suggest otherwise. Most knowledge of Shatsky Rise tectonics comes from magnetic lineations mapped around and within the rise. They show that the rise sits along the track of the Pacific-Farallon-Izanagi (PFI) triple junction from M21 to M3 time (147-125 Ma) and consists of three large volcanoes, separated by minimally-disturbed lithosphere, and a linear volcanic ridge. All volcanic edifices appear to be the same age as the lithosphere upon which they sit, implying progressive volcanism becoming younger to the northeast. The largest volcanic edifice, with a volume of 2.7 x $10^6$ $km^3$, erupted rapidly, as shown by its consistent reversed magnetic polarity and the near coincidence of dates from basalts cored on its upper flanks with the age of the lithosphere. Shallow water fossils from the upper reaches of this volcano imply its summit was above sea level. Magnetic lineations indicate that the triple junction jumped at least nine times, with larger jumps taking it to positions at the edges of the volcanic edifices and implying a connection between volcanism and ridge jumps. Furthermore, the triple junction migrated in a direction and with a velocity inconsistent with a single, stable configuration, as if its behavior were perturbed by factors other than plate velocities. These observations fit reasonably well with predictions of the plume or plume head hypothesis: (1) rapid and voluminous initial eruptions, (2) the volcano grew above sea level (dynamic uplift), (3) massive plume head eruptions transitioned to lesser-flux plume tail, and (4) extra heat and uplift from the plume caused the triple junction to jump repeatedly to the plume site. In addition, the trends of Shatsky and Hess rises are similar to that of the Mid-Pacific Mountains, implying all were formed by motion of the Pacific plate over mantle hotspots. Other observations fit the plume hypothesis less well. Geochemical and isotopic data mostly show MORB-like signatures, arguing against a plume source unless it was diluted or swamped by sub-ridge melting. More troublesome, however, is the affinity of Pacific plate plateaus for triple junctions. Shatsky Rise formed at a triple junction, beginning at the time of a plate reorganization that formed one or two microplates. Hess Rise and another microplate probably formed at the location of a later PFI triple junction jump. Furthermore, the Mid-Pacific Mountains, Magellan Rise, Manihiki Rise, and two additional microplates seem to have formed along the track of the Pacific-Farallon-Phoenix triple junction and the tracks of the two triple junctions have different trends (i.e., cannot be explained by motion over fixed hotspots). This coincidence of ridges and triple junctions only makes sense if plate boundary processes give rise to the plateau volcanism. In summary, Shatsky Rise has characteristics that fit formation either by plume or plate boundary processes, but new data are required to decide which. What's more, the connection between plumes, microplates, and triple junctions is unclear and seems fertile ground for further study.

### V31A-06 0930h

## A Cenozoic Alkaline Magmatic Province in the SW Pacific Without Rift or Plume Origin

Carol A. Finn[1] (cfinn@usgs.gov)

Dietmar Mueller[2] (dietmar@es.usyd.edu.au)

Kurt S. Panter[3] (kpanter@bgnet.bgsu.edu)

[1]U. S. Geological Survey, MS 964, Denver Federal Center, Denver, CO 80225, United States

[2]The University of Sydney, Department of Geology and Geophysics, Sydney, NSW 2006, Australia

[3]Bowling Green State University, Department of Geology, Bowling Green, OH 43403, United States

A large-scale, long-lived (ca. 55 Ma) alkaline magmatic province occupies discontinuous portions of the SW Pacific region including eastern Australia, New Zealand, west Antarctica and the oceanic plates between. Although this province, here named Pacific SW Alkaline Province (PSWAP), is aerially extensive, estimates of the total volume of upper crustal igneous rocks and the magma production rates are rather low. Comparison of the location of magmatic centers and seismic shear wave perturbation models shows that the PSWAP is largely limited to lithosphere less than 80 km thick underlain by distinct low seismic velocity anomalies extending to 200 km depth. Geochemical studies show that the magmatism is largely a result of small degrees of melting of a source enriched in incompatible elements relative to primitive upper mantle. Metasomatic enrichment of the upper mantle, including infiltration of volatile-rich fluids and melts into the overlying lithosphere, may explain the regional geochemical as well as low seismic velocity signatures. Metasomatism most likely occurred during Paleozoic-Mesozoic subduction along the Pacific margin of Gondwana and Jurassic plume-related activity. Models to explain the magmatism in separate parts of PSWAP include adiabatic decompressive melting due to rifting and strike-slip faulting, mantle plumes, or hundreds of hot spots, but all of these associations have flaws. Hot spot formation and associated magmatism have also been linked to faults and propagating fractures in geodynamic models of extending lithosphere above regions where upper mantle has been shielded from the cooling effects of subducting slabs. In addition, boundaries between thick cratons and thin lithosphere (such as in eastern Australia and West Antarctica) may drive small-scale convection, bringing hot sub-cratonic mantle toward thinner lithosphere with eruption occurring during extension- often during major plate reorganizations. But the Cretaceous break-up of Gondwana that rifted Australia and the New Zealand-Campbell Plateau region from Antarctica, regional extension of lithosphere over metasomatized mantle did not cause widespread magmatism as predicted by these models. Although the PSWAP magmatism has been linked broadly to tensional stress-fields, these are not requirements as evidenced by Australian volcanism under mildly compressional stress-fields. Therefore, extension probably did not trigger Cenozoic magmatism in PSWAP. A regional Cenozoic heating event may be more likely. We propose a new model that links sudden detachment and sinking of subducted slabs into the lower mantle beneath the PSWAP in the early Cenozoic, with vertical and lateral flow that triggered melting of metasomatized upper mantle. Small batches of magma leak through pre-existing faults and fractures in most regions, but larger volumes erupt in areas with moderate extension.

