V41E-06 1135h

Structures and Properties of Silicate Glasses and Melts at High Pressure: Multi-nuclear 2 Dimensional Solid State NMR and Statistical Mechanical Modeling

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Essential to the transport and thermodynamic properties of silicates at high pressure is the full understanding of atomic arrangement of system under pressure. Whereas there have been significant progresses in our understanding of the atomic structures of crystalline materials or molecules at high pressure, much less is known about the structures of amorphous silicates including glasses and melts. This is largely because conventional X-rays or optical spectroscopy can only provide limited information of the various aspects of atomic disorder in densified amorphous silicates. Recent development and advances of 2 dimensional solid state NMR have offered much improved resolution, allowing us to probe structural details of amorphous silicates (Lee, Fei, Cody, & Mysen, Geophys. Res. Lett., 2003, 30, 1845; Lee and Stebbins, J. Phys. Chem. B., 2003, 107, 3141). Here we present recent 2D NMR (MQMAS) spectra of silicate glasses, quenched from melts at 6-15 GPa in a multi-anvil apparatus at Geophysical Laboratory, which reveals previously unknown details of melt structures at high pressure. The atomic structures of model glasses at high pressure are significantly different from those at ambient pressure and show evidence of extensive chemical ordering among highly coordinated network polyhedra, such as $^{[5,6]}$Al and $^{[5,6]}$Si, which affects corresponding macroscopic properties. New oxygen sites in serious of sodium silicate and aluminosilicate glasses with varying degree of polymerization at high pressure include $^{[5,6]}$Al-O-$^{[4]}$Si, $^{[5,6]}$Si-O-$^{[4]}$Si and Na-O-$^{[5,6]}$Si. The fractions of these sites increase with increasing pressure mainly at the expanse of Na-O-$^{[4]}$Si. The fraction of $^{[5,6]}$Al in aluminosilicate glasses increases with pressure, but decreases with increasing degree of polymerization of melts from $(Na_2O)_{0.75}(Al_2O_3)_{0.25}3SiO_2$ to $NaAlSi_3O_8$ at constant pressure. The effect of these structural changes and chemical ordering to the diffusivity and configurational thermodynamic properties of silicate glasses at high pressure were also explored using statistical mechanical modeling and quantum chemical calculations, in conjunction with information of the extent of disorder from NMR data. These results and methods shed light on a new opportunity of studying atomic structures of amorphous solids at high pressure and provide improved prospects on microscopic origins of melt properties at the earth's interior.

V41E-07 1150h

Elasticity, Equation of State, and Pressure Calibration Studies on MgO Using Ultrasonics in Conjunction with Synchrotron X-radiation

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Combined ultrasonic and synchrotron X-radiation techniques allow us to measure sound velocities, equation of state (unit cell parameters), and axial strain (sample length change) simultaneously at high pressure and temperature. It is feasible in the laboratory to conduct such measurements on millimeter-sized solids and liquids to P greater than 10 GPa and T around 1600K using a DIA-type apparatus (SAM85) installed at X-17B2, NSLS/BNL, and to P greater than 25 GPa and T greater than 1500K using the multi-anvil apparatus installed at GSECARS/Advanced Photon Source, University of Chicago. In this study, we report our progress in pressure calibration by simultaneously measuring acoustic velocities and P-V-T on pressure standard material MgO. These measurements not only allow redundant determination of elastic properties using equation of state and acoustic velocities, but also provide direct determination of sample pressure that can be compared with the NaCl pressure scale used in current high pressure experiments. Such experiments have been conducted up to 10 GPa and 1273K using hot-pressed polycrystalline sample. The MgO sample used in this study has P and S wave velocities within 0.2 percent of previously published data at ambient conditions. Travel times, X-ray images of sample, and X-ray diffraction spectra were collected in multiple heating/cooling cycles at various pressures during decompression. A third-order Birch-Murnaghan equation of state fit to the P-V data yielded results compatible with previous static compression data. The pressure derivatives of the elastic moduli (K and G) determined without using secondary pressure scale are compatible with previous acoustic data, but the sample pressures determined using current data are higher than those determined using equation of state of NaCl. This finding is consistent with that found in simultaneous velocity and X-ray diffraction measurements on other materials.

V41E-08 1205h

Shock Pressures, Temperatures and Durations in L Chondrites: Constraints from Shock-Vein Mineralogy

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Shock effects in meteorites provide a record of major impact events on meteorite parent bodies. Shock veins in chondrites, which result from local melting during shock loading, are the location of all high-pressure minerals. Shock veins contain igneous assemblages, produced by the crystallization of shock-induced melt, and metamorphic assemblages, produced by solid-state transformation in entrained host-rock clasts and wall rock. The mineralogy, distribution of high-pressure minerals and microstructures in shock veins provide a record of crystallization pressures and quench histories that can be used to constrain shock pressures and pulse duration. Here we report mineralogical and microstructural studies of shock-induced melt veins in L chondrites that provide insight into the impact history of the L-chondrite parent body. Eight L6 chondrites were investigated using FESEM and TEM and Raman spectroscopy: RC 106 (S6), Tenham (S6), Umbarger (S4-S6), Roy (S3-S5), Ramsdorf (S4), Kunashak (S4), Nakhon Pathon (S4) and La Lande (S4). Igneous melt-vein assemblages, combined with published phase equilibrium data (Agee et al. 1996), indicate crystallization pressures from less than 2.5 GPa for Kunashack and La-Lande to approximately 25 GPa for Tenham. Because shock veins quench primarily by thermal conduction, crystallization starts at vein edges and progresses inward. Variation in the igneous assemblage across shock veins, combined with thermal modelling, provides constraints on quench times and pressure variation during quench. Most samples appear to have crystallized prior to shock release, whereas Kunashack and LaLande apparently crystallized after pressure release. RC 106 and Tenham (both S6), which have thick melt veins with uniform igneous assemblages, crystallized under equilibrium shock pressures of approximately 22-25 GPa during shock events that lasted at least 500 ms and 50ms, respectively. The fact that S6 samples do not appear to have crystallized at a pressures greater than about 25 GPa, suggest that the impacts that produced shock veins in chondrites had low relative impact velocities.

