

and unit (dm- to m-scale) morphology. Variations at thermal wavelengths are presumably related to surface variations in phenocryst abundance, vesicles/micron-scale roughness, and glass. Interpretations based on the TMS data are significantly limited by noise in available data covering the flow field.

The present study uses MASTER (MODIS/ASTER airborne simulator) data to extend the spatial and spectral coverage of the Mauna Ulu flow field. Preliminary analyses of the data (corrected for atmospheric effects) indicate that: (1) additional classes of surface units (such as shelly pahoehoe) can be identified within the flow field, and (2) systematic changes in emplacement occurred from the proximal to the medial and distal portions of the flow field. Comparison with ASTER images indicates that similar classes of surface units may be discriminated in both datasets, though MASTER is preferable for this study because it provides: (1) higher spatial resolution (especially in thermal bands), and (2) constant pixel size for all wavelengths. These factors allow for discrimination of smaller flow units and more accurate correlation of visible- and thermal-wavelength spectral signatures. The higher spectral resolution of MASTER does not appear to significantly enhance unit discriminability because the additional bands do not appear to be responsive to differences in surface units.

### V32F-09 1625h INVITED

#### Advances in Thermal Infrared Mapping of Volcanic Sulfur Dioxide Plumes

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The current tools for estimating the sulfur dioxide (SO<sub>2</sub>) concentrations of volcanic plume from multispectral thermal infrared (TIR) imagery were developed using data acquired from aircraft flying at altitudes less than 10 km. The advent of MODIS and ASTER TIR observations from space presents new challenges for the plume mapping procedures. The original mapping tools have been updated and modified to address these challenges.

Airborne remote sensing experiments have demonstrated that atmospheric water vapor is variable on spatial scales as small as 25 m. Despite this high potential for variation, the conventional practice in plume mapping has been to assume that the distribution of water vapor can be characterized with a few radiosonde measurements or single climatological model. This assumption is not valid for MODIS TIR data, which have a spatial resolution of 1 km (at nadir) and swath width of 2300 km. ASTER TIR data have higher spatial resolution (90 m at nadir) than MODIS data, but the width of an ASTER swath (60 km) ensures that there will be variations in water vapor within a scene. To address the challenge of characterizing the variations in water vapor, we have developed a technique to estimate the water vapor abundance on a pixel-by-pixel basis. This technique will also be used to characterize the distribution of ozone in the atmosphere.

The observations of volcanic plumes from low-altitude aircraft are typically confined to areas near the source vents and the conventional practice has been to assume that the unique radiometric signatures of plumes can be attributed to SO<sub>2</sub> gas. By providing synoptic views of entire plumes and clouds, MODIS and ASTER increase the likelihood that sulfate aerosols are present in the scene. The radiative transfer model used in the plume mapping procedure does not provide much flexibility with regards to aerosol size distribution, number density, and composition.

To address the issues of mapping sulfate aerosols in addition to SO<sub>2</sub> gas, we now isolate the radiative emission and absorption due to the plume from that of the rest of the atmosphere. This new strategy gives us explicit control over the aerosol parameters used in the radiative transfer calculations and allows us to model the combined effects of aerosols and gas. This modeling technique will be extended to silicate ash particles, water droplets, and ice particles.

### V32F-10 1640h

#### Satellite Images: Invaluable Tools for Localizing and Mapping Miocene Calderas Prospected for Epithermal Au in Northeastern Mediterranean Basin

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Remote sensing methods combined with field investigations have successfully localized two caldera structures in the 17 my volcanic complex of the island of Lesvos. The junctions of these structures with tectonic lineaments are very important for hydrothermal fluid circulation and deposition of epithermal Au.

In the central part of Lesvos island a major caldera structure that of Vatoussa, is traced on SPOT-PAN imagery with an elliptical shape and with its major axis trending northwesterly. The northeastern part of this nested caldera, which is a much larger structure and encloses the caldera reported in the literature, is presently under sea level.

The Vatoussa caldera is outlined and also encompasses volcanic domes, which are intensely hydrothermally altered. The western caldera wall displays well the radial caldera faults and is also marked by a megabreccia unit.

The Stipsi caldera is smaller than reported in the literature with a circular outline intercepted by a major northeasterly trending tectonic zone. Volcanic domes invading the periphery and the caldera floor follow this direction. Remote sensing techniques have localized numerous intense hydrothermal alterations internal and external to the Stipsi caldera.

### V32F-11 1655h

#### Temperature Distribution Analysis of July 2001 Mount Etna Eruption: a Multi-Sensor Image Data Comparison

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On July 17th and 18th 2001 several fractures opened on the southern flank of Mt. Etna originating different lava flows spreading both in Valle del Bove and towards Nicolosi town. On July 29th an airborne campaign equipped with an image spectrometer was performed over Mt. Etna to acquire image data of the eruption. The campaign was organized to permit a simultaneous acquisition with the TERRA, EO-1 and LANDSAT 7 satellites. This multi-sensor acquisition over an active lava flow represented a unique opportunity to study the temperature distribution and at the same time to compare the different sensors capabilities for this type of volcanic events. The preliminary observations of the different data sets enlighten the importance of the data quantification and of the gain setting of the instrument. Surface temperature analysis was performed on distinct lava flows by using dual-band and triple-band techniques. Temperature distribution is peculiar for each different lava flow and appears to be related to the ageing of the flows. This means that the monitoring of the lava thermal status may be used as powerful tool for volcanic hazard prediction especially if combined with a detailed study of the topography through Digital Elevation Model analyses. The airborne high-spatial resolution images allow for the creation of a mathematical and physical model of the temperature distribution. This model must be subsequently tested on satellite data characterized by a lower spatial resolution but a higher time frequency of acquisition.

