V31C-0951 0830h POSTER

Explosive and Effusive Silicic Magmatism in the Macolod Corridor, Luzon Islands, Philippines

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Silicic magmatism occurs in the Macolod Corridor, Luzon Island, Philippines. Luzon Island is an oceanic arc related to the subduction of the South China Sea plate eastward under the Philippine. Several silicic domes and voluminous pyroclastic deposits occur in the Macolod Corridor, which is a pull-apart rift zone that cuts across Central Luzon. The Laguna de Bay caldera occurs on the northern margin of the Corridor and has been the source of several pyroclastic flows that contain abundant silicic pumice fragments. Dating the different types of volcanic deposits reveals similar ages for the domes and some of the ash-flows sheets. Ar/Ar dates of three of the domes, Trapiche, Mt. Bulalo and Mt. Bijang has yielded ages of 43±17 ka, 15±7 ka, and 66±14 ka, respectively. ^{14}C dates of the pyroclastic samples from Laguna de Bay area used in this study are 42-47 ka (unpublished PHIVOLCS report, 1999). The silica concentrations for the high-silica portion for the domes and ignimbrites are also similar, averaging 66 wt.% SiO_2 (normalized anhydrous) for Laguna de Bay, and 68 wt.% for the domes. The chemical compositions of both the domes and Laguna de Bay samples put them outside the field of adakites. Thus, it is unlikely that the silicic magmas represent subducting slab melts. Despite the similar ages, SiO_2 concentrations, and proximity of the domes and caldera, they are chemically distinct with respect to both major and trace element concentrations. The Laguna de Bay samples have higher REE, Th concentrations and lower CaO and Na_2O concentrations than the dome samples. Negative Eu anomalies are present in the Laguna de Bay samples and not in the dome samples. These data are consistent with plagioclase fractionating from the dome magmas producing the Laguna de Bay magmas.

V31C-0952 0830h POSTER

Structural, Geochemical, and Isotopic Studies on Magmatic Dyke Swarms of the South Shetland Islands Volcanic Arc, West Antarctica - Revealing the Geodynamic History

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Between 2000 and 2002 areas of up to 100,000 m^2 have been mapped at several locations of the South Shetland Islands, mainly on King George and Livingston Islands. A structural analysis of the dykes and the host rocks was undertaken, and about 250 dykes were sampled for geochemical studies.
On Livingston Island six different strike directions were identified, yielding a reliable relative time sequence as deduced from field-relationships. Geochemically, these dykes can be separated into five different groups, correlating with the different strike directions, one of those groups comprising two directions. Analysis of the structural data shows, that at least on Livingston Island only minor changes of the tensional situation occurred.
Geochemical data reveal that all dykes of the South Shetland Islands belong to a calc-alkaline, arc-related suite, ranging from primitive basalts to highly differentiated rhyolites.
Interpretation of Sr isotopic data of the dykes proves difficult, as there are indications for sea-water induced Sr-alteration.
Nd isotopic analysis yield better results, revealing a three-stage development from the oldest dykes (ϵNd -0.2 to 0.6) on Livingston Island towards a second, younger group (ϵNd 2.8 to 4.2, also Livingston), terminating with a third one (ϵNd 5.2 to 7.6), which includes the youngest dykes on Livingston and all dykes on King George and also Penguin Island. Either two mantle sources were involved, or the amount of crustal contamination changed considerately with time. It may have been high during initial arc volcanism, because of a still unstretched crust, then decreasing continually with progressing volcanism. In any case, the pattern reflects a chronological sequence corresponding with other authors' hypothesis of a migrating arc volcanism from SW to NE, i.e. from Livingston (older dykes) towards King George Island (younger dykes).
Pb isotopic data, plottet together with MORB- and sediment-samples dredged from the Drake Passage, indicate a three-component mixture of the arc magma. Mixing of MORB- and sediment-sources alone cannot explain the observed pattern. An additional source, maybe the crust underlying the South Shetland block, was involved.

V31C-0953 0830h POSTER

Fast Orogenic to Anorogenic Magmatic Transition in Central Tyrrhenian Basin at Pontine Islands

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The location of the Pontine Archipelago makes it a key area to describe the initial Neogene volcanism in the Tyrrhenian basin. This archipelago is indeed at the connection between the Northern and the Southern Tyrrhenian basin. A new geochronological and geochemical survey of the two northernmost islands of Ponza and Palmarola permits a detailed examination of the complex tectonic and volcanologic evolution of this area. Previous studies suggested that volcanic activity began before 5 Ma on Ponza. Twenty-five new K-Ar ages, obtained by the Cassignol-Gillot technique, constrain the volcanic activity (mainly rhyolites) of Ponza to the last 4.2 Ma, with two episodes of quiescence between 3.7 and 3.2 Ma and between 2.9 to 1.0 Ma. At 1.0 Ma, a trachytic episode ended the volcanic activity in Ponza. A new volcanic episode dated at 3.2-2.9 Ma has been identified on the central and southern portion of the island, with emplacement of pyroclastic units. Palmarola has rhyolitic products with K-Ar ages from 1.6 to 1.5 Ma. Although only 6-8 km apart, the two islands show significantly different geochemical signatures. Trace element ternary diagrams and Y/Nb and Yb/Ta ratios show that Ponza Pliocene rhyolites are representative of magmas emplaced in a syn-collisional orogenic context, while Pleistocene products (Palmarola rhyolites and Ponza trachytes) are characteristic of a late- to post-collisional context. The source of these Pleistocene products is chemically close to OIB. The transition between orogenic to anorogenic magmatism in this portion of the archipelago has been estimated to last less than 1.3 Ma. Such a fast transition could be related either to a process of slab break-off starting during the Pliocene, or to a slab window in the subducted plate. This window could have channeled plume-type magmas from the lower mantle into Italian volcanic provinces. This would explain the progressive magmatic evolution we observe in Pontine Islands, from a calc-alkaline volcanic-arc type to an alkaline within-plate type volcanism

V31C-0954 0830h POSTER

Back-Arc Extension in Continental Lithosphere: Reflections From a Buoyant Mantle and Thin Crust.