### V31A-07 0945h

## Could Low Thermal Diffusivity Provide Runaway Melting in The Upper Mantle?

Anne M. Hofmeister (hofmeist@levee.wustl.edu)

Dept. Earth and Planet. Sci., Washington U., St. Louis, MO 63130, United States

Melting in the mantle has been attributed to thermal feedback associated with the temperature dependence of viscosity during deformation (Shaw, 1969, J. Petrol.). Visco-elastic heating has been explored in various geodynamics studies. In particular, Branlund et al. (2000, EPSL) found that a non-linear decrease of thermal diffusivity (D) with temperature (T) would enhance shear zone thinning and speed-up instabilities. Their result suggests that thermal feedback enhances melting in the uppermost mantle, without viscous heating, if considerable non-linearities exist in D(T) at the onset of melting. In fact, extreme non-linearities are indicated by theory and measurements. (1) Measurements of D of volcanic olivine-melilitite (Buettner et al. 1998, J. Volc. Geotherm. Res.) show large non-linearities in D(T) due to pre-melting effects, and a discontinuous decrease in D upon melting. This behavior should be general, because increasing disorder reduces D (e.g., Giesting and Hofmeister, 2002, Phys. Rev. B). (2) Our laser-flash measurements of various glasses show that D depends non-linearly on T. Melts will behave similarly. To quantify the function we are applying the melting experiments of Buettner et al. to Icelandic lavas and other relevant materials. In our runaway model, melting under ridges or hotspots does not define a magma chamber, but rather occurs on grain boundaries of the solid phases. A small amount of melting decreases D precipitously and raises the temperature which induces more melting. This phenomena is confined to low pressures (since D increases with P) and T below 2000 K (wherein radiative effects are unimportant), and can occur in a low temperature gradient. Thus, production of magmas at hot spots need not require a deep-seated mantle plume.

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# V31B MCC: 3008 Wednesday 0800h

## Messages from the Underworld: Linking Geophysical Signals to Magmatic and Hydrothermal Processes I *(joint with S)*

***Presiding:*** **J B Lowenstern,** U.S. Geological Survey**; J W Neuberg,** School of Earth Sciences, University of Leeds

### V31B-01 0800h

## A Trigger Mechanism for Volcanic Low-Frequency Seismic Events on Montserrat

Jurgen W Neuberg[1] (+44 113 343 6769; locko@earth.leeds.ac.uk)

Hugh Tuffen[2] (+49 89 2180 4271; tuffen@min.uni-muenchen.de)

Art Jolly[1] (+44 113 343 6620; a.jolly@earth.leeds.ac.uk)

David Green[1] (+44 113 343 6769; d.green@earth.leeds.ac.uk)

[1]School of Earth Sciences, The University of Leeds, Leeds LS2 9JT, United Kingdom

[2]Department of Earth and Environmental Sciences, University of Munich Theresienstrasse 41, Munich 80333, Germany

Seismic observations of low-frequency earthquake swarms on Montserrat point to a non-destructive, repeatable source mechanism in a confined area inside or near the conduit. While the seismic wave propagation pattern of the subsequent resonance in and around the conduit is well studied, the trigger mechanism has remained elusive. In this contribution we suggest a trigger mechanism based on new field evidence for fracture and healing of magma in volcanic conduits, together with seismic observations from Montserrat and finite element modelling of magma deformation during conduit flow. As a seismic trigger we suggest a stick-slip motion of highly-viscous magma in the glass transition, that periodically generates networks of seismogenic shear fractures a few metres in length. These fractures are rapidly filled by fine-grained material [cataclasite] that is generated by friction processes on the fracture surfaces, such as corner abrasion, and is locally redeposited by gas flowing within the fracture system. Filled fractures are then swiftly healed as reloading leads to annealing and a return to cohesive viscous deformation. Such a fast healing process, probably on the order of tens of seconds, leads to a repeatable trigger mechanism. Due to a strong lateral viscosity gradient in the conduit, highly-viscous magma near the conduit walls, which can exhibit brittle behaviour, co-exists with low-viscosity, fluid magma in the conduit centre; such that brittle failure provides the seismic trigger mechanism while the fluid part can still act as a seismic resonator.