### V32G MC: 304 Wednesday 1330h

#### Geomaterials: Melts and Melting

**Presiding:** N Bagdassarov, University of Frankfurt; J Webster, American Museum of Natural History

### V32G-01 1330h

#### Pressure Dependence of T<sub>g</sub> in Silicate Glasses From Electrical Impedance Measurements

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The pressure dependence of the glass transition temperature ( $T_g$ ) in silicates correlates with a pressure dependence of viscosity. For example, albite glass has a negative pressure dependence of shear viscosity and  $T_g$ , diopside and sodium trisilicate glasses have positive pressure dependence of  $T_g$  and viscosity. Electrical conductivity measurements are easier to conduct at high pressures than rheological measurements. By means of electrical impedance measurements  $T_g$  in glasses may be estimated from the temperature dependence of impedance, if the mobility of charged defects correlates with structural defects. Below  $T_g$  activation energy of electrical conductivity is less than that at  $T > T_g$ . The intersection point of two Arrhenius dependencies of electrical conductivity as function of  $1/T$  defines  $T_g$ . In this study  $T_g$  has been estimated for anorthite, albite, haplo-granitic and silica glasses in atmospheric furnace and in 3 types of high-pressure apparatus: piston-cylinder, belt and multi-anvil presses. Electrical impedance measurements were conducted in the frequency range 100 kHz - 0.01 Hz. The measured glass transition temperature in anorthite varies with pressure  $P$  (in GPa):  $T_g = 850^\circ\text{C} + 5^\circ/\text{GPa} \times P$ , in albite glass the pressure dependence on  $T_g = 685^\circ\text{C} - 8^\circ/\text{GPa} \times P$ ; in HPGS  $T_g = 777^\circ\text{C} - 45^\circ/\text{GPa} \times P$ ; and in silica glass  $T_g = 1050^\circ\text{C} + 17^\circ/\text{GPa} \times P$ . Dielectric relaxation times calculated from the imaginary component of the dielectric modulus are three orders of magnitude smaller than structural relaxation times and increases at high pressures. With the pressure increase activation energy of dielectric relaxation in anorthite increases having the activation volume of ca.  $10 \pm 5 \text{ cm}^3/\text{mol}$ , in albite glass the activation volume is small and negative  $-2 \pm 1 \text{ cm}^3/\text{mol}$ .

### V32G-02 1345h

#### Thermal Expansion of Supercooled Haplobasaltic Liquids Obtained via Container-based Dilatometry

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The thermal expansion of supercooled liquids in the haplobasaltic (anorthite-diopside) system have been determined using methods of container-based dilatometry. We have been investigating thermal expansivities over temperature ranges of up to 170 K.

The expansivity data obtained in this study agree well with estimates provided by previous dilatometric determinations in the system that have relied on alternative experimental strategies. The data have been combined with high temperature, superliquidus determinations of melt density to obtain expressions for the volume-temperature relationships of liquids in the anorthite-diopside system. The volume-temperature

data clearly indicate a non-linear temperature dependence of volume for all melts investigated. The data reveal a constant increase of coefficients of thermal volume expansion with increasing diopside content within the investigated system.

The expansivities obtained in this study cannot be reproduced using published models based on linear volume-temperature relationships. They require instead a reanalysis of existing PVT-EOS models for silicate melts.

### V32G-03 1400h

#### The true temperature dependence of CO<sub>2</sub> speciation in silicate melts

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The thermodynamics and kinetics of CO<sub>2</sub> speciation in silicate melts have been studied by measuring the concentration of CO<sub>2</sub><sup>mol</sup> and carbonate in jadeite glass annealed at 575<sup>circ</sup>C, 450<sup>circ</sup>C and 400<sup>circ</sup>C. Assuming that the reaction is CO<sub>2</sub><sup>mol</sup>.O<sub>br</sub> = CO<sub>3</sub>

where CO<sub>2</sub><sup>mol</sup>.O<sub>br</sub> represents a CO<sub>2</sub> molecule weakly bonded to a bridging oxygen in the network and CO<sub>3</sub> represents a bridging carbonate group with no net negative charge,  $\Delta H_{\text{forthe reaction}} = 17.3 \text{ kJ mol}^{-1}$  and  $\Delta S_{\text{is}} = 24.7 \text{ J K}^{-1} \text{ mol}^{-1}$ . The rate of equilibration of the species was measured at each temperature and the rate constants were deduced. The temperature dependence of the rate constants was used to determine the activation energy of the forward and reverse reactions which are 68 kJ mol<sup>-1</sup> and 86 kJ mol<sup>-1</sup> respectively. The data suggest that CO<sub>2</sub><sup>mol</sup> may be much more abundant in silicate melts than previously assumed on the basis of studies of CO<sub>2</sub>-bearing glasses.

### V32G-04 1415h

#### The Extent of Disorder among Charge-balancing Cations in Silicate Glasses and Melts: Spectroscopic Analysis and ab initio Molecular Orbital Calculations

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Aluminosilicate melts are one of the dominant components in upper mantle and crust. Essential to the thermodynamic and transport properties of these systems is the full understanding on the atomic arrangements and the extent of disorder. Recent quantification of the extent of disorder among 'framework cations' in silicate melts using NMR provided improved prospects on the atomic structure of the glasses and melt and their corresponding properties and allowed the degree of randomness to be evaluated in terms of the degree of Al-avoidance (Q) and degree of phase separations (P) (Lee and Stebbins, J. Phys. Chem. B 104, 4091; Lee and Stebbins, GCA in press).