V42A MCC: Level 1 Thursday 1330h

Frontiers in High-Pressure Research Posters II *(joint with GP, MR, DI)*

Presiding: **L F Dobrzhinetskaya,** Institute of Geophysics and Planetary Physics, University of California, Los Angeles**; J Hu,** Carnegie Institution of Washington

V42A-0317 1330h POSTER

OLIVINE LAMELLAE AND INTERSTITIAL BLEBS OF DIOPSIDE AND ENSTATITE EXSOLVED FROM MAJORITIC GARNET DURING DECOMPRESSION IN MULTIANVIL APPARATUS

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We present preliminary experimental data on the decompression of majoritic garnet primarily synthesized from a mineral mix of garnet peridotite bulk chemistry showing exsolution from majoritic garnet of olivine (Ol) in the form of oriented plates and pyroxenes as interstitial blebs. Experiments conducted at 14GPa/1673K demonstrate that all enstatite (En) and about 85% of diopside (Di) were dissolved into garnet yielding run products of approximately 40% Ol + 55% Grt + 5% Di. Garnet was found to be supersilicic with Si=3.17-3.31 p.f.u. Repeat of such experiments followed immediately by re-annealing at 13 and 12 GPa yielded exsolution of both Di and Ol. Olivine exsolved as micron-size plates nucleated within garnet on low-angle boundaries. In contrast, diopside exsolved abundantly as tiny blebs at garnet grain boundaries, exhibiting no typical exsolution microstructures. Similarly, in specimens annealed at 5 GPa after previous equilibration at 8GPa/1673K, En exsolved as small blebs at garnet boundaries. Under conditions similar to the latter experiments, interstitial blebs of natural enstatite also occur at garnet grain boundaries (Van Roermund et al., 2001) in Norwegian deep-seated (>200 km) subduction zone grt-peridotite. Our experiments show that Ol as well as En and Di may exsolve during decompression of majoritic garnets in the course of Grt peridotite exhumation. Examples of preservation of pyroxene exsolution lamellae in former majoritic garnets come from both xenoliths in kimberlites (Haggerty and Sautter, 1990; Sautter et al., 1991) as well as from very large garnets in subduction-zone peridotites (van Roermund and Drury, 1998). However, many other garnet peridotites from subduction zones contain Di, En, and/or Ol along grain boundaries within larger polycrystalline garnets and within embayments at the margins of smaller amoeboid garnets (e.g. Dobrzhinetskaya et al, 1996, Green and Dobrzhinetskaya, 2003). Such garnets also may contain rounded non-oriented inclusions of each of these minerals, or all three together, consistent with the results of majoritic garnet decompression presented above.

V42A-0318 1330h POSTER

Partitioning of H_2O on high pressure phase transformation of olivine

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Water is the most abundant volatile component on the Earth's surface, and it has been supplied to the Earth's interiors by subducted slab. Water influences the physical properties and melting temperature of minerals. Olivine is the most abundant mineral in the

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mantle, and it is clarified that the high-pressure polymorphs of olivine, wadsleyite and ringwoodite, can contain 3wt% of H_2O in their crystal structures (e.g. Inoue et al., 1995, 1998). However, the partitioning of H_2O among these minerals has not been clarified yet except for olivine-wadsleyite transformation (Chen et al., 2003). We have determined the partitioning of H_2O between wadsleyite and ringwoodite and between ringwoodite and perovskite, and clarified the distribution of H_2O among upper mantle, mantle transition zone and lower mantle. High-pressure experiments were conducted by MA-8 type (Kawai-type) high-pressure apparatus in Ehime University, and the chemical compositions were determined by EPMA. The water contents of minerals were measured by SIMS in Tokyo Institute of Technology. We succeeded to synthesize large (approximately 50 μm) coexisting crystals of wadsleyite and ringwoodite, and of ringwoodite and perovskite, and we could clarify the partitioning of H_2O between those coexisting minerals. The partition coefficients between wadsleyite and ringwoodite and between ringwoodite and perovskite were about 2 and about 10 or more, respectively. We (Chen et al., 2003) have already determined that the partition coefficients between wadsleyite and olivine is about 5, so the partitioning among upper mantle, 410-520km and 520-660km of mantle transition zone, and lower mantle are 4:20:10:1. Thus the mantle transition zone should be a strong water reservoir in the Earth's interiors.

V42A-0319 1330h POSTER

A Model for Shear Mechanism in the Pyroxene-Ilmenite Transition in $MgSiO_3$

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Phase transition mechanisms of silicate minerals under high-pressure play significant roles to the rheological properties and transformation kinetics in the EarthOs mantle. To understand the dynamics of the EarthOs interior, previously, many researchers have studied the transformation mechanisms of olivine, which is the most abundant mineral in the upper mantle, to wadsleyite or ringwoodite structures. Poirier (1981) first proposed a shear-promoted mechanism for the transition from olivine to ringwoodite in Mg_2SiO_4. This diffusionless mechanism forms coherent lamellar intergrowths of product high-pressure phases in the host minerals. Pyroxene is the second major constituent of the upper mantle. However, there is no direct experimental work for the transition mechanism of $MgSiO_3$-rich pyroxene under high pressure. In a natural shocked chondritic meteorite, $(Mg,Fe)SiO_3$ ilmenite (akimotoite) (Tomioka and Fujino 1998) was found to be intergrown in the host $(Mg,Fe)SiO_3$ clinopyroxene and they have topotaxial relationships similar to that formed by the shear mechanism. In this study a model of shear mechanism for the $MgSiO_3$ clinoenstatite to akimotoite transition based on their natural occurrences and the topological study on both the structures is proposed. The shear mechanism in the high pressure clinoenstatite (s.g.C2/c)-akimotoite (R-3) transition can be expressed by the sweeping of partial dislocations associating cation shuffling without long-range atomic diffusion. The shortest translation vector [001] of clinoenstatite on (100) plane would dissociate into 1/3[001]+1/6[011]+1/3[001] +1/6[0-11] and the first two partial dislocations bring about the hcp oxygen sublattice for the akimotoite structure. This transition mechanism possibly occurs under high shear stress or under high overstepping pressure at relatively low temperature like that was suggested for the olivine-ringwoodite transition.

