endothermic peak at 550°C, which corresponds to the Curie temperature of this sample. This peak was absent on cooling the sample, therefore, again this transition is irreversible, as indicated above. The DSC data are in agreement with the thermal-expansion data. Rietveld Structure refinements of the high temperature synchrotron data are in progress.

## MR61A-1024 0830h POSTER

## Structure and Elasticity of Natural Magnetite

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Magnetite ( $\text{Fe}_3\text{O}_4$ ) is ubiquitous in the oxidized portion of Earth's crust and upper mantle, where it forms a solid-solution with spinel-hercynite ( $\text{Mg,Fe}$ ) $\text{Al}_2\text{O}_4$ . Magnetite forms during secondary alteration and diagenesis, as well as in primary igneous genesis, so it occurs in nearly all rock types and the stony meteorites.

We measured the structure, compressibility and elastic constants of a natural single-crystal of magnetite from Urals. Magnetite has the inverse-spinel structure ( $Fd\bar{3}m$ ) with structural formula  $\text{VI}(\text{Fe}^{2+}, \text{Fe}^{3+})_2 \text{IV}(\text{Fe}^{3+}, \text{O}_4)$ . The only general atom-position parameter is the ( $x/a$ ,  $x/a$ ,  $x/a$ ) fractional coordinate of oxygen,  $x = 0.25462(16)$ , determined from a single-crystal X-ray structure refinement of our material. At room pressure, the cell parameter is  $a = 8.39639(14)$  Å, for a calculated density of 5.196(1) g/cm<sup>3</sup>. The cell volume was measured under isothermal compression in alcohol to a maximum pressure of 8.3 GPa using both quartz and ruby for internal pressure calibration. Using pressures calculated from the quartz volume we obtain third-order Birch Murnaghan equation of state parameters:  $V_0 = 592.19(3)$  Å<sup>3</sup>,  $K_{0T} = 180(1)$  GPa, with  $K' = 5.2(4)$ , or  $K_{0T} = 184.1(5)$  GPa when  $K' = 4.0$  is fixed. Using the ruby-pressure scale, we obtain  $V_0 = 592.19(4)$  Å<sup>3</sup> and  $K_{0T} = 182.8(7)$  GPa with  $K' = 4.0$  fixed.

Single-crystal elastic constants are being measured using gigahertz ultrasonic interferometry. In the diamond anvil cell, preliminary P-wave measurements to a maximum pressure of ~7 GPa indicate that the pressure dependence of the  $c_{11}$  elastic constant for magnetite is  $dc_{11}/dP = 5.5(3)$ .

## MR61A-1025 0830h POSTER

## Iron-Nickel Phosphides at High Pressures and Temperatures

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The phosphide minerals schreibersite ( $\text{Fe,Ni}$ ) $\text{}_3\text{P}$ , barringerite ( $\text{Fe,Ni}$ ) $\text{}_2\text{P}$ , and rhadbite ( $\text{Fe,Ni}$ ) $\text{P}$  are found in many iron-nickel meteorites and enstatite chondrites. Many iron meteorites were affected by high pressure impact metamorphism. Also it has been suggested that phosphorous may be one of the light elements in the Earth's core. It is therefore important to assess the behavior of iron-nickel-phosphides at high pressures and temperatures and determine the stability and crystal structures of any high-pressure phases. Iron and nickel phosphides have been synthesized with grain sizes up to about 50 microns and are being studied using both energy-dispersive synchrotron radiation at beamline X-17C, NSLS, Brookhaven National Laboratory and angle-dispersive synchrotron radiation at beamlines 13BM-D and 13ID-D, GSECARS, Argonne

National Laboratory. Pressures ranged to 70 GPa and temperatures to about 2000 degrees C. The ambient-pressure structures of  $\text{Fe}_2\text{P}$  and  $\text{Ni}_2\text{P}$  have been determined to be  $P$ -62m and  $P321$  with lattice parameters of  $a = 5.8748$ ,  $c = 3.4602$ , and  $a = 5.7525$ ,  $c = 3.3268$  angstroms, respectively. Phase changes in both  $\text{Fe}_2\text{P}$  and  $\text{Ni}_2\text{P}$  were observed, and Equations of State are being calculated.

## MR61A-1026 0830h POSTER

Dolomite-II: A new high pressure polymorph of  $\text{CaMg}(\text{CO}_3)_2$ 

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We have measured the infrared spectra and x-ray diffraction of  $\text{CaMg}(\text{CO}_3)_2$ -dolomite to pressures of 50 GPa at 300 K. We observe both splittings and disappearances of x-ray diffraction peaks between 15 and 20 GPa, as well as new bands in the infrared spectrum of dolomite. The onset of the changes in both the x-ray and infrared data appears to be gradual, and thus kinetically impeded; this is consistent with previous shock results. The infrared and x-ray data are consistent with dolomite adopting a calcite-III-like structure. The net volume change associated with the transition based on a calcite-III monoclinic unit cell is 4 percent. We calculate that the high pressure phase of dolomite has a volume virtually indistinguishable from that of magnesite plus aragonite. Similarly, an assemblage of the high pressure phase of dolomite and magnesium silicate perovskite has an essentially volume to a magnesite plus calcium silicate perovskite assemblage. Our results thus indicate that high-pressure polymorphism in dolomite could stabilize  $\text{CaMg}(\text{CO}_3)_2$  in the deep mantle, and thus that high-pressure polymorphs of dolomite could represent the main reservoir for carbon storage within Earth's lower mantle.

