variations in composition of spinel and adjacent olivine record entrapment during the magmatic crystallization interval from near-liquidus (> 1300 C) to near-solidus (ca. 1125 C) temperature. Three published olivine-spinel Fe-Mg thermometers (Roeder et al, 1979; Sack and Ghiorso, 1991; Jianping et al., 1995) were used to evaluate the T dependence of olivine-spinel Fe-Mg partitioning in analyzed pairs. Calculations show that the olivine-spinel pairs undoubtedly record thermal evolution of the basanite magma during crystallization, however all thermometers appear to underestimate absolute crystallization temperatures. This is particularly evident for the final stages (at lower T) of the co-crystallization of the olivine-spinel pairs, probably due to significant concentrations of the usp end member in the most fractionated magmatic spinels (approx. 70 mol% usp). Ti is not taken into account in calibrating two of the thermometers (Roeder et al. and Jianping et al.) and apparently is not fully accounted for in the spinel solid solution model (Sack and Ghiorso). A direct test of calculated T is possible due to a set of 1-atm crystallization experiments done on the basanite some years ago (in collaboration with E. Stolper). Experimental runs contain olivine microcrystals containing spinel inclusions, and both minerals were analyzed. T calculated using the three thermometers was compared with the known T of each crystallization experiment. Data show approximately linear relationships between Ti content and T- underestimation for all 3 thermometers.

V41C-0315 0830h POSTER

Composition of Olivine, Melt Redox State, and Oxygen Fugacity

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The compositions of ferro-magnesian silicates in equilibrium with melts are a function of oxygen fugacity. This was demonstrated experimentally in the case of olivine by Roeder and Emslie (1970). In principle, therefore, the composition of coexisting olivine and melt (with total Fe as FeO) allows melt redox state and hence oxygen fugacity to be calculated if the equilibrium distribution of Mg and Fe between olivine and melt is known. It has been found that the expression given by Gee and Sack (1988) accurately describes this distribution over a wide range of liquid compositions, so that melt redox state and oxygen fugacity can be calculated from the compositions of olivine-melt pairs. Oxygen fugacities have been calculated from published data for olivine-melt pairs produced in 160 experiments at 10^5 Pa at known oxygen fugacities (from 3 log units below to 7.6 log units above QFM) over a range of T from 1080 to 1339^{O}C. Melt compositions in these experiments include tholeiitic and alkali-olivine basalts, picrites, andesites, and highly alkaline lavas (nephelinites, leucitites, ugandites). Forsterite compositions of olivines range from 0.98-0.55, whereas melt Mg-no's range from 0.75-0.25 (all Fe as FeO). There is excellent correlation (0.99) between calculated and experimental values. The maximum difference between calculated and experimental values is about 0.5 log units, but the average uncertainty (calculated at the 1-sigma level) is 0.24 log units. The results indicate that the expression given by Kress and Carmichael (1991) better describes the relationship between melt redox state and oxygen fugacity than that given by Kilinc et al. (1983). The results suggest that oxygen fugacities can be retrieved from coexisting olivine-melt pairs in natural samples. However, the non-linear relationship between olivine composition, melt ferric-ferrous iron ratio, and (log) oxygen fugacity indicates relatively large uncertainties at oxygen fugacities more reducing than about one log unit below QFM. In addition, it is not clear that this method works for Fe-rich liquids (Mg-no's less than about 0.3). On the other hand, the method does provide a rigorous test for equilibrium between experimentally produced olivines and melts.