### V31B-02 0815h

## Magmatic Dike Resonances Inferred From Very-Long-Period Signals

Hiroyuki Kumagai[1] (kumagai@bosai.go.jp); Koji Miyakawa[1] (miyakawa@bosai.go.jp); Hiroaki Negishi[1] (negishi@bosai.go.jp); Hiroshi Inoue[1] (inoue@bosai.go.jp); Kazushige Obara[1] (obara@bosai.go.jp); Daisuke Suetsugu[2] (dai@jamstec.go.jp)

[1]National Research Institute for Earth Sciece and Disaster Prevention, 3-1 Tennodai, Tsukuba, IBA 305-0006, Japan

[2]Institute for Frontier Research on Earth Evolution, Japan Marine Science and Technology Center, 2-15 Natsushima, Yokosuka, KNA 237-0061, Japan

Hachijo Island is a volcanic island located 280 km south of Tokyo. Renewed activity began on 13 August 2002, when a swarm of volcano-tectonic (VT) earthquakes accompanied by deformation of the volcano was detected. On 20 August, when the VT seismicity was almost waned, a swarm of very-long-period (VLP) events began beneath the island. The VLP signals show simple decaying harmonic oscillations with periods near 10 seconds and lasting for about 300 seconds. We analyze the waveforms of the VLP signals on 4 September. These were observed by two permanent and three temporary broadband seismic stations on this island. Spectral analysis of the decaying harmonic oscillations in the tail of the VLP waveforms identifies two clear peaks at the periods of 7.3 and 11.4 s with quality factors (Q) of about 30. The source mechanism analysis of the VLP signals shows that the moment-tensor solution is dominated by volumetric change components with oscillatory signatures, indicating the resonance of a vertical crack at a depth of 5 km below the northern flank of Mt. Hachijo Fuji. We perform numerical simulations based on a fluid-filled crack model, and find that the basalt-steam mixture with gas-volume fraction around 20 % produces the crack resonance with Q around 30. We further find that the frequency ratio for two longitudinal modes with the wavelengths of 2L/7 and 2L/9, where L is the length of the crack, is similar to the observed frequency ratio. We calculate the synthetic waveform generated by the excitation of a vertical crack containing the basalt-steam mixture, which reproduces the feature of the observed VLP waveform. We may therefore reasonably interpret that the VLP signals originate in the resonance of a dike filled with a basalt-gas mixture, which may be the result of magma intrusion beneath this island as evidenced by the VT earthquake swarm and deformation of the island. The VLP activity continued for about 8 months between August, 2002 and April, 2003. The observed two peaks at around 7 and 11 s were stably observed during this period, although the frequencies showed a slight increasing trend within 5 % change since January, 2003. This suggests that the dike system stably existed beneath Hachijo Island during this interval. The stable existence of the dike system may not be explained by a simple magma cooling process, and implies the magma circulation between the dike and a possible magma chamber beneath the Island.

V31B-03 0830h

## Quasi-Periodic Episodes of Volcanic Tremor at Okmok Volcano, Alaska

Celso G. Reyes[1] (907-474-5517; celso@giseis.alaska.edu)

Stephen R. McNutt[1] (907-474-7131; steve@giseis.alaska.edu)

[1]Alaska Volcano Observatory, UAF Geophysical Institute 903 Koyukuk Drive P.O. Box 757320, Fairbanks, AK 99775, United States

A new seismic network, consisting of nine short-period stations, was installed at Okmok volcano, Alaska, in summer 2002. Continuous data began to be recorded in April 2003. Eventually, this array will be expanded to include four additional 3-component broadband stations and four co-located continuous GPS stations. The most recent eruption occurred in February - April 1997 and, like most historical eruptions, issued from Cone A - which is still steaming as of this writing. INSAR measurements of post eruptional deformation show that the volcano is inflating at a rate of ~10 cm/yr (Mann and Freymueller, 2002). Seismically, there are very few local earthquakes; however, there has been nearly continuous low level tremor with stronger amplitude bursts occurring at a rate of about 2 per hour (2.2 ± 0.8). These bursts have durations generally in the range of 5-8 minutes. Most bursts begin abruptly, reach a maximum amplitude within 3 minutes, then decline gradually over the next several minutes. Many bursts resemble each other quite closely, suggesting that there is a single main process or source location. No systematic trends have yet been observed between duration and either amplitude or the length of the preceding interval. The tremor is composed of irregular waves with a broad range of frequencies between ~1 and ~20 Hz, with main peaks at ~2.2 and ~6.2 Hz, and with a lesser peak at ~5.5 Hz. Okmok is the only volcano out of 25 monitored Aleutian volcanoes to display this type of tremor. This activity may be linked to magma transport and the observed high rate of deformation.

