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OIB are generally thought to be derived as melts of subducted ocean crust. Nd and Sr isotopes are consistent with this model and require long term source depletion. But this model is difficult to reconcile with OIB chemical compositions. (1) Sun and Hanson (1974), in the first attempt at trace element inversion, showed that the OIB mantle source is LREE enriched . But recycled MORB are LREE depleted. (2) OIB incompatible element ratios are not consistent with recycled MORB converted to eclogite or pyroxenite, which would melt to large extents in the upwelling mantle, and highly incompatible elements would not be fractionated. (3). Primitive OIB have magnesian major element compositions that suggest equilibration with peridotite, and are generally inconsistent with being partial melts of recycled MORB. (4) Volatiles are released during subduction, so recycled materials should be volatile poor, and primitive noble gas signitures should be absent. Instead, OIB are volatile- and 3He-rich. These are the geochemical aspects of the OIB Paradox. There are also geological contradictions. While OIB are believed to come from plumes derived from recycled ocean crust, the OIB magma type is not restricted to hot spot locations. OIB-like lavas occur throughout the ocean floor, in and behind convergent margins, in continental rifts, and elsewhere- as also pointed out by Sun and Hanson.

A solution to these contradictions is that OIB reservoirs form by addition of low degree melts of subducted ocean crust to surrounding mantle. Generically, this model accounts for the problems listed above. Low degree melts contain most of the radiogenic elements and therefore impart the isotope signature of the recycled materials. The low degree melts do not modify the major element composition of the mantle significantly, and therefore allow OIB to be melts of peridotite. Very low extents of melting are able to fractionate highly incompatible elements and create relatively constant incompatible element ratios because F is as low as D. Low F melts would transport volatiles and have them be incorporated into the source. Therefore a low F melt source solves the OIB problem in ways that recycled ocean crust cannot.

There is then the geological question of where the source is created. It could be created above subduction zones where slabs are hot enough to melt subducted crust at depths greater than the volcanic front. Large contiguous volumes of melt-metasomatized mantle could be created in this way. In this environment, the fertilized mantle wedge overlying the slab could be carried to depth in the mantle where it acquires a high 3He signature and rises to form plumes. Minor amounts of volatile-depleted eclogite could also be involved directly in some cases (e,g, perhaps Hawaiian tholeiites). But what we find striking about ocean island geochemistry is the rarity of the eclogite signature. Koolau is an outlier, not a paradigm.

Similar alkali basalt source compositions could be created from any eclogite that reaches shallow levels in the mantle, because the eclogite has so much lower a solidus temperature than does peridotote. Given the mantle thermal structure, this process allows alkali basalt sources to be created throughout the upper mantle as an inevitable consequence of mantle convection. The uniform character of the OIB magma type then comes from the relative partition coefficients of trace elements in garnet and pyroxene, which imparts a commonality to low F melts in diverse environments. This model accounts for the petrological and geochemical features of OIB, and also permits the ubiquity of their geographical occurrence.

### V51E-11 1120h

## A New Pb Isotope Perspective on Oceanic Basalts: Reading Between the Lines

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Recent high-precision Pb isotope analyses (∼100 ppm) obtained using double and triple spikes demonstrate that much of the scatter in previous, conventionally obtained data is analytical in origin. Here we pool together all the currently available high-precision Pb isotope data on oceanic basalts to provide a new "sharpened up" picture of the gross Pb isotope heterogeneity in the mantle. These Pb isotope data are from MORB glasses from the East Pacific Rise (EPR) and South Atlantic (26°S, Ascension), seven Hawaiian volcanoes, Pitcairn, Rurutu, the Azores (all MPI data), Mangaia (Woodhead, 1996), and St. Helena and Iceland (Thirlwall, 2000), totalling around 250 samples.

The high-precision data for a given location do not form the "clouds" in Pb-Pb isotope space seen in conventional literature data. Rather, each data set forms tight linear arrays in both Pb isotope spaces. More surprising, though, is that the samples lying on a given array cover a limited geographic extent: (1) In the case of the EPR, six distinct arrays are found, each of which is confined to a particular range in latitude along the ridge, corresponding to length-scales of ∼100 to 5000 km. The same is true of MORB samples from the South Atlantic (2) Distinct arrays are resolved for individual volcanoes along the Hawaiian chain, indicating that the heterogeneities within the Hawaiian plume are tapped in a long-lived and highly systematic fashion.

It is also quite clear that these data are not readily interpretable in terms of mixing between notional end-member "components" in the mantle. For example, the EM1 "component" present in Pitcairn is quite clearly different in Pb isotope space from that sampled by Koolau. Similarly, the HIMU "component" present in the Austral-Cook chain is distinct in the islands Mangaia and Rurutu, and is not the same as that found in St. Helena. In all of these cases it is impossible to find common crossing points of the arrays in both Pb isotope spaces. Moreover, none of the arrays "point" towards any of the putative end-member "mantle components." If such common end-members do exist in the mantle, almost perfect premixing between them would be required to form viable intermediate end-members to each of the arrays observed.

Overall, these new Pb isotope data pose the questions: (1) What is the significance of the linear arrays and why are there so many of them?, and (2) how can such heterogeneities survive intact in the convecting mantle over long periods of time?

# V52A MC: Hall D Friday 1330h
## General Volcanology

***Presiding:*** **C F Waythomas,** USGS, Alaska Volcano Observatory

### V52A-1032 1330h POSTER

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Geologic mapping and a gravity study of the Black Point tuff cone located on the NW shore of Mono Lake, near Lee Vining, California ($38^{0}02$ latitude, $119^{0}06$ longitude) was performed in this study. Black Point is a Surtseyan-style tuff cone that erupted approximately 13,300 years ago beneath glacial Lake Russell. The goal from the gravity study was to test models for the subsurface geometry. Specifically, to determine the distribution of consolidated versus unconsolidated tephra observed near the summit of Black Point. These models were developed based on observations of the consolidation of extruded tephra by a process called palagonitization following the eruption of the Surtsey tuff cone in Iceland in 1963. Measurements using a Worden gravimeter were captured over a three-day span, covering 185 individual stations. Stations were spaced at 5-20 meter intervals across the principal area of the main vent. Two perpendicular arrays were followed, striking approximately N56E and N34W respectively. Both arrays transect suspected main vent area for Black Point. Rock samples were obtained and analyzed for their densities, which were then used to generate best-fit models matching the observed gravity using the Grav-2D program. The observations (in mgals) collected using the Worden gravimeter have been corrected for elevation above the geoid, local topography, local mass and density of rock, drift of Earth, and terrain, to provide an anomaly without background noise. Two simple models were generated to demonstrate the idealized two-dimensional subsurface of Black Point in proximity to the suspected main vent. These models imply that palagonitization occurs to significant depths, and, occurs on either side of the suspected main vent at Black Point. Both models assume that surface densities can be extrapolated to a depth of at least 300 meters. Further southeast of the vent, the tuff cone is underlain by a deep-rooted, high-density (approximately 3.0 $g/cm^{3}$) body suggesting a dike swarm or feeder dike system bypassing the Mono Craters magma chamber. The correlation of the consolidated tephra alongside the vent implies that palagonitization may have occurred in direct response to localized hydrothermal activity near the vent. The models are in direct contrast to work by others who suggest that this phenomenon will only occur after all heat is lost via the interaction of rainwater percolation. Clearly, by gravity models constructed, this is not so.

### V52A-1033 1330h POSTER

## Western Alborz Volcanic Rocks, a new Geochemical Viewpoint

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Volcanic and pyroclastic rocks of Eocene age comprise vast outcrops of Alborz Mountain Range, a fold-thrusted structural unit extending across northern Iran for 2000 km in a curvilinear pattern. In his account of structural evolution of Iranian plateau, Berberian (1983; p. 55) ascribed these rocks to a subduction-type magmatism. Based on a tectonostratigraphic study, these rocks are attributed to an arc-type magmatism (Alavi; 1996, p. 29).