V41C-0316 0830h POSTER

Experimental Study of the Effects of Dissolved Sulfur on Olivine-Liquid Ni Partitioning Behavior

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The partitioning of Ni between olivine and a silicate melt is best described in terms of the Nernst partition coefficient, D_{Ni} which is equal to (wt % Ni)^{oliv} / (wt % Ni)^{melt}. Ni in a silicate melt may partition into olivine according to the following reaction NiO^{melt} + $Fe_2Si_{0.5}O_2{}^{oliv}$ = $Ni_2Si_{0.5}O_2{}^{oliv}$ + FeO^{melt}. In the presence of dissolved S, the oxide species in the melt may react via the following reactions FeO^{melt} + 0.5 $S_2{}^{melt}$ = FeS^{melt} + 0.5 $O_2{}^{melt}$ NiO^{melt} + 0.5 $S_2{}^{melt}$ = NiS^{melt} + 0.5 $O_2{}^{melt}$ Thus the abundances of FeO and NiO in the melt and, therefore, the value of D_{Ni} between olivine and a silicate melt are a function of both fS_2 and fO_2 in the melt. Because natural magmas may contain significant amounts of dissolved S, those values of D_{Ni} determined in sulfur-free systems may not be applicable to natural magmas. To address the extent to which D_{Ni} may be a function of dissolved S content, a series of one-atmosphere crystallization experiments were conducted on a moderately evolved MORB lava to which was added 10 % (by weight) powdered San Carlos olivine (MgO = 10.9 wt. %, Ni ~ 300 ppm). All experiments were conducted at 1245^o C where approximately 5-10 volume % olivine (Fo_{88}) coexisted with melt. fO_2 was maintained at a constant value of $10^{-9.5}$. fS_2 was varied from 0 to $10^{-1.9}$, the latter being well below the theoretical sulfide saturation point. Over this range of fS_2, the dissolved S content in the melt increased from 0 to 480 ppm and the value of D_{Ni} decreased from 8 to 2.4. These results confirm a strong dependence of D_{Ni} on the amount of dissolved S in the melt and suggest that experimentally determined D_{Ni} values in sulfur-free systems should be used with caution.

V41D MCC: 3006 Thursday 1020h

Birth, Growth, and Death of Magmatic Arcs: Comparisons Among Arcs in Different Settings IV *(joint with T)*

Presiding: **K Klepeis,** University of Vermont**; J P Davidson,** University of Durham

V41D-01 1020h INVITED

Thermal Evolution of the Deep Roots of a Magmatic Arc, Fiordland, New Zealand

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Reconstruction of detailed thermal profiles and histories in magmatic arcs is crucial for understanding arc development and evolution, because deformation, metamorphism, crustal melting, and a wide range of physical properties are temperature dependent. Fiordland, New Zealand contains a rare exposure of the deep roots of a Mesozoic magmatic arc, and provides an exceptional opportunity to develop high-resolution cooling histories through its middle and lower crust. The ca. 120 Ma granulite-facies Western Fiordland Orthogneiss is a > 10 km thick batholith dominated by dioritic rocks. New U-Pb thermochronologic data in rocks within the upper part of the Western Fiordland Orthogneiss exposed in Doubtful Sound record post-magmatic cooling through the 650-600^{o}C closure temperature of titanite at ca. 113 Ma. Subsequent slower cooling below 400^{o}C is recorded by rutile from the Western Fiordland Orthogneiss at ca. 74 Ma. The upper contact of the Western Fiordland Orthogneiss is defined by the Doubtful Sound extensional shear zone, with mid-Paleozoic metasedimentary cover of the Deep Cove Gneiss of the Tuhua Sequence in the hanging wall. A calcsilicate within the Deep Cove Gneiss immediately above the shear zone yields metamorphic titanite with a U-Pb date of ca. 113 Ma. This suggests new metamorphic titanite growth during heating of the cover sequence associated with emplacement of the Western Fiordland Orthogneiss. Additional U-Pb thermochronologic data from the base of the Western Fiordland Orthogneiss will allow us to better evaluate the cooling history across the entire thickness of the batholith. The integration of these thermal histories with structural and metamorphic data through this middle and lower crustal profile will provide a unique multi-dimensional view of the evolution of this magmatic arc.