V31B-04 0845h

## Precursory Seismic Activity at Guagua Pichincha Volcano, Ecuador: Implications for the Magmatic System of an Arc Volcano

Darwin R. Villagomez[1,2] (darwin@newberry.uoregon.edu)

Mario Ruiz[1] (ruiz_mario@hotmail.com)

Hugo Yepes[1] (geofisico@igepn.edu.ec)

Minard L. Hall[1] (geofisico@igepn.edu.ec)

[1]University of Oregon, 1272 Geological Sciences, Eugene, OR 97405, United States

[2]Instituto Geofisico, Ladron de Guevara s/n, Quito 17, Ecuador

Earthquake activity at volcanoes can offer insight into the nature of the transport and storage of magma beneath active volcanoes. Understanding the relation between volcano seismicity and the magmatic system is important in long and short-term forecasting of volcanic activity. Guagua Pichincha, a dacitic volcano located in the western cordillera of the Ecuadorian Andes, showed two years of progressive reactivation that culminated with a dome extrusion and several dome collapses and eruptions in 1999. During the reactivation period, the volcano was continuously monitored using a network of 13 seismic stations. Guagua Pichincha showed three main types of seismic precursors. First, persistent occurrence of long-period earthquakes located 2-10 km S of the volcano (3-15 km depth) preceding the eruption by at least 20 months. Second, swarms of tectonic high-frequency events beneath the city of Quito, 10-15 km NE of the volcano (12-20 km depth), preceding the onsets of volcanic activity by 2-3 months. And third, swarms of high-frequency and long-period events, occurring below the crater (1-4 km depth), days before and during the extrusion of the lava dome. These events suggest the existence of a magmatic reservoir beneath the crater at 4-5 km depth. The deeper long-period events S of the volcano are evidence of magma being transported from mid-crustal levels to this shallower magmatic reservoir. The earthquakes of the Quito swarm may be the result of changes in the local stress regime caused by these deep magma movements. Few days before the first eruption, a rupture event manifested as swarms of high-frequency earthquakes below the crater opened the magmatic reservoir. The swarms of long-period events that followed could indicate rising magma and its interaction with the hydrothermal system. This sequence of events shows that the movement of magma and magmatic fluids through the plumbing system of a volcano could be revealed by the different types of seismicity it generates. And more importantly, that volcano seismicity can constraint the nature and time scale of these processes.

V31B-05 0900h

## Hydrothermal disturbances at the Norris Geyser Basin, Yellowstone National Park (USA) in 2003

Jacob B Lowenstern[1] (650-329-5238; jlwnstrn@usgs.gov)

Henry Heasler[2] (307-344-2441; Henry_Heasler@contractor.nps.gov)

Robert B Smith[3] (801-581-7129; rbsmith@mines.utah.edu)

[1]U.S. Geological Survey, 345 Middlefield Road, MS 910, Menlo Park, CA 94025, United States

[2]Yellowstone National Park, YCR, Mammoth, WY 82190, United States

[3]University of Utah, Department of Geology and Geopysics, Salt Lake City, UT 84112, United States