Recently a new data set of major and trace element (including REE) analyses of volcanic rocks from western Alborz, some 50 km west of city of Qazvin, has been made available (Asiabanha, 2001). Careful examination of the data (i.e., those of basic-intermediate rocks) in present study revealed, for the first time, some geochemical characteristics which have important implications on the geodynamic synthesis of this structural unit. The rocks contain 50-60 wt% $SiO_2$. They lie in the midalkaline-to-subalkaline domain of TAS diagram (Middlemost, 1997; p.216) and fall in the calcalkaline field of AFM diagram.

The volcanic rocks display two distinct chondrite-normalized REE patterns, one is MREE-depleted while the other is a rather smooth uniform M-HREE pattern. These are called MREE-depleted and smooth M-HREE series. Basic rocks from the latter contain higher silica than the former (>53 vs. >50 wt%), yet they show lower incompatible elements (e.g., K and Rb) and HFSE contents. These features can not be explained by differentiation and might be interpreted as implying the involvement of two source regions. Chondrite-normalized trace element patterns of the MREE-depleted series is more akin to the island arc calcalkaline (IACA) basic rocks than the basic rocks from any other tectonic settings. However, island arc products, known for being depleted in HFSE relative to other incompatible elements, differ from the MREE-depleted series which is rich in both HFSE and incompatible elements. One may advocate the role of OIB-type mantle components to explain the HFSE-enrichment of the MREE-depleted series. Alternatively higher Zr/Y ratios and MREE-depletion in the series might be considered as indicating amphibole presence in its source region.

Selected Reference:

Asiabanha, A. 2001. Geology and petrogenesis of volcanic facies in Youzbashichay region. PhD thesis, Tarbiat Modares Uni., in Persian, 320 p.

### V52A-1034 1330h POSTER

## Groundwater Flow System of Unzen Volcano, Japan

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Unzen volcano (peak 1486 m) is developed on the western part of Beppu-Shimabara Graben (20 km NS wide and 200 km EW long) located at Kyushu island, SW Japan. We have been studied groundwater system of the volcano using geochemical and hydrological technique in order to estimate flux of magmatic volatiles through the groundwater. We have collected over 150 sample waters from springs, rivers, and wells, and they are analyzed for major chemistry and stable isotope ratios. Over 50 pore waters were extracted from 100-1200m-deep drilled cores at the eastern flank of the volcano by a centrifugal separator. The results are summarized as follows:

1) Flow rates of springs and rivers indicate that most of the groundwater recharged at Unzen volcano flew down the slope directed to the east, which is restricted by graben structure.

2) All the groundwaters and spring waters collected inside the graben area are isotopically homogeneous, i. e., -48 -45 permil for hydrogen isotope ratio, indicating that the groundwater is well mixed during flowing.

3) In spite of the isotopic homogeneity, the groundwaters are chemically different from each other. In particular, bicarbonate concentration ranged from 20 to 180 mg/l, and it is inconsistent with the isotopic results. There are some active faults parallel to the

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graben, and bicarbonate anomalies are found close to the faults. Therefore, the chemical variation is likely to be made due to the addition of deep-seated CO2 ascending through the faults.

4) Linear relation between 1/DIC and carbon isotope ratio of DIC indicates that the DIC in groundwater is explained by simple mixing with two source, magmatic and organic matters. Combining the flow rate data, DIC concentrations and carbon isotope ratios, we estimated the magmatic CO2 flux as 30 t/d through the fault system.

5) Pore waters at 100-300m deep have similar isotopic composition to the present shallow groundwater and river waters, suggesting that those pore waters occupy a part of the shallowest aquifer. On the other hand, pore waters collected from the drilled core at greater than 500m show isotopic discontinuity in the vertical variation, indicating that stagnant aquifers formed at deeper levels.

### V52A-1035 1330h POSTER

## Volcanotectonic history of Shimabara Peninsula and the evolution of Unzen volcano in Southwest Japan

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Geologic, geochronologic and geochemical studies are performed on Pliocene-Quaternary volcanic rocks in the back-arc region of SW Japan in order to verify the relationship between back-arc volcanism and regional tecotnism. Shimabara Peninsula is located in the western Kyushu Island, and Pliocene-Quaternary volcanic rocks cover most of its surface. Active Unzen volcano sits in the middle of the peninsula, and is displaced by an E-W trending active Unzen graben. Volcanic products of Unzen subsided more than 1000 m beneath the sea level inside the graben. Two drillings at the northeastern and eastern flank of Unzen volcano and associated field research have revealed the detailed volcanic history in the Shimabara Peninsula. Even though the oldest volcanic rocks are ca. 6 Ma, volcanism widely occurred in the whole peninsula between 2.5 Ma and 0.5 Ma. Monogenetic volcanoes of olivine basalt and pyroxene andesite are major components. Some andesite lavas carry small (<1.5mm) hornblende phenocrysts. Major element chemical variations of these volcanic rocks are clearly on a simple fractional crystallization trend even though andesites have lower Nb contents than basalts. At 0.5 Ma, monogenetic volcanism stopped and Unzen volcano started to grow in the central part of the peninsula. Except for the earliest eruptives, all Unzen products are hornblende andesites and dacites, and are characterized by abundant large (>3mm) phenocrysts of plagioclase and hornblende. Major elements variations are on a straight mixing line between basaltic and rhyolitic endmembers. Unzen volcanics have higher K2O but lower FeO*/MgO ratios than pre-Unzen volcanics at given SiO2 contents. Formation of Unzen graben became significant after the birth of Unzen volcano. Crustal thinning and the consequent mantle uplift are synchronous with the graben formation, and this may have urged the magma formation and ascent to be centralized in the middle of the Unzen graben at 0.5 Ma. A steady-state magma chamber was formed to mix mafic and felsic magmas, and then have fed mixed magma to the surface and have formed the composite Unzen volcano.

### V52A-1036 1330h POSTER

## Core stratigraphy of the Unzen Scientific Drilling: Volcanic History of the Unzen Volcano, Kyushu, SW Japan

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Unzen volcano is an active composite volcano developed in the Beppu-Shimabara volcanotectonic graben. The major constituents are thick lava flows and domes, which are flanked block-and-ash flow, debris avalanche and debris flow deposits. The basement of the volcano has been subsided to 1000 m below sea level, while the volcano has grown to a height of 2400 m from the basement. In order to examine the volcanic history and internal structure of this volcano, the Unzen Science Drilling Project (USDP) has made two drillings at the northeastern and eastern flank.

Recovered cores from depths up to 1500m contain five stages of volcanic activity. The first stage (ca. 500 ka) is characterized by andesitic block-and-ash flow and debris flow deposits. Small hornblende phenocrysts are specific to the constituent andesitic clasts. The second stage (ca. 400-500 ka) is characterized dacitic pumice flow and air-fall pumice deposits. The third stage (ca. 300-400 ka) is characterized by andesitic to dacitic lava flows, pyroclastic flows and lahars that constitute the major part of the volcanic fan. The fourth stage (ca. 150-300 ka) is characterized by dacitic pyroclastic flow and lahar deposits, which are confined mainly within the graben. Thick phreatomagmatic products, perhaps of the fourth stage in the eastern flank drill core suggest that subsidence of basement was accelerated at this stage. The last fifth stage (150 ka - recent) corresponds to the growth of Younger Unzen volcano on the eastern harf of the previous edifice (Older Unzen volcano). Younger Unzen volcano is composed of many volcanic centers collectively named from the representative peaks: Nodake (150-70 ka), Myokendake (40-25 ka), Fugendake (25 ka - recent) and Mayuyama (4 ka).