V42A-0320 1330h POSTER

Seismic Properties of Rocks at High PT Conditions. Laboratory Measurements on Mafic and Ultramafic Rocks Representative of Subduction Zones

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The geological interpretation of geophysical data requires the knowledge of the physical properties of rocks and in particular of the effects of confining pressure and temperature. Of particular interest for the interpretation of the structures in subduction zones is the relationship between seismic anisotropy and rock fabric. Eclogites, peridotes and pyroxenites as well as some amphibolitic mylonites were collected in the western gneiss region in Norway and in the Bragansa massif in NE-Portugal. For each sample the modal composition and density was determined and on some selected samples the CPO was also measured. P wave velocities were measured on three orthogonal cylinders cut parallel (or normal) to the foliation and lineation (when visible) at elevated pressures and temperatures. The velocity measurements were correlated with predictions based on the determined modal composition, CPO and rock microstructure. The velocities were measured using the pulse transmission technique in an internally heated argon gas confining medium Paterson apparatus, up to 500 MPa confining pressure, and temperatures up to 700°C for specimens of 22mm diameter and up to 1200°C for specimens of 15 mm diameter (in all cases length is about 30mm). In order to keep the transducers away from the hot zone, buffer rods of PSZ or Al2O3 were introduced. Advantages of this setup are: Pressure is really hydrostatic and can be determined within 1 MPa: Temperature, is within 1K over the whole sample length at 700°C and 20K at 1200°C. Another advantage is that no cracking of the sample occurs after PT cycling. This means that no local stresses are raised, and therefore several runs can be performed with the same specimen. Here we will present the first measurements on a chlorite-peridotite, and the several improvements of the experimental set up and the measuring technique. The peridotite has a mean velocity of 7.9 Km/s at 500 MPa. Pressure derivative is of 2E-4 km/s/MPa and temperature derivative is -5E-5 km/s/K. The seismic anisotropy at 500 MPa was about 5.5%.

V42A-0321 1330h POSTER

Diamondiferous Peridotite Tomography: Precursor to Xenolith Dissections.

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Three-dimensional, high-resolution computed X-ray tomography (HRCXT) of diamondiferous peridotite xenoliths from Siberia has successfully imaged diamonds and their textural relationships with co-existing minerals. This is an extension to the tomography and xenolith dissections performed previously on diamondiferous eclogites (e.g., Taylor et al., 2000, Int'l Geol Rev 42; Anand et al., 2003, 8th Int'l Kimb Conf). Spatial relationships between diamonds and their surroundings provide clues to the processes that control diamond crystallization. These relationships can be determined by rotating and viewing the 3-D model at different perspectives and orientations to look for specific associations/alignments. It is possible to render some of the phases transparent and display only one or two minerals at a time. Then by rotating the model, it is possible to look for spatial relationships between different crystals of the same mineral or different minerals. The maps obtained from the tomography form the basis for the delicate dissections of the xenoliths, revealing the diamonds as they formed in their mantle host rocks. Diamondiferous peridotites appear to be sparse carriers of diamonds compared to eclogites, where one unusual eclogite of 65 g contained 74 macro-diamonds. Although kimberlites always contain considerably more peridotite xenoliths than eclogites, the diamond population may actually be more indicative of eclogitic origin. The diamonds appear to be preferentially located in zones with a prominent sub-planar fabric of secondary mineralization - i.e., zones of increased permeability. Diamond was never observed in direct contact with any fresh, primary minerals. Also, there is insufficient sulfide mineralization to call upon an immiscible-sulfide melt as the diamond-forming medium. The association of the diamonds with secondary minerals strongly suggests that the diamonds formed after the initial host peridotite or eclogite, perhaps in conjunction with introduction of metasomatic fluids.

V42A-0322 1330h POSTER

X-ray Stress Analysis in Deforming Materials: Models and Observations

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The relationship between the stress field and strain field in a polycrystalline system that is undergoing deformation has been the focus of many materials science studies since the late 1920's. The Taylor and Sachs models assume that the plastic process is enabled by dislocation flow on specific lattice planes and specific Burger's vectors. Then the relationship between stress and strain is controlled by the orientation of an individual grain with respect to the stress field, von Mises criteria, and the critical resolved stress on the dislocation that is necessary for flow. We use the Taylor model, the Sachs model and a self-consistent model to predict the flow-stress during plastic deformation of polycrystalline MgO with slip system of (110)(1-10), (111)(1-10), (100)(011) at different critical resolved shear stress ratios (CRSS) on the different dislocations. The prediction of the models is correlated with the results of X-ray diffraction measurements. Uniaxial deformation experiments on polycrystalline and single crystalline MgO (periclase) samples were conducted in situ using white X-ray diffraction with a multi-element detector and multi-anvil high-pressure apparatus at pressure up to 6 GPa and temperature up to 1300 K. A deformation DIA (DDIA) was used to generate pressure and control a constant compression speed. Elastic strains and plastic strains were monitored using X-ray diffraction spectra and X-ray imaging technique respectively. The correlation of the data and models suggests that Taylor and Sachs model should represent the extreme upper- and lower- bound for the polycrystal models with the presence of plasticity, while the Reuss and Voigt models are appropriate for the elastic region of deformation, before the onset of plastic deformation. The similarity of elastic strains among different lattice plane suggests that 110 slip systems is marginally the most significant slip systems in MgO at high pressure at high temperature with the selected critical resolved shear stress ratio less than 2.

V42A-0323 1330h POSTER

Torsion Experiments on Wadsleyite under Transition Zone Conditions

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Although wadsleyite is the main constituent of the Earth's transition zone, the rheological properties of wadsleyite are poorly constrained because of the difficulty in conducting well-defined deformation experiments under its stability conditions. In order to quantitatively study rheological properties and microstructural development in wadsleyite (and other high-pressure minerals), we are developing a new apparatus for deformation experiments under high-pressure and high-temperature. A rotational actuator is attached to a Drickamer-type opposed anvil apparatus. A thin disk shaped sample is pressurized and heated and then a torque is applied to deform a sample in simple shear. The geometry of deformation is inferred from the geometry of a strain-marker and sample thickness. We find that significant shortening occurs in the initial stage as well as during deformation. Initial stage deformation could influence rheology and microstructural development by introducing dislocations with low-temperature slip systems. To reduce the effects of initial stage deformation, we anneal a sample at a given P and T for 1 hour. The microstructure of the annealed samples indicates nearly equilibrium grain-boundary morphology suggesting that annealing is nearly complete. Deformation experiments have been made on wadsleyite (as well as for (Mg,Fe)O). The wadsleyite samples were synthesized at 15 GPa and 1273 K for 4 hours and then prepared as discs with diameter of 1.6 mm and thickness of 0.2 mm. Deformation experiments on wadsleyite were conducted at 15 GPa and 1473 K at a constant rotation rate and the shear strain up to 2 was obtained. Deformation experiments on wadsleyite at higher temperature to large-shear strain, and microstructural observations of samples particularly lattice preferred orientation are being performed. Quantitative rheology measurements will be conducted

using the X-ray stress measurements technique at one of the synchrotron beam lines in near future.