Quantitative estimation of the extent of disorder among 'charge-balancing cations' including Na in aluminosilicate glasses, however, has remained an unsolved problem and these cations have often been assumed to be randomly distributed. Here, we explore the intermediate range order around Na in charge-balanced aluminosilicate glasses using Na-23 NMR and Near-edge X-ray absorption fine structure (NEXAFS) with full multiple scattering (FMS) simulations combined with ab initio molecular orbital calculations. We also quantify the extent of disorder in charge balancing cations as a function of Na-O bond length (d(Na-O)) distribution with composition and present a structural model favoring ordered Na distributions.

Peak position in Na-23 magic angle spinning (MAS) spectra of aluminosilicate glasses with varying R (Si/Al) at 14.1 T varies from -10.28 ppm (R = 0.7) to -19.98 ppm (R = 6). These results suggest that average d(Na-O) increases with increasing R, which is confirmed by Na-23 multiple quantum MAS spectra where the chemical shift moves toward lower frequency with increasing Si and shows the individual Gaussian components of Na-O distributions such as Na-(Al-O-Al), Na-(Si-O-Al) and Na-(Si-O-Si). Calculated d(Na-(Al-O-Al)) of 2.57 Å is shorter than d(Na-(Si-O-Si)) of 2.88

Å. Strong compositional dependence is further manifested in Na K-edge NEXAFS spectra for aluminosilicate glasses that are characterized by two main peaks at about 1057 eV (A) and 1062 eV (B). The intensity ratio between peak A and B increases with increasing R, which is consistent with our FMS simulations of model clusters with R and implies that the Na has rather well ordered oxygen coordination and Na-O distribution depends on the types of nearby framework cations.

The potential energy surfaces for model six-member rings (NaAl<sub>2</sub>Si<sub>4</sub>O<sub>6</sub>(OH)<sub>12</sub>, with and without Al-O-Al) were calculated using ab initio calculations at the HF/6-311G(d) level in order to investigate the equilibrium atomic configurations around Na. The results manifest the varying bonding preference of Na to different framework oxygens. Na is located at single deep and narrow basin in potential energy surfaces. The motion of Na is therefore restricted to near equilibrium position even at higher temperature contrary to conventional random distribution model with moderate Na mobility, demonstrating that dynamics of Na should be associated with the collective motions of framework cations and oxygens.

In this study, we provide new insights into the nature of disorder in charge-balancing cations in silicate glasses using spectroscopy combined with simulations, highlighting more complete, atomic-level understanding on the dynamic processes in silicate magmas.

### V32G-05 1430h

#### Experimental Determination of Sulfur Solubility in Basaltic Melts at Sulfide vs. Sulfate Saturation. Possible Implications for Ore Formation.

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Two sets of experiments were conducted to determine the differences in sulfur solubility in sulfide-saturated (reduced) vs. sulfate-saturated (oxidized) basaltic systems. The experiments were performed in a piston-cylinder apparatus at 1.2 GPa and 1315 °C, pressure and temperature roughly representative of conditions in the upper mantle. Five weight percent elemental sulfur was added to the experimental charges as FeS, CaSO<sub>4</sub> or FeSO<sub>4</sub>. Various synthetic glasses, some of them deficient in Ca or Fe, were prepared as starting materials and used in combination with sulfur-bearing phases to ensure the same bulk composition in all experimental charges.

For sulfide-saturated experiments, reducing conditions were obtained by using graphite capsules enclosed by welded platinum capsules. The graphite capsules buffer the redox conditions to the C-CO equilibrium (ca. 1.25 log units below FMQ). The presence of iron sulfide in the run products, regardless of sulfur being added as calcium sulfate, iron sulfate or pyrrhotite was used as an indication of equilibrium having been achieved. For these runs, the sulfur concentration is [S]=0.12 ± 0.01 wt%, consistent with other experimental data under similar conditions.

For sulfate-saturated experiments, oxidizing conditions were obtained by adding sulfate as starting material and using Au<sub>75</sub>Pd<sub>25</sub> capsules. The combination of AuPd capsules and Pyrex or alumina as packing material was sufficient to preserve calcium sulfate as the stable sulfur phase. In analogy with the previous set, the presence of calcium sulfate in the run products regardless of sulfur being added as calcium or iron sulfate, and the similarity in the glass composition was used as an indication of equilibrium. Redox conditions between +2.54 and +3.75 log units above FMQ were estimated by using the fayalite-ferrosilite-magnetite equilibrium in the olivine-orthopyroxene-spinel assemblage coexisting with the melt. Under these conditions [S]=1.4 ± 0.2 wt% (n=5), one order of magnitude higher than under reduced conditions.

We suggest that under very oxidized conditions sulfides are no longer stable in basaltic magmas, and siderophile-chalcophile element distribution may instead be controlled by equilibria among melt, alloys, oxides, and silicates. Conversely, any process that reduces a sulfate-bearing melt would drastically decrease sulfur solubility, change the sulfur speciation in the melt, and induce the precipitation of sulfides.

### V32G-06 1445h

#### The Dramatic Effect of Chlorine on Magmatic Phase Relations

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Recent investigations indicate that some mafic magmas evolve to extreme Cl enrichments. Olivine-hosted silicate melt inclusions from Raivavae in the Austral Islands contain up to 2.5 wt.% Cl (Lassiter and Hauri, 2001), and computations based on apatite-melt partition coefficients indicate that compositionally evolved, late-stage fractions of magma of the Bushveld and Stillwater intrusions may have contained even more Cl (Webster and Mathez, 2001). Recent work on the Skaergaard intrusion indicates that Cl had an important effect on the partitioning of trace elements and on the trend of differentiation of the magma. The role of Cl as a volatile fluxing component in magma and its influence on phase relations in silicate melts are poorly understood.

