wind trajectories, but also ash plumes following distinctly different SW trajectories which TOMS did not detect.

V41A-0981 0830h INVITED POSTER

Automated Volcanic Eruption Detection Using MODIS

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The Moderate Resolution Imaging Spectroradiometer (MODIS) flown on-board NASA's first EOS platform, Terra, offers complete global data coverage every 1-2 days at spatial resolutions of 250, 500, and 1000-m. Its ability to detect emitted radiation in the short (4 micron) and long-wave (12 micron) infrared regions of the electromagnetic spectrum, combined with the excellent geolocation of the image pixels (200-m), make it an ideal source of data for automatically detecting and monitoring high-temperature volcanic thermal anomalies. This presentation will describe the underlying principles of, and results obtained from, just such a system, developed at the Hawaii Institute of Geophysics and Planetology. Our algorithm interrogates the MODIS Level 1B stream for evidence of high-temperature volcanic features. Once a hot-spot has been identified its details (location, emitted spectral radiance, satellite observational parameters) are written to an ASCII text file and transferred via FTP to HIGP, where the results are posted on the internet (http://modis.higp.hawaii.edu). The global distribution of volcanic hot-spots can be examined visually at a variety of scales using this web-site, which also allows easy access to the quantitative data contained in the ASCII files themselves. We outline how the algorithm has proven robust as a hot-spot detection tool for a wide range of eruptive styles at both permanently and sporadically active volcanoes including Soufriere Hills (Montserrat), Popocatepetl (Mexico), Bezymianny (Russia), and Merapi (Java), amongst others. We also present case studies of how the system has allowed the onset, development and cessation of discrete eruptive events to be monitored at Nyamuragira (Congo), Piton de la Fournaise (Reunion Island), Shiveluch (Russia), Kilauea (Hawaii) and Etna (Sicily).

V41A-0982 0830h POSTER

Geomorphometric Analysis of Debris Flow Terraces at Mount Rainier, WA Using Spacecraft Acquired Topography

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Methods used in extracting digital topography from remote sensing data include photogrammetry, interferometry, altimetry and photoclinometry. Two recent spaceborne missions use some of these methods for generating global DEM coverages at horizontal resolutions less than 100 m per pixel. This study evaluates and compares the utility of such data for estimating inundation levels of past debris flows based on the upslope heights and cross-sectional extents of terraces preserved in river valleys. Deposits from Mount Rainier representing debris flow volumes spanning several orders of magnitude are used as case examples for testing this idea.

ASTER DEMs are derived photogrammetrically by measuring the parallax between a stereo pair of images acquired simultaneously by nadir- and aft-viewing instruments. The two channels used (3N and 3B) have near-infrared bandwidths of 0.76-0.86 microns and a base/height ratio of 0.6 for the stereo pair. SRTM DEMs are currently being produced interferometrically from C- (5.6 cm wavelength) and X-band (3 cm wavelength) synthetic aperture radar (SAR) by measuring the phase differences between SAR images acquired by two antennas spaced 60 m apart.

Terraces of the Electron mudflow, National lahar, and Tahoma lahar deposits were all resolved in cross-sectional profiles extracted from the ASTER DEM. These profiles were compared to profiles from a level 2 USGS DEM that was corrected for systematic errors such as canopy, and resampled to the 30 m resolution of the ASTER DEM. The ASTER DEM was co-registered to the USGS DEM, which will later be co-registered to the SRTM DEM when it becomes available.

About 28 km downstream of Mount Rainier, both datasets reveal a terrace of the Electron mudflow at least 25 m high above the channel of the Puyallup River. The ASTER DEM appears to resolve tributary drainages more clearly than the USGS DEM, but unfortunately derives topography at the top of the canopy, which is up to 26 m above the floor of the terrace at this location. Photogeologic interpretation of ASTER VNIR channels confirms that this part of the valley is forest covered. About 8 km further downstream, the ASTER DEM resolves the shape of a landslide deposit younger than the Electron mudflow, which was not as clearly resolved in the USGS DEM. Errors in the measured heights of debris flow terraces will be compared between the ASTER and SRTM data, as well as the utility of interpolation-based resampling methods for reducing its effects and enhancing the signature of the underlying terrain.