V42A-0324 1330h POSTER

Elasticity of Unquenchable High-Pressure Clinopyroxene at High Pressures and Temperatures

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A phase transformation in (Mg,Fe)SiO3, one of the common constituent of the Earth's crust and upper mantle, from orthorhombic (OEN) to monoclinic symmetry is likely to occur in the deeper portions of the upper mantle (Pacalo and Gasparik, 1990; Kanzaki, 1991). Angel et al. (1992) confirmed that the clinoenstatite phase above 8 GPa is an unquenchable high pressure monoclinic phase (HP-CEN), space group C2/c. Due to its unquenchable nature, this high pressure clinoenstatite has to be synthesized within its stability field in order to study its elasticity. The elasticity measurements were carried out using the ultrasonic technique in the large volume apparatus in conjunction with in-situ X-radiation techniques (X-ray diffraction and X-radiography). The experimental setup has made possible to monitor the length change of sample during experiment, as well as the measurements of travel times and density of the sample simultaneously. The starting material for the acoustic experiment was a well-sintered OEN polycrystalline specimen, which was hot-pressed at conditions of 5 GPa, 1000 degree C for an hour prior the experiment. After the OEN fully transformed to the HP-CEN at pressure of 13 GPa, 1000 degree C during the acoustic experiment, elasticity and X-ray data have been collected along a series of heating/cooling cycles at different pressures during the decompression. The data collection was stopped at 6.5 GPa because of the phase transition from HP-CEN to LP-CEN at lower pressure. The resulting bulk and shear moduli at different P-T conditions were treated as linear functions of both pressure and temperature with adjustable parameters: moduli at 6.5 GPa, room temperature, the pressure derivatives at constant temperatures, and the temperature derivatives at constant pressures. Compared with OEN (Flesch et al., 1998), our results show that the pressure derivatives of the bulk and shear moduli of HP-CEN are similar to those of OEN when the conditions of 6.5 GPa, room temperature. We also compared the elasticity of HP-CEN to those of olivine at high pressure and temperature (Li et al., 2003). Reference: Pacalo and Gasparik, J. Geophys. Res., 95, 15853-15858, 1990.Kanzaki, M.,Phys.Chem. Min., 17, 726-730, 1991. Angel et al., Nature, 358, 322-324, 1992. Flesch et al., Am. Miner. 83, 444-450, 1998. Li et al., submitted Phys. Earth, Plant. Inter., 2003.

V42A-0325 1330h POSTER

The Partial Molar Volume and Thermal Expansivity of Fe2O3 in Alkali Silicate Liquids: Evidence for the Average Coordination of Fe3+

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Ferric iron is an important component in magmatic liquids, especially in those formed at subduction zones. Although it has long been known that Fe3+ occurs in four-, five- and six-fold coordination in crystalline compounds, only recently have all three Fe3+ coordination sites been confirmed in silicate glasses utilizing XANES spectroscopy at the Fe K-edge (Farges et al., 2003). Because the density of a magmatic liquid is largely determined by the geometrical packing of its network-forming cations (e.g., Si4+, Al3+, Ti4+, and Fe3+), the capacity of Fe3+ to undergo composition-induced coordination change affects the partial molar volume of the Fe2O3 component, which must be known to calculate how the ferric-ferrous ratio in magmatic liquids changes with pressure. Previous work has shown that the partial molar volume of Fe2O3 (VFe2O3) varies between calcic vs. sodic silicate melts (Mo et al., 1982; Dingwell and Brearley, 1988; Dingwell et al., 1988). The purpose of this study is to extend the data set in order to search for systematic variations in VFe2O3 with melt composition. High temperature (867-1534°C) density measurements were performed on eleven liquids in the Na2O-Fe2O3-FeO-SiO2 (NFS) system and five liquids in the K2O-Fe2O3-FeO-SiO2 (KFS) system using Pt double-bob Archimedean method. The ferric-ferrous ratio in the sodic and potassic liquids at each temperature of density measurement were calculated from the experimentally calibrated models of Lange and Carmichael (1989) and Tangeman et al. (2001) respectively. Compositions range (in mol%) from 4-18 Fe2O3, 0-3 FeO, 12-39 Na2O, 25-37 K2O, and 43-78 SiO2. Our density data are consistent with those of Dingwell et al. (1988) on similar sodic liquids. Our results indicate that for all five KFS liquids and for eight of eleven NFS liquids, the partial molar volume of the Fe2O3 component is a constant (41.57 ± 0.14 cm3/mol) and exhibits zero thermal expansivity (similar to that for the SiO2 component). This value was obtained in a fit to a linear volume equation in which the other oxide components have the following fitted partial molar volumes (cm3/mol) at 1100°C: SiO2 = 26.85±0.04, Na2O = 26.57±0.07, K2O = 42.34±0.10, and FeO = 12.84±0.28, and the following fitted fitted partial molar thermal expansivities (10-3 cm3/mol-K): Na2O = 7.73±0.12, K2O = 11.99±0.24, and FeO = 2.88±1.22. For the three sodic liquids not included in this regression, the most iron-rich (18.2 mol% Fe2O3) has a value for VFe2O3 of 44.1 cm3/mole, whereas the most iron-poor (4.4 mol% Fe2O3) has a value for VFe2O3 of 37.0 cm3/mole. This trend may reflect a greater proportion of four-fold ferric iron in iron-rich liquids, which mirrors the trend of increasing ferric-ferrous ratios in sodic liquids as a function of total iron content (Lange and Carmichael, 1989). The most polymerized liquid in our data set was a sodic liquid that has a value for VFe2O3 of 45.0 cm3/mole. It thus appears that most (13 of 16) of our experimental liquids, which span a wide compositional range, lead to a VFe2O3 (41.6 cm3/mol) which is constant with composition and temperature. However, there are three important outliers that may have implications for the appropriate value to apply to magmatic liquids.

V42A-0326 1330h POSTER

Monitoring the Evolution of Electronic Band Gaps in Simple Molecules at High Temperature and Pressure

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We present the first results from a new technique for tracking changes in electronic band gaps as a function of temperature, pressure, and wavelength in a diamond-anvil cell. We use the inner faces of the diamond anvils to form a Fabry-Perot interferometer, which allows us to measure the index of refraction of the sample as a function of pressure into the megabar range. By using ultrapure type IIa diamonds, we are able to monitor the index of refraction from the intrinsic band gap of diamond (5.5 eV or 240 nm) to the near infrared (1100 nm). Furthermore, by resistively heating the diamond-anvil assembly, we are able access a greater region of P-T space. The dispersion of the index of refraction is very sensitive to changes in electronic band structure, so we can map out the pressure-induced changes in the electronic band structure and use the temperature dependence of the dispersion to distinguish between direct and indirect band gaps. This technique has been applied to both ordered and disordered phases; as an example, we present preliminary results on the evolution of the band gaps of water, ice, solid, and fluid hydrogen.