Hydrothermal experiments were conducted with PtCl<sub>2</sub> and various mixtures of plagioclase and clinopyroxene (with trace olivine and oxides) from Skaergaard rock samples to determine the influence of Cl on melting behavior and other phase relations at 1500 bars, temperatures of 950° to 1160° C, and under oxidizing conditions. The comparatively dry melts contain 2 to 4 wt.% Cl, and results from these experiments were compared with water-saturated melts for the same P-T conditions. These Cl concentrations dramatically promote melting of plagioclase and clinopyroxene, and the effect on melting is nearly equivalent to the effect of water during melting at PH<sub>2</sub>O of 1500 bars. In addition, as run temperatures were lowered and the extent of crystallization increased, the residual fractions of Cl-enriched melt evolved to compositions enriched in (Ca + Mg) relative to (Al + Na + K). In contrast, the water-saturated residual melts generated at the same temperature exhibited significantly lower (Ca + Mg) relative to (Al + Na + K).

These observations are consistent with the results of another set of experiments that were conducted to determine the solubility of Cl in 40 comparatively anhydrous, aluminosilicate melts at 2000 bars and apparent speciation reactions for Cl in these melts. These experiments demonstrate that the solubility of Cl is most strongly controlled by Ca and Mg in dry melts, followed by Fe, F, Na, K, and Al (in that order).

These experiments suggest that Cl associates with Ca and Mg in aluminosilicate melts, which should promote the evolution of Cl-enriched magmas toward compositions enriched in (Ca + Mg) relative to (Al + Na + K). Enhanced levels of Cl should also tend to destabilize Ca- and Mg-enriched minerals relative to Ca- and Mg-enriched melts, and Cl should tend to lower the liquidus temperatures of mafic minerals relative to plagioclase (opposite to the effect of PH<sub>2</sub>O on phase relations).

Lassiter, J.C. and Hauri, E.H. (2001) Proc. of 11th Ann. Gold. Conf., #3639pdf.

Webster, J.D. and Mathez, E.A. (2001) Proc. of 11th Ann. Gold. Conf., #3164pdf.

### V32G-07 1520h

#### Constraints on the Depth of Andesitic Magma Storage Beneath Mt. Mazama from Infrared Spectroscopy and Experimental Petrology

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Andesitic scoria erupted after voluminous rhyolitic pumice during the climactic eruption of Mt. Mazama are categorized by their distinct modal mineralogy and Sr concentration in plagioclase and matrix glass. The andesite includes: high Sr scoria, the most voluminous component (with modal hbl > cpx + opx), later erupted low Sr scoria (cpx + opx > hbl), and olivine + pyroxene-rich scoria (high modal olivine + pyroxene, ± hbl ± ilm) that contain high Sr, or low Sr matrix glass and are the most mafic material erupted. Total dissolved H<sub>2</sub>O concentrations in homogenized, olivine-hosted, andesitic glass inclusions measured by FTIR, range from 2.4 wt.% to 5.8 wt.%. High Sr glass inclusions (>1300 ppm) contain from 3.4 wt.% to 5.8 wt.% total H<sub>2</sub>O. Pre-eruptive temperatures calculated for H<sub>2</sub>O-rich high-Sr glass inclusions (5.3 to 5.8 wt.%) range from 955° C to 972° C (liquid thermometer of Sisson and Grove 1993). These temperatures are higher than new pre-eruptive temperatures calculated from touching Fe-Ti oxide pairs in less mafic high Sr andesitic scoria (890° C to 934° C using QUILF) containing ilmenite. Pre-eruptive temperatures from Fe-Ti oxides are probably biased to lower values due to absence

of ilmenite in mafic scoria. Low Sr andesitic inclusions (<1000 ppm) in olivine contain from 2.4 wt.% to 4.3 wt.% total H<sub>2</sub>O by FTIR. Dissolution of 5.8 wt.% H<sub>2</sub>O in high Sr andesitic melt requires 2.0-2.1 kbars total pressure at 950-975°C.

Water-saturated experiments were conducted at 2 kb between 950°C to 990°C (logfO<sub>2</sub> from NNO+1 to NNO+2) on representative high-Sr and low-Sr andesitic compositions. Amphibole, identical in composition to that in natural samples, is stable in water-saturated high-Sr andesitic melts at 950°C to 975°C, and up to 950°C in low-Sr melts. Forsterite content of olivine in 975°C experiments (Fo80) matches the composition of host olivines in high-Sr samples. Glass compositions in 950°C - 975°C experiments closely match the glass inclusions. Experiments at 950°C lack olivine. Experiments at 990°C lack plagioclase and amphibole and contain olivine with higher forsterite content (Fo82). Experimental data indicate a pre-eruptive temperature range of 950°C-975°C for H<sub>2</sub>O-rich high-Sr andesitic magma and attainment of fluid saturation at 2.0 to 2.1 kb, roughly 8 km below Mt. Mazama. Low Sr andesitic magma would have attained fluid saturation at approximately 1.1 to 1.3 kb, or roughly 4-6 km depth. Lower dissolved H<sub>2</sub>O concentrations of 3.4 - 4.2 wt.% measured in high Sr glass inclusions are associated with lower dissolved sulfur and chlorine concentrations and probably indicate deep (>6 km) pre-eruptive gas loss from fluid-saturated high Sr andesitic magma and late entrapment.