### V52A-1037 1330h POSTER

## The Online GVP/USGS Weekly Volcanic Activity Report: Providing Timely Information About Worldwide Volcanism

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The awesome power and intricate inner workings of volcanoes have made them a popular subject with scientists and the general public alike. About 1500 known volcanoes have been active on Earth during the Holocene, approximately 50 of which erupt per year. With so much activity occurring around the world, often in remote locations, it can be difficult to find up-to-date information about current volcanism from a reliable source. To satisfy the desire for timely volcano-related information the Smithsonian Institution and US Geological Survey combined their strengths to create the *Weekly Volcanic Activity Report*. The Smithsonians Global Volcanism Program (GVP) has developed a network of correspondents while reporting worldwide volcanism for over 30 years in their monthly *Bulletin of the Global Volcanism Network*. The US Geological Surveys Volcano Hazards Program studies and monitors volcanoes in the United States and responds (upon invitation) to selected volcanic crises in other countries. The *Weekly Volcanic Activity Report* is one of the most popular sites on both organizations websites.

The core of the *Weekly Volcanic Activity Report* is the brief summaries of current volcanic activity around the world. In addition to discussing various types of volcanism, the summaries also describe precursory activity (e.g. volcanic seismicity, deformation, and gas emissions), secondary activity (e.g. debris flows, mass wasting, and rockfalls), volcanic ash hazards to aviation, and preventative measures. The summaries are supplemented by links to definitions of technical terms found in the USGS photoglossary of volcano terms, links to information sources, and background information about reported volcanoes. The site also includes maps that highlight the location of reported volcanoes, an archive of weekly reports sorted by volcano and date, and links to commonly used acronyms.

Since the *Weekly Volcanic Activity Reports* inception in November 2000, activity has been reported at over 60 volcanoes, with an average of 10 volcanoes discussed each week. Notable volcanic activity during November 2000-November 2001 included an eruption beginning on 6 February at Nyamuragira in the Democratic Republic of the Congo; it issued low-viscosity lava flows that traveled towards inhabited towns, and also produced ash clouds that adversely effected the health of residents and livestock near the volcano. Eruptions at Mayon in the Philippines on 24 June and 25 July caused local authorities to raise the alert to the highest level, close area airports, and evacuate thousands of residents near the volcano. Most recently a large flank eruption at Etna in Italy began on 17 July and gained worldwide attention as extensive lava flows threatened a small town and a tourist complex. While the information found in the *Weekly Volcanic Activity Report*, ranging from large eruptions to small precursory events, is of interest to the general public, it has also proven to be a valuable resource to volcano observatory staff, universities, researchers, secondary schools, and the aviation community.

URL: http://www.volcano.si.edu/gvp/usgs/

### V52A-1038 1330h POSTER

## Reconstruction of the 1730-1736 eruption of Montana Colorada, Lanzarote

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Determining the eruptive style of a volcano purely from its deposits has long been an area of much research. Attempts to classify eruptive style based on one sole deposit type such as ash dispersal have been made but misdiagnosis is possible.

A cinder cone, Montana Colorada, on Lanzarote in the Canary Islands, was chosen as the field area based on its wide range of deposits and the one eyewitness account that is available, to illustrate the need to analyse all deposits of a vent to reconstruct its complex history. The Canarian Archipelago, in which Lanzarote, is situated has a similar geological setting to that of Hawaii and the vent displays aspects of both Hawaiian and Strombolian activity. The cinder cone formed, is similar to that seen in volcanic fields such as the San Francisco Volcanic Field which are usually described as being Strombolian, however, on closer inspection the cone at Montana Colorada displays a greater degree of welding more like that seen in the Hawaiian islands. The bulk of the cone formed from ash and a'a lava flows, containing sizeable peridotite nodules. Both of these deposits are typical of Hawaiian style lava fountaining: the grains of the ash blankets here are highly reticulitic and SEM analysis shows its similarity to the ash found on Kilauea Iki. The presence of peridotite in the lava flows implies continuous and high eruption rates that are fountain fed. With time the intensity of the eruption appears to have dropped and the lava accumulated in the vent: large meter-sized blocks are found at distances of greater than 500m from the vent and are the result of a transient explosion of this accumulated lava which was partially solid. This type of eruption reflects a more Strombolian nature. From modeling of clast distribution these blocks were ejected at about 70-100 m/s. The eruption continued to decrease in intensity and a lava pond sits in the crater to this day with a lava flow running down the north flanks of Montana Colorada as the pond breached its levees. This displays the need for a better classification of eruptions styles from deposits and shows how the nature of a volcano can be reflected by the analysis of all the deposits available. The implication of this study is that misclassification of other vents may have occured in the past and the difference in intensity between Hawaiian or Strombolian eruptions can have a significant effect in future predicted eruptions.

### V52A-1039 1330h POSTER

## Sustained Residence Times for Miocene Silicic Magmas of the Yellowstone Hotspot

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The length of time over which large volume silicic magmas may persist in the crust is poorly constrained, and recent estimates have ranged from a few tens of thousands of years to over 1.0 myr. Compositional relationships among the ten eruptive units of the 12.7 - 10.5 Ma Cougar Point Tuff suggest that a common, long-lived reservoir for these magmas persisted throughout the 2.2 myr explosive phase of the Bruneau-Jarbidge eruptive center along the track of the Yellowstone hotspot. Low crystal content and high temperatures (usually greater than 900 degrees C) indicate that the magmas were close to their liquidi. Evidence for the persistence of several discrete magma volumes in the reservoir is contained in multiple compositional modes of glass in basal fallout tuffs and in the recurrence of identical sets of mineral compositional modes in successive eruptions. Multiple modes of glass composition are a common feature in many explosive eruptions of the Yellowstone hotspot. In the Cougar Point Tuff, recurrence intervals of identical modes of glass and pyroxene range from 0.3 to 1.1 Ma, and suggest residence times of similar duration. Pyroxene thermometry indicates that compositionally distinct liquids erupted in the same event differed in temperature by 25-70 degrees C.

Eruption ages, pyroxene and glass compositions, magma temperatures, and isotopic ratios for the Cougar Point Tuff are consistent with a long-lived, dynamically evolving magma reservoir that was chemically and thermally zoned in a step-wise fashion, and composed of multiple discrete compositional layers. A continental hotspot, where heat is supplied continually to the lower crust by advection of basalt from the mantle, is the optimum tectonic setting for sustaining silicic melts near their liquidi for extended durations. Neodymium isotopic ratios in the Cougar Point Tuff increase systematically with successive eruptions (eNd -8.5 to -6.6), and record a substantial and increasing mantle contribution to the generation of silicic hybrid magmas from an initial 60 percent at 12.7 Ma to 70 percent in the final magma erupted at 10.5 Ma. These magmas evolve in an open system, and data will be presented on interstratified and post Cougar Point Tuff rhyolites that have bearing on the long-term evolution of the magma system.

## V52A-1040 1330h POSTER

### 40Ar/39Ar Age Constraints on Caldera Formation of the Emmons Lake Volcanic Center, Alaska Peninsula, Alaska

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The Emmons Lake Volcanic Center located on the Alaska Peninsula is a large shield/stratovolcano complex composed of basaltic to andesitic lava flows and dacite to rhyolite pyroclastic flows, domes and ashfall. Two caldera forming eruptions in Pleistocene time each produced more than 50 cubic kilometers of silicic ejecta and created a nested depression measuring 20 km long and 10 km wide.

We conducted 40Ar/39Ar whole rock dating of units associated with the first caldera forming event, which because of broad geochemical similarities, has been suggested as a possible source of the Old Crow Tephra, dated throughout interior Alaska and the Yukon at about 140 ka. Samples dated ranged in composition from 62 to 69 wt % SiO2 and contained 2 - 3 wt % K2O. For each sample, 15 specimens, consisting of small (∼1 mm) whole rock chips, were fused with an argon ion laser. From these analyses, weighted mean and isochron ages were calculated. For all samples, the initial 40Ar/36Ar ratio was indistinguishable from that of the present-day atmosphere (295.5), indicating that these samples do not contain significant quantities of excess argon.