V41B MC: 305 Thursday 0830h

New Directions in Experimental Mineralogy and Petrology I *(joint with T, MR, HG)*

Presiding: **R Angel,** Virginia Tech**; G Fiquet,** Universite Paris

V41B-01 0830h INVITED

Some challenges for Seismology and Mineral Physics Research

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The seismological challenges for a better understanding of the dynamics, composition, and evolution of Earth's mantle are many but focus on (1) the upper mantle transition zone (wavespeed variations, radial gradients, and nature of and depth to seismic discontinuities), (2) the fate of deep sinking slabs and the relative wavespeed variations in the lower mantle, and (3) the seismologically inferred complexity just above the core mantle boundary. In the past decade our ability to map lateral variations in seismic wavespeed in Earth's mantle has improved significantly mainly as a result of dramatic increases in computer power and quantity and quality of seismic data, and results of seismic imaging are now routinely interpreted with constraints from mineral physics. However, the interpretation of the inferred wavespeed variations (e.g. in terms of temperature, composition, volatiles, anisotropy) is difficult because the coverage of data used to construct S wave models differs from that used for P models and the magnitude of wavespeed variations is often poorly constrained owing to uneven sampling, regularization of seismic inversions, and wave propagation effects such as wavefront healing. But some interesting observations can still be made. We - and others - have inferred changes in the character of wavespeed variations near 1500-2000 km depth, but there is no convincing evidence for any interface in that depth range. Recent studies have detected differences in the behavior of P and S wavespeed, e.g., the increase of the ratio dlnVs/dlnVp with depth, in particular beneath 1500 km depth. This is unlikely to be a global phenomenon and may occur primarily in regions away from zones of recent subduction (e.g., Saltzer et al, GRL, 2001). Analysis of the available theoretical and experimental data on elastic parameters suggest that these observations cannot be explained by thermal variations alone, but for a more specific and quantitative interpretation we need a better description (or extrapolations) of the elastic properties as a function of temperature, pressure, and composition, including the effects of Al and Ca, for silicates at lower mantle conditions. Furthermore, an adequate (multi component) description of the phase transformations (e.g., element partitioning, pressure and Clapeyron slope of the transition) is required to understand the seismological observations pertinent to the discontinuities and the deformation of subducted slabs in the upper mantle transition zone. Finally, numerical models based on thermal convections are likely to oversimplify the processes in Earth's interior, and more realistic thermochemical modeling should be considered to investigate, for instance, the fate of the slab fragments that have sunk into the lower mantle (e.g., compositional buoyancy), the presence of any pressure-induced compositional gradients, and the effects on dynamics of the temperature and pressure dependence of such physical parameters as thermal expansion and diffusivity. These pose some of the challenges for a concerted effort to understand to composition and evolution of our planet over geological time.

V41B-02 0900h INVITED

Electrical Properties of Deep Earth Materials

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Knowledge of the electrical properties of Earth materials at high P and T can contribute to knowledge of the phases present at depth and of the temperature profile of the interior. Electri-cal properties of rocks are strongly dependent on temperature and on the presence (or ab-sence) of highly conducting mineral phases, fluids or melts, or pathways. Recent laboratory determinations of mineral conductivities allow comparison of observed mantle conductivity profiles with conductivity models that include temperature and composition constraints. The influence of hydrogen or water on electrical conductivity of nominally anhydrous minerals is just beginning to be measured experimentally; preliminary results are consistent with an in-crease in conductivity due to the presence of H, but the effect may be modest at transition zone temperatures. Calculations and point defect models are beginning to shed light on the en-ergetics of hydrogen defects. Such models are important for complete understanding of the process and extrapolation to conditions not easily experimentally studied, such as oxygen and or hydrogen fugacity variations at very high pressures. Inferred conductivities of hydrogen-bearing olivine have lead to interpretation of oceanic conductivity profiles away from ridges as indicating the presence of H-rich sublithospheric mantle and the interpretation of continental conductivity profiles as indicating that sub cratonic mantle is unusually dry. The bulk electrical response of partially molten rock systems, the influence of melt compositional variations at low melt fractions, and the influence of textural equilibration under high-pressure, high-temperature conditions have begun to be studied directly, although detailed calculation of full bulk properties from the starting point of the real melt distributions, including melt pockets and blind alleys as well as interconnected channels, is yet to be achieved. New visualization meth-ods such as high resolution X-ray tomography will be needed to obtain novel results in this area. A developing area is that of electrochemical interactions between metals (molten and solid) and silicates such as may occur at the core-mantle boundary. Such interactions may not mimic those occurring at low pressures, and the results may have implications for generation of mantle plumes and propagation of the Earth's magnetic field.