## MR61A-1027 0830h POSTER

## Ultra-hard polycrystalline diamond synthesized by direct conversion of graphite using multianvil apparatus

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Occurrence of sintered polycrystalline diamonds, such as carbonado and ballas, has been reported in some diamond mines, although the production rate has been very limited and their origin has been unsolved. These polycrystalline diamonds are most valuable in industrial applications because they are often harder than single crystal diamonds, whose hardness depends largely upon the crystallographic directions. Synthesis of pure polycrystalline diamond, however, has been unsuccessful, whereas single crystal diamond has been produced using some catalysts or solvents by high-pressure synthesis since its success in 1950's. Here, we report the first synthesis of a pure massive polycrystalline diamond by direct conversion of graphite without any catalysts/solvents under static high pressure and high temperature. Thus synthesized diamond at pressures 12-25 GPa and temperatures 2300-2500°C was optically transparent and colorless, and consisted of minute crystals of typically 10<ETH>20 nanometers. Moreover, it was found that the Knoop hardness of the present diamonds is 110-140 GPa, which is higher than those of any known materials, including high quality synthetic type IIa diamond

## MR61A-1028 0830h POSTER

## Microstructures and Superelasticity in Natural Diamond

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Diamonds of distorted shapes from Pipe 50 in China often display microstructures such as densely distributed lamellae, twinned patterns and twin-wedges growing inward from the edge. The latter two probably form precursors to major deformation systems. An X-ray investigation revealed that planar surfaces between the parent diamond and its lamellae are (-111) planes across which the lamellar structure has rotated 39 degrees, forming a "twinning" relation with the parent. This relation is no longer true when we discovered microcrysts of lonsdaleite in the lamellae, apparently derived from martensitic transformation of diamond (austenite). Metal alloy martensites formed during cooling may cause strain induced plasticity and shape distortion, but shape recovery may occur upon heating. Conversion of diamond to lonsdaleite involves very high strains, while the later is reversible if the stress is released. This phenomenon is known as superelasticity. The small amount of residual lonsdaleite remaining in the lamellae indicates that the superelastic property of diamond is quite significant. When complete reversal has restored cubic symmetry to the whole diamond, the only clue to the diamond's transformation history would lie in the distorted shape if the crystal had experienced permanent plastic deformation. This observation is important as we evaluate the mechanical properties of diamond.

#### MR61A-1029 0830h POSTER

##### Single Crystal Raman Spectroscopy and Thermodynamics of Garnet Solid Solutions I: Grossular-Andradite

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Garnets are ubiquitous in the crust and mantle and are key minerals in geothermometry and geobarometry. Macroscopic properties, such as enthalpy and volume, exhibit non-linear behavior in garnet solid solutions. Insights into the cause of the non-linearity of such properties may be found by investigating the effects of compositional variation using a microscopic technique such as vibrational spectroscopy. A further advantage of using vibrational spectroscopy is the ability to probe the effect of small changes in vibrational frequencies on the thermodynamic properties by using vibrational modeling. Investigating the grossular-andradite binary allows the examination of effect of doubling the mass on the octahedrally coordinated cation. Previous infrared spectra of these same natural garnets on the grossular-andradite binary revealed linear variation for most modes versus composition.\* Two modes associated with translations of the octahedral cation were found to display two-mode behavior. We have investigated the same series of garnets by single crystal Raman spectroscopy and find that most of the modes show linear behavior across the series. However, there are also modes that display clear non-linear behavior in the low frequency range, where modes consistently had a lower frequency than expected. The effect of adjusting vibrational models for this non-linear frequency shift as well as the two mode effect will be further discussed. \*McAloon and Hofmeister, Am. Min., 80, 1145-56, 1995

#### MR61A-1030 0830h POSTER

##### Sulfur Speciation and Network Structural Changes in Sodium Silicate Glass: Raman Spectroscopic Study

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Information about the state of sulfur (S) in silicate glasses is important in geo- and material sciences. S dissolves as sulfide in silicate glasses under reduced conditions, whereas it dissolves as sulfate under oxidizing conditions<sup>1</sup>. However, the effects of sulfur speciation on silicate melt structure have not been quantified. Here, we present a systematic study of the relation between S speciation and network structure in sodium silicate glasses by micro-Raman spectroscopy. Nominal compositions of synthesized glasses were Na<sub>2</sub>Si<sub>2</sub>O<sub>5</sub>+S, Na<sub>2</sub>Si<sub>2</sub>O<sub>5</sub>+Na<sub>2</sub>S,

Na<sub>2</sub>Si<sub>2</sub>O<sub>5</sub>+Na<sub>2</sub>SO<sub>4</sub> and Na<sub>2</sub>O+SiO<sub>2</sub>+Na<sub>2</sub>SO<sub>4</sub> along the Na/Si=1.0.