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Back-arc extension within the continental lithosphere of New Zealand has produced a zone of thin crust and mantle of unusual geophysical properties. The Central volcanic region (CVR), central North Island, New Zealand is the apparent extension of the Havre Trough back-arc basin, which has opened since 5ma. The area has ∼ 12 times the continental heat flow and numerous geothermal systems and volcanic complexes. Seismic data shot in 2001 as part of the NIGHT (North Island GeopHysical Transect) project show low crust and upper mantle velocities and two unusual reflectors beneath the volcanic area. The first is interpreted as a crust-mantle transition zone or "Moho" reflector that shallows to ∼ 16 km beneath the area of highest extension and volcanic activity. The second is a strong reflection at 35 km depth, which for the CVR is in the mantle. The three defining attributes of this reflector are: it has an apparent lateral extent equivalent to the surface expression of the CVR, it is of low frequency and it is of high amplitude compared to the crust-mantle reflection and Pg arrivals. AVO analysis of the mantle reflection indicates it is likely to be produced by a layer of negative impedance contrast equivalent to at least 80% drop in S-wave velocity. Laboratory studies on naturally organised, realistically orientated melt inclusions indicates such an S-wave drop could be produced by 11 - 15% partial melt. We therefore interpret the reflector to be a body of melt pooled at a viscosity boundary in the mantle. Despite the thin crust of the CVR, the topography of the area defines a broad dome with average elevation ∼ 300m above sea level. The low Pn wave speed measured in the area and the presence of melt in the mantle beneath the region of thinnest crust and highest extension indicates a possible contribution from decompression melting and the support for the thin crust being supplied by a mantle of increased buoyancy.

V31C-0955 0830h POSTER

Constraints on the Mechanism and Timing of Sediment Recycling Beneath the Tonga-Kermadec arc From Be isotopes

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The fate of sediment subducted beneath island arcs and where and how portions of this becomes returned to the surface in arc lavas has profound implications for the thermo-mechanical nature of the mantle wedge and crustal evolution. Here we compare the ^{10}Be/^{9}Be isotope ratios in Tonga-Kermadec arc lavas with a ^{10}Be/^{9}Be profile from the subducting sediments which confirms previous evidence that the sediment component takes several Myr longer than the subducting plate to reach the magma source region beneath Tonga. We also show that the arc lavas trend towards Th/Be and Li/Be ratios which are much lower than either the bulk sediment or the mantle wedge. This cannot be explained by bulk sediment addition and so requires addition of a sediment partial melt. Experimental data on these sediments constrain this to occur at approximately 775 degrees C between 0.5 and 2 GPa. The data require a hotter thermal structure and a more complex pattern of convection in the mantle wedge than has previously been inferred in models assuming a simple mechanical coupling between the wedge and the subducting plate. This may be linked to evidence for southward flow of the mantle parallel to the trench axis.

V31D MCC: Level 2 Wednesday 0830h

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

Presiding: **S R Shieh,** National Cheng Kung University

V

V31D-0956 0830h POSTER

Electron Channelling Spectroscopy of Iron in Majorite and Silicate Perovskite

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Results from high temperature and pressure experiments indicate that $MgSiO_3$ silicate perovskite is likely the most important carrier mineral phase for trivalent cations such as aluminium and ferric iron in the Earth′s lower mantle. Due to their substitution into $A^{2+}B^{4+}O_3$ perovskite, a certain amount of oxygen vacancies might be stable in the crystal structure. The incorporation mechanisms are expected to play a major role in determining the physical and chemical properties of perovskite. The crystal structure has two potential lattice sites for trivalent cations. To clarify the crystal chemistry of Al^{3+} and Fe^{3+}-bearing perovskite, it is necessary to determine the site-specific affinities. Majorite and silicate perovskite assemblages synthesized from natural pyroxene in the multi-anvil press and diamond-anvil cell were studied by energy dispersive X-ray spectroscopy (EDXS) and electron energy-loss spectroscopy (EELS) in a transmission electron microscope (TEM) to quantify the composition and oxidation state of iron. In these assemblages of the $(Mg,Fe)SiO_3$-Al_2O_3 system, ferric iron has a much stronger affinity to silicate perovskite than to majorite at the same pressure, temperature and oxygen fugacity. To determine the site occupancy of iron in majorite and silicate perovskite, we have also performed both spectroscopic techniques (EDXS and EELS) under channelling conditions. Electron channelling spectroscopy enables us to distinguish the octahedral sites of both phases from other cation sites by variations in the intensity ratios of the EDXS and EELS spectra acquired systematically at tilting conditions about the channelling-sensitive crystal plane and zone axis. In majorite almost all of ferric iron is partitioned into the octahedral site, whereas in silicate perovskite both ferrous and ferric iron substitute preferentially into the pseudo-dodecahedral site of the perovskite structure. The latter is charge-balanced by aluminium in the octahedral site.

V31D-0957 0830h POSTER

High-Temperature Phase Transition in Enstatite : Raman Spectroscopic Results

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$(Mg,Fe)SiO_3$ enstatite has various polymorphs of which orthoenstatite with space group Pbca is the most common in natural rocks. The existence of a high temperature form has been suggested from various experiments but its symmetry remains unknown. Recent high-temperature Brillouin measurements on nearly pure $MgSiO_3$ show that this transition is first order with a strong hysteresis (Tc at about 1200-1250°C with increasing temperature, Tc around 1000°C with decreasing temperature; Jackson et al, 2003). It is accompanied by strong pretransitional softening of some elastic constants and has some important consequences in the understanding of upper mantle seismic properties especially in hot regions. In order to more fully understand the nature of this transition and possibly the structural changes associated with it, we have performed in situ Raman spectroscopy on pure enstatite up to the transition temperature. The transition is observed in the same temperature range with increasing temperature, and is characterized by a decrease of the number of Raman modes, which can be interpreted as the transition to a space group with reduced Wigner-Seitz cell. Pretransitional effects are observed especially on a low frequency mode at 80 cm^{-1}, which displays pronounced anharmonic behaviour. Possible space groups are Pbcn (protoenstatite), C2/c (high-clinoenstatite) or a previously unreported Cmca structure. The latter is a supergroup of Pbca and could account for the pretransitional softening. On decreasing temperature, backtransformation to orthoenstatite is marked by the appearance of cracks along simple crystallographic directions, which eventually leads to the breaking of the submillimeter-sized single crystals used as starting materials. Areas of untransformed high-temperature phase can be preserved down to about 750°C. This large hysteresis is strongly controlled by crystal shape and size as well as thermal history. In a parallel experiments, needle shaped thin (5x50 micrometers) crystals with the high-temperature structure have been quenched from a melt down to room temperature. Finally, preliminary experiments on a natural Fe bearing orthoenstatite from San Carlos show that iron increases the transition temperature that could not be observed up to 1260°C for this composition.