V41D-02 1035h

Space-Time Variations in Lower Crustal Rheology and Thermal Structure and its Effects on the Evolution of Arc Crust

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Studies of magmatic arcs in different settings have shown that the rheology and thermal structure of the lower crust are extremely heterogeneous and can change quickly during cycles of magmatism and crustal melting. However, determining the length and time scales of these variations, and their effects on crustal evolution are especially problematic. We present results from a deeply eroded Cretaceous arc exposed in Fiordland, New Zealand that reveal the presence of steep thermal gradients and rheological contrasts in the lower crust (~45 km paleodepth)on length scales of ~100 km^2. Metamorphic and geochronologic data collected from near Milford Sound suggest that part of the lower crust experienced rapid cooling from 750^{o}C<T<850^{o}C to T=650-700^{o}C following a period (126-120 Ma) of mafic-intermediate magmatism and lower crustal melting. Cooling was aided by the thrusting of relatively cool pre-existing crust below hot, partially molten new crust and by the efficient extraction of melts out of the lower crust. Simple thermal models of conductive heat loss suggest that the thermal pulse accompanying magmatism near Milford Sound was short-lived (a 3-4 m.y. duration)and had decayed to temperatures of T=650-700^{o}C by ~116 Ma. These models are in accordance with metamorphic ages obtained using U-Pb dates on zircon from pegmatite and tonalite dikes. However, less than 100 km to the south of Milford Sound, U-Pb zircon ages and metamorphic data suggest that lower crustal temperatures there remained at T=800^{o}C until ~108 Ma. These observations indicate that the thermal structure and rheological transitions linked to magmatism and the partial melting of lower crust were much more spatially heterogeneous and transient than previously believed. These variations created localized hot spots in the lower crust that affected deformation patterns during cycles of extension and contraction within the arc. Hot weak zones preferentially developed large (1 km thick) extensional shear zones that thinned the lower crust at ~108 Ma. Structural relationships and geochronology indicate that these lower crustal shear zones formed simultaneously with extensional core complexes and narrow rift basins at mid-upper crustal levels. In contrast areas that were relatively cool at ~108 Ma lack extensional structures and preserve older contractional shear zones that thickened the crust. The Fiordland setting shows that the development of localized hot spots in the lower crust strongly influences deformation partitioning within arc crust. This process helps explain along-strike variability in arc structure, including the development of highly localized zones of extension in the upper crust.

V41D-03 1050h

Generation and Evolution of Lowermost Crust of an Arc: Examples From Fiordland, New Zealand

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Questions regarding the composition, structure and rheology of the lowermost crust continue to arise due to the acknowledgement that heterogeneity, both spatially and temporally, is the rule rather than the exception in most studied examples. To better understand the origin of lowermost crust in a magmatic arc setting, we are using Fiordland, New Zealand as a natural laboratory. Rock exposures in southwest NZ once formed the ancient Gondwana margin and now represent exhumed crustal levels of 50 km depth within the magmatic arc. In the Fiordland block, we find that the lowermost crust is heterogeneous, particularly in terms of heat and rheologic behaviour. Studies point to several elements which compose the lowermost arc crust and suggest that its heterogeneity resulted from the relative contributions of three components: (1) lower crust generated by the injection of mafic, mantle-derived partial melts and the addition of cooler mafic material through collision and arc building; (2) modification of lower crustal composition by tectonically burying supercrustal material; (3) compositional modification of the lowermost crust and arc crust by in-situ melting and remobilization of crustal-derived partial melts. Integration of field studies with targeted partial melting

experiments has helped elucidate the relative contribution of this latter process and has established possible partial melt compositions derived from potential source material of magmas now observed in the arc. Results from metadiorite experiments under both static and dynamic conditions and from metabasaltic dikes that have been interpreted to represent underplate material emplaced during arc generation also help evaluate whether or not there are different extraction mechanisms for partial melt that lead to different temperature and heat distribution in the lowermost crust. Experimental deformation studies suggest that the mafic lowermost crust in Fiordland remained rheologically strong during melting. LA-ICPMS results show glasses from both compositions to be HREE depleted, LREE enriched, with high Sr/Y ratios. Direct partial melting of basaltic underplate, in addition to that of dioritic lowermost crust, may provide a source for the observed Sr/Y enriched magmas observed in middle to upper Fiordland crust.