V42A-0327 1330h POSTER

Deformation of olivine at high pressures using the Deformation-DIA

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The rheological behavior of olivine, the most abundant component of the Earth's upper mantle, under high pressures is essential for understanding the dynamic processes occurring within the Earth's interior. Conventional gas- and solid-medium experiments to date have been limited to pressures of about 3 GPa. We report here results from recent tests on olivine using the Deformation-DIA (D-DIA). The D-DIA is capable of constant-pressure deformation tests at pressures to 15 GPa and is configured to allow operation at a synchrotron x-ray beam line in order to provide in-situ measurement of pressure, differential stress, and sample length as a function of time. Experiments have been conducted on polycrystalline olivine samples cold-pressed from mixtures of olivine plus 5% enstatite powder. A 1 mm long × 1.1 mm diameter sample is encapsulated with 0.025-mm thick Ni foil, and assembled along with fully-densified Al_2O_3 or MgO pistons, a boron nitride sleeve, and graphite resistance heater into a 6-mm edge length cubic pressure medium of boron-epoxy resin. During experiments, the cell is first pressurized isotropically to desired levels and then deformed in compression at constant pressure. Experiments have been conducted at constant displacement rates of $\sim 0.5 - 8 \times 10^{-5}$ s^{-1} over axial strains of 10 -20% at temperatures of 773 -1473 K and pressures of $\sim$ 5 - 6 GPa. The oxygen fugacity and silica activity of the olivine sample are buffered by Ni/NiO and the presence of enstatite, respectively. Using x-ray diffraction, we determine pressure (i.e., mean stress) and differential stress from the strain of various lattice planes measured as a function of orientation with respect to the stress field. At this point we are able to measure elastic strains from several prominent reflections in the olivine, and they indicate qualitatively that the in situ environment is significantly nonhydrostatic. For polycrystalline olivine deformed at high temperature and a constant rate of deformation, the differential lattice strains first increase steadily and then level off as deformation proceeds, indicating that deformation begins with a transient stage before reaching a quasi-steady state. In one test at 1273 K and a pressure of $\sim$ 5 GPa, it took about two hours to reach the quasi-steady state at a deformation rate of 6.5 $\times 10^{-6} s^{-1}$. Such observations are helpful in understanding the details of deformation behavior not normally observable in conventional deformation rigs. In addition, the length change of deforming samples is precisely measured from periodic x-radiographic images. In-situ measurement at high pressure of stress, pressure, and plastic strain is a distinct feature of this study, and opens new ground for studying other minerals at high pressures.

V42A-0328 1330h POSTER

Compressibility of Na_2O-$2SiO_2$ Liquid and Melt to 8 GPa Using Brillouin Scattering

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Brillouin scattering measurements have been carried out on Na_2O-$2SiO_2$ glass and liquid under *in situ* pressures to 8 GPa at temperatures from 300 K to 850 K. For the first time, the "modified" platelet scattering geometry has enabled us to determine V_P independently from refractive index, and hence adiabatic compressibility and density of silicate melt as a function of pressure and temperature. In accordance with existing models for densification of silicate glasses and melts, the more compact arrangement of atoms has been assumed to account for the observed increase in density of the melt and glass phases formed at high P-T conditions. A marked change in pressure derivative of adiabatic bulk modulus ($dK/dP=K'$) exists between the liquid ($K'= 6.3$) and glass ($K'= 4.8$) forms of Na_2O-$2SiO_2$: the notably higher K' of the liquid is consistent with the liquid being able to access a wider range of compressional mechanisms. The large K' of the liquid thus illustrates that the means of compaction of the liquid may differ substantially from that of the glass.

V42A-0329 1330h POSTER

Aluminum coordinations for aluminosilicate glasses at 1 atm. and 3GPa: a ^{27}Al MAS NMR study

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In this study, we used ^{27}Al MAS NMR to investigate the distribution of different aluminum coordinations in ambient pressure and moderate pressure (3GPa) aluminosilicate glasses with compositions of $M^{x+}_{(9-3x)}Al_2Si_6O_{18}$, where M= Ca^{2+}, Na^{+}, and K^{+}. These spectra were collected at 18.8 Tesla to minimize the peak broadening due to second-order quadrupolar effects, which causes overlapping peaks for different coordinations of Al. Aluminum is thought to be mostly tetrahedrally coordinated in ambient-pressure aluminosilicate glasses where $M^{+}_{(2-x)}O >= Al_2O_3$, but ^{27}Al NMR studies have shown that small concentrations of high-coordinated Al are present in both charge balanced (Toplis et al. 2000; Stebbins et al. 2001) and "depolymerized" ($M^{+}_{(2-x)}O > Al_2O_3$) aluminosilicate glasses (Stebbins and Farnan 1992). The ^{27}Al spectra of samples of this study show that these ambient pressure glasses all contain $^{[5]}$Al. Interestingly, the NAS (Na-aluminosilicate) glass contains more $^{[5]}$Al than the KAS glass (0.6 vs. 0.3, respectively), which is opposite of that observed for $SiO_{[5]}$ groups in binary silicate glasses (Stebbins and McMillan 1993). The CAS glass spectrum shows a shoulder at 25 ppm, but the $^{[4]}$Al peak is too broad to assign a reliable percentage for the amount of $^{[5]}$Al. Previous studies of high-pressure glasses have shown that Al transforms to higher coordinations with increasing pressures (Yarger et al. 1995). In this study, we observe that the ^{27}Al MAS spectrum of the 3 GPa NAS glass shows that 7% $^{[5]}$Al and 1% $^{[6]}$Al species exist. Additionally, the spectra of the KAS glass shows that 2% $^{[5]}$Al and possibly some $^{[6]}$Al are present at 3 GPa. These spectra clearly show for the first time that pressure induced Al-coordination changes occur in aluminosilicate glasses at pressures of 3 GPa. Recent ^{27}Al NMR spectra of high-pressure "depolymerized" aluminosilicate glasses with different fictive temperatures have shown that the amount of high-coordinated Al increases with increasing temperature, which suggests that these results represent a minimum value for the melt (Allwardt et al 2003). Further work will focus on obtaining data at higher pressures to determine the pressure dependence for the generation of these species.