### V32G-08 1535h

#### An Experimental Study of Harzburgite Reactive Dissolution in an Alkali Basalt

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Dissolution of a melt-bearing harzburgite (Ol:Opx ~ 1:1 in mass, and 10±2% melt) in an alkali basalt was examined at 1260 - 1290°C and 0.6-0.75 GPa using a piston cylinder apparatus. One of the purposes of this study is to examine the systematic variations in mineralogy, mineral chemistry and melt porosity that are associated with harzburgite reactive dissolution. Such information, along with dissolution rate, is essential in quantitative understanding of melt transport in the mantle. Using natural starting materials, dissolution couples were formed by juxtaposing pre-synthesized rocks of alkali basalt and harzburgite (1290°C and 0.6 GPa or 1260°C and 0.75 GPa, 4 - 37 hrs) in Pt and graphite lined Mo capsules, and were run at the respective P and T for 0.4 to 8 hrs. Harzburgite (olivine Mg# = 88.5) dissolves incongruently into the alkali basalt (Mg# 54) forming an olivine + melt reactive boundary layer. The thickness of the reaction zone (X<sub>b</sub>, in μm) is proportional to the square root of experimental run time (t, in seconds), with X<sub>b</sub> = 1.40(±0.09) \* sqrt(t), r = 0.91. The olivine crystals in the reaction zone (5-60 μm) are euhedral, and some contain melt inclusions. The average porosity of the reactive boundary layer varies from 20% to 24% among the 15 experiments analyzed to date, whereas grain scale porosity of the reaction zone is quite heterogeneous (15% to 38%) in a given sample.

The Mg#, as well as the NiO and CaO contents of the olivine crystals in the reaction zone vary systematically as a function of distance and time. The Mg# and NiO content in the olivine decrease from 89 and 0.39 wt%, respectively, at the interface with the harzburgite to 83 and 0.15% at the interface with the alkali basalt. The CaO content of the olivine is inversely correlated with the Mg#, ranging from 0.1% to 0.3%. The larger olivine crystals (> 16 μm) in the reactive boundary layer are strongly zoned with core compositions similar to the original olivine composition in the harzburgite (Mg# = 88.5, NiO = 0.39%, CaO = 0.08%). The Mg# of the interstitial melt in the reaction zone varies over the range of 45 to 60, which is less than the expected values for melts in equilibrium with the olivine in the reaction zone (Mg# = 60-70). Variations in the mineral and melt compositions are consistent with a dissolution, reprecipitation, and diffusive exchange model for reactive dissolution. Orthopyroxene in the harzburgite dissolves into the adjacent melt and is transported through the reaction zone. The dissolved materials are then reprecipitated around the partially dissolved olivine forming compositionally zoned, melt inclusion bearing olivine crystals.

Our study helped to identify two regimes of reactive dissolution: diffusion in melt limited and diffusion in solid limited dissolution. Diffusion in liquid limited dissolution produced a sharp mineralogical front, separating undissolved harzburgite from the olivine + melt reactive boundary layer. The latter will be transformed into dunite once the interstitial melt is drained (or solidified). Diffusion in solid is a much slower process than diffusion in the melt. Hence diffusion in solid limited dissolution and reprecipitation resulted in a broad compositional boundary layer. This strong decoupling between mineralogy and mineral chemistry is characteristic of reactive dissolution. Using typical melt transport rate and diffusion coefficients, we found that me-

ter scale or larger concentration gradients can present (and may be preserved) in the upper mantle that had experienced reactive infiltration.

### V32G-09 1550h

#### Ultracalcic Magmas or Ankaramitic Picrites as Primitive Magmas in Island Arcs

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Ultracalcic magmas (> 14 wt% CaO) or ankaramites occur as whole rocks (arcs, OI) and melt inclusions (arc, OI, MOR). Whereas some rocks are clearly cumulative, most UCMs in arcs have trace element signatures of typical primitive arc picrobasalts. We investigate a hy-normative alkaline-poor composition from Epi, Vanuatu arc, which represents one extreme of the arc UCM-array. This composition is more similar to typical hy-normative MOR UCM-inclusions (Kogiso and Hirschmann 2001, CMP) than to the other extreme of the arc UCM-array defined by neph-normative alkaline-rich glass inclusions (Schiano et al 2000, G<sup>3</sup>).

The liquidus of this composition was investigated at 15 and 20 kbar but only cpx was present (X<sub>CO<sub>2</sub></sub>=0.0-1.0). Thus, in a series of assimilation experiments the Epi composition was allowed to saturate in opx, ol, Cr-sp, and cpx. The resulting liquids at intermediate to high X<sub>CO<sub>2</sub></sub> and T=1340-1375 °C were moderate in CaO (12-14 wt%) but high in CaO/Al<sub>2</sub>O<sub>3</sub> (1.4-1.6) and MgO (15-19 wt%). The most primitive Epi magmas can thus be derived from our experimental ankaramitic picrite liquids in equilibrium with opx+ol+sp+cpx through 5-7% olivine and 1-1.5% spinel fractionation. The primary magmas in this case are not ultracalcic but have an elevated CaO/Al<sub>2</sub>O<sub>3</sub> ratio. The mantle which is to melt in order to obtain our primitive liquids is already refractory and can be modelled through extraction of 12-15% first stage melt from a pyrolytic mantle. First stage melting results in depletion of alkali elements and Al<sub>2</sub>O<sub>3</sub> and increased CaO/Al<sub>2</sub>O<sub>3</sub> ratios in the source. It is emphasized that our starting composition is the estimated primitive parent magma characterized by olivine and diopside phenocrysts to Fo<sub>92</sub> and X<sub>Mg94</sub> and spinels with Cr#80-85 (Bardsell & Berry 1990, JPet).

The necessary elevated temperatures require vigorous mantle convection. In the arc setting a convenient model includes first stage melting during backarc spreading (present in the Vanuatu arc, however, first stage melting could also happen aegons before), second stage melting would then intervene after addition of a CO<sub>2</sub>-H<sub>2</sub>O-component below the arc. The addition of CO<sub>2</sub>-H<sub>2</sub>O is necessary as pure H<sub>2</sub>O or dry experiments did not yield suitable parental magmas.