V41D-04 1105h

Position and Life Span of Volcanic Arcs - What Link to Present-day Kinematic Parameters in Subduction Zones ?

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Since slabs can be located at depth by geophysical methods, correlations are sought between the position of volcanic arcs above slabs and kinematic subduction parameters (subduction angle, velocity, burying rate...). However, the only (rough) correlation found so far, is between arc width and subduction angle, reflecting the projection of a slab depth-interval to a surface width. Volcanic arcs result from fluid and/or melt release from the slab (which occurs more or less continuously to >200 km depth), in most cases in combination with mantle wedge melting. Volcanic arcs may simply form above a zone with a sufficient extent of melting in the mantle and thus dominantly reflect the thermal structure in the mantle wedge which in turn mostly depends on mantle wedge convection. We argue that on geological time scales, pathways to actual (observable) subduction zone parameters are not unique as kinematic constraints in nature are fuzzy. Subduction systems do not converge to a steady state, implying that mantle wedge convection, the resulting thermal regime, loci of metamorphic reactions (i.e. fluid/melt release from the slab), and their surface manifestations, evolve continuously. As a consequence, present day kinematic parameters are not simply linked to the geometry of the volcanic arc (e.g. position of the volcanic front). An evolution of kinematic subduction parameters and their volcanic surface expression with time is documented in back arc basins which have an average life span of 11±6 Ma. About 48% of present intraoceanic subduction zones have or have had a Neozoic back arc and therefore they are highly dynamic systems strongly diverging from a steady state system with fixed kinematic boundaries. Other geologically short lived phenomena are aseismic ridge, oceanic plateau, and mid-ocean ridge subduction which modify buoyancy forces, slab geometry, and thermal structure within a subduction zone and thus cause changes in volcanic activity and melt type. In some continental subduction zones (e.g. SVZ, Sumatra), the volcanic arc simply locates on a major fault which apparently provides pathways for melt arriving at the base of the crust. We conclude that the position and life span of volcanic arcs is controlled by thermal and flow fields that evolve over geological time scales and as a consequence, any attempt to understand volcanic arcs mainly through a correlation with present day kinematics becomes futile. Only a time-integrated kinematic analysis is, on principle, able to provide a feasible solution to the volcanic arc dilemma.

V41D-05 1120h

A Plate Tectonic Scenario for the Formation of Intra-oceanic Magmatic Arcs and Associated Back-arc Basins

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During prolonged periods of Mariana-type intra-oceanic subduction, a series of island arc and back-arc basins are formed on the over-riding plate. The remnant arc-back-arc-active arc sequence is particularly prevalent in the marginal seas of the Western Pacific, Scotia and Mediterranean Seas. The initiation, location and development of intra-oceanic island arcs are dependent, among other things, on the behaviour of the subduction zone (shape, orientation, roll-back) and on the properties of the subducted slab (age, dip, composition). We present reconstructions of the age distribution of the oceanic crust (including subducted oceanic crust) using a revised absolute plate motion model based on moving hotspots and including the motion between East and West Antarctica in the global plate circuit. Our plate reconstructions allow us to identify the tectonic conditions prior to, during and after subduction initiation and the subsequent development of the island arc and back-arc basin. Palaeoagegrids provide valuable time-dependent information regarding the age of the subducting slab, the orientation of the MOR relative to the subduction hinge and the convergence rates and directions of the down-going plate. Our preliminary results on the intra-oceanic convergent margins of the SW Pacific, Philippine Sea and Scotia Sea suggest that: (1)The age of the downgoing slab when a back-arc basin is formed is never younger than 30 m.y. This provides an important constraint on the location of the Benioff zone through time. (2)The MOR and seafloor spreading isochrons on the down-going plate are orthogonal to the strike of the subduction zone. (3)Changes in convergence rates between the downgoing and over-riding plates influence the spreading in the back-arc basin and as a result must influence island arc development. Linking geophysical observations and plate reconstructions with the volcanic history of island arcs will not only provide better constraints on the factors influencing magmatic arc formation but also on the entire remnant arc-back-arc-active arc sequence.