V42A-0330 1330h POSTER

Simultaneous Determination of Elastic and Structural Properties Under Simulated Mantle Conditions Using Multi-Anvil Device MAX80

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The resolution and amount of seismic data from the Earth's deep interior increased dramatically during the last few years. To improve our understanding of Earth's deep interior, the interpretation of these data requires measurements of elastic properties of Earth materials under simulated mantle conditions, simultaneously at high pressure and temperature conditions,. We use ultrasonic interferometry to measure travel time with high precision, on samples enclosed in a high-pressure multi-anvil device (MAX80). In addition to travel times the determination of wave velocities requires the knowledge of the exact sample length under in situ conditions. Nowadays, two possibilities are used - scanning the interfaces of the sample (Mueller et al., 2003) and X-radiography (Li et al., 2001). Besides elastic properties structural characteristics are investigated at the same time. To determine travel time, the classical digital sweep interferometry is used, which is very time consuming. For example a 60 MHz frequency sweep with 100 kHz steps lasts for more than 30 minutes. Therefore, a single measurement of Vp and Vs requires more than 1 hour. This is a serious limitation for measurements under transient conditions and limits the data collection at elevated temperatures. To avoid this, an ultrasonic transfer function technique (UTF) was installed, related to the technique described by Li et al. (2002), which allows the generation and emission of all the frequencies simultaneously (Mueller et al., 2003). The "GFZ" type UTF technique allows to consider the characteristics of the transducer-glue-anvil combination (Mueller et al., 2003) and to determine Vp and Vs within less than 2 minutes. Some results on non-quenchable phase transitions will be given to discuss the different interferometric techniques. The precision of sample length determination by X-radiography will be compared to the scanning of the interface technique. Li, B.; Vaughan, M.T.; Kung, J.; Weidner, D.J., NSLS Activity Report 2001, 2-103-106, (2001). Li, B.; Chen, K.; Kung, J.; Liebermann, R.C.; Weidner, D.J., J. Phys.: Condens. Matter 14, 11337-11342, (2002). Mueller, H.J.; Wunder, B.; Lathe, C.; Schilling, F.R., Phys. Earth Plan. Int., submitted, (2003).

V42A-0331 1330h POSTER

Effects of Iron and Aluminum on Thermoelastic Properties of Magnesium Silicate Perovskite

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In the present study, effects of iron and aluminum on thermoelastic properties of magnesium silicate perovskite have been studied by in-situ X-ray diffraction experiments using a Kawai-type apparatus with sintered diamond anvils as the second stage anvils. Two kinds of starting materials were used; one is a powder of San Carlos orthopyroxene that contained iron (5.9 wt percent) and aluminum (4.4 wt percent), and the other is a powder of single crystal of enstatite, which was mixed with gold as an internal pressure calibrant. These two starting materials were enclosed separately in two sample capsules made of semi-sintered magnesia, in the same pressure cell. Thus, we were able to measure unit cell volumes of end-member MgSiO3-perovskite and the iron and aluminum-bearing counterpart (0.05 Al and 0.05 Fe for 3 oxygens) under identical pressure and temperature conditions. The unit cell volumes were measured at pressures of 19-32 GPa and temperatures of 300-1500 K. Specific volumes (V/V0) of these two perovskites that are measured at the same pressure and temperature conditions are consistent with each other within experimental errors through the whole pressure and temperature range, which suggests that incorporation of iron and aluminum has no observable effect on thermoelastic properties of silicate perovskite at these pressure and temperature conditions. The determined bulk moduli of MgSiO3- and iron and aluminum-bearing perovskites at ambient conditions are 248(6) GPa and 250(4) GPa, respectively, which is consistent with the study using diamond anvil cell coupled with CO2 laser-annealing technique by Andrault et al. (EPSL, 193, 501-508, 2001).

V42A-0332 1330h POSTER

Raman spectroscopic study of synthesized Na-bearing majoritic garnets

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Majoritic garnets in diamond have been considered as the sample from mantle transition zone (e.g. Moore and Gurney, 1985). For non-destructive, in-situ Raman analysis, Gillet et al. (2002) systematically checked chemistry and Raman peak of various majoritic garnets in diamond. They treated majoritic component as number of excess-silica than 3.0 per formula unit. However, in the basaltic system, majorite garnets also have significant amounts of Na. Na substitution is coupled with Si and Ti as follows; Na +Ti = Ca +Al (Ringwood and Lovering, 1970), Na +Si = Ca + Al (Sobolev and Labrentav, 1971; Ringwood and Major, 1971) or Na + Si = Mg + Al (Gasparik, 1989). Each component in garnet is defined as follows; Mj (majorite) component = ((Si-3)-Na)/2), NaSi (Na2MSi5O12 where M= Ca, Mg, Fe2+) component = (Na-T)/2, and NaTi component = Ti/2. Okamoto and Maruyama (2003) conducted UHP experiments in the MORB + H2O system (KNCFMATSH) at 10-19 GPa. They show that 1) Mj and NaTi component are constant and lower than 0.1 at T = 900 °C, and 2) NaSi component increases drastically above 15 GPa although it is neglibly small at P<15 GPa. Raman spectra was newly analyzed using Okamoto and Maruyama (2003)'s run charges. Above 15 GPa, there is a characteristic sharp peak at 910 cm-1 and broad shoulder between 800 and 900 cm-1 as well as broad band near 960 cm-1. Gillet et at (2002) concluded that the former peak at 910cm-1 is the only reliable signature for the majoritic garnet (Si>3). They also implied that the latter two broad peaks are diagnostic feature for Ti rich garnet (> 1wt% of TiO2) as well as peak at 1030 cm-1. However, in all P range (10-19 GPa) of the present study, TiO2 is higher than 1wt%, and there is a peak at 1030 cm-1. Additional Ti-free experiment at 16 GPa, 1200 °C clearly revealed that Na-bearing majoritic garnet has a significant shoulder at 800-900 cm-1. Ref; Gasparik (1989) CMP, 102,389, Gillet et al. (2002) Am.Min., 87, 312, Moore and Gurney (1985)Nature, 318, 553, Okamoto and Maruyama (2003)PEPI, in press, Ringwood and Lovering (1970) EPSL, 7, 371, Ringwood and Major (1971)EPSL, 12, 411, Sobolev and Labrentav (1971)CMP, 31, 1.

V42A-0333 1330h POSTER

Single Crystal Preparation for High Pressure Experiments in the Diamond Anvil Cell.