First, S-free sodium silicate glasses were prepared from reagent grade Na<sub>2</sub>CO<sub>3</sub> and SiO<sub>2</sub> at ambient pressure. S-added glasses were loaded in Pt capsules, and held at 1000°C and 1-2kbar for 1h and were quenched to glasses in IHPV. All glasses were clear and no crystals were observed by optical microscope. Glasses were yellow or colorless, however quenched sulfur (2μm) was observed in glasses, and this was eliminated by CS<sub>2</sub>. After this treatment, sulfur contents in glasses were measured by ion chromatography. SKα shift was measured by EPMA. Micro Raman spectra were obtained using both 514.5 nm Ar-ion laser and 532 nm YAG laser radiation. In order to obtain quantitative relationships, we fitted the high frequency envelope to Gaussian lines.

Based on SKα shift systematics, sulfur dissolved mostly as sulfide (> 70%) in native-S added glasses, whereas it dissolved as sulfate in sulfate-added glasses. As for the S-free glass, a strong high frequency peak at 1100cm<sup>-1</sup> can be attributed to the symmetric Si-O stretching of Q<sub>3</sub> species within the glass, and a peak at 950 cm<sup>-1</sup> is caused by Si-O stretching of Q<sub>2</sub> species. Raman bands in the 500-600cm<sup>-1</sup> region are associated with bending vibrations of the Si-O-Si linkage, and these frequencies depend on degree of polymerization of the silicate units<sup>2</sup>.

As for the S-bearing glasses, the intensity of the 950cm<sup>-1</sup> relative to that of 1100cm<sup>-1</sup> peak decreases systematically with increasing S contents, indicating a decrease in the proportion of Q<sub>2</sub> species. The intensity on the high-frequency side of the 1100cm<sup>-1</sup> increased, indicating an increase in the proportion of Q<sub>4</sub> species. These spectral changes show that sulfur causes melt polymerization. This is consistent with a systematic shift of the Si-O bending band (from 571 to 556 cm<sup>-1</sup>).

S may be combined with network-modifying ion, and dissolved according to (1)1/2S<sub>2</sub>(gas)+O<sup>2-</sup>(melt) <=> 1/2O<sub>2</sub>(gas)+S<sup>2-</sup>(melt) or (2) 1/2S<sub>2</sub>(gas)+3/2O<sub>2</sub>(gas)+O<sup>2-</sup>(melt) <=> SO<sub>4</sub><sup>2-</sup>(melt). These equations are consistent with previous experiments of S solubility<sup>3</sup>. The same applies to sulfate-bearing glasses, and there is little difference between sulfide and sulfate as far as degree of polymerization. As for S-bearing glasses, the peak at 990cm<sup>-1</sup>, which is related to sulfate, was also observed. However, there was no relation between S content and peak intensity, because fO<sub>2</sub> and fS<sub>2</sub> were not controlled. The degree of network structural change depends on S contents in S-bearing silicate glasses, and seems to be independent of S speciation.

<sup>1</sup>Fincham C.J.B. and Richardson F.D. (1954)  
<sup>2</sup>McMillan P. (1984) <sup>3</sup>Nagashima S. and Katsura T. (1973)

#### MR61A-1031 0830h POSTER

##### Temperature Induced Crystallization of Amorphous Silica at High Pressures

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Silica is a major component of the Earth's interior. The study of the high-pressure behavior of its different phases plays a significant role for understanding the Earth's deep interiors. Various types of polymorphism in silica are possible at high pressures. A number of post-stishovite phases at higher pressures are reported. However, there are contradictions among different groups on phase transformation of SiO<sub>2</sub> at high pressures. The CaCl<sub>2</sub>, -PbO<sub>2</sub>, I<sub>2</sub>/a, baddelyite, fluorite, and Pa3 structures were proposed from different groups. The analysis of published data indicates that such diversity could be consequences of using different forms of SiO<sub>2</sub> as starting material and degree of hydrostaticity as well in a pressure chamber. To minimize the effect of starting material on high pressure behavior of the amorphous silica was used in this study. A sol-gel technique was used to synthesize the highly disordered polymer-like silica network. In the sol-gel process, hydrolysis of the metal alkoxide produces reactive monomers, which through polycondensation reactions promotes cross-linking, leading to a three-dimensional matrix. The silicon atoms are bonded to oxygen atoms in an irregular non-crystalline network, thus forming a gel. The high temperature phase transitions of the synthesized amorphous silica have been studied at pressures up to 62 GPa. In a pressure range of 45 - 62 GPa and temperatures above 800K, a new high pressure polymorph of silica was observed, which further transformed to stishovite phase after temperature increasing above 1200K. The structure and properties of

the new high pressure phase will be reported, and phase transition mechanism in silica will be discussed.