V41D-06 1135h

Mantle Melting as a Function of Water Content in Arcs

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Subduction zone magmas are characterized by high concentrations of dissolved H_2O, presumably derived from the subducted plate and ultimately responsible for melt generation in this tectonic setting. Almost ten years ago, Stolper and Newman (EPSL, 1994) illustrated a linear relationship between the concentration of water (H_2O_o) and the fraction of melting (F) in the mantle beneath the Mariana back-arc. Here we report new major element and volatile data for olivine-hosted melt inclusions from the Mariana Islands to test this relationship for melting beneath an arc. Basaltic melt inclusions from the Mariana arc have water contents (2.3-6.1 wt% H_2O) significantly higher than all basaltic glasses or melt inclusions from the Mariana back-arc (0.2-2.2 wt% H_2O). We use TiO_2 as a proxy for F, after correcting for crystal fractionation, and evaluate the Ti source composition with a model based on Ti/Y variations in mid-ocean ridge basalts (MORBs). Each calculated F thus represents the amount of mantle melting for a single melting episode. Even after accounting for mantle depletion, the TiO_2 concentrations in Mariana arc magmas record higher extents of mantle melting (F = 10-30%) than recorded in back-arc magmas (F = 5-24%). As a whole, the Mariana arc broadly extends the linear H_2O_o-F array defined by the back-arc, although in detail the islands show important differences. Two islands from the Mariana arc (Guguan and Pagan) define a H_2O_o-F slope similar to the Mariana back-arc, suggesting similar mantle potential temperature beneath the arc and back-arc (~1360 ± 20°C). Melts from Agrigan island, however, indicate a steeper slope suggestive both of cooler mantle beneath Agrigan and of along-strike thermal variations beneath the Mariana Islands. Both the arc and back-arc arrays project to finite F at zero water in the mantle, providing evidence for decompression melting in both settings. These relationships may be extended globally to other back-arc and arc systems, using published data. For back-arc basins (Mariana, Lau, Scotia, Manus), the main factor contributing to regionally distinct trends in H_2O_o vs. F is mantle potential temperature, which may be determined in dry back-arc melts using the same geochemical criteria as MORBs, and spans a similar range (~1300-1500°C; see Plank and Kelley, this meeting). Increasing mantle temperature leads to a progressive change in slope and intercept in the back-arc H2Oo-F arrays. In the Cascadian, Central American, and Mexican arcs, the wet melting functions indicate overall colder mantle potential temperatures in arcs (~1100-1300°C) than in global back-arcs, presumably due to proximity to the cold subducting plate. The simple relationships between water and melt fraction recorded in arc magmas thus allow for quantitative separation of the factors affecting mantle melt production in subduction zones, namely water addition from the slab, decompression, and mantle temperature.

V41D-07 1150h

Constraints on Melting Processes Beneath Subduction Zones from U-Pa Disequilibria