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Measuring the effects of pressure on geomaterials in deep Earth's P-T conditions using the diamond anvil cell (DAC) is essential for understanding the phase transition mechanisms, the mechanical properties (which derives directly from the determination of the elastic constants), and the transport properties of deep-Earth materials. To date, most DAC research has been performed with polycrystalline samples. While these are sufficient for determining orientationally averaged properties of solids (*i.e.* bulk modulus, P-waves and S-wave aggregate velocities, etc...), single crystals offer the ability to measure a range of direction dependent properties (*i.e.* thermal and electrical conductivity, elasticity and plasticity, etc...). Subsequent comparison of measurements on single- and poly-crystalline materials can, for instance, make it possible to address the effects of pressure on the elastic anisotropy and preferred orientations in deep Earth's conditions. In order to achieve pressures above 1 Mbar, one must produce single crystal samples $\sim$25 μm in diameter and less than 10 μm thick. We have developed procedures to produce extremely high-quality metallic single crystals of this size from commercially available material with millimeter dimensions. Critical to the final product is the preservation of crystallinity during thinning and cutting. Our surface preparation methods include the use of selected abrasives, colloidal silica polishing and chemical etching. Samples are cut to final shape using a laser-ablation facility that can handle both conductive and insulating materials. To date, we have been successful in maintaining an extremely high degree of crystallinity and orientation in the final samples. Presently, we have analyzed cobalt and molybdenum samples with both white-light interferometry and synchrotron x-ray diffraction and are in the process of extending these methods to other metals and minerals, such as zinc, sapphire, and olivine.

V42A-0334 1330h POSTER

In Situ High Pressure Angle Dispersive X-ray Diffraction Experiments:With Sagittally-Bent Double Laue Monochomator

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A Sagittally-bent double Laue monochomator is used at the wiggler beam line X17C of NSLS, BNL. It can provide high-energy X-ray tunable from 20 keV to 40 keV. The monochomator consists of two Si crystals of 0.76 mm thick, with surface corresponding to the (001) planes. The 111 reflections of both crystals are used to diffract the x-ray. The two crystals are bent Sagittelly to 1 m radius and used in the Laue mode [1, 2]. The bent Laue crystals provide high energy-resolution beam with a flux one order of magnitude greater than that of a flat-crystal monochromator. For high-pressure diamond-anvil cell experiments using angular dispersive x-ray diffraction, K-B mirrors are used to focus the incident beam from 0.180mm x 0.180mm to 0.025mm x 0.025mm. Two samples were studied with different x-ray energies. The Ag2O2 sample was studied at pressures up to 20 GPa using energy of 38.9246 keV (0.031851 nm) x-ray. The problem of strong Ag

fluorescence causing Ge-detector to saturate in energy dispersive x-ray diffraction was not an issue in the present angular dispersive experiments. With energy of 30.4912keV (0.040663 nm) x-ray, NaMgF3 was studied to 30 GPa. Exposure time was 1 to 6 minutes for different pressures. No phase transition was found in the pressure range. The P-V data fitting to a third order Birch- Murnahgan equation yields a bulk modulus Ko=68.9 1.7 GPa and Ko'=6.3. [1] Z. Zhong, et. al., Acta. Cryst. A 59 (2003) 1-6 [2] Z. Zhong, et. al. J. Appl. Cryst., 34 (2001) 646-653

V42A-0335 1330h POSTER

Neighborite Under High Pressure: *In Situ* Angle Dispersive X-ray Diffraction Study Using Synchrotron Radiation

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The neighborite ($NaMgF_3$) is an ideal analogue model for silicate perovskite ($MgSiO_3$) due to the similarities between their crystal and electronic structures. The advantage of the analogue study is that the weaker bonding feature of neighborite grants us the opportunity to simulate behavior of silicate perovskite at lower mantlei. e.high pressure and high temperature condition, at relatively lower P-T conditions. The previous high pressure studies for neighborite were reported by Zhao et al [1, 2]. Energy dispersive x-ray diffraction data were achieved within 10GPa and 1000^{o}C, while angle dispersive x-ray diffraction data were obtained only at 4.9GPa and room temperature.More information of atomic position change is required to reveal the role of MgF_6 octahedral framework tilting during its phase transition process responding to heating andcompressing. Thus the high-resolution monochromatic x-ray powder diffraction studies on $NaMgF_3$ perovskite at high pressure were carried out using diamond anvil cell at X17C of National Synchrotron Light Source (Brookhaven) and HPCAT of Advance Photon Source (Argonne). The orthorhombic structure keeps stable under pressure up to 30 GPa, and the crystal structure is refined using Rietveld method. The result indicates that tilting angle of the MgF_6 octahedral framework increases continually while the octahedral Mg-F bond length decreases slightly with increasing pressure.Difference between the tilting angles derived from macro-structure (lattice parameters) and from micro-structure (atomic positions), as well as the trend of change in the tilting angle with temperature and pressureare discussed. [1]. Zhao YS, Weidner DJ, Ko JD, Leinenweber K, Liu X, Li BS, Meng Y,Pacalo REG, Vaughan MT, Wang YB, Yeganehhaeri A,J.Geophys. Res. Solid Earth, 99 (1994) 2871. [2]. Zhao YS, Parise JB, Wang YB, Kusaba K, Vaughan MT, Weidner DJ, Kikegawa T, Chen J, Shimomura O,Am.Miner., 79 (1994) 615.

V42A-0336 1330h POSTER

A High Pressure X-Ray Diffraction Study of CaCO3-Aragonite: Implications for the Post-Aragonite Phase Transition

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The volume and lattice parameters of CaCO3-aragonite have been measured as a function of pressure to 50 GPa using angle-dispersive synchrotron x-ray diffraction at 300 K. The Birch-Murnaghan equation of state of aragonite yields a best-fit bulk modulus (K0) of 83 (+/- 3) GPa, assuming a value of dK/dP of 4. A progressive pressure-induced change takes place in the diffraction patterns, with the (021) and (111) diffraction lines converging on one another with compression. This change is accompanied by a significant (85 percent) loss in relative intensity of the (202) and (041) peaks. This convergence and shift in intensity of diffraction lines implies that CaCO3-aragonite is approaching a transition to a trigonal structure, such as occurs within BaCO3 at pressures of 7 GPa. Indeed, the b/a ratio of aragonite at 50 GPa approaches the square root of 3: the critical value for producing a transition to a trigonal structure, and close to that of BaCO3 at low pressure. A short extrapolation of our results indicates that a phase transition, with minimal volume change, is expected in CaCO3-aragonite at pressures exceeding 60 GPa. This result is in general accord with the systematics of phase transitions in aragonite-structured divalent cation carbonates. If free CaCO3 exists in the deep mantle, we anticipate that it will occur in a trigonal structure.