V31D-0958 0830h POSTER

Pressure Dependency of Viscosities of MORB Melts

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MORB (Mid Ocean Ridge Basalt) melt is one of the most abundant magmas observed in the surface of the Earth. Therefore, it is important to determine the physical properties of the melt at high pressure in order to discuss the eruption and transportation processes of the magmas. In the previous studies, viscosities of basaltic melts were measured by quenching falling sphere method using a piston cylinder apparatus. They showed that viscosities of the basaltic melts decrease isothermally to 2 GPa with increasing pressure. In the present study, we used the falling sphere X-ray radiography method together with the conventional quenching method in order to investigate the pressure dependence of viscosity of the basaltic melts above 2.0 GPa. Experimental conditions were from 1.5 to 4.4 GPa at 1873 K and from 3.5 to 5.2 GPa at 2023 K. Falling sphere X-ray radiography method was performed using KAWAI (MA-8) type multianvil press system installed at BL04B1 beamline at SPring-8 (SPEED1500). Cell assembly and experimental details are the same as Suzuki et al. (2002). Pt or Re sphere with a diameter of 100-150 mm were used as the falling sphere. Pressures and temperatures were determined from the equation of state of h-BN and MgO. Quenching falling sphere method was made using the KAWAI multianvil press system installed at Tohoku University. We used a diamond grain which is not the perfect sphere as the falling sphere marker. We made the correction for the shape of diamond marker by using liquid whose density and viscosity were known before the experiments. Experimental details were the same as that used by Mori et al. (2000). The viscosity of the MORB melt decreases with increasing pressure up to 3.0 GPa, which is consistent with the previous studies. However, it increases above 3.0 GPa with increasing pressure. The result shows the existence of minimum in viscosity at around 3 GPa. It implies that MORB melt moves most smoothly up to the depth of 100 km (3 GPa) in the Earth's mantle and it might accumulate at the shallower depth to form the magma reservoir because of the viscosity minimum at high pressure. Reference Suzuki et al., Phys. Chem. Minerals. 29 (2002), 159-165 Mori et al., Earth Planet. Sci. Lett., 175 (2000) 87-92.

V31D-0959 0830h POSTER

The Anvils as Pressure Calibrants in the Hydrothermal Diamond Anvil Cell

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Throughout the crust and the upper part of the mantle, water is an important agent of heat and mass transport in processes ranging from metasomatism to magma generation in arc environments. One of the important properties of water in this regime: its ability to dissolve significant amounts of solids, presents a substantial challenge to the experimental study of water-rich systems. Many commonly used pressure standards, such as quartz and ruby, dissolve in water under the conditions accessible to the hydrothermal diamond anvil cell (up to 1200 K and 5 GPa). For this reason, it is important to develop alternative pressure calibrants. Two methods have been developed by other groups for pressure calibration in the HDAC in the presence of water. One method relies on the equation of state of the ambient fluid and the observation that the sample chamber remains approximately isochoric on heating. Disadvantages of this method include our imperfect knowledge of the equation of state of water over the relevant pressure-temperature interval, possible changes in fluid composition, and sample chamber assembly relaxation at temperatures above 800 K. The second method is based on the Raman signal from diamond chips loaded with the sample. Synthetic ^{13}C diamond is used to avoid overlap with the much stronger signal from the anvils. Diamond is an ideal pressure sensor since it is chemically inert and unaffected by water. Therefore, we use the tips of the diamond anvils as "internal" sensors. The primary disadvantage of this method is that the stress distribution inside the anvils is non-hydrostatic and inhomogeneous, although the normal stress across the diamond-sample interface must be continuous. Using confocal micro-Raman spectroscopy we are able to characterize both the inhomogeneity and the non-hydrostaticity of the diamond stress field by combining axial and radial transects with peak shapes. We find that on room temperature loading there is substantial inhomogeneity in the diamond stress field: variations of up to 2.3 cm^{-1} or about 0.8 GPa over a pressure range of 0 to 3.5 GPa. However, heating substantially reduces inhomogeneity in the vicinity of the diamond-sample interface allowing the derivation of a useful pressure calibration. Preliminary results show that the primary Raman line of diamond shifts with respect to temperature according to the equation 1332.15 - 0.0016x - 3.5e-5x^2 + 7.1e-11x^3 where x is temperature. The same Raman line of diamond shifts with pressure according to the equation 1332.15 + 3.4*P where the pressure, P, is in GPa. We find that the effects of temperature and pressure are independent of one another so that an independent measurement of temperature (with thermocouples) together with the measured Raman shift determines the pressure with an accuracy of 0.27 GPa at 800K and 2 GPa. We compare our calibration to the quartz and ruby calibration scales over the range where they are stable. We also compare our calibration to previous experiments using independent pressure calibrants.