The age of a welded tuff interpreted to be from the opening plinian phase of the eruption is 233 +/- 6 ka, and is identical to the age of a post-collapse rheomorphic tuff (234 +/- 5 ka). A lithic fragment from a syn-collapse lag breccia has an age of 419 +/- 9 ka, which we interpret as representing incorporation of older material. Younger tuffs and domes were dated at 99 +/- 7 ka and 16 +/- 10 ka and imply that the complex was active throughout the late Quaternary.

Based on these new age data, and subtle but significant trace element differences in glass and Fe-Ti oxide composition, we conclude that the first major caldera building event occurred at approximately 230 ka, and is probably not responsible for the deposition of the Old Crow tephra.

## V52A-1041 1330h POSTER

### Caldera-Forming Eruptions of the Emmons Lake Volcanic Center, Alaska Peninsula, Alaska: Probable Source of the Dawson Creek Tephra in Yukon Territory, Canada

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The Emmons Lake volcanic center on the Alaska Peninsula of southwestern Alaska is the site of at least two large-volume (>50 $km^3$ each) caldera-forming eruptions of late Quaternary age that are among the largest known of numerous caldera-forming eruptions in the Aleutian arc. Pyroclastic deposits produced by these eruptions are widespread, and their association with Quaternary glacial deposits on the Alaska Peninsula enhances the likelihood of establishing geochronological control on Quaternary glacial events in the region. Pyroclastic-flow deposits (rhyolite to dacite composition) range from densely welded, glassy ash-flow tuff and rheomorphic tuff associated with the first known episode of caldera formation (C-1) to loose, granular, pumice-flow deposits associated with a second caldera-forming eruption (C-2). Pyroclastic-flow deposits from both eruptions extend for tens of kilometers beyond Emmons Lake caldera, reaching both the Bering Sea and Pacific Ocean coastlines north and south of the caldera. Coarse-grained airfall deposits underlie or grade vertically into deposits of C-1 welded tuff and were produced during the early plinian or ultraplinian phase of the C-1 eruption. Airfall deposits associated with the C-2 event have not been discovered in the Emmons Lake area but may be preserved as fine distal ash in loess deposits in western Canada.

Subtle but significant trace-element differences in glass chemistry, and in Fe-Ti oxide minerals indicate that the C-1 event probably did not produce the regionally extensive, well-known ca. 140-ka Old Crow tephra as we had previously reported. Furthermore, $^{40}Ar/^{39}Ar$ ages on C-1 welded tuffs indicate that they were emplaced ca. 233 ka and are thus older than the Old Crow tephra. Although limiting $^{14}C$ ages on the C-2 event are pending, compositional data on C-2 pyroclastic-flow deposits indicate a very close correlation with the Dawson tephra (Westgate et al., 2000), a widespread bed of silicic ash found in west-central Yukon, Canada, and thought to have been deposited ca. 22-12 ka.

## V52A-1042 1330h POSTER

### Physical and Chemical Evolution of San Miguel Volcano, El Salvador

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San Miguel Volcano is a composite volcano in eastern El Salvador with a classic symmetrical, concave upwards, cone shape. Its summit crater is 344 m deep and consists of several nested craters with nearly vertical walls. Spatter and scoria cones commonly occur at flank vents that erupted historic lava flows. One conspicuous feature of the volcano is an arcuate flat area about 200 m below the summit on the eastern flank of the volcano. This "shoulder" extends about 45° around the volcano and appears to form a break point in the volcano's slope. The dominant eruptive product at San Miguel has been lava flows. Geochemical analyses of lavas, tephras, and block and ash flow deposits erupted from San Miguel indicate that the majority of activity has been mafic in character, ranging between 51 and 53% $SiO_2$. Historic flank lavas plot at the mafic end of the chemical range and are basaltic. The most evolved flank lavas are basaltic andesites and comprise a chemically distinct subset. They occur only on the eastern and southeastern flanks of the volcano, below the arcuate "shoulder". Mineralogically, they contain phenocrystic magnetite, distinguishing them from the other lavas. A stratigraphic sequence of 22 crater lavas has the most restricted compositional range and exhibits two chemical trends. One trend suggests an episode of growth punctuated by repose periods, while the other trend suggests rapid growth with little to no repose between lavas. Based upon physical volcanology, geochemistry, and historic activity we have developed a model for the evolution of San Miguel Volcano. This model consists of two periods of cone construction and two summit collapse events.

## V52A-1043 1330h POSTER

### A History of Protracted Volcanism on the Patton-Murray Seamount Platform, Gulf of Alaska

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Many of the seamount chains in the Northeast Pacific and Gulf of Alaska are generally age-progressive in the direction of Pacific plate motion, which is consistent with a hotspot model for their formation, but they lack the "enriched" isotopic signatures expected for deep-seated mantle plumes. However, some of these enigmatic seamount chains are neither continuous enough nor have been surveyed in sufficient detail to be unambiguously attributed to specific hotspots. The best-studied of these seamount chains is probably the Cobb-Eickelberg-Patton chain, stretching from the current location of the Cobb hotspot beneath Axial seamount on the Juan de Fuca Ridge toward the northwest to the Patton-Murray seamount platform, which is a 200 km x 60 km cluster of seamounts in the Gulf of Alaska 300 km southeast of Kodiak Island.

The Patton-Murray seamount platform is elongate in the direction of Pacific plate motion, and backtracking to the age of the oldest rocks (33 Ma) drilled on the platform (ODP Leg 145) places it directly above the Cobb hotspot. We undertook a detailed study of Patton seamount, consisting of multibeam mapping and stratigraphically-controlled geologic sampling with the ALVIN submersible, to determine if its volcanic history is consistent with the hotspot model, and especially to see if the 17 Ma nonhotspot volcanism documented at the ODP drill site near Murray seamount (versus the 33-27 Ma hotspot volcanism at the same location) was a widespread phenomenon on this seamount platform.

Several of the seamounts on Patton-Murray seamount platform rise to less than 500 m depth, but the peak of Patton seamount, the largest in the group, is only 150 m deep. Patton is conical but slightly elongate in a NNE-SSW direction, and has steep sides and a broad, gently sloping summit region capped by several summit cones aligned in a WNW-ESE direction. A series of submersible dives along an approximate depth transect from 3300 m to 150 m revealed that the lower and middle slopes of Patton consist of pillows and massive flows of aphyric to slightly plagioclase-phyric alkalic basalts, while the upper slopes and summit cones consist of massive basalt flows and platy evolved lavas (hawaiites and benmoreites), plus hyaloclastite and volcanic breccia. Many of the samples are highly altered, and some have manganese crusts up to 5 cm thick. $^{40}Ar$-$^{39}Ar$ incremental heating ages of the samples cluster in two groups at 26-27 Ma and 29-30 Ma. The younger group only occurs above 1000 m, but the older group occurs at nearly the full range of depths (although none of the samples from shallower than 430 m were suitable for dating).

The ages and compositions of the 26-27 Ma samples are similar to some of the samples that were dredged (Dalrymple et al., 1987) and drilled (Keller et al., 1997) from Murray Guyot at the other end of the seamount platform, while the 29-30 Ma group of samples is similar in age and composition to samples dredged from Patton seamount (Dalrymple et al., 1987). Thus, although late-stage hotspot-related volcanism appears to have occurred over most of the 200 km length of the seamount platform at about 27 Ma, we were not able to find evidence on Patton seamount for the anomalous, nonhotspot volcanism that occurred on Murray seamount at 17 Ma.