### V32G-10 1605h

#### The 5 GPa mantle solidus revisited

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We critically examine the recent claim that inter-laboratory discrepancies in the solidus temperatures of nominally dry, fertile mantle peridotite between 4 and 6 GPa are related to encapsulating material (Re-foil capsules [1] versus graphite-lined Pt capsules [2]). Herzberg et al. [1] argue that reaction between silicate and graphite produces CO<sub>2</sub>, which causes a substantial freezing point depression of the peridotite solidus (>50°C at 5 GPa). We report results of a direct experimental comparison of peridotite melting in Re-foil and graphite-lined Pt capsules. We locate both capsules, containing fertile peridotite KR4003 [2], into the central portion of a stepped graphite heater, where thermal gradients are modest and well-characterized. Our experiments are performed in a MA6/8 multianvil, using octahedra of Ceramacast 584 cast with fins to fit 10-mm truncated edge length carbide anvils and calibrated by [3]. We insert axial W-Re (D-type) thermocouples into both ends of the furnace; butting thermocouple leads against the metal capsules to complete

the circuit. This arrangement closely matches the thermocouple configurations used in the studies of [1] and [2]. Thermocouple voltage, power consumption, and load are recorded continuously during the experiment. Temperature is controlled by the thermocouple connected through the Pt capsule. We find that the voltage from the second thermocouple drifts significantly above 1650°C, and gives false temperatures after only 10 minutes at the set point temperature. We also find that the phase assemblages in both capsules of a given experiment are identical down to conditions with trace amounts of quenched melt. At 1670°C, based on the control thermocouple, KR4003 was partially melted to ~35% and has a residual mineralogy of olivine, orthopyroxene, and garnet. This run temperature is 15°C below the 5 GPa solidus of [1]. Extrapolation of melt fraction versus temperature data gives a solidus temperature for KR4003 of 1600±15°C, consistent with [2]. We believe that the differences between our results and [1] are related to the drift in the W-Re thermocouple in contact with the Re capsule; not accounted for in the experiments of Herzberg and coworkers [1, 4]. Previous interlaboratory differences cited by [1] cannot be attributed to encapsulating material. The most important implication of this work is that the onset of melting of nominally dry lherzolite at high pressure occurs at significantly lower temperatures than previously assumed.

[1] Herzberg et al., 2000, GC 000089; [2] Walter, 1998, JP 39; [3] Tinker and Leshner, 2001, GCA 86; [4] Zhang and Herzberg, 1994, JGR 99.

### V32G-11 1620h

#### Trace Element Partitioning Between Vacancy-rich Eclogitic Clinopyroxene and Anhydrous Silicate Melt at 3.0 GPa and 1335-1365 °C

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Recycled eclogite may be entrained in upwelling mantle and contribute to OIB and MORB petrogenesis. Eclogite partial melting experiments at 2-7.5 GPa show that near-solidus clinopyroxene (cpx) is Al<sub>2</sub>O<sub>3</sub>-rich (11-17 wt.%) and can contain significant M2 site vacancies. Trace element partitioning between silicate liquid and vacancy-rich cpx has not been determined previously, making it difficult to predict the trace element characteristics of partial melts from eclogitic sources. We conducted partitioning experiments for such cpx at conditions and compositions relevant to near-solidus melting of quartz eclogite in the upper mantle.

Cpx has ~17 wt.% Al<sub>2</sub>O<sub>3</sub>, is cation deficient (~3.92 per 6 O), and coexists with andesitic melt with ~57 wt.% SiO<sub>2</sub>, quartz, and rutile. The cation deficiency indicates abundant vacant M2 sites in form of the Ca-Eskola component (Ca<sub>0.5</sub>[<sub>0.5</sub>AlSi<sub>2</sub>O<sub>6</sub>]). Cpx-melt partition coefficients (D<sub>s</sub>) were determined for Sr, Y, Zr, Nb, REE, Th, and U by SIMS, and for Sc, V, Cr, Mn, Co, Ni, K, and major elements by electron microprobe. Compared to previous studies of cpx with > 10 wt.% Al<sub>2</sub>O<sub>3</sub>, D<sub>s</sub> are elevated for monovalent cations (D<sub>Na</sub> ~1.0, D<sub>K</sub> = 0.027), and reduced for trivalent cations in the M2 site, particularly for LREE (D<sub>La</sub> = 0.029). Th and U are particularly low (0.0017-0.0037), and D<sub>U</sub>/D<sub>Th</sub> is apparently > 1. These effects on the D<sub>s</sub> for M2 site cations are attributable to the low average charge (1.53-1.57) of the site, which increases the number of configurations available to charge balance 1+ cations, but decreases the number of available configurations to balance cations of higher valence. D<sub>s</sub> for cations substituting into the M1 site show relatively little effect from the high vacancy concentrations in M2, but partitioning systematics may be obscured by strong crystal field stabilization of Ni<sup>2+</sup>, Cr<sup>3+</sup>, and V<sup>3+</sup> in M1.

Compared to data from earlier studies, the new partitioning results cause small increases in Sm/Yb of liquids produced by modest extents of melting of quartz eclogite. Also, (<sup>230</sup>Th)/(<sup>238</sup>U) activity ratios >1.15 are expected for decompression melting at upwelling rates below 5 cm/year. Following Wood and Blundy (EPSL 188: 59-71, 2001), who predicted increasing compatibility of Ar and He relative to K, Th, and U in cpx with increasing pressure, we speculate that rare gases should be particularly stable in vacancy-bearing eclogitic cpx. This could facilitate recycling of atmospheric gases during subduction and allow partial retention of noble gases during high-pressure partial melting.