V41B-03 0930h

Mineralogy of the Lower Mantle by the Combined Method of Laser-heated DAC and ATEM

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The development of laser-heated diamond anvil cell (DAC) experiments enable us to study the mineral compositions of the lower mantle. However, it is generally very difficult to precisely characterize the materials synthesized by DAC with the conventional methods because those materials are very fine-grained, mostly submicron. An analytical transmission electron microscope (ATEM) is a very powerful tool to characterize those materials because by ATEM we can analyze both structures and compositions of those materials in a nanometer scale. Therefore, the combination of laser-heated DAC and ATEM is a very promising approach for the study of the mineralogy of the lower mantle.

Although they are powerful, both laser-heated DAC and ATEM have several problems to be settled. We present our recent attempts to solve those problems, focussing on ATEM. Ultrahigh pressure materials are very weak against an electron beam and easily become amorphous. We are trying to overcome this problem by introducing a high-sensitive TV camera for TEM by which we can observe electron images and diffraction patterns under the very weak electron beam. Another problem with ATEM is the selective removal of elements during ion-thinning of the ultrahigh pressure

materials to obtain TEM foils. We are examining ultramicrotomy, in stead of ion-thinning, in which samples embedded in polymeric resins are sectioned into TEM foils by a diamond knife. So far, we could section the DAC samples into TEM foils of 40 nm thick.

Preliminary results on the phase relations of the system CaMgSi2O6 - CaFeSi2O6 under the lower mantle conditions, aimed to explore the solubility relations between (Mg,Fe)SiO3 and CaSiO3 perovskites, indicate that at 20-40 GPa and 1800-2300 K the solubility of Ca in MgSiO3 perovskite is very low, nearly 1 mole percent or less, and the solubility of Fe in (Mg,Fe)SiO3 perovskite is around 15 mole percent.

V41B-04 1015h INVITED

Grain-Size, Pressure, Temperature and Frequency: Laboratory Determination of K, G and Q^{-1} of Earth Materials

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The challenge of experimental work in Earth sciences is for the laboratory conditions to approach those of the Earth as closely as possible. Failing this one needs to make extrapolations, assuming we appreciate the effects of these excursions into the unknown.

Experimentalists started determining the bulk and shear modulus of Earth materials by measuring P- and/or S-wavespeeds on single crystals at pressure (∼1 GPa) or temperature (∼600K) some 40 years ago. Most of the techniques used were for high frequency waves from MHz (ultrasonics) to GHz (light scattering techniques). A simple extrapolation in pressure and temperature was then required to approach the conditions of the Earth. Shock-wave, diamond anvil and resonance techniques increased the range of temperature and pressure over which K and G could be determined.

In the last decade we have come to appreciate the need to perform measurements at seismic frequencies - as we compare laboratory data with seismic data. Thus instead of simply measuring wavespeeds, we must measure both attenuation and speed of stress waves travelling through Earth materials as a function of frequency, pressure and temperature.