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^{231}Pa is the longest-lived intermediate daughter nuclide produced by the decay of ^{235}U, and has a half-life (32,700 y) intermediate between those of ^{230}Th and ^{226}Ra. Pa^{5+} is highly incompatible during mantle melting, and is thought to be highly insoluble in aqueous fluids, compared to U, thus there is potential for large U-Pa fractionation during fluid-present melting in subduction zones. We have analysed ^{231}Pa concentrations in a suite of 47 lavas from 7 different convergent margins, using isotope dilution and MC-ICPMS. The samples are from plate margins with a wide range in subduction rate, lithosphere thickness, fluid flux, subducting plate age and sediment thickness. All samples are of known eruption age, and have previously been analysed for major and trace elements, radiogenic isotopes, and U-Th-Ra disequilibria. Measured ($^{231}Pa/^{235}U$) ratios in these samples range from 0.82 to 2.42 with one lava from the Aleutians having a ratio of 3.49. For the dataset as a whole, there is a broad positive correlation of ($^{231}Pa/^{235}U$) with ($^{230}Th/^{238}U$), and samples with higher ($^{231}Pa/^{235}U$) also tend to have lower ratios of Ba/Th and U/Nb (smaller slab fluid input). There is no simple relationship between ^{231}Pa excess and subduction rate, subducting plate depth or sediment flux. Although U/Nb ratios indicate that up to 98% of the U in these lavas is derived from the subducting plate, all but one of the samples have ($^{231}Pa/^{235}U$) >1.0, and several have >100% ^{231}Pa excess. This could indicate that a period of several half-lives of ^{231}Pa elapsed between the timing of fluid addition from the slab and the final melting event. On the other hand, most samples have ^{226}Ra excess, indicating that the last episode of Ra addition to the melting zone occurred less than 8000 years ago. The large Pa excesses imply that significant fractionation of U and Pa occurs during separation of melt from the mantle. As both U and Pa are highly incompatible in mantle minerals, melting must occur at low porosity over a period of time that is significant relative to the half life of ^{231}Pa to allow ^{231}Pa in-growth in the melting region, either by dynamic melting in the mantle wedge at low melting rate, or during melting of continuously-fluxed mantle. More detailed modelling of the melting process is in progress.

V41D-08 1205h

Pre-Eruptive Exsolution of Chlorine-Enriched Volatile Phases at Augustine Volcano, Alaska: Evidence from Silicate Melt Inclusions and Cl Solubility Modeling

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Augustine volcano has experienced 6 explosive eruptions in historic time and is located in Cook Inlet, Alaska, approximately 330 km from Anchorage. Most lavas and tephra range from primitive andesite to dacite, but minor basalt flows crop out on the island. The matrix and silicate melt inclusion glasses are more felsic, however. Volcanic gases collected from the Augustine crater during and immediately after the most recent eruptions in 1976 and 1986 were strongly enriched in HCl (Symonds et al., 1990). The presence of elevated Cl levels in magmatic gases is consistent with high concentrations of Cl in silicate melt inclusions in plagioclase and pyroxene phenocrysts in materials erupted from Augustine in 1976 and with the conclusion that the 1976 magma was saturated in a Cl-enriched fluid/vapor prior to eruption (Johnston, 1978). To determine the role of Cl and other volatiles in magmatic and volcanic processes at Augustine volcano, we have begun a systematic study of silicate melt inclusions in tephra erupted at Augustine in 1986 and also erupted $\sim$ 1000, $\sim$ 1400, $\sim$ 1700, $\sim$ 2100 years ago. We analyzed glassy silicate melt inclusions in plagioclase and pyroxene phenocrysts for major, minor, and some trace elements (including Cl, S, and F) by electron microprobe and for H_2O and CO_2 by FTIR. Preliminary results show that each of these magmas was strongly but variably enriched in H_2O, S, and Cl. Sulfur ranges from 100-700 ppm, and Cl varies from 2000 to more than 8000 ppm. Trends involving Cl, H_2O, S, and major elements in tephra from all 5 of the eruptions that we studied are consistent with the exsolution of aqueous-carbonic, S- and Cl-charged volatile phases well before eruption. Moreover, the Cl contents of most melt inclusions are quite high, and the most recently erupted (e.g., 1976 [Johnston, 1978] and 1986) magmas were particularly enriched in Cl. In fact, the Cl abundances of some inclusions approach that of the 2000 bar chloride solubility limit for felsic magmas. Thus, some fractions of the late-stage, dacitic Augustine magmas, erupted in 1976 and 1986, would have exsolved a S-bearing, hydrosaline chloride liquid with or without a S- and Cl-bearing, aqueous-carbonic vapor at 2000 bars before eruption. In summary, the geochemistry of melt inclusions of the eruptive units studied so far indicates that the exsolution of Cl-charged volatile phases is a common process that preceeds most of Augustine's explosive eruptions. (D. Johnston, 1978, Unpublished Ph.D. Diss., Univ. of Washington) (Symonds et al., 1990, Bull. Volcanol. 52:355-374)