The Norris Geyser Basin in north-central Yellowstone National Park (YNP) experienced a series of notable changes during 2003, including formation of new hot springs and fumaroles, renewed activity of dormant geysers and elevated ground temperatures. This abstract provides a short synopsis of the new hydrothermal activity. In 2000, Yellowstone's tallest geyser, Steamboat, erupted after a dormant period of nearly 9 years. It erupted twice in 2002 and then again on 26 March and 27 April 2003. Surges in flux of thermal water preceding the eruptions (preplay) were recorded by a couplet of temperature data loggers placed in the outlet stream. The data indicated pulses of water flow with 1 and 3 day intervals. On 10 July 2003, a new thermal feature was reported just west of Nymph Lake, 3.5 km northwest of the Norris Museum. A linear series of vigorous fumaroles, about 75 m long had formed in a forested area, 200 m up a hill on the lake's west shore. Fine particles of rock and mineral fragments coated nearby vegetation. Fumarole temperatures were around the local boiling temperature of water (92°C). After two months, somewhat reduced steam emission was accompanied by discharge of 3-10 gallons per minute of near-neutral thermal water. Trees within 4 meters of the lineament were dead and were being slowly combusted. Porkchop Geyser in Norris' Back Basin had been dormant since it exploded in 1989, littering the nearby area with boulders up to over 1 m in diameter. Since that time, its water had remained well below the boiling temperature of water. From 1 April through 1 July 03, the temperature of waters in Porkchop's vent increased continuously from 67° to 88°C. Each Summer, Norris' Back Basin experiences an "annual disturbance" where individual hot springs and geysers typically show anomalous boiling, and have measurable increases in turbidity, acidity and SO4/Cl ratios. The disturbance has been linked to depressurization of the hydrothermal system as the hydrostatic pressure of the snowmelt-fed groundwater table wanes each summer. This year, the "Norris disturbance" is estimated to have begun on 11 July 2003,when pronounced changes were noted, including thermal pools that were boiled to dryness (e.g., Pearl Geyser), creating fumaroles. Porkchop Geyser erupted for the first time since 1989 on 16 July. New mud pots formed along the Back Basin Trail and increased ground temperatures were noted over an 500 x 300 m area. Park staff noted temperatures up to 94°C at 1 cm beneath the ground surface in areas that were previously cool. Vegetation in the area immediately died and began to break down due to the high temperatures. Yellowstone National Park closed the Back Basin Trail to all visitor travel on 22 July 2003. During the first week of August 2003, the Yellowstone Volcano Observatory installed a temporary monitoring network in the Norris Geyser Basin. University of Utah staff, with equipment and personnel made available by IRIS, UNAVCO, USGS and YNP, installed seven broadband seismometers and five continuous GPS receivers. In addition, YNP deployed a series of temperature data-loggers to record changes in flow from thermal features within the Norris Back Basin. The network is intended to identify ground motions associated with fluid flow within the geyser basin that may accompany eruptions of geysers, boiling episodes or events precursory to hydrothermal explosions. The monitoring network will remain operational for between four and twelve weeks.

URL: http://volcanoes.usgs.gov/yvo

V31B-06 0915h

## Seismic and GPS Monitoring of the 2003 Norris Geyser Basin Hydrothermal Disturbance, Yellowstone National Park

Jamie M Farrell[1] (801-581-7089; jfarrell@mines.utah.edu); Gregory P. Waite[1] (gpwaite@mines.utah.edu); Robert B. Smith[1] (801-581-7129; rbsmith@mines.utah.edu); Christine M. Puskas[1] (801-581-7856; cmpuskas@mines.utah.edu); Henry Heasler[2] (Henry_Heasler@contractor.nps.gov); Beth Bartel[3] (bebartel@unavco.edu); Chris Dietel[4] (dietel@usgs.gov)

[1]University of Utah, Dept. Geol. & Geophys. 135 S. 1460 E., Salt Lake City, UT 84112

[2]YCR, Yellowstone National Park, Mammoth, WY 82190

[3]UNAVCO, 3340 Mitchel Lane, Boulder, CO 80301

[4]USGS, 345 Middlefield Rd., Menlo Park, CA 94025

Norris geyser basin experienced an unexpected change in normal geyser and hot spring activity beginning July 2003. This disturbance included an increase in ground temperatures of up to 94°C over a 0.1 km $^2$ area killing vegetation along a 200 m long zone and prompted closure of the area to visitors. In response to these changes, a temporary seismic and geodetic monitoring network was deployed by the Yellowstone Volcano Observatory with the assistance of UNAVCO and IRIS. Data collection began in August 2003, with a dense, 0.75 km $^2$, array of 7 broadband seismographs and 5 precision GPS stations across the disturbed area. Results from the seismic monitoring should allow us to track the presence and movement of hydrothermal fluids, while the GPS data should indicate if ground deformation accompanied seismic or hydrothermal activity. Together with ancillary temperature and fluid flow data by the NPS, this information will help identify the size and location of the source of hydrothermal related deformation. We hope to track the progress of the disturbance to better understand the hydrothermal and tectonic processes involved and to capture any hydrothermal eruption, should one occur.

V31B-07 0930h

## A FORWARD LOOK AT THE INTERACTION BETWEEN REMOTE EARTHQUAKES AND VOLCANIC ERUPTIONS, AND ITS IMPLICATION ON THE VOLCANIC HAZARD: THE CASE OF SUMATRA (JUN. 2000) AND DENALI (NOV. 2002) EARTHQUAKES.