V32G-12 1635h

**Near-Solidus Trace Element Partitioning at 3.0 GPa on the Peridotite Solidus.**Paula McDade<sup>1</sup> (Paula.McDade@bristol.ac.uk)Bernie Wood<sup>1</sup> (b.j.wood@bristol.ac.uk)Jon Blundy<sup>1</sup> (Jon.Blundy@Bristol.ac.uk)<sup>1</sup>Department of Earth Sciences, University of Bristol, Queens Road, Bristol BS8 1RJ, United Kingdom

Many results on the trace element and isotopic compositions of MORB indicate that melting beneath ridges begins within the garnet peridotite stability field. This conclusion is based on excesses in the activity of 230Th over its parent 238U, on enrichments in 176Hf relative to its parent 176Lu and on the general HREE pattern of MORB glasses. Garnet is unstable on the peridotite solidus at pressures below 2.8 GPa. This implies that potential temperatures of about 1450°C are required to generate significant amounts of anhydrous melt from garnet peridotite. Under these circumstances, the paradoxical result is that melting should produce about twice the thickness of oceanic crust observed and thus an alternative mechanism must exist by which to impart the garnet signature. Possible mechanisms include the entrainment of garnet pyroxene partial melts produced at <2.8 GPa, or the presence of water in the garnet peridotite melting regime, resulting in melt production at lower temperatures and hence volumetrically less melt. An alternative explanation which negates the presence of garnet in the MORB source was proposed by Blundy et al. (1997) who attributed the 'garnet signature' to HREE compatibility in near-solidus aluminous clinopyroxene at 1.5 GPa spinel-bearing lherzolite. Since MORB is thought to represent the accumulated small volume fractional, and hence near-solidus melts, this observation is of particular significance. However since this result is not directly relevant to the onset of most MORB melt production in that it pertains to melting at cold, deep ridges, it is not clear whether these aluminous clinopyroxenes can account for the entire 'garnet signature'. In an attempt to quantify the likely contribution to MORB of spinel lherzolite melts relative to those from garnet lherzolite, we have determined the partition coefficients of the REEs, HFSEs (Zr, Hf, Nb, Ta) and Li, Sr, U and Th between cpx, opx, grt and melt at 3.0 GPa, 1500°C. These experiments use the 4-phase-saturated, near-solidus garnet lherzolite melt composition determined by Dalton et al. (in prep.) (49.9 wt% SiO<sub>2</sub>, 3.5 wt% Na<sub>2</sub>O, Mg# 82), doped with trace elements at the ppm level, and seeded with equilibrium composition ol, grt, opx and cpx. Our new partitioning data are incorporated into a dynamic melting model in order to assess the relative contribution of spinel and garnet lherzolite melts to MORB.

**V41A MC: Hall D Thursday 0830h****Volcanic Observations From Space: New Results From the EOS Satellite Instruments II (joint with G, P)**

**Presiding:** M Ramsey, University of Pittsburgh; L Flynn, University of Hawaii at Manoa

**V41A-0972 0830h POSTER****Analysis of Vulnerability Around The Colima Volcano, MEXICO**Suarez Plascencia Carlos<sup>1</sup> (36381543; csuarez@cencar.udg.mx)

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The Colima volcano located in the western of the Transmexican Volcanic Belt, in the central portion of the Colima Rift Zone, between the Mexican States of Jalisco and Colima. The volcano since January of 1998 presents a new activity, which has been characterized by two stages: the first one was an effusive phase that began on 20 November 1998 and finish by the middle of January 1999. On February 10 of 1999 a great explosion in the summit marked the beginning of an explosive phase, these facts implies that the eruptive process changes from an effusive model to an explosive one. Surez-Plascencia et al, 2000, present hazard maps

to ballistic projectiles, ashfalls and lahars for this scenario. This work presents the evaluation of the vulnerability in the areas identified as hazardous in the maps for ballistic, ashfalls and lahars, based on the economic elements located in the middle and lower sections of the volcano building, like agriculture, forestry, agroindustries and communication lines (highways, power, telephonic, railroad, etc). The method is based in Geographic Information Systems, using digital cartography scale 1:50,000, digital orthophotos from the Instituto Nacional de Estadística, Geografía e Informática, SPOT and Landsat satellite images from 1997 and 2000 in the bands 1, 2 and 3. The land use maps obtained for 1997 and 2000, were compared with the land use map reported by Surez in 1992, from these maps an increase of the 5 percent of the sugar cane area and corn cultivations were observed compared of those of 1990 (1225.7 km<sup>2</sup>) and a decrease of the forest surface, moving the agricultural limits uphill, and showing also some agave cultivation in the northwest and north hillslopes of the Nevado de Colima. This increment of the agricultural surface results in bigger economic activity in the area, which makes that the vulnerability also be increased to different volcanic products emitted during this phase of activity. The degradation of the soil by the agriculture and forestry, mainly in the east hillslope of the volcano is another factor that generate remoulded material that in the event of an extraordinary rainfall during an explosive events, could increase the size of the lahar or generate flows of mud that may affect the towns, villages (like Atenquique, which has been affected in 1957 by a large lahar), and could generate strong damages to the communication lines affecting distant places as Guadalajara city and the Port of Manzanillo.