## V52A-1044 1330h POSTER

### Dynamics of the Ljotipollur Phreatomagmatic Eruption, S. Central Iceland

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The Ljotipollur explosion crater formed during the 1480 AD Veidivotn eruption, when a basaltic dike propagated >100 km SW from Bardabunga volcano. The crater measures 1.6x0.8 km, and is elongate along the NE-SW trend of the fissure. Extending to the SW of Ljotipollur, the eruptive fissure is flanked by spatter ramparts and is the source of a lava flow, evidently the result of purely magmatic activity. In contrast, the eruptive products at Ljotipollur consist of proximal welded airfall tuffs, spatter, and rheomorphic lavas, medial and distal deposits of tephra and pillow fragments, and a field of large lithic blocks. Extensive ejecta accumulation on the SE rim generated basaltic pyroclastic flows, exposed as a succession of ash lenses in the cliffs east of the crater. The block field is primarily distributed to the NW, covering an area of 1.2x0.8 m, and consists predominantly of angular blocks of agglutinate up to 3.3 m in size, with a minor proportion of smaller, sub-rounded hyaloclastite blocks.

We interpret this eruption to have started with a purely magmatic phase leading to construction of spatter ramparts along the eruptive fissure, similar to those immediately SW of the explosion crater. At some point the dike intersected an aquifer or hydrothermal system and the resulting access to water led to a transition to a phreatomagmatic phase. This was sufficiently powerful to destroy and eject the spatter ramparts, generate pyroclastic flows, and core through tens to >100 meters of preexisting hyaloclastite, subglacial pillows, and river gravels.

We have modeled the dynamics of the phreatomagmatic explosions to derive vent conditions from the distribution of ejecta in the block field. By addressing the explosive expansion of material out of the vent and computing the trajectories of ejected blocks, we can obtain the initial pressure and water mass required to produce the observed deposit. We will present the results of our modeling and discuss the implications for water supply. There is abundant evidence for explosive magmawater interactions elsewhere along this highly active rift system. Eruptions along this dike swarm occur every ~80 years, so developing an understanding of the formation of these deep explosion craters, and the hazards associated with them, is essential.

### V52A-1045 1330h POSTER

## Groundmass Crystallization of A'a and Pahoehoe flows of Cerro Azul, Galapagos and Mauna Loa, Hawaii

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Crystallinities of 1998 lavas from Cerro Azul, Galapagos are distinguished from 1843 Mauna Loa, Hawaii lavas by higher modal proportions of groundmass plagioclase crystals. In both cases, a'a lava was erupted first, followed by emplacement of pahoehoe flows. The 1843 Mauna Loa eruption lasted 90 days and produced both a'a and inflated pahoehoe flows (1). The 1998 Galapagos flows were emplaced over the course of 37 days, and the transition from a'a to pahoehoe flow morphology corresponds with decreased eruption rate during the last week of the eruption. Samples were collected along the length of flows from both volcanoes. Modal groundmass plagioclase increases down-flow for each flow type from each volcano. A'a and pahoehoe flows of Cerro Azul consistently have higher crystallinities (41% and 14%) than equivalent flow types at Mauna Loa (29% and 7%). Whereas Cerro Azul groundmass crystals are exclusively plagioclase, the groundmass of Mauna Loa lavas consists of plagioclase and pyroxene crystals, similar to Kilauea lavas. Proportions of plagioclase crystals and flow morphologies are consistent with predictions that groundmass crystal morphology plays a significant role in the development of crystal networks and yield strength, which instigates the development of a'a flow morphology (2, 3). Galapagos volcanoes tend to have more a'a than their Hawaiian counterparts Mauna Loa and Kilauea. Volcano slopes do not appear to control the proportion of each flow type (4); rather, abundance of groundmass plagioclase appears to be the distinguishing factor. An important distinction between the two systems is that Galapagos lavas have consistently higher Al2O3 content than Hawaiian volcanoes. High Al203 results in a comparatively high abundance of groundmass plagioclase, and may partly explain the prevalence of a'a. We note that while the relative abundance of a'a and pahoehoe flow morphologies on other volcanoes is rarely quantified, Mount Etna is also distinguished by abundant a'a. Interestingly, Etna magmas have both high Al2O3 and high volatile contents that drive extensive pre-eruptive degassing-induced plagioclase crystallization (5).

(1) Barnard, 1990 (2) Philpotts and Carroll, 1996 (3) Saar et al., 2001 (4) Rowland, 1996 (5) Sparks and Pinkerton, 1978

### V52A-1046 1330h POSTER

## Complex Explosive Phonolitic Volcanism From Tenerife, Canary Islands: the Diego Hernandez Formation

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The Diego Hernandez Formation (DHF) consists of several phonolitic pyroclastic packages erupted between 0.53 and 0.196 Ma. Here we focus on the most intense period of DHF explosive phonolitic activity, from 0.32 - 0.28 Ma, during which three major plinian sequences with intraplinian ignimbrites, respectively the Aldea (0.320 ± 0.008 Ma), Fasnia (0.309 ± 0.012 Ma) and Poris Members (0.276 ± 0.016 Ma) were emplaced. A minor disconformity, representing a pause of perhaps a few weeks' duration, separates lower and upper parts of the Fasnia Member. Volumes are difficult to estimate due to substantial offshore deposition, but each of the three has a minimum volume of a few cubic kilometers DRE. The dominant phonolite component in all three units shows broad chemical variations that suggest a similar magmatic lineage. However, details of trace element covariations do not support evolution of phonolite from a common parent, while the order of extraction of different compositions within a single eruption is complex. The Aldea and the lower Fasnia contain highly evolved phonolitic pumice (Zr up to 2,000 ppm), variably mixed with mafic and intermediate magmatic components. Plinian fall units in the upper Fasnia have little admixed mafic material yet are significantly less evolved than preceeding units (Zr = 850 - 1500 ppm), and show overall normal compositional zoning. However, highly evolved phonolite reappears towards the end of the Fasnia eruption sequence, and is more abundant in interbedded ignimbrites than in plinian fall units. The Poris Member contains phonolite similar to the least evolved compositions in the upper Fasnia, with a minor population of a much less differentiated phonolite (Zr = 600 - 650 ppm) that has little affinity with the the rest of the sequence, but resembles magmas erupted during a later DHF cycle. Both Poris phonolite types mingled with basaltic liquid. The repeated eruption of multiple felsic magmas with distinct trace element signatures, variably mixed with mafic magma, points to a model for DHF magmatism of co-existing phonolitic magma bodies that are periodically mobilized by injection of mafic magma.

### V52A-1047 1330h POSTER

## Probable Mid-Miocene Caldera in the Modoc Plateau, Northeast California

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Regional geologic mapping within the Modoc Plateau has resulted in the discovery of a large volcanotectonic anomaly some 21-km in diameter approximately 50-km WSW of the city of Alturas in Modoc County, California. Centrally located within this anomaly lies a structural depression some 11-km in diameter which, based on structural, lithologic, and geophysical characteristics, is believed to represent a deeply eroded mid-Miocene caldera.

The region extending outward some 5-km from the proposed caldera displays a sharp, localized structural deflection from a NNW to a WNW structural grain. Lying inboard of this deflection, a series of regionally discordant E-W to NE trending, generally down to the north, normal faults were discovered which are believed to represent rim faults to an ancient caldera. Bedding within the hanging wall of these discordant structures displays highly contorted and regionally anomalous dips. By stereographic removal of the regional northeast dip overprinting the area, the anomalous dips were found to display a radial, steeply inward dipping pattern in close proximity to the proposed rim structures while dips located further inboard are generally flat-lying. Lithologies within the proposed caldera are regionally anomalous and include abundant tuffaceous and flow dominated breccias, closed basin organic sedimentary facies, and an anomalous concentration of volcanic centers of both mafic and felsic compositions. One of these intrusives was age dated at 12.9 Ma indicating the anomaly formed during mid-Miocene time. The location of the proposed caldera is associated with a +20 mgal gravity high, which stands in contrast to a lesser high of +10 mgal associated with the Medicine Lake Caldera some 50-km to the northwest.