Jacopo Selva[1] (00390514151453; selva@bo.ingv.it)

Warner Marzocchi[1] (marzocchi@bo.ingv.it)

Francesca Zencher[2] (francesca@ibogeo.df.unibo.it)

[1]INGV Bologna, via Donato Creti 12, Bologna 40128, Italy

[2]Univerita' degli Studi di Bologna - Dipartimento di Fisica - Sezione di Geofisica, viale Berti Pichat 8, Bologna 40127, Italy

Until few years ago, the volcanoes were usually considered systems without significant interactions with the surrounding regions. This paradigm was recently put in doubt by the finding of a coupling between large explosive volcanic eruptions and tectonic earthquakes occurring from years to few decades before and at distances up to hundreds of kilometers. This coupling has been explained theoretically by modeling the co- and post-seismic stress variations induced by the regional earthquakes on the volcanoes at the onset of the eruptions. The stress variation consists of the elastic response of the lithosphere, and the viscoelastic relaxation of the asthenosphere and mantle, computed through a spherical, stratified, self-gravitating, viscoelastic earth model. Here, we apply this model to two recent large tectonic earthquakes occurred in Sumatra (June 2000) and Alaska (Denali earthquake, November 2002), in order to estimate the stress perturbation (dilatation/compression and shear) on the Indonesia and Alaska volcanic chains. Then, we estimate the effects of such seismic stress perturbations on the future volcanic hazard in Indonesia and Alaska.

### V31B-08 0945h

## On the Trail of Missing Heat: Forward Gravity Modeling of the San Francisco Volcanic Field, Northern Arizona

Bill N Fry[1] (928-523-7131; Bill.Fry@nau.edu)

Paul Morgan[1] (928-523-7175; Paul.Morgan@nau.edu)

[1]Northern Arizona University, PO Box 4099, Flagstaff, AZ 86011, United States

The San Francisco volcanic field is a Quaternary field in northern Arizona, the age and size of which suggests there is a high possibility for an associated exploitable high temperature geothermal resource. Sunset Crater, the youngest dated feature in the field, erupted less than 1000 years ago. The youngest felsic volcanism in the area, located near Strawberry Crater, has been dated at about 51,000 years b.p. Felsic magmas are viscous, and therefore felsic magmatism is generally associated with upper crustal plutons, whereas mafic magmas commonly form surface flows. Heat from felsic magmatism tends to remain near subsurface ponds of the magma. Felsic magmatic systems can sustain substantial geothermal heat for tens to hundreds of thousands of years after emplacement. Knowledge of the quantity and distribution of felsic magmatism is therefore paramount to understanding the geothermal potential of the field. Surface heat flow in the study area ranges from ~20 to ~50 mW/m$^2$, anomalously low for the region. Hydrological characteristics of the San Francisco volcanic field are thought to mask increased surface heat flow from the magmatic system. The deep water table (>300m) and a 2-level hydraulic system prevent characteristic surface manifestations of hydrothermal potential, such as hot springs and elevated surface heat flow. Lack of these thermal features at the surface precludes analysis of the resource based solely on surficial mapping and measurements. Forward modeling of the gravity field of a 50 km x 45 km area covering the eastern San Francisco volcanic field has been completed. Results suggest that a large felsic body (~-0.15 g/cc contrast) trends northeastward under the Sugarloaf Mountain-O'Leary Peak-Strawberry Crater magmatic trend. This trend parallels a regional basement fabric, likely of early- to middle-Proterozoic origin. These results are being correlated with new surface geologic mapping and radiometric dating of young felsic volcanic rocks to guide an exploratory drilling program.

# V31C MCC: Level 2 Wednesday 0830h

## Birth, Growth, and Death of Magmatic Arcs: Comparisons Among Arcs in Different Settings I Posters

*(joint with T)*

***Presiding:*** **M Rioux,** University of California, Santa Barbara**; R Flowers,** Massachusetts Institute of Technology

### V31C-0938 0830h POSTER

## Evidence of Magma Mingling in the Tiribí Tuff, Valle Central Costa Rica

Jonathan K Eaton[1] (eaton@geology.wisc.edu)

John Valley[1] (valley@geology.wisc.edu)

Thomas A Vogel[2] (vogel@msu.edu)

Lina C Patino[2] (patinol@msu.edu)

[1]Department of Geology and Geophysics, University of Wisconsin-Madison 1215 W. Dayton St., Madison, WI 53706

[2]Department of Geological Sciences, Michigan State University 206 Natural Science Building, East Lansing, MI 48828-1115