V42A-0337 1330h POSTER

A High Pressure Infrared Spectroscopic Study of PbCO3-Cerussite: Constraints on the Structure of the Post-Aragonite Phase

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We have measured the infrared spectrum of aragonite-structured PbCO3-cerussite to 42 GPa at 300 K in the diamond anvil cell. The in-plane bending, symmetric stretching, and asymmetric stretching vibrations of the carbonate group each shift to higher frequencies to pressures of 17 GPa at rates between 1.1 and 4.0 cm-1/GPa, while the out-of-plane bending vibration shifts to lower frequency by -1.3 cm-1/GPa. This softening is likely due to pressure-induced strengthening of the Pb-O bond. A phase transition is observed beginning at 17 GPa: this is in accord with previous Raman spectroscopic and x-ray crystallographic work on PbCO3 under pressure. The phase transition is manifested by a splitting of the out-of-plane bending vibration, and a broadening and dramatic decrease in amplitude of the symmetric stretching vibration: the absolute positions of the remaining bands are essentially identical between the low- and high-pressure phases, implying that the bonding environments of the carbonate unit in the two phases are similar. However, the pressure shifts of the vibrational bands are lower in the high pressure phase, with shifts between 0 and 0.3 cm-1/GPa: these smaller rates suggest that the carbonate group in the high pressure phase is less compressible than within the aragonite-structured phase. No further phase transitions were observed to 42 GPa. The high pressure phase has been proposed to crystallize in the orthorhombic space group P2sub122 with 16 formula units in the unit cell by Lin and Liu (1997). Yet, the band splittings and disappearance of the symmetric stretching vibration in the spectra of the high pressure phase are instead consistent with a substantially smaller trigonal unit cell, with space group P-31c: this is the same as that of the high pressure phase of BaCO3 (Holl et al., 2000), and our spectra strongly resemble those of this phase. Our results thus indicate that the post-aragonite high pressure phase in carbonates may generally be a comparatively high symmetry trigonal structure. Such a structure thus represents the most likely candidate for the ultra-high pressure structure of CaCO3-aragonite.

V42A-0338 1330h POSTER

Cation Order-Disorder of Dolomite at High Pressure and Temperature

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The structure of dolomite, $CaMg(CO_3)_2$, was determined at a constant pressure of about 4 GPa and from 25 to 1345^{o}C by *in-situ* synchrotron X-ray diffraction ($\lambda = 0.91997$ Å) at ID30 of the ESRF, France. The sample (packed into a Au capsule) was first compressed and data were then collected at different temperatures. Previous studies on the ordering in dolomite were done on quenched samples, but the kinetics of reordering upon quenching were too rapid to preserve the high-temperature disorder state. In fully ordered dolomite, the fraction of Ca cations on the 3*a* site is $x_{Ca} = 1$, whereas in a disordered dolomite, $x_{Ca} = 0.5$. Alternatively an order parameter $S = 2x_{Ca}$-1, varies from $S = 1$ (where $x_{Ca} = 1$) for a completely ordered dolomite to $S = 0$ (where $x_{Ca} = 0.5$) for a completely disordered dolomite. The ratio of intensities of reflections sensitive and insensitive (ratio = $I_{(105)}/I_{(006)}$) to ordering was also used to test the disorder in dolomite, and this ratio shows that dolomite disorders with temperature. These methods for characterizing the order-disorder reaction is compared to the results obtained from Rietveld refinement methods. Initially, $S = 1.0$ ideally for ordered dolomite. On heating, there is no change in cation ordering until the temperature is high enough to cause exchange of Ca and Mg between the two octahedral sites to occur. This activation barrier is overcome beyond about 1000^{o}C, where the sample starts to disorder. On further heating the sample continuously disorders along a smooth pathway to the maximum temperature studied ($T_{max.} = 1345^o$C, $S = 0.2(2)$). Trace amounts of CaO and MgO were observed in diffraction patterns at and beyond 1135^{o}C. This would indicate either decomposition or partial melting, but dolomite was still the dominant phase. This reaction may cause a slight deviation from the ideal stoichiometry for the remaining dolomite.

V42B MCC: Level 1 Thursday 1330h

Eruptive Behavior of Hazardous Volcanoes II Posters

Presiding: **C A Neal,** U.S. Geological Survey**; P Stelling,** University of Alaska, Anchorage

V42B-0339 1330h POSTER

Flow-Package Emplacement of the Valley of Ten Thousand Smokes Ignimbrite During the 1912 Novarupta, Alaska, Eruption

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The Valley of Ten Thousand Smokes (VTTS) ignimbrite was emplaced by 9 sequential flow packages, each with distinct compositional proportions of rhyolite (R), dacite (D) and andesite (A) pumice clasts that permit us to map their boundaries and flow paths from vent to distal extents. Changing R:D:A proportions link ignimbrite formation to contemporaneous fall deposition during the first ∼16 hours (Episode I) of the eruption. Documentation of pumice compositional proportions in the ignimbrite was accomplished by counts on at least 100 lapilli-sized pumice clasts at multiple levels in vertical sections wherever accessible, and more widely over most of the ignimbrite surface in the VTTS. An initial 100% rhyolite flow package (time-equivalent to regional fall Layer A) was followed by packages with increasing proportions of andesite then dacite (time-equivalent to regional fall Layers B1-B3). The coeval regional fall deposits are locally intercalated with the ignimbrite and show parallel changes in R:D proportions, but lack significant amounts of andesite. Andesite is thus inferred to represent only a low-fountaining component in the eruption column, and is preferentially represented in packages filling the VTTS north of vent. Maps of the packages show that the most-extensive deposits occur midway through the sequence (B1 and early-B2 times) where flow mobility and volume were optimised; the earlier all-rhyolite flows were highly energetic but less voluminous, while later packages were less voluminous. Boundaries between flow packages are expressed as one or more of: sharp color changes corresponding to compositional variations, persistent finer-grained basal parts of flow units, compaction swales filled by later packages, erosional channels cut by the flows that fill them, lobate accumulations of material of one composition, and (particularly south of vent) intercalated fall deposit layers. Emplacement of the VTTS ignimbrite involved accumulation of successive, largely overlapping packages of material, with breaks in deposition only locally apparent, typically between the products of non-successive packages.

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Dacite Dome Growth and Disruption During the 1912 Novarupta Eruption: The Missing Episode

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