V41E MCC: 3008 Thursday 1020h

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

Presiding: **V Prakapenka,** University of Chicago**; J Chen,** State University of New York at Stony Brook

V41E-01 1020h

Viscosity of Fluids in the Diamond-Anvil Cell

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Measurement and modeling of the viscosity of fluids under high pressures is necessary to an understanding of fluid processes within the Earth and other planets. Areas of interest include terrestrial vulcanism, the flow of supercritical fluids which may induce metasomatism over large regions of Earth's upper mantle, and the dynamics of the fluid envelopes of the larger planets. We report here the application of rolling ball viscometry to supercritical fluids within the diamond-anvil cell. Recent results and the accuracies and potentials of the technique are discussed. For many fluids, viscosity as a function of pressure seems to follow Doolittle's empirical equation, roughly justified on the basis of free-volume theory. However, based on a survey of published data it has also been hypothesized that above twice the critical density the viscosities of simple, supercritical fluids are linear functions of pressure to a very high accuracy. These two functional forms are mutually exclusive and may diverge by an order of magnitude over the pressure-temperature regime of mantle fluids. Here we show that over the extended range of densities and pressures available to the diamond-anvil cell supercritical fluids are, in fact, better fit by the Doolittle equation. We show also that the law of corresponding states may still be of reasonable accuracy even at large compressions where the differences among intermolecular potentials might be supposed to preclude such scaling.

V41E-02 1035h

Pressure induced structural changes in amorphous silicates

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The study of amorphous structures provides a basis for understanding the chemical-physical properties of glass and liquid materials at extreme conditions. However, there are only a few experimental reports available characterizing amorphous silicates at high pressures. The main reason for limited experimental studies is related to the weak scattering of non-crystalline silicates in the small pressure chamber of the diamond anvil cell (DAC) and the associated small accessible 2-theta range. In this work, we have used a modified DAC with x-ray transparent cubic BN seats that results in a maximum momentum transfer above 110 nm^{-1}. The diffraction patterns were collected in full solid angle using an on-line imaging plate detector and brilliant, high energy (37.44 keV) synchrotron x-radiation at GSECARS undulator beamline (APS). For background corrections we recorded x-ray scattering patterns from an empty cell (without sample, but at the same position and conditions used for high pressure data collection). The high pressure behavior (compress/decompress) of amorphous SiO_2 and $MgSiO_3$ was studied up to 70 GPa with steps of $\sim$5 GPa at room temperature. The starting materials were synthesized by a sol-gel technique, which allows the formation of highly disordered polymer-like three-dimensional matrices where silicon/magnesium atoms are bonded to oxygen atoms in an irregular non-crystalline network. For both SiO_2 and $MgSiO_3$, we have observed clear pressure-induced structural changes rather than isotropic contraction. On decompression, reversible structural behavior was found for both silicates. The observed structural changes in the medium-range order of the amorphous network and the kinetics of this process in SiO_2 and $MgSiO_3$ provide a basis for understanding the dynamical properties of high-density non-crystalline materials at extreme conditions.

V41E-03 1050h

Direct Magnetic Measurements at High Pressures

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Direct magnetic measurements of extremely small sample volumes at high pressure are difficult, primarily because of interference from the high magnetizations of the pressure vessels. For this reason, we developed a "non-magnetic" beryllium-copper, membrane-type diamond cell that houses a system designed to measure the reversible magnetic susceptibility of micron-sized samples under pressures in excess of 30 GPa. Our system employs two unequal pick up coils wound in opposition around a diamond resulting in a virtually null magnetic surface. Around these is an inducing coil, mounted in null mutual inductance. A lock-in amplifier measures the output of the sensing coil. The cell and detection system are placed in the confines of an electromagnet. Thus the pressure of the cell is remotely controlled and the ac (reversible) susceptibility (Xrev) is measured as a function of applied field (H), with H varying from -1.2 T to +1.2 T. Because the integral of Xrev(H)dH is proportional to the magnetic moment (of the reversible part of the remanence, or Mrev), we can measure the reversible hysteresis parameters of ferromagnetic materials as a function of pressure. Example measurements and details of the method will be presented.