This study is part of a larger oxygen isotope investigation to sort out the role of assimilation and crustal melting in the formation of abundant, large-volume silicic ignimbrites in Central America. The 0.33 Ma Tiribí Tuff of Valle Central Costa Rica is a large-volume, compositionally heterogeneous ash flow sheet (25 km$^3$ dense rock equivalent) that did not form in the presence of evolved continental crust. Glassy pumices, from the dominant ash flow sheet within the Tiribí, have been sub-divided into three groups based on their textures and whole rock compositions: a low-silica group (55.1-65.6 wt% $SiO_2$), a mingled group (58.6-67.7 wt% $SiO_2$), and a silicic group (66.2-69.2 wt% $SiO_2$). Variations in major and trace elements within the low-silica group are best explained by fractional crystallization. However, differences in trace element data between the low and silicic groups cannot be explained by this same process. The mingled group has been interpreted as mingling of the low-silica and silicic magmas based on petrographic evidence and trace element data. Oxygen isotopes can provide an excellent test for the proposed origin of the magma groups in the Tiribí Tuff. If crustal material has been incorporated into a primitive magma, the $\delta^{18}$O (WR) of the whole rock will typically vary with increasing $SiO_2$(WR). The $\delta^{18}$O of 10 Tiribí samples range from 3.27$^o/_{oo}$ to 3.90$^o/_{oo}$ for magnetite and 5.15$^o/_{oo}$ to 5.63$^o/_{oo}$ for clinopyroxene. These data suggest $\delta^{18}$O (WR) values consistent with derivation from mantle melts or melting of primitive crustal rocks. Likewise, fractional crystallization in the absence of contamination causes a predictable correlation of $\delta^{18}$O to wt% $SiO_2$. Oxygen isotope thermometry of magnetite and clinopyroxene demonstrates that these phenocrysts have preserved magmatic $\delta^{18}$O values and further divides the low-silica from the silicic group, suggesting formation of these magmas at 1200$^o$C and below 1100$^o$C, respectively. These $\delta^{18}$O data of magnetite and clinopyroxene are not consistent with fractional crystallization of the low-silica magma to produce the silicic magma. The $\delta^{18}$O data better support a model where the low-silica and silicic magmas were two separately generated magma batches that, in part, mingled shortly before or during eruption.

### V31C-0939 0830h POSTER

## The Geochemical Evolution of Arenal Volcano, Costa Rica

Louise L Bolge[1] ((732)-445-2124; lbolge@rci.rutgers.edu)

Michael J Carr[1] ((732)-932-7494; carr@fas.rutgers.edu)

Mark D Feigenson[1] ((732)-445-3149; feigy@rci.rutgers.edu)

Guillermo E. Alvarado I.[2] (GAlvaradoI@ice.go.cr)

[1]Rutgers University, 610 Taylor Rd, Piscataway, NJ 08854, United States

[2]Instituto Costarricense de Electricidad, Apdo. 10032-1000, San Jose 34020, Costa Rica

Arenal is a small stratovolcano located in northwestern Costa Rica, along the Central American volcanic front. It is the youngest and most active volcano in Costa Rica. Field studies by Soto et al. (1996) have discovered over twenty distinct tephra layers and several lavas. This sequence spans approximately 7000 years. The geochemistry of these tephras and lavas show many variations in La/Yb, Zr/Hf, and Nb/Ta indicating changes in percent melting over time. Specifically, the percent of melting appears to increase for the first 4000 years, then decrease for the last 3000 years. Trace element ratios that track the subducted slab signal, such as Ba/La, U/Th and Pb/Ce correlate positively with the apparent percent of melting. These slab signal indicators increase during the first 4000 years of Arenal's history and then decrease for the last 3000 years. Because of Arenal's high rate of eruption and the comprehensive sampling of major units, it is possible to show small temporal changes in the amount of flux melting in the mantle wedge beneath Arenal.

### V31C-0940 0830h POSTER

## Systematic Variations in the Trace Element and Isotopic Compositions of High-$K_2O$, Medium-$K_2O$, and High-$TiO_2$ Volcanic Rocks From the Zitácuaro-Valle de Bravo Region of Central Mexico

Dawnika L Blatter[1] (dawnika@eps.berkeley.edu)

Ian S.E. Carmichael[1] (ian@eps.berkeley.edu)

G. Lang Farmer[2] (farmer@cires.colorado.edu)

[1]Department of Earth and Planetary Science, University of California, Berkeley, CA 94720-4767, United States

[2]Department of Geological Sciences and CIRES, University of Colorado, Boulder, CO 80309, United States