#### MR61A-1032 0830h POSTER

##### Pressure-Induced Amorphization and Phase Transformations in LiAlSiO<sub>4</sub> β-ecryptite

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It has been well-established that β-ecryptite (LiAlSiO<sub>4</sub>), a structural derivative of β-quartz (SiO<sub>2</sub>), exhibits negative thermal expansion along the c axis and near-zero volume thermal expansion over a wide temperature range of 300-1400 K. This behavior makes this compound a good candidate for testing model predictions of a connection between negative thermal expansion and pressure-induced amorphization. Such a connection, as already demonstrated in compounds such as ice, silicon, and ZrW<sub>2</sub>O<sub>8</sub>, may help extend our understanding of the underlying mechanisms.

In this study, β-ecryptite has been investigated under static compression up to 25 GPa using in-situ x-ray diffraction and quenching techniques. High-pressure x-ray diffraction patterns revealed that β-ecryptite underwent progressive amorphization at pressures above 3 GPa and became completely amorphous at 19 GPa. Quench experiments showed that, at pressures of 7.5, 14, and 17 GPa, the original crystalline phase was retained after pressure release. A complete amorphous phase, however, was recovered in the experiment conducted at 25 GPa. The observed amorphization at relatively low pressures extends previous model predictions for tetrahedrally bonded networks, which are restricted to compounds exhibiting negative volume thermal expansion. In addition, β-ecryptite does not appear to have structural memory when it becomes completely amorphous. For comparison, there seems to exist some non-deformable units within the partially amorphous β-ecryptite samples that allow the reversion back to the ordered state.

β-ecryptite has also been studied at high pressure and temperature. At 1173 K and 11 GPa, β-ecryptite was decomposed to a mixture of spodumene (LiAlSi<sub>2</sub>O<sub>6</sub>) and LiAlO<sub>2</sub>. At 14-16 GPa and 1273 K, the two phases were recombined into a single phase with a spinel structure. At 22 GPa and 1673 K, we observed a mixture of oxides, MgO, Al<sub>2</sub>O<sub>3</sub>, and a new phase of Li<sub>2</sub>O. These observations suggest that the pressure-induced amorphization in β-ecryptite is likely caused by kinetically frustrated phase transformations to another crystalline state.

#### MR61A-1033 0830h POSTER

##### Estimating Shock Pressures in Chondrites From High-Pressure Minerals in Shock-Induced Melt Veins

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High-pressure minerals are common in highly shocked (S6) L6 chondrites, occurring within or adjacent to shock-induced melt veins and melt pockets. They provide natural examples of high-pressure minerals that make up the Earth's transition zone (410 to 660 km depth) and lower mantle, as well as a record of high-pressure and temperature conditions during impact events on chondrite parent bodies. The high-pressure minerals that crystallize in melt veins and pockets can be used as an alternative means of investigating shock pressure. We used transmission electron microscopy (TEM) to characterize the shock-vein mineralogy in seven L6 chondrites ranging from shock stage S6 to S3: Tenham (S6), Umbarger (S6), Roy (S3-5), Ramsdorf (S4), Kunashak (S4), Nakhon Pathon (S4) and La Lande (S4).

Tenham contains assemblages that reflect variable cooling rates during crystallization. Majorite plus magnesioferrite occur in the center of melt veins, whereas ringwoodite, akimotoite and round amorphous grains (probably vitrified MgSiO<sub>3</sub>-pervoskite) occur along melt-vein edges. In addition, a symplectitic intergrowth of majorite and an amorphous phase has been observed, which probably represents clinopyroxene that has dissociated into majorite plus CaSiO<sub>3</sub>-pervoskite. High pressure minerals in the Umbarger melt veins include: ringwoodite, akimotoite ((Mg,Fe)SiO<sub>3</sub>-ilmenite), augite, and hollandite-structured plagioclase. In addition, Fe<sub>2</sub>SiO<sub>4</sub>-spinel (new mineral) and stishovite occur in SiO<sub>2</sub>-FeO rich

melt. High-pressure minerals in the Roy melt veins include ringwoodite and majorite. Melt veins in Ramsdorf, Kunashak, Nakhon Pathon and La lande contain fine-grained olivines and pyroxenes that are defect free and interpreted as having crystallized from the melt.