Recent high temperature forced oscillation measurements on polycrystalline materials have shown that shear wavespeed and attenuation are dependent upon the grain-size of the sample. Thus, at least for the small strains ($<10^{-4}$) associated with the propagation of seismic waves through the Earth, the shear wavespeed and attenuation of polycrystalline Earth materials need to be investigated as a function of P, T, frequency and grain-size

The future challenge in the measurements of shear wavespeed and attenuation is the need to investigate the grain-size dependence of G and Q^{-1}; together with the further question of whether the shear deformation mechanism which results in the observation of viscoelasticity of polycrystalline Earth materials in the laboratory is applicable to the larger strains associated with post-glacial isostatic rebound, and convection in the mantle; or whether a number of different deformation mechanisms operate within the Earths mantle as a function of stress, strain and strain-rate.

V41B-05 1045h

Multi-anvil Press with an X-ray Probe

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Multi-anvil presses now populate synchrotron beamlines on several continents. They provide an environment for high pressure and high temperature with simultaneous x-ray exposure. This combination of facilities provides many opportunities. Differential stress can be measured from diffraction at different angles around the x-ray beam. Coupled with imaging of sample length to define total strain, this forms the basis of rheological studies. Pressurizing devices that can maintain a differential stress on the sample leads to the classic constant stress deformation type studies. Now, however, confining pressure is limited to about 30 GPa. X-ray metrics potentially provide extremely precise measurements of these properties. The sample itself may serve as the load cell, and deformation is measured directly on the sample as well.

Acoustic velocities will be possible in these systems up to 30 GPa and 3000K. Acoustic interferometry can measure travel times very accurately and sample lengths can be defined by the sample image. Additionally, information on the static elastic properties can be defined by the shapes of the Debye rings for the different diffraction lines. Comparison of static and ultrasonic elastic properties promises to help define the role of attenuation on velocity dispersion.

Inelastic scattering of x-rays promises to provide new information on the phonon properties of Earth materials. Density of states will supplement the P-V-T equation of state, phonon velocities may be a source of elastic property information, soft phonon behavior may be observable and related to phase transormations.

V41B-06 1100h

Rheology of San Carlos Olivine at High Pressure and Low Temperature

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Olivine, α-$(Mg,Fe)_2SiO_4$, represents a large fraction of the cold lithospheric material sinking into the mantle in subduction zones. The low-temperature (typically $T < 800^{\circ}$C) olivine rheology, thus, must control the rheology of subducting slabs. Despite its importance, olivine low-temperature rheology is still poorly documented, mainly because of the experimental complications resulting from the high differential yield stress (σ_m) of olivine in this range of temperature (e.g., $\sigma_m > 5$ GPa at $T > 100$ °C, e.g., Evans and Goetze, 1979). At low temperature and low pressure (typically $P < 300$ MPa) only indentation measurements can be performed without breaking apart the specimen. Although several attempts have been made to study the olivine rheology at high pressure, they were until recently either limited to room temperature measurements or inaccurate in the determination of specimen yield stresses and/or strain rates.

We report here new results using a new experimental method (see Weidner, 1998) for investigating the low-temperature olivine rheology. San-Carlos olivine rheological properties were studied at high pressure, during relaxation experiments carried out in a large-volume cubic-anvil (SAM85, DIA-type) press, by using in-situ synchrotron X-ray diffraction at the NSLS (Brookhaven, NY) and APS (Argonne, IL) facilities. The olivine elastic strain and strain rate were measured from the broadening of the olivine diffraction peaks. The stress in olivine was deduced from the elastic strain using the olivine elastic constants. Assuming a constant total strain (sum of both the elastic and the plastic strains), a classic assumption for relaxation experiments for which the loading pressure is maintained constant, the olivine plastic strain rate was deduced from the elastic strain rate, ultimately leading to the olivine rheological law at low temperature. The run products were investigated by transmission electron microscopy (TEM) in order to interpret the rheological data in terms of olivine microstructures. We will present these results with particular attention to highlighting the future prospects regarding these new techniques which today allow accurate rheological measurements at high pressure.

Evans, B., and Goetze, C. (1979) The temperature variation of hardness of olivine and its implication for polycrystalline Yield stress, J. Geophys. Res., 84: 5,505-5,524.