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Frontiers of High-Pressure Research: Synchrotron Infrared Spectroscopy

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High-pressure spectroscopy provides crucial and often unique information on the properties of Earth and planetary materials from near-surface conditions to those of the deepest interiors. Vibrational infrared/Raman spectroscopy, for example, provides detailed information on bonding properties of crystals, glass, and melts, thereby yielding a microscopic description of thermochemical properties. The high brightness of synchrotron infrared radiation is ideally suited to high pressure investigations in which both small sample area and a narrow beam are required in order to generate extremely high pressure with a diamond anvil cell. The dedicated high-pressure beam line U2A on the VUV ring of the National Synchrotron Light Source, Brookhaven National Laboratory is an integrated facility for a wide range of microspectroscopic studies from ambient to ultrahigh pressures and at variable temperatures. The beam line has high IR brightness, particularly at long wavelengths, with its 40 x 40 mrad aperture. The facility includes a FT-IR vacuum spectrometer (Bruker IFS 66v/S) along with a nitrogen purged high-pressure, long working distance microscopes for high pressure (and variable temperature) applications, a vacuum microscope system for far IR high-pressure absorption measurements and a commercial, high-magnification infrared microscope for diffraction-limited micro-infrared measurements of samples at ambient and high pressures. Recently, the beamline has been upgraded to further improve the performance in far-IR range. The facility thus permits systematic high-pressure studies addressing a range of problems in Earth and planetary science. These studies include high pressure (and variable temperature) studies of planetary gases and ices; minerals of the Earth's crust, mantle, and core; geochemical reactions; organic geochemistry; surfaces and interfaces and whole-rock samples; and extraterrestrial samples. These investigations complement optical laser spectroscopy, x-ray diffraction and spectroscopy, and transport measurements carried out on the same materials. High-pressure studies of various ices continue, with new phases being uncovered by these methods. New far-IR measurements have been carried out to test proposed pressure-induced phase transformations in ice at low temperature. These techniques have also been applied to biological molecules under pressure. Far-IR spectroscopy measurements down to 20 cm-1 have been used to characterize the low-frequency dynamics of model heme Fe-CO compounds, including the long-sought doming mode in which the iron atom moves out of the porphyrin plane. New single-crystal CVD diamond has been characterized from the far- to near-IR, including both as-grown and annealed material. The method has also been used to examine a variety of natural diamonds. Examples of recent experiments also include studies of hydrous mineral, such as gypsum, OH-clinohumite, and OH-chondrodite.

V41E-05 1120h

Relaxation flow law of Fe_2SiO_4 olivine and spinel at high pressure: A stress and strain measurement using x-rays

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Synchrotron x-rays have become an extremely compelling tool in studying material properties under high pressures. In addition to exploring means to reveal the information of material properties that is not obtainable before, developments using synchrotron x-rays have also enabled many reformations of traditional experiments. In this report, we present the results of stress and strain measurement at high pressures and temperatures using synchrotron x-ray diffraction and radiograph imaging techniques. For the first time, rheological properties of both the low pressure phase (olivine) and the high pressure phase (spinel) of Fe_2SiO_4 sample are derived from a single experiment. A clear strengthening in the material due to the phase transformation is observed. The stress and strain rate data measured at temperatures up to 1075K are used to derive the Periels plasticity flow law ($\varepsilon' = \varepsilon'_0 \exp(-\frac{Q}{RT}(1-\frac{\sigma}{\tau})^2)$) for each phase, and yield an activation energy and Periels stress of 480$\pm$20 kJ/mol and 6.7$\pm$0.5 GPa for olivine phase and 460$\pm$20 kJ/mol and 6.5$\pm$0.5GPa for spinel phase. Compared with existing data for San Carlos olivine, a significant weakening by increasing iron content in the structure is revealed. Technical details and data processing for the experiment will be discussed.