Crystallization pressures can be inferred from the mineral assemblages in the melt veins and available phase equilibrium data. Melt veins in Tenham crystallized at pressure of approximately 25 GPa; Umbarger at pressure between 18 to 25 GPa; Roy at pressure between 14 to 22 GPa; Ramsdorf, Kunashak, Nakhon Pathon and La lande at pressure up to 15 GPa.

#### MR61A-1034 0830h POSTER

##### Pressure-Temperature History of Shock-Induced Melt Veins

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Shock-induced melt veins that occur in chondrites commonly contain metastable high-pressure phases such as (Mg,Fe)SiO<sub>3</sub>-perovskite, akimotoite, ringwoodite, and majorite, that crystallized from the melt at high pressure. The metastable high-pressure minerals invert rapidly to stable low-pressure phases if they remain at high temperatures after the pressure is released. Although shock compression mechanisms permit rapid heating of the vein volume, adiabatic cooling on decompression is negligible because of the relative incompressibility of the material in the vein. The presence of metastable mantle minerals in a vein thus implies that the vein was quenched via thermal conduction to adjacent cooler material at high pressure. The quenching time of the vein can be determined from ordinary heat flow calculations (Langenhorst and Poirier, 2000), given knowledge of the vein dimensions and the temperatures at the time of vein formation in both the vein and the surrounding material.

We have calculated a synthetic Hugoniot for the Tenham L6 chondrite to estimate bulk post-shock and shock temperatures as a function of shock pressure. Assuming a superliquidus temperature of 2500°C for the melt vein, we use a simple thermal model to investigate then thermal histories of melt veins during shock. The variation in crystallization assemblages within melt veins can be explained in terms of variable cooling rates. Survival of (Mg,Fe)SiO<sub>3</sub>-perovskite in Tenham (Tomlioka and Fugino, 1997) requires that melt veins cooled to below 565°C before pressure release, which further constrains shock pressure, duration of the pressure pulse and cooling histories.

#### MR61A-1035 0830h POSTER

##### Library Retrieval of Remotely Sensed Reflectance Spectra Based on Spectral Matching Algorithms

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Reflectance spectroscopists have witnessed a steady increase in the utilization of spectrum matching techniques of computer assisted programs specifically designed for the interpretation of reflectance or absorption spectra. In an attempt to minimize the tedious and time consuming of interpreting reflectance or absorption spectra via a manually oriented library search, this study was conducted for evaluating quality, limitations and criteria of selection of a proper searching algorithm and method. The study tested five computerized algorithms (absolute difference, squared difference, squared derivative, Euclidean vector distance, and correlation coefficient) for identification of evaporites and salt crusts. These algorithms were selected because they can be found in several software packages such as Spectral ID, Winfirst, and others. The study considered evaporites and salts as the targets of interests because they are of interest to environmental scientists and engineers, and their library search constitutes essential part of their identification process via ground-based remote sensing techniques. The study found that successful attempts for spectral matching using computerized techniques depend on the quality of the signal processing algorithms and the degree of perfection in matching them with the known spectra. There are additional components that make the processes problematic when dealing with natural evaporites crusts or even mixed crusts. In evaporite crusts case, the automated search does not enable accurate matching of mixtures against libraries of pure salts spectra due to factor related to nature of salt formation or layering.

For example, upon evaporation of mixed saline solutions, layered salt crusts is evolved, and it was proven that the very thin surface of the salt crusts dictate the spectral features of the system. Additional factors made the search more problematic, such as variances in spectra due to quantity per unit area (content) or grain size differences or even moisture content. However, satisfactory spectral searches were performed with three of presented algorithms with ranking that range from 72% to 88%. Squared difference yielded the worse results because it emphasizes peak positions more than peak heights and, as a result, tends to minimize the effect on the match value when the search spectrum exhibits a sloping base line or broad nonspecific spectral features like in the case of gypsum and thenardite. In essence, if the spectrum of the unknown target in the spectral library it will match with target references spectrum by existing method without difficulty in most cases, except when differences in abundance, or grain size or moisture content occurs, but if the spectrum of the unknown is not in the spectral library, the search results are not always good enough. The library search of salt and evaporates is not necessary to be representative of the average chemical composition of the crust because spectra of the crust are controlled by very thin surface.