Weidner (1998) Rheological studies at high pressure, in Ultrahigh-pressure mineralogy: Physics and chemistry of the Earths deep interior, R. J. Hemley Ed., Reviews in Mineralogy, vol.37, Mineralogical Society of America, Washington D.C., pp.493-524.

V41B-07 1115h

An Experimental Test of the Reliability of Extrapolation of Diffusion Data to low Temperatures

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A common problem in the application of diffusion data to the modeling of natural systems has been that typically, diffusion coefficients are measured at high temperatures and then extrapolated over many hundreds of degrees for the applications (when obvious structural changes e.g. those due to phase transitions or exsolution do not intervene). The crucial question has been: Are such extrapolations valid? Or are there changes in the diffusion mechanism (e.g. from intrinsic to extrinsic) that invalidate such extrapolations? While recent experimental data and theoretical analysis indicate that such extrapolations should be valid over large ranges of temperature [1], other studies [2] argue that this is not the case. Recent improvements in experimental techniques (e.g. thin films produced by laser ablation) have allowed us to use a number of different analytical techniques (EMPA, RBS and analytical transmission electron microscopy) to measure Fe-Mg diffusion rates in olivine over a large temperature range of 700-1300 °C. Simultaneously, the actual defect structure in the diffusion couples were characterized using TEM. At each temperature range, two or more experimental / analytical methods were used on samples from different sources to eliminate any systematic, technique specific errors. We find no evidence of a change in the activation energy (i.e. diffusion mechanism) of ca. 220 kJ/mol, either along the [001] or the [010] crystallographic directions. This also means that we do not find any evidence of the change in diffusion anisotropy with temperature. Direct measurements to such low temperatures implies that diffusion data need not be extrapolated anymore for most applications, thereby eliminating one of the primary sources of uncertainties of diffusion models. We demonstrate that some recent determinations of low activation energies [2] are artifacts of the experimental techniques used. This also reduces the significance of the related computer models to explain diffusion behavior [2].

[1] Chakraborty, S. JGR 1997, Vol. 102, S. 12317, [2] Jaoul, O. et al., 1995, PEPI, 89, S. 199

V41B-08 1130h

Investigating the Transport Properties of Silicate Liquids at Mantle Pressures

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Understanding the effects of high pressure on silicate liquid properties, such as viscosity, ionic diffusion and thermal diffusivity, is critical for modeling magmatic processes in the mantle. Until recently, measurements of such properties were restricted to pressures of less that 2.5 GPa. However, with the development of multianvil systems together with experimental techniques utilizing synchrotron radiation, the pressures of such measurements have now been extended to 13 GPa in the case of viscosity measurements and 17 GPa for ionic diffusion experiments. The use of multianvil presses on synchrotron beamlines together with the recent development of a new cell for in-situ falling sphere viscometry has facilitated viscosity measurements up to 13 GPa at temperatures greater than 2000 °C. This method allows accurate and precise determinations for even very low-viscosity depolymerised liquids such as diopside and komatiite. Ionic self-diffusion in depolymerised silicate liquids has also been investigated at pressures up to 17 GPa using a large volume 5000-ton multianvil system at the Bayerisches Geoinstitut. The ability to compare direct viscosity determinations and oxygen or silicon self-diffusion coefficients for diopside liquid at high pressure has proved the Eyring relation to be valid. Thus, diffusion experiments provide a valuable means of estimating viscosity at considerably higher pressures than are currently attainable in falling sphere experiments. Compared to more polymerized silicate and alumino-silicate compositions, diopside and komatiite liquids show only a small effect of pressure on viscosity up to 17 and 7 GPa respectively. Prospects for the future include extending diffusivity measurements to 24 GPa and making direct viscosity determinations of very low viscosity silicate liquids over a large pressure range. Measurements on peridotitic liquids, in particular, will enable better constraints to be placed on the dynamics and crystallization behavior of a deep magma ocean during the early history of the Earth.

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