V31D-0960 0830h POSTER

High Pressure Elasticity of Iron Alloys From Nuclear Resonant Inelastic X-ray Scattering and X-ray Diffraction

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As major constituents of the Earth's core, Fe and its alloys have long been of great interest to geophysicists. Information on their high-pressure, vibrational dynamic behavior is essential for interpreting seismic observations and for numerical modeling of the Earth's deep interior. Silicon and hydrogen have been suggested as possible lower atomic weight components in the Earth's core. Previous work has shown that the addition of a modest amount of Si to Fe can have a profound effect on the Fe. However, Fe-rich Fe-Si alloys have not been investigated above 100 GPa, thus requiring extrapolation of lower pressure data to core conditions. Hydrogen in the core could have profound implications on the H budget within the Earth and our understanding of the physics and chemistry of the core. X-ray diffraction (XRD) experiments show that stoichiometric FeH is formed at 3 GPa from the reaction of Fe and fluid hydrogen, and this compound is stable to at least 62 GPa. With the limitation of XRD alone, however, important geophysical and crystal chemical information about FeH is still lacking. We have conducted XRD experiments under hydrostatic conditions with He as a pressure-transmitting medium to 50 GPa and under nonhydrostatic conditions to over 200 GPa. We have conducted nuclear resonant inelastic scattering (NRIXS) experiments on FeH to over 50 GPa at ambient temperature. The collected NRIXS spectra have been summed, and converted to a partial (Fe related) phonon density of state (DOS) for final analysis. The initial slope coupled with hydrostatic equation of state data yields VP and VS for comparison to seismic observations for insight into core chemistry and physics.

V31D-0961 0830h POSTER

Magnetic and structural transition in Fe_3S at high pressures

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Fe_3S, containing 16.1 wt% sulfur, is the most iron rich compound in the Fe-FeS system. If sulfur is a dominant light element in an iron bearing planetary core, Fe_3S could be a major stable phase together with iron in a solid core. We have studied magnetic properties of Fe_3S at high pressures to 31 GPa in a diamond anvil cell. The Fe_3S sample was synthesized in a large volume press. By measuring the pressure dependence of Fe Kβ fluorescence line using x-ray emission spectroscopy, we have observed a magnetic transition in Fe_3S at pressures around 20-25 GPa and at room temperature. The relative intensities of spectral features indicate the collapse of the 3d electron magnetic moment at the transition. This magnetic transition is found to be reversible with pressure, and associated with a structural transition as evidenced from x-ray diffraction measurements.

V31D-0962 0830h POSTER

Liquids in the Diamond Anvil Cell: High Pressure-Temperature Chemistry of Formic Acid

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The chemical and physical properties of liquids under high pressures and temperatures are of continuing interest and application to the planetary science community. Using near-simultaneous FTIR and Raman spectroscopy including high-resolution optical video, we have begun to study the behavior of formic acid (HCOOH) at conditions observed on Europa, Ganymede and Callisto. We present a phase diagram, including melting curve, proposed reaction mechanisms and solid-state phase transitions, over a temperature range from 300-550 K and a pressure range from .1 to 9 GPa. Reaction products, including CO_2 and amorphous carbons ($COOH_n$) have been identified. Preliminary results from FTIR studies are used to determine reaction rates, and pressure dependent activation energies. We have also employed a detailed kinetic reaction mechanism to study the decomposition of formic acid at extreme conditions by using a fluid exponential-6 equation-of-state for the reacting species. We have used first principles DFT and semi-empirical tight binding methods to predict properties of solid formic acid under isotropic and uniaxial compression. We compare the results of both simulations to our experimental observations.

V31D-0963 0830h POSTER

Fluid and Hydrous Melt Compositions in Equilibrium With K-Free Eclogite at 6 GPa and Temperatures of $900 - 1400^\circ$C

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Fluid or hydrous melt compositions in equilibrium with K-free basaltic eclogite were determined experimentally at 6 GPa and $900 - 1400^\circ$C. Each capsule contained 15-26 wt% H_2O, the eclogitic starting material mixed with CsOH solution, and a thin layer of diamond aggregates as a fluid/melt trap. The liquid (fluid or melt) compositions were determined using a novel analytical technique, the freezing approach: the capsule was frozen prior to opening and kept frozen during analyses to prevent any fraction of the fluid to be lost prior to analysis. The liquid composition was thus analyzed as solid ice using a laser-ablation ICP-MS employing Cs as an internal standard (which partitions completely into the liquid). Parallel set of experiments was performed and analyzed following a conventional, water evaporation approach, whereby the exsolved water/fluid is dried out of the capsule prior to analysis. The trapped quench solute was analyzed using the laser-ablation ICP-MS and the residual eclogitic mineralogy was analyzed using an electron microprobe. The liquid compositions were calculated using mass-balance constraints. The two analytical approaches are in good agreement, suggesting that the freezing approach can be applied to experimentally problematic systems, e.g., K-bearing, in which a significant portion of K still resides in the exsolved water/fluid after quench and is then lost while drying the capsule in the water evaporation approach. At 6 GPa, the liquid phase shows a smooth change in composition from an aqueous fluid to hydrous melt with increasing temperature. The liquid contains 85 wt% H_2O in equilibrium with residual eclogite at 900°C that gradually changes into a hydrous melt with 5 wt% H_2O at 1400°C, indicating that at this pressure, a K-free eclogite is above its second critical endpoint. Similarly, Na_2O content increases from 1 wt% at 900°C to 5 wt% at 1400°C. Subtle changes in the smooth trends correlate with phase boundaries: TiO_2 concentration increases with increasing temperature from 900°C to 1100°C and remains constant with further increase in temperature. These trends concur with the eclogitic mineral assemblages and modal proportions reflecting an increase in the relative mode of garnet while clinopyroxene and rutile are consumed with increasing temperature.