This combination of structural, lithologic, and geophysical evidence leads to the interpretation of a caldera at this location, herein termed the Stone Coal Valley Caldera.

### V52A-1048 1330h POSTER

## Dynamics of Obsidian Flows Inferred From Microstructures: Insights From Microlite Preferred Orientations

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The flow of obsidian lavas leads to crystal alignments that reflect both the accumulated strain and the type of flow across the surface. Microlite preferred orientations were used to investigate the emplacement dynamics, strain history, and the structural evolution of Obsidian Dome, eastern California. Measurements of three-dimensional microlite trend and plunge in samples from the flow front, dike, and conduit show: 1) flow directions along the dome margins 2) the flow type (e.g., pure versus simple shear) at the dome margins and, 3) the variation in strain as a function of position within the system. Microlites form well developed lineations in the plane of flow banding in all samples. Stereographic projections indicate that lineations trend normal to the flow front and shallowly plunge away from the margin. These results highlight a strong correlation between microlite trend the and bulk flow direction inferred from the geometry of the flow front (assumed to be normal to the flow front). The radial flow pattern indicated by measurements suggests that extrusion was from a roughly cylindrical vent. Orientation distributions may further indicate that radial spreading accompanied by flattening was the dominant mechanism for flow emplacement. Comparisons of measured orientation distributions with theoretically predicted distributions (e.g., Blanchard, 1979) suggest that microlite fabrics developed in a pure shear flow. Variance in microlite trend provides a measure of the amount of strain acquired during flow. Standard deviation in trend decreases from the conduit to the flow margins, reflecting progressive alignment of microlites during transport. Pure shear strain inferred from orientation distributions increases from approximately 0.5 in the conduit to about 1.5 at the flow front. The difference between these strains is a measure of the strain associated with flow emplacement. Such strain is similar in magnitude to that estimated (1.6) for horizontal spreading of a fluid whose volume is equal to that of Obsidian Dome. These techniques can be applied to interpret older dissected lavas where erosion has erased much of the original flow front or where larger scale structures indicative of flow directions are poorly preserved.

### V52A-1049 1330h POSTER

## Lithological Characteristics of the Basement of an Izu-Ogasawara(Bonin) Arc Volcano: 1450 Meter Core Sample from the Hakone Volcano, Central Japan

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The lithologic character of the basement of the Izu - Ogasawara (Bonin) arc provides insight into the initiation of ocean island arc volcanism. We obtained core containing rare fresh volcanic succession recovered during hot spring drilling on the southwestern flank of the Hakone volcano, northern tip of the Izu-Ogasawara arc, central Japan.

The recovered core, from the lower part of the 1450m drilling, is mainly composed of submarine volcaniclastic rocks. Foraminifera and calcareous nannoplankton taken from 624m drilling depth are 5.8 to 4.18Ma and 4.2 to 3.66Ma in age. The core sample

is divided into three main facies and 14 stratigraphic sub-units based on lithological characteristics. Facies I is mainly composed of turbidites of basaltic andesite to dacite glassy aphiric lapilli. The chemical composition of these rocks show low K2O and high Al2O3 values. Facies II consists of basaltic andesite lava and hyaloclastite . The lava gradually changes to hyaloclastite upward. The chemical characteristics of these lavas are similar to the present frontal volcanos of Oshima and Hachijo-jima in the Izu arc. Facies III, uppermost in the core, consists of volcanic sand and lapilli. Some lapilli shows reddish color on their surfaces because of high temperature oxidization. Lithological unit I (1450m to 1340m drilling depth) may represent distal portions of the andesitic to dacitic volcano. Unit II (1340m to 1216m) consists of basaltic andesite hyaloclastite and Facies I. This unit may represent the proximal portion of the frontal volcano. Unit III (1216m to 1200m) is composed of volcanic sand and lapilli similar to Facies III. This unit represents sub-aqueous to sub-aerial eruption.

## V52A-1050 1330h POSTER

### Rubbly Pahoehoe: Implication for Flood Basalt Eruptions and their Atmospheric Effects

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Rubbly pahoehoe flows consist of a brecciated flow top, a pahoehoe base, and an interior similar to inflated pahoehoe flows. Rubbly pahoehoe flows can be found in many localities, making up ∼20% of the Columbia River Basalt Group, ∼50% of the lavas drilled on the Kerguelen Plateau, and a substantial fraction of the Icelandic lava flows. They are rare in the tholeiitic shield portions of the Hawaiian volcanoes, but are more common in the alkalic flows. They also appear to be the dominant type of Martian flood lava flow.

Based primarily on observations from the 1873-1874 Laki Flow Field in Iceland, we suggest that rubbly pahoehoe flows form when the flux of lava within an inflating pahoehoe flow is so large that it rafts away the upper crust. This crust is then broken into large slabs and fragmented lobes, intruded by liquid lava from below, and folded into pressure ridges. This brecciation process quickly builds an insulating crust; for the Laki case a crust >4 m thick developed in less than a week. This rapid formation of a thick insulating crust allows lava to be transported over great distances with minimal cooling in eruptions lasting only weeks-months.

Flood basalt flows emplaced in this manner could have had eruption rates on the order of $10^4$ - $10^5 m^3 s^{-1}$. If active fissure segments were of the order of 10 km long, the volcanic plumes should have risen 9-16 km – penetrating the stratosphere in most cases. The injection of ∼10 Gt of $SO_2$, F, and Cl into the stratosphere could have had serious climatic effects, thus further strengthening the plausible link between flood basalt eruptions and mass extinctions.

## V52A-1051 1330h POSTER

### Products of the complex, long duration, AD 1305 rhyolitic eruption of Tarawera, New Zealand

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The youngest rhyolite eruption in New Zealand is the 4 km3 (DRE) Kaharoa eruption episode from Tarawera volcano at 1305AD. The complex eruption sequence occurred from seven magmatic vents which define an 8-km linear fissure across the volcano. The main events were: 1) phreatic blasts; 2) sub-plinian/plinian eruptions dispersing fallout over the northeastern North Island; 3) a rhyolite dome extrusion; 4) more sub-plinian fall units and pyroclastic flows, including at least two plinian fall units widespread to the NW over the North Island; 5)a final effusive phase producing three large lava domes. The total eruption duration is unknown, but the time required to extrude the lava domes indicates that it may have spanned several years to perhaps a decade. Collapse of the domes generated extensive block-and-ash flow deposits (BAFD). Four BAF fans were constructed during this time. The two largest fans are 1x108 m3 (N) and 5x107 m3 (SE), with the NW and W fans contributing 1x107 m3 and 4x106 m3 respectively. Unconfined BAFs within the SE fan reached a distance of 7.6 km from the dome margin. The N fan comprises a region of unconfined BAFD which reach 5.4 km from the source, and two valley-confined deposits that reach 9.2 km from source. Despite a complex internal stratigraphy, due in part to the irregular underlying topography, only three block and ash flow depositional units and associated ash cloud deposits may be identified in each of the two major fans. The block and ash flows of the Kaharoa eruptive episode are significantly larger and more widespread than many documented in the literature (Unzen, Japan; Soufriere Hills, Montserrat; Merapi, Indonesia; Mount St Helens, USA). Enhanced mobility of the Kaharoa block and ash flows is interpreted to be principally due to the large volumes of each collapse, involving substantial amounts of hot dome lava. BAF-related ash clouds and their deposits, which were so devastating at Unzen, may extend for up to 20 km from source. The potential for such voluminous and far-reaching BAFs and ash cloud deposits at Tarawera has clear implication for volcanic hazard assessment for future eruptions of this type.