#### MR61A-1036 0830h POSTER

##### Reflection-Transmission of Bounded Pulses at Fluid-Solid Boundaries: Application to Rock Physics Experiments

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The angle-of-incidence reflectivity of elastic waves from a fluid-filled porous and permeable medium has never been experimentally tested. This is important to understand because such materials host a second, slower, and highly attenuating longitudinal mode, and this converted mode must consume a portion of the input wave energy at the expense of the regular elastic waves. We are presently carrying out experimental studies of this problem using a specially constructed acoustic goniometer that includes a large (7.6-cm X 10.2-cm) ultrasonic transmitter and a near point source receiver. Laboratory studies of elastic wave reflectivity are complicated by the fact that the sending transducer must have a finite aperture. The reflected amplitude of such a bounded pulse can differ significantly from the predicted for a mono-frequency, plane wave. These complications arise because such a bounded pulse, even though highly directional, may be decomposed into many plane waves with slightly varying propagation directions. In particular, the measured reflectivity curve will exhibit unusual features a few degrees above the shear limiting angle of incidence (Rayleigh angle). Here, we develop the theory for the reflectivity of such a bounded pulse. This is first applied to describe the pulse produced in water by the ultrasonic transmitting transducer in our goniometer as reflected from three well characterized elastic solids, a soda-lime glass plate, a copper plate, and an aluminum plate. The good match between the predicted and observed reflectivity curves confirm the theory and allow calibration of our acoustic goniometer system. The theory is now being applied to the interpretation of reflectivity curves obtained from the surface of water saturated, artificial sandstones composed of sintered glass beads: porous materials that we know transmit the second, or slow, P-wave.

#### MR61A-1037 0830h POSTER

##### Analyses of Impedance Microstructure and Wave Propagation Characteristics in Rocks

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Seismic methods are our primary tools to image subsurface structures and to derive information about microstructural properties at subsurface that are pertinent to exploration. However, velocity - physical property transforms are mostly empirical or qualitative in nature, mainly because microstructural descriptions are qualitative. Although, sedimentary systems produce distinctive textures that influence physical properties and seismic signatures, these textures are not quantified in terms comparable to seismic. We present a method to quantify microstructure in terms of acoustic impedance and show how these microstructural

impedance maps can be used to analyze wave propagation characteristics in rocks. Using image analyses techniques, the texture of the calibrated scanned images is quantified by spatial autocorrelation functions and binary morphological operations. Parametric modeling of the empirical autocorrelation functions is used to estimate the textural anisotropy.

We quantify microstructural impedance anisotropy and compare these textural maps to ultrasonic velocity anisotropy measurements. Inclusion based effective medium theory is used to upscale the impedances at the microstructural scale to the core plug scale.

In the example of optically opaque kerogen-rich shales, we find that

1. Acoustic impedance in kerogen shales increases with shale maturity,

2. Impedance measured on a micrometer scale and centimeter scale match well, indicating that seismic wave propagation are controlled by the microtexture

3. With increasing maturity, there is a transition from kerogen supported to grain supported framework

We thank the Fraunhofer Institute for Nondestructive Testing (IZFP) for use of AM facilities, Walter Arnold (IZFP) for discussions about acoustic microscopy, ARCO and SRB Project for support. This work was performed under the auspices of National Science Foundation (Grant No. EAR 0074330) and Department of Energy (Award No. DE-FC26-01BC15354). URL: <http://pangea.stanford.edu/~manika/manika.html>

#### MR61A-1038 0830h POSTER

##### Use of well data for estimation of seismic anisotropy

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A proper combination of geological and seismic data is considered to be important for enhancing the information about lithology and reservoir properties (e.g. porosity, pore fluid, saturation et cetera) obtainable from such data. Well data are combined with seismic data mainly to achieve lithological classification of the various reflection events. Furthermore, sonic logs provide P- and S-wave velocities which can be used to improve the seismic processing and imaging schemes for seismic data acquired in the vicinity of the well site.

We here show how acoustic rock models can be applied to obtain an integrated use of sonic P- and S-wave velocities (measured parallel to the borehole axis), porosity, mineralogy and fluid saturation, for an estimation of the small scale (i.e. decimeter) anisotropic properties. In turn, these are used for the estimation of the corresponding large scale (i.e. seismic) properties. We use an acoustic model developed for shales to predict a so-called grain orientation distribution function, characterizing an internal rock texture, and the anisotropy. The estimation strategy is applied to a set of well data from the North Sea. Our results show that the degree of anisotropy depends strongly on the physical properties of small scale rock properties, i.e. the minerals and fluids. This also pinpoints the importance of recovering the acoustic properties of the various minerals and fluids composing the rock, and which enter into the rock acoustic modelling.

URL: <http://src.ifjff.uib.no/src/>

#### MR61A-1039 0830h POSTER

##### Biot Theory, BISQ Model, and Volume-Averaged Theory of Poroelasticity

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The Biot theory is known to under predict experimentally measured values of ultrasonic P-wave velocity and attenuation. Attempts have been made to account for this deviation on the basis of postulating "squirting" oscillation of fluid within pores (BISQ model; Dvorkin and Nur, Geophysics, 1993). In this approach the macroscopic fluid pressure equation of the Biot theory is modified on a heuristic basis by introducing an adjustable parameter, although, the macroscopic solid pressure equation of the theory remains unchanged.

In a deformable porous medium the porosity perturbation is an integral part of any deformation process, however, it does not appear in the Biot's constitutive relations explicitly. On the basis of macroscopic mass balance equations we have worked out the macroscopic fluid and solid pressure equations in terms of porosity perturbation. By comparing these pressure equations with those of Biot's pressure equations, the specific

form of the porosity perturbation term implicitly embedded in the Biot framework is deduced, which turns out to be solely dependent on the pressure difference of the two phases.