V31D-0964 0830h POSTER

Finite Element Modeling of Elastic Volume Changes in Fluid Inclusions: Comparison with Experiment

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Inclusions within mineral grains in rocks of all types are widely studied because they contain information about either the environment of formation of the mineral grain or conditions since. Understanding the mechanics of the inclusion-host system caused by differences in thermal expansion and compressibility is often essential for interpreting measurements made on the inclusion. We are studying the mechanics of inclusions by comparing elastic volume changes and deformation of synthetic pure water inclusions in quartz with finite element models of the individual inclusions. Synthetic fluid inclusions are ideal for such a study because the mechanical boundary conditions as well as the resulting deformation are either known or can be determined from the homogenization temperature and equation of state of the fluid. The experiments for this study were conducted using a hydrothermal diamond anvil cell with water as the pressure medium. The homogenization temperature of the inclusions was used to determine the inclusion volume at various confining pressures. The confining pressure was obtained from the homogenization or the ice I liquidus temperature of the pressure medium. After the experiment the homogenization temperature of the inclusion at 1 atm confining pressure was re-determined to confirm that the deformation of the inclusions was completely elastic. The inclusion shape for each model was determined from optical photomicrographs. The thickness of the synthetic fluid inclusions is consistently about 1 micron. We used a commercially available engineering package, MSC MARC/Mentat, to create and analyze two-dimensional and three-dimensional finite element models of the inclusions. The inclusions are assumed to have at least one mirror plane (parallel to the plane of the photograph) permitting a portion of the inclusion to be modeled. We assume a linear elastic response for the quartz host and have used both isotropic and anisotropic elastic moduli. Within the uncertainties associated with the inclusion's cross sectional shape and orientation within the quartz, the 3D models can reproduce the observed elastic volume changes for each loading condition. We also observe that sheet-like inclusions experience greater elastic volume changes than do elongate inclusion. For elongate inclusions, the length to thickness ratio has no measurable effect on the compressibility of the inclusion. This is consistent with systematics observed in our 2D axisymmetric models of prolate ellipsoids and cylinders terminated by cones. For these inclusions, the compressibility of the inclusion is highly dependent on its aspect ratio below about 5:1 and only slightly dependent on the aspect ration above 10:1. Ongoing work is focusing on improving the 3D characterization of the inclusions and on refining the estimates of stress in the quartz host.

V31D-0965 0830h POSTER

Ultrasonic Shear Waves in the Diamond-Anvil Cell and Shear-Mode Softening in (Mg,Fe)O

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Pure-mode elastic shear waves have been transmitted into the DAC using a new P-to-S conversion buffer rod for GHz-ultrasonic interferometry. The advance has wide application to the Earth and material sciences. Both longitudinal and shear-wave travel times can now be measured in optically dark (or opaque) single-crystal minerals (or metals) at mantle pressures. Wüstite-FeO and magnesiowüstite-(Mg,Fe)O containing more than 50% iron exhibit pressure-induced $C44$ mode softening over the experimental pressure range to 10 GPa, whereas ferropericlase closer to expected lower-mantle compositions (25%) exhibits increasing shear velocities more similar to MgO. The pressure derivatives ($dC44/dP$) are: -1.06(3), -0.95(1), -0.16(1) and 1.24(5) for Fe0.95O, and (Mg,Fe)O with 78, 56, and 24 mol% FeO respectively. The observed shear-mode softening in iron-rich (Mg,Fe)O may be due to strong magnetoelastic coupling (as in FeO) and indicates an instability in the rocksalt ($B1$) structure at high pressure.

V31D-0966 0830h POSTER

High-Pressure Studies of Hydrogen- and Carbon-Bearing Minerals

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The study of volatile-bearing minerals (e.g., hydroxides, hydrous silicates, and carbonates) at high pressures and temperatures is of great importance to understand the dynamics of volatile transport and recycling in the Earth's deep interior. Results from x-ray diffraction can provide rich information such as the equation of state, crystal structure, and strain state. Results from spectroscopic studies can provide detailed local information as compared with x-ray diffraction. Therefore, these two powerful tools are mutually complementary for characterization of materials. Here we utilize x-ray, Raman, and infrared techniques to study H-bearing and C-bearing materials at high pressure. Calcite ($CaCO_3$) was compressed in a diamond cell and examined at room temperature be persist to the highest pressures. However, upon laser heating at 20-80 GPa calcite-III transformed to a previously unidentified new phase which could be temperature-quenched. Upon decompression of samples heated at 40 GPa or less, the high-pressure phase persisted until pressures close to 1 bar, at which point it transformed to a mixture of aragonite and calcite. Phase E and superhydrous phase B are two of the dense hydrous magnesium silicates (DHMS) and are regarded as potential H-host candidates in the Earth's mantle. The nonstoichiometric nature of phase E and lack of long-range order make it an interesting material to study. Phase E was compressed to about 42 GPa in a diamond anvil cell. Our quasi-hydrostatic data showed that the phase E did not encounter any structural change at pressure up to 42

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GPa. Similar results were also observed from IR spectroscopic measurements. Superhydrous phase B, with is stoichiometric, was compressed to 58 GPa in a diamond anvil cell. Again, no phase transformation was observed to this pressure at room temperature. Cobalt hydroxide is isostructural with brucite, a prototype H-bearing material that has been extensively studied under compression. Here we report energy-dispersive x-ray diffraction data to 48 GPa to complement our previously reported Raman spectroscopy data (Shieh and Duffy, 2002). The new structural data are used to examine the equation of state, compressional anisotropy and have implications for H-sublattice amorphization and H. . . H repulsion in this fundamental material.

V31D-0967 0830h POSTER

In Situ High P-T Raman Spectroscopy and Laser Heating: Applications to Volatiles Under Deep Earth Conditions

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The high P-T behavior of volatile species as CO_2, H_2O, H_2, O_2, etc. is essential for understanding the nature of deep planetary interiors. These species are also model systems for physics and chemistry. New in situ techniques are reached to detail the vibrational states, chemical reactivity, and formation of new phases in these systems. We present new measurements of Raman spectra of materials at very high pressure and temperature, in diamond anvil cells, using the laser heating technique. A Nd:YLF laser is employed to heat the samples with a typical power of tens of watts and spot sizes of about 30-40 μm. For transparent materials, a thin metal Re or Pt foil (10-20 μm) is employed to absorb efficiently the laser energy and transfer it to the sample. A small hole (10-20 μm) is drilled through the foil and the sample is uniformly heated, and is investigated by Raman spectroscopy. The temperature of the foil is monitored by mean of a dedicated monochromator-CCD set up, which detects the gray body radiation coming from it. An argon laser is employed as Raman excitation source; a 0.45 focus monochromator and a CCD camera are used to disperse and detect the scattered light respectively. One of the most important goals achieved by this technique was the capability to detect the real sample temperature given by the stokes/antistokes ratio, which typically results lower than that obtained from the grey body radiation. This result opens the way to perform quantitative experiments dealing with the usual high pressure laser heating procedures, and to investigate the thermodynamic properties of the systems with good accuracy. We present preliminary results on solid CO_2, as a basic test of our technique. Both the external and internal vibrational frequency regions of the molecular crystal were detected, above 10 GPa and metal foil temperatures as high as 2000 K. The stoks/antistoks balance was achieved from both kinds of excitation. Some important features of the high P-T phase diagram have been clarified. The technique can now be used to study broad range of related materials, including hot dense fluids, at deep mantle conditions.