## V52A-1052 1330h POSTER

### Cenozoic Leucitite in Lhasa block, Tibet

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1:250000 Dangxiong, Tibet mapping in 2001 discovered leucitite in the eastern edge of Yangbajing-Dangxiong graben, which is one of the most important progresses gotten in the past twenty years in Lhasa block. The goal of the work presented here is to constrain the timing and geochemistry of this ultrapotassic volcanic rock. The motivation for our study is that, although it is widely recognized that the constitute and geochemical characteristics of Eocene Linzizong formation calc-alkaline volcanic rocks in Lhasa block are of fundamental importance for both, tectonic models of subduction of Indian plate northward to Eurasian plate as well as time constrain on collision of two plate. Our understanding of the late Tertiary volcanism in Lhasa block is limited. The presently available data are largely based on studies along the north part of Gangdise magma-arc belt. We report preliminary results of field work in Yangbajing-Dangxiong graben which was carried out during the summers of 2001 as part of the projects DKD9901001, NSFC49902006. The study area is located near Yangbajing (ca. 3012.8'N, 9039.6'E), where the potassic-ultrapotassic volcanic rocks are distributed along NE-SW trending active normal fault systems of eastern edge of Yangbajing-Dangxiong graben defined a ca. 20 km long and 1 km wide, and the leucitite intruded in the upper layer of the volcanic rocks. The main objectives of our work in this area are to: 1) provide a minimum age of the leucitite, and 2) constrain the geochemical charateristicsof this rock, and 3) discuss the significant of the apearence of this rock in this area. The leucitite contains different minerals with phenocrysts include leucite(more than 30%), plagioclase(ca. 10%), sanidine(ca. 5%) and clinopyroxene(ca. 3%).

## V52A-1053 1330h POSTER

### Inferring emplacement processes of radial dikes at Summer Coon volcano, Colorado, from geometry and AMS-derived magma flow directions

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Because population centers tend to cluster around the bases of volcanoes, the most distal flank eruptions can be the most hazardous. The emplacement mechanisms of radial dikes that commonly feed these extrusions are poorly understood. Consequently, we mapped and analyzed about 20 large silicic dikes which, along with hundreds of mafic dikes, are exposed in a radial pattern at Summer Coon, an eroded stratovolcano in the eastern San Juan Mountains, Colorado. In contrast to intrusions mapped at other centers, silicic dikes at Summer Coon tend to thicken with increasing radial distance. Shallower burial depths and decreasing elastic moduli away from the center of the volcano cause an increase in the dike driving pressure, and are the most likely sources of the observed teardrop form. All silicic dikes are broken into en echelon segments dominated by right-stepping offsets. Segment geometries around the volcano do not agree with previously proposed dike segmentation mechanisms including stress field rotation, intrusion into preexisting fractures, and variations in host rock properties. Flow directions determined from measurements of anisotropy of magnetic susceptibility (AMS) at 33 sites on two different dikes suggest that offsets near the center of the volcano form when magma fills echelon fractures that opened in front of the propagating dike. Distal segments probably form by the same mechanism, however both segment tips may propagate due to higher driving pressures far from the center of the volcano.

Observations from Summer Coon suggest that radial dikes rise sub-vertically from depth beneath the volcano and then propagate laterally away from the center of the volcano along a neutral buoyancy surface between the base of the edifice (which is composed of low-density volcanic rocks) and the higher-density basement. The dike will thicken with increasing radial distance, favoring more voluminous eruptions at lower elevations. Future detailed geodetic studies of active stratovolcanoes (for instance, InSAR measurements of deformation at South Sister Volcano in Oregon by Wicks and others, in review, GRL), combined with additional AMS studies of dikes from eroded volcanoes may help confirm these inferred emplacement paths.

## V52A-1054 1330h POSTER

### $^{14}C$ Dating for the Younger Unzen Volcano, Japan

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Unzen volcano is situated in a volcanotectonic depression, ∼70 km west of the volcanic front of SW Japan. The volcanic products of Unzen volcano cover a wide area with many lava domes, thick lava flows, and pyroclastic deposits of andesite to dacite composition. The composite volcanic edifice can be subdivided into Older and Younger Unzen volcanoes. The Older Unzen volcano (500-200 ka) is thought to be a complex volcanic edifice originally centered near the present Younger Unzen volcano, but it has been displaced by several faults and deeply eroded. The Younger Unzen volcano (<100 ka) comprises Nodake, Myokendake, Fugendake and Mayuyama volcanoes, the primary topographic features of which remain well preserved. As stratigraphic relation between the volcanic products can be hardly observed directly, the present stratigraphy of the eruption products was established roughly by locally exposed tephras and sparsely accumulated radiogenic ages (K-Ar, FT, TL and $^{14}C$). $^{14}C$ is considered to be an ideal method to apply for the Younger Unzen volcano. The scarcity of charcoal in Unzen volcano forced us to base most of the AMS $^{14}C$ dates on the buried soil organic carbon of bulk sample underlying the volcanic eruption products.

The $^{14}C$ dating of the bulk soil organic matter is a polemic subject, mainly due to the complexity of the soil formation and to the variable contamination from several sources. The reliabilty of most $^{14}C$ dates for buried soils in this study was supported by lack of significant age deviations in double organic extracts of soil (humin and humic acid fractions), agreement of dating results obtained for different materials (buried soil and charcoal), and normal sequence in soil-pyroclastic/lava sections.

The $^{14}C$ results based on surface and USDP borehole materials clarified the initial eruption ages of the Younger Unzen volcano, i.e., Myokendake: 35 ka; Fugendake: 25 ka; and Mayuyama: 4.5 ka BP. In particular, the Fugendake volcano is characterized by the repeated eruptions occurred at 24, 20, 19, 14, 11, 10, 9, 7, 4, 1.6 ka BP and recently AD 1300, 1663, 1792 and 1991∼95.

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V52A-1055 1330h POSTER

### A structural model guide for geothermal exploration in Ancestral Mount Bao, Leyte, Philippines

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The Tongonan Geothermal Field, located on the eroded flank of Ancestral Mount Bao (AMB) volcano, is the largest producing geothermal field in the Philippines. It produces about 640 MW of energy supplying power to the grid of Luzon, Visayas, and Mindano, the three major islands of the Philippines. The Tongonan geothermal field is host to several major power plants that tap geothermal power from the northern flank of the AMB volcano. I present a structural model guide for delineating exploration targets in other flanks of the ~1,200 km2 area of the AMB volcano. The model limits the exploration area, where more detailed investigations involving geophysical, and geochemical methods can be applied. This structural model guide is based on analogue sand cone experiments, their comparison with the natural prototype (i.e. AMB volcano), and the observation of the geographic positions of producing geothermal power plants within the Tongonan Geothermal Field. Based on this structural model, I suggest an ideal exploration target on the south-southeastern flank of the AMB, directly overlying the left-lateral Philippine fault.

V52A-1056 1330h POSTER

### Holocene Volcanic Records in the Siple Dome Ice Cores

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Using both the $SO_4{}^{2-}$ and $Cl^-$ time series and tephrochronological analyses, a highly detailed record of Holocene volcanism is being reconstructed from the Siple Dome A ice core. The volcanic glaciochemical record is being developed at a 2-4 year resolution for the last 10,000 years. Volcanic peaks were identified as those having a concentration of $2\sigma$ above the mean positive residual of the spline fit, as was done for the GISP2 volcanic record. We identified about 70 volcanic events for the mid-late Holocene. The largest sulfate signal (350 ppb) over the time period evaluated occurs at 2242 years ago. Large signals of volcanically enhanced sulfate in the ice core record also occur around 720 years ago (1280 C.E.;194-249 ppb)and 4710 years ago (378ppb). Ages for large equatorial or southern hemisphere volcanic eruptions are synchronous with identified sulfate peaks in the reconstructed volcanic record. However, the continuous scan for volcanic glass in these same samples yielded glass compositions more in-line with Antarctica volcanic zones (i.e., local eruptions). Nevertheless, our record provides important information on the atmospheric impact of volcanism in Antarctica geochemical cycles.