A modification of the elastic parameter in the Biot fluid pressure equation, as being sought in the BISQ model, implies that the form of underpinning porosity perturbation term is being altered. It turns out that for such a modification the porosity perturbation term must assume the dependence on the pressure difference as well as the total pressure of the two phases. Since the same porosity perturbation term underlies the Biot solid pressure equation also, this equation must also be modified accordingly.

We find that once the correction for squirt flow is properly incorporated in the Biot theory by modifying its both, fluid and solid, pressure equations on account of porosity perturbation term being dependent on the pressure difference as well as the total pressure of the two phases, the resulting framework is the volume-averaged theory of poroelasticity (de la Cruz and Spanos, *Geophys.* 1985; Sahay et al., *GJI* 2001).

#### MR61A-1040 0830h POSTER

### Applying Statistical Rock Physics to Quantify the Effects of Geologic Heterogeneities on Seismic AVO Signatures in Offshore Venezuela

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The objective of this study was to better understand observed amplitude anomalies, and quantify the geologic uncertainty associated with the feasibility of using seismic AVO signatures to detect hydrocarbons in offshore Venezuela region. Data from four wells were analyzed. Prediction of shear velocity was carried out in selected wells as none of the wells have shear logs. Sand and shale properties were estimated from selected zones based on the gamma-ray logs and geologic information about the formations. Fluid substitution was carried out within the sand zones taking into account the properties of the reservoir fluids. Monte-Carlo (MC) simulations, incorporating statistical variability and correlations of rock properties, were used to compute normal-incidence reflectivity and AVO gradient for different pore fluid conditions: brine sands, oil sands and gas sands. The computed seismic signatures were used to evaluate the feasibility of using seismic AVO for pore fluid and lithology discrimination. Forward modeling of CDP gathers was carried out and AVO signatures from synthetic CDP gathers were compared to MC simulations.

The main conclusions are: statistical rock physics and AVO modeling analyses of data from wells indicate that Pliocene gas/oil sands are expected to have observable seismic amplitude and AVO signatures, with negative R(0) and small gradient G at top sand. However, the signature changes from Pliocene to Miocene sands. Depth-dependent geologic trends in AVO patterns were identified using data from Pliocene and Miocene sands. Directly using Pliocene AVO patterns to interpret amplitudes from Miocene sands without correcting for the trend could lead to potential pitfalls. Miocene sands are expected to have much weaker fluid signatures, as they are high velocity, stiff sands. Volcanoclastics and carbonates are other possible sources of strong amplitude and AVO signatures, and hence may cause false alarms if not properly interpreted. A combination of reflection polarity and strong AVO gradient can help to distinguish volcanics and limestones from the sands.

#### MR61A-1041 0830h POSTER

### Standing Torsional Waves in Fluid-Saturated Porous Circular Cylinder

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For dynamic measurement of elastic constants of a porous material saturated with viscous fluid when resonance-bar technique is applied, one also observes attenuation of the wave field. The current practice is

to interpret it in terms of solid-viscosity by assuming a viscoelastic rheology for porous material.

The likely mechanisms of attenuation in a fluid saturated porous material are: 1) motion of the fluid with respect to the solid frame and 2) viscous loss within the pore fluid. Therefore, it is appropriate to assume a poroelastic rheology and link the observed attenuation value to fluid properties and permeability. In the framework of poroelastic theory, the explicit formula linking attenuation to the properties of solid and fluid constituents and permeability are not worked out yet. In order to establish such a link one has to work-out solutions of appropriate boundary value problems in such a framework.

Here, we have carried out the solution of boundary value problem associated with torsional oscillation of a finite poroelastic circular cylinder, casted in the framework of volume-averaged theory of poroelasticity. Analysing this solution by a perturbative approach we are able to develop explicit expressions for resonance frequency and attenuation for this mode of vibration. It shows how the attenuation is controlled by the permeability and the fluid properties, and how the resonance frequency drops over its value for the dry porous frame due to the effect of the fluid-mass.

#### MR61A-1042 0830h POSTER

### Standard-free Pressure Measurement by Ultrasonic Interferometry in a Multi-Anvil Device

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A key question to all high pressure research arises from the reliability of pressure standards. There is some indication and discussion of an uncertainty of 10-20% for higher pressures in all standards. Simultaneous and independent investigation of the dynamic (ultrasonic interferometry of elastic wave velocities) and static (XRD-measurement of the pressure-induced volume decline) compressibility on a sample reveal the possibility of a standard-free pressure calibration (see Getting, 1998) and, consequently an absolute pressure measurement.