V31D-0968 0830h POSTER

Finite-Element Modeling of the Thermal Structure in Laser-Heated Diamond Anvil Cell Experiments

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Laser-heated diamond anvil cell experiments (LHDAC) form an integral part of the exploration of the physical properties of planetary materials at pressures and temperatures characteristic of planetary interiors. While it is possible to measure the radial temperature distribution in LHDAC experiments it is far more difficult to study the axial temperature gradient in these experiments. However, experimental observations are commonly made along the DAC axis and the observed signal represents a volume average of the thermal structure along the DAC axis. It is therefore important to analyze the effect of different sample assemblages and different insulating materials on the axial temperature gradient. In order to address these issues we have performed finite element simulations for different geometries and insulating media. All calculations were performed in (2d) cylindrical geometry with dynamic grid refinement. Our steady-state calculations confirm previous studies in that the diamond anvils remain essentially at room temperature, regardless of the insulating medium. Furthermore we identify the thermal conductivity contrast of sample and insulating medium as a key parameter to determine the thermal structure in LHDAC experiments. Based on these insights we have been able to develop a simple analytical model that allows us to predict the axial temperature distribution to within 10%. The analysis of different experimental geometries shows that the microfurnace assemblage reduces the axial gradient most efficiently, followed by double sided laser heating geometries. These results also indicate that finite-element modeling is a viable tool to assess and design new LHDAC experiments.

V31D-0969 0830h POSTER

Nuclear Magnetic Resonance Spectroscopy in the Diamond Anvil Cell

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Nuclear magnetic resonance (NMR) of materials under pressure provides unique information on structure and dynamics, complementing many scattering, diffraction, and other spectroscopic methods. High-pressure NMR measurements can be important for Earth and planetary materials, particularly disordered systems, under deep interior conditions. Previous studies have pointed out the great potential of combining NMR with diamond-anvil cell (DAC) techniques but studies to date have been generally limited because of the low signal levels involved. In a effort to extend this technique, we have set up a NMR system operating at 200 MHz proton resonance frequency with a wide-bore superconducting magnet in which a specially designed nonmagnetic DAC[1] is installed. This system is capable of measuring spin relaxation in liquid samples in the DAC at high pressures. Preliminary results, including signal/noise ratios in different rf coil configurations around the diamond anvils, will be reported.

[1]T. Okuchi, Phys. Earth Planet. Inter., HPMPS special issue, to be published

V31D-0970 0830h POSTER

High-Temperature Phase Transitions and Elasticity of Low-Pressure Silica Polymorphs.

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Low-pressure silica polymorphs are common rock-forming mineral phases in igneous, sedimentary and metamorphic rocks, play a vital role in crustal processes and are important industrially. Therefore, knowledge of the high-temperature properties of silica polymorphs and the high temperature phase relations of pure silica are of great importance. Silica has three major low-pressure crystalline modifications: quartz, cristobalite, and tridymite. All of these are related to each other through reconstructive phase transitions. The transition of β-quartz to HP-tridymite is thought to occur at 867°C but this transition has never been observed in pure silica without using a flux (e.g. $NaWO_4$). β-Quartz can exist metastably up to the β-cristobalite stability field at 1470°, however β-quartz - β-cristobalite transition usually takes place at lower temperatures (>1150°C) as a metastable inversion. The temperature of the β-quartz to β-cristobalite metastable inversion is still unclear due to the reconstructive nature of this transition and sluggish kinetics. We measured the single-crystal acoustic velocities of α- and β-quartz by Brillouin spectroscopy to a maximum temperature >1500°C at room pressure. From these data the single-crystal elastic moduli were calculated up to 1050°C. This exceeds the temperature range of previous studies by 350°C for elastic moduli and by 710°C for acoustic velocities. The ordinary refractive index (n_o) of α- and β-quartz was also measured from room temperature to 800°C. Brillouin scattering is a technique for observation of phase transitions, as the change in acoustic velocities across the phase transitions can be a sensitive indicator of the appearance of small quantities of new phases. At a temperature of 1238°($\pm$5°C) in the [100] direction we observe the appearance of new non-quartz Brillouin peaks. The peaks persist on temperature decrease. The room-temperature velocities corresponding to the new non-quartz peaks are in good agreement with those of α-cristobalite in $\sim$[100] direction. In the temperature interval from $\sim$950°C to 1000°C a subtle but reproducible change in temperature derivative of the longitudinal acoustic velocity was observed in platelet geometry for all measured directions. The high-temperature acoustic velocity data are suggestive of a second phase (possibly β-cristobalite) below 1000°C.

V31D-0971 0830h POSTER

Elastic properties of hydrous ringwoodite at high pressures

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Phase transitions among olivine and its high-pressure polymorphs, wadsleyite and ringwoodite (α, β, and γ-Mg_2SiO_4), are thought to be responsible for the seismic velocity discontinuities in the transition zone of the mantle (400 $\sim$ 660 km). Measurements of sound velocities in these minerals are therefore necessary to interpret seismological information on these discontinuities in terms of transition zone composition and temperature. Recent studies have demonstrated that ringwoodite can contain up to $\sim$3wt% H_2O by weight, thereby making it possible to store vast quantities of water in the transition zone. It has also been shown that the incorporation of water into the crystal structure of ringwoodite results in a substantial decrease in the elastic moduli. However, inferences concerning the water content of the transition zone are still highly uncertain because there is little experimental data on the elasticity of hydrous ringwoodite under high-pressure and high temperature conditions.