Within the Zitácuaro-Valle de Bravo region of the central Mexican Volcanic Belt, three series of lava have erupted during the Quaternary period. These lava series are defined based on their major and trace element compositions to be: 1.) Shoshonitic (high-$K_2O$), 2.) Medium potassium (med-$K_2O$) basaltic andesites through dacites, and 3.) High-$TiO_2$ basalts and basaltic andesites. The distribution of these distinct compositions is systematic; with the high-$K_2O$ volcanism at the arc front, the med-$K_2O$ volcanism concentrated along the central axis of the arc, and the high-$TiO_2$ volcanism at the middle to back portion of the arc. The high-$K_2O$ compositions are extremely enriched in large ion lithophile elements (LILE's) and light rare earth elements (LREE's), with a narrow range of distinctly enriched $^{87}$Sr/$^{86}$Sr values from 0.704245 to 0.704507 and $\epsilon_{Nd}$ values ranging from 4.27 to 5.63. The med-$K_2O$ compositions are only moderately enriched in the LILE's and LREE's and have the largest range of $^{87}$Sr/$^{86}$Sr values from 0.703227 to 0.704287 and $\epsilon_{Nd}$ values ranging from 3.39 to 6.03. In contrast, the high-$TiO_2$ compositions have no enrichments in LILE's or LREE's and instead are enriched in the high field strength elements (HFSE's). The high-$TiO_2$ lavas have $^{87}$Sr/$^{86}$Sr values ranging from 0.703549 to 0.704095 and a narrow range of $\epsilon_{Nd}$ values from 2.98 to 3.47. The isotopic compositions of the Zitácuaro-Valle de Bravo lavas correlate with their major and trace element characteristics, as well as the spatial distribution of the lavas within the arc. The systematic spatial distribution of these distinct lava types is similar to that of the Quaternary lavas in the Michoacan-Guanajuato Volcanic Field, directly to the west. However, in distinct contrast, the Quaternary lavas in the Sierra Chichinautzin Volcanic Field, to the east, are not spatially distributed according to composition. Instead, their distribution appears to be predominantly controlled by several conspicuous faults.

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## Magmatic processes at Popocatepetl volcano, Mexico: petrology, geochemistry and Sr-Nd-Pb isotopes

Peter Schaaf[1] (+52 55 56224221; pschaaf@geofisica.unam.mx)

Jim Stimac[2] (+ 632-845-8478; jstimac@unocal.com)

Claus Siebe[1] (+52 55 56224146; csiebe@geofisica.unam.mx)

José-Luis Macías[1] (+52 55 56224146; macias@geofisica.unam.mx)

[1]Instituto de Geofísica, UNAM, Ciudad Universitaria, Mexico-City, DF 04510, Mexico

[2]Philippine Geothermal Inc., 8741 Paseo de Roxas, Citibank Tower, Makati-City xx, Philippines

Popocatepetl volcano is one of the most famous and most active stratovolcanoes of the Trans-Mexican Volcanic Belt (TMVB). It is located 60 km south-east of Mexico-City and 40 km west of the city of Puebla, both cities have more than 30 million inhabitants. In this contribution we present a study of Late Pleistocene to Recent products of Popocatépetl (Popo) volcano and surrounding scoria cones to better establish their genetic relationship and magmatic history. Popo and flanking vents are located within the central portion of the Trans Mexican Volcanic Belt, which is related to oblique subduction of young oceanic lithosphere. Current activity of Popo can be understood in the context of its past eruptions and those from surrounding scoria cones. The latest cycle of eruption began Dec. 21, 1994 with continuous to pulsating emission of phreatic ash. The last important event happened on July 19, 2003, covering Mexico-City with a thin ash-layer. Both Popo and surrounding scoria cones produced moderate-K, calc-alkaline rocks, with the two groups differing mainly in degree of differentiation, water content, and oxidation state. Some vent samples on the immediate flanks of Popo and have phenocryst assemblages and compositions transitional between typical flanking vent and stratovolcano samples. Monogenetic vents produced mainly basaltic andesites to andesites, primarily by crystal fractionation of Ol (Fo80-90)+chromite, 2Pyx±Ol, and 2Pyx±Plag±Hb assemblages, with minor assimilation of crustal debris. The andesitic to dacitic rocks of Popo are dominated by Plag-2Pyx-2Oxide±Hbl assemblages, with variable amounts of Ol (Fo70-90)+chromite xenocrysts. A few Popo samples contain locally abundant xenolithic debris of cognate-granitoid intrusions and their metasedimentary wall-rocks. The two suites share parental Mg-rich basaltic andesite magmas, with the Popo magmas reflecting longer residence in the crust, and enhanced hydration and oxidation due to the resulting processes of crystallization, recycling, assimilation, and degassing in relatively evolved magma chambers. The 1996 and 1997 dome eruptions confirm that dacitic magma currently resides beneath Popo and is episodically recharged by more mafic magma, fostering eruption and excess degassing. Two-oxide thermometry and the presence of FeCu sulfide globules confirm that these magmas erupted at T = 930$^o$C and fO2 = -10.2 log, below anhydrite stability. 87Sr/86Sr, e-Nd and 206Pb/204Pb ratios are between 0.70365 and 0.70463, +6.4 and +3.0, and 18.618 and 18.781, respectively. Andesitic to dacitic rocks of Popo formed by mafic recharge, fractionation, and mixing of dacitic to basaltic magmas in mature crustal chambers. Plagioclase accumulation and recycling related to protracted fractionation and assimilation of earlier emplaced magmas and their wall-rocks was also important.