**V41A-0973 0830h POSTER****Advantageous GOES IR Results for Volcanic Ash Mapping at High Latitudes: Cleveland Eruptions 2001**Yingxin Gu<sup>1</sup> (906 487 1782; yigu@mtu.edu)W I Rose<sup>1</sup> (906 487 2367; raman@mtu.edu)D J Schneider<sup>2</sup> (djschneider@usgs.gov)<sup>1</sup>Michigan Technological University, Geological Engineering and Sciences, Houghton, MI 49931, United States<sup>2</sup>USGS/Alaska Volcano Observatory, 4200 University Dr, Anchorage, AK 95508, United States

The February 2001 eruptions of Cleveland Volcano, Alaska allowed for comparisons of volcanic ash detection using two band thermal (10-12 micron) infrared remote sensing using MODIS, AVHRR and GOES data. The data sets differ in spatial resolution and satellite zenith angle. Whereas MODIS data has zenith angles generally <40 degrees, the GOES has zenith angles for the Cleveland volcanic clouds at 60-65 N that are around 70 degrees. Because of the geometry the rectified footprint of GOES volcanic cloud areas is much larger than MODIS and the magnitude of the negative brightness temperature difference is sometimes 2 to 3 times higher. The differences are explained by distortion of the cloud's lateral extent because of the side-looking aspect and the longer path length through the volcanic cloud because of the high zenith angle. The shape of the cloud with respect to the GOES look angle is also important to understand the differences. Results show that high latitude GOES volcanic cloud sensing up to about 65 degrees is significantly enhanced, and that corrections for zenith angle are important for GOES data interpretations. Similar enhancements should occur for volcanic clouds at locations at low latitude which are visible by GOES but displaced from the GOES geostationary latitude.

**V41A-0974 0830h POSTER****Developing a Long-term Hazard Mitigation Plan for Consequent Volcanic Sedimentation Hazards at Santiaguito Dome Complex, Guatemala**Elly Bunzendahl<sup>1</sup> (sebenzen@mtu.edu)Gregg J Bluth<sup>2</sup> (gbluth@mtu.edu)William I Rose<sup>2</sup> (raman@mtu.edu)Samantha L Reif<sup>2</sup> (sreif@mtu.edu)Otoniel Matias<sup>2</sup> (rmatiasg@mtu.edu)<sup>1</sup>Michigan Technological University, Department of Civil and Environmental Engineering, 870 Dow BLDG, Houghton, MI 49931, United States<sup>2</sup>Michigan Technological University, Department of Geological Engineering and Sciences, 630 Dow BLDG, Houghton, MI 49931, United States

Continuous volcanic activity at Santiaguito, accompanied by seasonal monsoons, results in sediment inputs downslope into the Ro Ixpatz and Ro Samal river

channels. This threatens the lives and economic stability in populated downstream areas of Guatemala's coastal slope, a region responsible for major contributions to Guatemala's foreign exchange earnings. The changing riverbeds are host to sediment and water quality problems; subsequent flooding threatens villages, nearby cropland, infrastructure, and transportation. Current research suggests that the volcanic activity results in costs equal to millions of US dollars per year. Mitigation efforts are needed to protect lives, fertile land, and valuable crops located along the river valleys and plains in the down-slope region of the volcano.

The goal of this work is to build a GIS database for the areas affected by Santiaguito to facilitate the development of a long-range (several decades) plan for hazard mitigation and infrastructure development. The GIS will include multiple TM images which have been used to quantify activity and downslope aggradation patterns (Matias et al, this meeting), digital topography obtained from IGN and USGS/VDAP, land use maps and infrastructure overlays from IGN, Guatemala, and volcanic hazard zonation maps from INSIVUMEH, Guatemala. We expect to also use LAHARZ (Iverson, R.M., Schilling, S.S., Vallance, J.W., GSA Bulletin, 1998) to supplement GIS analysis. Additionally, we plan to work with local agencies within Guatemala to improve the current mitigation strategy which mainly involves extensive annual river and near-bridge dredging and is reactive on short time scales.

**V41A-0975 0830h POSTER****Analysis of Hot Springs in Yellowstone National Park Using ASTER and AVIRIS Remote Sensing**Melanie J. Hellman<sup>1</sup> (1-412-624-9324; mjllst80@pitt.edu)Michael S. Ramsey<sup>1</sup> (1-412-624-8772; ramsey@ivis.epps.pitt.edu)<sup>1</sup>University of Pittsburgh, Department of Geology and Planetary Science, 321 Old Engineering Hall, Pittsburgh, PA 15260, United States

Remote sensing data from multispectral ASTER and hyperspectral AVIRIS are used to detect and analyze terrestrial hydrothermal deposits. ASTER is beneficial for determining regional characteristics of hydrothermal areas, whereas AVIRIS has the necessary spectral resolution for detection of specific alteration minerals. Because detection of potential Mars relic hot springs will be done remotely, it is important to understand how we detect and can study these deposits on Earth. The THEMIS (Thermal Emission Imaging System) instrument, onboard Mars Odyssey, will search for thermal anomalies associated with hot springs on Mars. THEMIS and ASTER have similar spatial and spectral resolutions, therefore it is crucial to use ASTER to understand the thermal characteristics of terrestrial hydrothermal springs.

ASTER and AVIRIS data are being used to characterize the hot spring deposits in the Lower, Midway, and Upper Geyser Basins of Yellowstone National Park in the visible to thermal infrared wavelengths. ASTER data are being analyzed to determine broad scale characteristics of the hot springs and their deposits, identify thermal anomalies, and create large scale mineral maps of these basins. Image processing shows differences in these basins, including extent of thermal alteration, alteration minerals, and classifications. Comparisons of active, near-extinct, and extinct geysers are also being completed through remote sensing.

Field observations of these basins provide ground truth for comparison to the results of the remote sensing data. Fourteen study sites were selected based on diversity in size, types of deposits, and activity. This study included detailed site surveys such as land cover analysis, photography, Global Positioning Satellite data collection, radiometric analysis, and field spectroscopy. Samples of hot spring deposits, geyser deposits, and soil samples were collected and are being analyzed with a laboratory spectrometer that gathers information from the visible to thermal infrared wavelengths.

The results of this remote sensing and field study will lead to a greater understanding of spectral differences in active versus extinct springs, how to search for similar features on Mars, and what characteristics and anomalies the potential Martian hydrothermal features may have in the thermal infrared region.