We have therefore undertaken a study of the sound velocities and single-crystal elastic moduli of hydrous ringwoodite at high pressure by Brillouin spectroscopy. Single crystals of hydrous Mg end-member ringwoodite containing 2.3wt% H_2O were synthesized in a multi-anvil press at 19 GPa and 1300°C. Samples were loaded into a Merrill-Bassett-style diamond anvil cell with various pressure media. We have thus far obtained results for the single-crystal elastic moduli, the bulk modulus K_S, and the shear modulus G to P $\sim$14 GPa. Our results indicate that the pressure derivatives of the adiabatic bulk modulus and shear modulus are very similar to the values for dry ringwoodite. We conclude that water does not significantly affect the pressure derivatives K_S' or G'. Therefore, hydration does not significantly change the velocity contrast between the β and γ polymorphs of Mg_2SiO_4 at high pressure. As a result, if the $\beta \rightarrow \gamma$ transition is responsible for a seismic discontinuity near 520 km depth, the magnitude of this discontinuity will not depend on the presence of water in the transition zone. Velocity gradients in at least the lower part of the transition zone are also insensitive to the degree of hydration.

V31D-0972 0830h POSTER

Microstructures of Olivine in the Weakly Shocked Divnoe Meteorite

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Many microstructural observations of minerals in meteorites show evidences of shock effect, but rarely give data about the parent body. However, the microstructures of minerals in achondrites may retain the important information about the parent body which gives a basic idea about the formation of internal structural of the Earth. We carried out microstructural and microfabric analyses of olivine grains in the Divnoe meteorite by optical microscopy, electron probe microanalysis, electron back-scattered diffraction (EBSD) analysis, and transmission electron microscopy (TEM) with the selected area electron diffraction, in order to search the microstructures produced in the parent body. The Divnoe meteorite is a granoblastic, olivine-rich primitive achondrite. Neither black shock veins nor pockets of silicate melt typical of heavily shocked meteorites were found. Most olivine grains exhibit weak undulose extinction. Some grains show mosaic extinction though this is not as pronounced as in heavily shocked meteorites, and lamellar Fe-Mg zoning (2 to 4 mole percent Fa). The weak shock metamorphism experienced by Divnoe is consistent with the shock stage S3. The EBSD analysis of the Divnoe olivine grains reveals a distinct crystallographic preferred orientation (CPO) characterized by a [001] density maximum and girdle distributions of [100] and [010] around the [001] maximum. This type of fabric is not known in crystal-plastically deformed Earths mantle rocks, and can be explained by rigid body rotation of olivines in matrix flow. It suggests that this CPO was formed by rotation of olivine grains in strong melt flows on the meteorite parent bodies, so that their longest [001] axes were aligned parallel to the flow direction. Therefore, Divnoe should preserve an initial CPO of olivine formed during crystallization in the parent body that has not been significantly disturbed by later processes such as thermal and shock metamorphism. Now, the microstructures such as dislocations and inclusions within the single crystal olivines showing the CPO which should retain the important information about the parent body are examining by TEM.

V31E MCC: Level 2 Wednesday 0830h

Arc and Continental Magmatism I Posters

Presiding: **R Conrey,** Washington State University

V31E-0973 0830h POSTER

Geochemical Characteristics of Volcanic Rocks from the Southern Okinawa Trough and its Implications for Tectono-magmatic Evolution

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The Okinawa Trough is a site of ongoing backarc rifting behind the Ryukyu arc-trench system. Recent intensive surveys, including submersible dives, at the southern Okinawa Trough (SOT) have revealed details of bathymetric, geological, and geophysical features. Here, we present the petrological and geochemical characteristics of volcanic rocks collected during these cruises, and discuss its relation to the evolutionary stage of rifting. Based on bathymetirc and magmatic features, SOT can be divided into two (i.e., eastern and western) segments with non-transform offset at $\sim$ 123.5° E. The eastern segment represents a well-developed rift system with E-W-trending central graben and separated NE-SW-trending volcanic front; these two features merge at $\sim$ 125° E. In contrast, the western segment is in the incipient rifting stage; rift axis exists close to 100 km contour of the Wadati-Benioff zone. The most notable feature is the presence of 'abnormal' volcanic chain (Cross Backarc Volcanic Trail, CBVT), which trends NE-SW and is obviously oblique to the axial trend. All rocks are subalkaline, but range from basalt to rhyolite; dacite-rhyolite are dominant in the eastern volcanic front and CBVT. Basalts from both segments are low-K tholeiites; they have high abundance of LILEs relative to HFSEs, negative Nb anomalies on MORB-normalized diagrams, and range of $^{143}Nd/^{144}Nd$ (0.5128-0.5129) and $^{87}Sr/^{86}Sr$ (0.7034-0.7048). Pb isotope systematics indicate $^{206}Pb/^{204}Pb$=18.398-18.582, $^{207}Pb/^{204}Pb$=15.594-15.652 and $^{208}Pb/^{204}Pb$=38.570-38.912, clearly above the Northern Hemisphere Reference Line. These elemental and isotopic variations are compatible with derivation from Indian Ocean MORB-like mantle with strong overprint of subduction components from the slab. There is clear difference among more felsic rocks between two segments. At similar silica contents, most of felsic rocks from the western segment, including CBVT rhyolites, have higher LILE contents, $^{87}Sr/^{86}Sr$ and $^{208}Pb/^{204}Pb$ and lower $^{143}Nd/^{144}Nd$; these feature can be explained by significant crustal contamination of mantle-derived magmas. On the other hand, the eastern segment felsic rocks have a similar range of Sr-Nd-Pb isotopes for basalts. We suggest that the marked spatial differences in geochemical characteristics of felsic rocks reflects different stage of the backarc rifting. Geophysical surveys provided evidence that crustal thickness is relatively thin ($\sim$ 20km) under the eastern segment, whereas thick continental crust ($\sim$ 25-30km) without significant thinning have been proposed in the western segment. Sibuet et al. (1998) proposed the linkage of subducted Gagua Ridge for CBVT rhyolites, because of a sharp change in subduction angle (slab tear?) near 123° E. The CBVT rhyolites are, however, not adakitic. Instead, we suggest mantle flow originated from the magmatism at the Northern Taiwan Volcanic Zone, which commenced since $\sim$ 3 Ma and was resulted from post-collisional extensional collapse, have important implications for required heat source and comparatively depleted mantle source inferred from mafic inclusion in CBVT rhyolites.