The glass (i.e., tephra) found in various samples indicate that volcanoes within the McMurdo Volcanic Center (Victoria Land and the islands off its coast) including Mt. Melbourne, The Pleaides and Buckle Island appear to be the most active in Antarctica during the late Holocene. Rhyolitic shards of a composition not found in Antarctica also are present in some layers, although they are not overly abundant. The presence of dust with a Patagonian origin in East Antarctica ice cores as well as the nature of the Antarctica vortex indicate that material from this part of the southern hemisphere can reach various parts of Antarctica. Common circulation patterns around the Ross and Amundson Seas as well as the satellite trace of aerosols from the 1991 Cerro Hudson eruption, Argentina, provide a possible transport route for glass to reach the Siple Dome site. Our tephra work is providing a new chronology of Antarctica volcanism.

## V52B MC: 304 Friday 1330h

## Geochemical and Isotopic Tracers of Earth Processes: Earth Reservoirs and Continental Mantle/Crust System (a session in honor of Gil Hanson) *(joint with H, T, GC, MR)*

***Presiding:*** **S B Shirey,** DTM**; P I Nabelek,** University of Missouri

V52B-01 1330h

### Trace Element and Os-Hf-Nd-Sr Isotope Systematics of Pervasively Metasomatised Ancient Lithospheric Mantle at the Southeastern rim of the Siberian Craton

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Spinel peridotite xenoliths in Late Cenozoic basalts from the Aldan-Stanovoi shield show effects of Meso-Cenozoic tectonic re-activation and magmatism on the ancient lithospheric mantle. Most of the xenoliths are harzburgites and cpx-poor lherzolites; less common are fertile lherzolites and olivine-rich cumulates. Petrographic and chemical data indicate profound metasomatic alteration of the refractory peridotites, possibly due to interaction with evolved magmatic liquids: precipitation of secondary clinopyroxene and gabbroic interstitial material, low Mg-numbers of olivine and whole-rocks in combination with high Cr in spinel; high whole-rock Ca/Al, enrichments in highly incompatible elements and/or inversely U-shaped REE patterns.

Re abundances in all xenoliths are <0.06 ppb; Os abundances range from 0.1 to 4 ppb. Re and Os (0.9-3 ppb) in a subset of samples (including all cpx-rich lherzolites) that show no or limited metasomatism are positively correlated with modal clinopyroxene or whole-rock Al. 187/188Os in those xenoliths show linear correlations with Al or modal cpx consistent with a depletion age about 2 Ga and the formation of the lithosphere in the Precambrian. By contrast, the metasomatised refractory (2-7% cpx) xenoliths show a broad range in Os abundances and 187/188Os values (0.116-0.127), possibly due to disturbance of the Re-Os system during metasomatism. 176/177Hf is above the N-MORB average in one clinopyroxene separate and range between BSE and MORB values in the few other samples analysed. The 176/177Hf variations could be explained by mixing of ancient depleted mantle with an OIB-type metasomatic agent.

We conclude that the xenoliths represent cratonic mantle strongly modified by metasomatism in hot-spot or subduction-related environments, possibly following removal of the cratonic keel and involving underplating of basaltic melts and their cumulates.

V52B-02 1345h

### Tracing Archaean Intracrustal Processes With Hf, Nd and Pb Isotopes: TTGs and Granites From the Barberton Mountain Land, South Africa

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The petrogenesis of the oldest silicic rocks preserved on earth, the Tonalites-Trondhjemites-Granodiorites (TTGs), and the first appearance of 'classical' K-granites (GRs) have been intensely discussed over the last few decades. In this study TTGs and GRs from the Barberton Mountain Land (Kaapvaal Craton, South Africa) were compared using a multi isotope approach (Sm-Nd, Lu-Hf, Pb-Pb) to constrain and date early lithospheric evolution and intracrustal differentiation.

For the petrogenesis of the GRs a one-stage process combined with extraction from a source with near-chondritic composition is proposed. The GRs display similar mean Hf and Nd mantle extraction ages of 3.26+/-0.08 Ga (calc. after Kramers et al. (2001), EUG XI Abstr. Vol.: 421) and 3.26+/-0.09 Ga (calc. after Naegler and Kramers (1998), Precam. Res., 91: 233-252), respectively. Additionally, the Pb/Pb-errorchron gives an age of 3.15+/-0.08 Ga, which agrees well with their mean intrusion age of 3.1 Ga as calculated from U/Pb-zircon ages (Kamo and Davis (1994) Tectonics, 13: 167-192). No intracrustal recycling is seen in their geochemical fingerprint as no decoupling behaviour is visible for the pairs Th/U and Nd/Hf. Supportingly, initial isotope compositions of Nd and Hf scatter around chondritic values and their mean mu-value of 8.84 agrees well with the range for the Archaean mantle of 7 to 9 giving evidence for a juvenile dominated source.

A two-stage petrogenetic process combined with anatectic melt origin from hydrated and metamorphosed basaltic crust is proposed for the TTGs. Their mean Nd mantle extraction age of 3.46+/-0.13 Ga agrees well with existing U/Pb-zircon ages of 3.4 Ga to 3.5 Ga. However, their mean Hf model age is 3.35+/-0.11 Ga, which is similar to the Pb/Pb-errorchron age of 3.35+/-0.16 Ga. These ages are interpreted to date the two main events of the TTG-petrogenesis. Firstly, crystallisation of the mafic precursor and secondly, anatectic melt extraction, which has resetted the common Pb and Hf chronometer. Supportingly, intracrustal recycling is evident by a decoupling of the pairs U/Th and Hf/Nd and a higher mean mu-value of 11.2. Therefore, the recalculation of Hf isotope composition of the TTGs to the zircon age is too far back in time and results in positive epsilon values. This is not the case for Nd isotope composition as this is still connected to the zircon age. In conclusion no highly differentiated Archaean mantle is needed to explain isotope characteristics of TTGs.

V52B-03 1400h INVITED

### Geochemical and Geophysical Constraints on Diamond Formation and Lithospheric Mantle Evolution Beneath Southern Africa.

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Seismic study of the lithospheric mantle of the Kaapvaal-Zimbabwe-Limpopo cratons has produced a detailed picture of the lithospheric mantle at depths within the diamond stability field. Tomographic inversion of P-wave velocity shows that at 150-225 km depths, the craton has relatively faster lithospheric mantle that occurs in two prominent, irregularly shaped lobes separated by a broad west-northwest trending band of relatively slower mantle. Thus, Jwaneng, Letlhakane, Orapa, Premier, and Venetia diamonds were hosted in slower lithospheric (P-wave velocity anomalies of -0.4 to 0.0 %) whereas DeBeers Pool, Finsch, Roberts Victor, Jagersfontein, and Koffiefontein diamonds were hosted in faster mantle (P-wave velocity anomalies of +0.1 to +0.5 %). Diamonds from the seismically slower areas show a 1.0-2.9 Ga age range in sulfide inclusions, a greater percentage of younger sulfide inclusion ages, and consistently younger silicate inclusion ages. The only locality with no appreciable Proterozoic inclusion component (sulfide or silicate) is the DeBeers Pool which sits directly within one of the seismically faster lobes of Archean lithosphere. Nonetheless, 2.9 Ga sulfide inclusion Re-Os ages are common at every locality studied so far and confirm the importance of an Archean eclogitic diamond paragenesis. The range in carbon isotopic composition between diamonds hosted in seismically fast vs slow lithosphere is similar ($\delta^{13}$C of 1 to 24) with a higher percentage diamonds from seismically slow lithosphere in an isotopically light histogram tail with $\delta^{13}$C ranging from 8 to 20. This seismically light tail is dominated by eclogitic paragenesis diamonds which, with the exception of Venetia and Jagersfontein, are found to greater abundance in the seismically slower areas of