Ultrasonic interferometry is used to measure velocities of elastic compressional and shear waves in the multi-anvil high pressure device MAX80 at HASYLAB Hamburg enabling simultaneous XRD and ultrasonic experiments. Two of the six anvils were equipped with overtone polished lithium niobate transducers of 33.3 MHz natural frequency, for generation and detection of ultrasonic waves with a frequency sweep between 5 and 55 MHz. Different buffer - reflector combinations were tested to optimize the critical interference between both sample echoes. NaCl powder of 99.5 % purity (analytical grade by Merck) was used as starting material for manufacturing the samples used as pressure calibrant after Decker (1971). The medium grain size was 50  $\mu\text{m}$ . The powder was pressed to a crude sample cylinder of 10 mm diameter and a length of 20 mm using a load of 6 tons resulting in an effective pressure of 0.25 to 0.3 GPa. The millimeter sized samples (diameter 2.4 mm and 1.6 mm length for 6 mm anvil truncation and diameter 3.1 mm and 1.1 mm length for 3.5 mm anvil truncation) for the high pressure experiments were shaped with a high-precision ( $\pm 0.5 \mu\text{m}$ ) cylindrical grinding machine and polished at the front faces. From the ultrasonic wave velocity data we calculated the compressibility of NaCl. This requires in situ density data. Therefore the sample deformation during the high pressure experiments was analyzed in detail and the results were compared with models published by different authors. The experimental results measured with different set-ups under different pressure conditions were compared with EoS-data derived from static compression experiments up to 5 GPa (Bridgman, 1940) and up to 30 GPa (Holland & Ahrens, 1998; Birch, 1986) using experimental data from Boehler & Kennedy (1980) and Fritz et al. (1971). At 1.2 GPa and 5.3 GPa the results of static compression data exactly correspond to our velocity-based data, polynomial-fitted up to the power of 7. In the range between 2 and 4 GPa our dynamical data have 1.5 - 3 % higher values. Furthermore the pressure revealed according to Decker (1971) is in accordance to our standard-free pressure calibration within the uncertainty of the experiment.

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#### MR61A-1043 0830h POSTER

### A New Method of Determining the Specific Storage and the Hydraulic Conductivity of a Rock Sample

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We describe a new and relatively straightforward technique of determining the specific storage and the hydraulic conductivity of a tight core sample from a record of the upstream or/and the downstream hydraulic heads generated by constant-rate flow pumping. First, an analytic solution of the general diffusion equation is derived, subject to proper boundary conditions in which a flow pump injects fluid into a cylindrical specimen placed between two reservoirs. The solution for the hydraulic head consists of two parts: an asymptotic limit at long time scales, and a transient part that decays with time and eventually converges to zero. Based on our solution, the hydraulic heads of the upstream and downstream reservoirs will increase linearly with time after the transient. The slope of the linear function depends on the specific storage of rock sample for a given test condition. The intercept of the linear function and the difference in hydraulic head between the two reservoirs are related to both rock hydraulic properties and the other test system parameters. This result suggests that we can obtain the specific storage from the increasing rate of hydraulic head, and the hydraulic conductivity from the intercept or the difference in hydraulic head if the other test system parameters such as the compressive storage of the reservoirs and the dimension of rock specimen are known. The most important merit of our new method is that both the specific storage and the hydraulic conductivity can be simply determined from a single test record. No tedious history matching with a transient curve is required. We applied the new technique to a tight micritic limestone from the Gulf of Corinth, Greece, using a core sample 38mm in diameter and 15mm in length. For the simplicity of our test system, we removed the downstream reservoir. The measurement of the hydraulic head versus the flow generated by the pump yields  $5.9 \times 10^{-10} \text{ m}^2$  of the upstream compressive storage. We recorded the upstream hydraulic head generated by the flow pumping into one end of rock specimen with a constant flow rate of  $10^{-10} \text{ m}^3/\text{sec}$ . After a transient stage, the curve stabilised at a constant increasing rate, as predicted. The linear increasing rate of the head and the intercept of the linear function yielded the specific storage as  $2.8 \times 10^{-6} \pm 5.9 \times 10^{-7} (\text{m}^{-1})$  and the hydraulic conductivity as  $4.1 \times 10^{-14} \pm 5.3 \times 10^{-15} (\text{m}/\text{sec})$ , equivalent to  $4.1 \times 10^{-21} \text{ m}^2$  in permeability units.

#### MR62A MCC: Hall C Saturday 1330h

### Applications of Measurements of Physical Properties of Rocks to Large-Scale Tectonic Processes III Posters (joint with P, S, T, DI)

**Presiding:** B Evans, Massachusetts Institute of Technology; H De Bresser, Utrecht University

#### MR62A-1044 1330h POSTER

### Effects of Melt and Pyroxene Content on the Rheology of Naturally Deformed Peridotites

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Although the rheology of the shallow mantle beneath oceanic spreading centers is generally approximated by the behavior of polycrystalline olivine aggregates, laboratory experiments demonstrate that