V31E-0974 0830h POSTER

Continued Magmatic Unrest: Geochemical Evolution of Recent Eruptions from Mt. Cleveland, Aleutian arc, AK

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Mt. Cleveland, a previously unstudied composite volcano (1730 m) in the central Aleutians, last erupted in 1994 and 2001. Mt. Cleveland occupies an unusual tectonic setting, near the transition from sub-arc continental crust to oceanic crust further west. It and the other Islands of Four Mountains are closer to the fore-arc trench than any other Aleutian volcanoes, and the close configuration of five Quaternary volcanoes is unusual and not understood. To constrain the magmatic evolution and hazard potential of Cleveland and to better understand this unstudied region of the arc, we present new mapping and geochemical results related to field seasons in 2001-2003. The edifice is mainly constructed of lava flows, lahars and isolated domes. Collapse of the summit sometime between September 2002 and August 2003 indicates active magma withdrawal, perhaps temporary, at the agitated volcano. Lava and tephra from both recent eruptions are basaltic andesite (56.7-58.3 wt. % SiO_2; 3.9-4.3 wt. % MgO), and these more mafic compositions compared to most, older Cleveland lavas (58-70.7 % SiO_2, 1.8-3.7 wt. % MgO, n=20 samples) substantiates that influx of new magma preceded the recent eruptions. Disequilibrium mineral textures and zoned plagioclase compositions (An_{90-58}) confirm that open system processes, including recharge and mixing, have been a dominant characteristic of the magmatic system. Correlation between major elements and trace elements (e.g., Sr, Cr) indicate that some lavas were influenced by fractionation of olivine and plagioclase. Mantle-normalized REE concentrations are not strongly light-element enriched (La_N/Lu_N=1.9-2.3), and the relatively flat, similar patterns corroborate limited olivine and plagioclase fractionation (Eu_N/Eu_N*= 0.8-1.0). New Sr, Nd, Pb and Hf isotopic analyses will demonstrate the extent of source variability and allow comparison to the regionally radiogenic Sr and Pb isotopic compositions found at Yunaska and Seguam Islands ~300 km to the west.

V31E-0975 0830h POSTER

Magmatic Evolution of the Skye Igneous Center, Western Scotland

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Geochemically complex igneous suites are the result of interplay between deep and crustal-level processes. Quantitatively modeling the contribution that crustal-level processes such as magma recharge, crustal assimilation, and fractional crystallization have is critical for developing realistic models of how magma transport/storage systems evolve. The Energy-Constrained Recharge, Assimilation, and Fractional Crystallization simulator (EC-RAFC, Spera & Bohrson, 2001, 2002; Bohrson & Spera, 2001, 2003) provides a means to model thermal, compositional, and magma volume data for complex magmatic systems. The Skye igneous center, western Scotland, spanning the period 60.53 $\pm$ 0.08 Ma - 53.5 $\pm$ 0.8 Ma and characterized by a well-documented suite of lavas and intrusive rocks of picritic to granitic composition, is the first natural data set to which the EC-RAFC model has been applied in detail. Based on analysis of published field, stratigraphic, petrographic, and chemical data, we propose that the Skye Tertiary magmatic sequence be divided into four petrogenetically related lineages. EC-RAFC results indicate that each lineage is characterized by a unique parental magma that has undergone distinct episodes of RAFC. Model results, constrained by published data on the nature of the crust beneath Skye, indicate that the character of the assimilant changes upsection, suggesting that the associated magma reservoirs migrated to shallower levels as the magmatic system matured. The magmatic products of each group also record the fingerprint of multiple episodes of magma recharge, where the character of the recharge magma also evolves with time. The image of the magma transport system that emerges is one in which magma is initially intruded at lower crustal levels and undergoes a distinct RAFC episode. Residual magma from this event then migrates to shallower levels, where mid-crustal wallrock is assimilated; recharge magma is characterized by increasingly crustal chemical and thermal signatures. For some of the stratigraphically youngest rocks, results also suggest that magma reservoirs ascended into and interacted with upper crustal sediments. While the quantitative details provided by the Skye simulations support the hypothesis that the Skye igneous center can be characterized by a relatively small number of compositionally similar parental magmas to which complex RAFC processes occur, they also allow detailed predictions to be made about the geochemical, thermal and magma volume characteristics of the magmatic system. Further study that builds on these predictions at locations such as Skye promise to enhance our understanding of the evolution of complex magmatic systems on Earth.

URL: http://magma.geol.ucsb.edu/

V31E-0976 0830h POSTER

Olivines in the Egersund Dikes (SW Norway): Evidence for the Evolutionary History of Neoproterozoic Tholeiitic Magmas.

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The Neoproterozoic Egersund dikes in Sw Norway intruded at 650-600 Ma, and the majority formed by intrusion of olivine tholeiites and tholeiites that are geochemically similar to modern OIB. The olivine tholeiites are remarkably well preserved, with glassy chilled margins that contain olivine and plagioclase. Olivines show a range of textural and compositional characteristics that potentially provide information about the evolutionary history of the magmas. Olivine microphenocrysts in the chilled margins are euhedral, and sometimes skeletal indicating rapid cooling. Their compositions (Fo_{80-82}) are appropriate for equilibrium with the host melt at oxygen fugacities 0-1 log unit below QFM. Resorbed macrocrysts are more magnesian

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