

# International Conference on Evolution, Transfer and Release of Magmas and Volcanic Gases

# Taipei, 22-27 April 2007

# **Preliminary Abstract Volume**

## Sponsored by:

The National Science Foundation, USA The National Science Council, Taiwan, ROC The Institute of Earth Sciences, Academia Sinica The Geochemical Society, USA The International Association of Volcanology and Chemistry of the Earth's Interior

### Sunday, 22. April:

Arrival of participants

1600-1800: Registration in the Activities Centre. Distribution of detailed program, abstract volume, and fieldtrip guide.

1800-2000: Welcoming reception in Laurent restaurant.

#### Monday, 23. April: Fluid and gas geochemistry, volcano monitoring

- 0630-0830: Breakfast in T-Life Cafe
- 0730-0830 Registration for Taiwanese participants
- 0820-1200: Morning session
- 0820-0830: Introduction
- **0830-0900:** Tobias Fischer "Volcanic Gas Emissions: Sources, Variations and Implications"
- 0900-0930: Discussions among participants
- 0930-1045: Poster sessions and coffee break

#### 1045-1115: David Pyle

"Degassing fluxes from subduction zone volcanoes"

- 1115-1145: Discussions among participants
- 1145-1345: Poster sessions, laboratory visits, and lunch
- 1345-1730: Afternoon session

#### 1345-1415: Simon Carn

"The state of the art of measuring volcanic degassing from space"

- 1415-1445: Discussions among participants
- 1445-1600: Poster sessions and coffee break

#### 1600-1630: Hiroshi Shinohara

"Continuous Degassing Caused by Magma Convection in a Conduit: Constraints and Consequences"

- 1630-1700: Discussions among participants
- 1700-1830: Poster sessions and drinks
- 1830- : Dinner in AS Activities Centre

#### MAG 2007 Conference Abstract

#### Tuesday, 24. April: Igneous geochemistry, petrology, and other fields

- 0630-0830: Breakfast in T-Life Cafe
- 0830-1200: Morning session

## **0830-0900: Ken Sims** "From Source to surface: U-series constraints on the processes and timescales of magma generation, evolution and degassing"

- 0900-0930: Discussions among participants
- 0930-1045: Poster sessions and coffee break

## **1045-1115: Jon Blundy** "Magma Storage and Volatile Fluxes beneath Mount St. Helens, 1980-86"

- 1115-1145: Discussions among participants
- 1145-1345: Poster sessions, laboratory visits, and lunch
- 1345-1730: Afternoon session

#### 1345-1415: Catherine Annen

"The incremental growth of magma reservoirs: implications for magma differentiation and shallow magma storage"

- 1415-1445: Discussions among participants
- 1445-1600: Poster sessions and coffee break

#### 1600-1630: David Peate

"Mechanisms and time scales of crustal assimilation: a review"

- 1630-1700: Discussions among participants
- 1700-1830: Poster sessions and drinks
- 1830- : Leave for conference dinner at the Wasabi Restaurant at 1900.

### Magmatic Evolution of Barren Island Volcano (Andaman Sea, Indian Ocean)

<u>Mohammad Ayaz Alam</u><sup>1</sup> (ayaz@iitb.ac.in), D. Chandrasekharam<sup>1</sup>, Orlando Vaselli<sup>2</sup>, Bruno Capaccioni<sup>3</sup> and Pierro Manetti<sup>4</sup>

<sup>1</sup>Department of Earth Sciences, Indian Institute of Technology Bombay, India

<sup>2</sup>Department of Earth Sciences, University of Florence, Florence, Italy

<sup>3</sup>Institute of Volcanology and Geochemistry, University of Urbino, Urbino, Italy

<sup>4</sup>CNR-Institute of Geosciences and Earth Resources, Pisa, Italy

Barren Island (12°16'40"N, 93°51'30"E) is a part of the Andaman-Java-Sumatra-Andaman volcanic arc and is located in the Andaman Sea (Indian Ocean). It has witnessed several episodes of eruption in prehistoric, historic and recent times. Prehistoric eruptions are represented by the caldera wall (remnant of the primitive volcanic cone, which collapsed to form a caldera) forming a ridge around the island with a breach towards west. All the later eruptions were confined to the central part of the caldera depression. Based on time of eruption, volcanism has been classified in three cycles (?) by Ravi Shankar et al. (2001), viz. Prehistoric, Historic (18th and 19th centuries) and recent (1991, 1994–95 and later), which cannot be justified based on geochemistry. Rather, based on geochemical evolution of the lava flows, three cycles can be identified, if at all there is cyclic nature (!) of eruption: first cycle took place during prehistoric times, second cycle that began in historic times ended with 1991 eruption and third cycle that commenced with 1994-95 eruption continues. Whereas lavas of Sunda Arc, which varies from low-K tholeiites to High-K shoshonites, Barren Island lavas are low-K tholeiites and low-K Basaltic Andesites. Prehistoric flows are quite similar in major, minor and trace element chemistry and K/La, K/Nb, K/Rb, K/Ti ratios, C1-Chondrite normalized trace element and REE patterns to the Quaternary low-K lavas of Sunda Arc (Wheller et al., 1977). Such a similarity between prehistoric flows of Barren Island and low K lavas of Sunda Arc indicates that Barren Island lavas might have evolved from a source similar to that of the Sunda Arc lavas during Quaternary period (Alam et al., 2004). However, Barren Island lavas are not as much evolved, which can be explained in terms of the presence of a shallow magmatic source, also evident by seismic gap between 90 and 100 km depths in the Andaman Benioff zone (Dasgupta and Mukhopadhyay, 1997).

Alam, M.A., Chandrasekharam, D., Vaselli, O., Capaccioni, B., Manetti, P. and Santo, P.B., 2004. Petrology of the prehistoric lavas and dyke of the Barren Island, Andaman Sea, Indian Ocean. Proc. Indian Acad. Sci. (Earth Planet. Sci.) 113, 715-722.

Dasgupta, S. and Mukhopadhyay, M., 1997. Aseismicity of the Andaman subduction zone and recent volcanism. J. Geol. Soc. India. 49, 513-521.

Ravi Shanker, Haldar, D., Absar, A. and Chakraborty, S.C., 2001. Pictorial monograph of Barren Island volcano: the lone active volcano in the Indian Subcontinent. Geol. Surv. India Sp. Pub. 67, 88.

Wheller, G.E., Varne, R., Foden, J.D. and Abbott, M.J., 1987. Geochemistry of Quaternary volcanism in the Sunda-Banda Arc, Indonesia and three component genesis of island arc basaltic magmas. J. Volcanol. Geotherm. Res. 32, 137-160.

# The incremental growth of magma reservoirs: implications for magma differentiation and shallow magma storage

<u>Catherine Annen</u><sup>1</sup> (catherine.annen@terre.unige.ch), Jon Blundy<sup>2</sup>, Michel Pichavant<sup>3</sup>, Bruno Scaillet<sup>3</sup>, Steve Sparks<sup>2</sup>

<sup>1</sup>Section des Sciences de la Terre, Université de Genève, 13 rue des Maraîcher, 1205 Genève, Switzerland

<sup>2</sup>Department of Earth Sciences, University of Bristol, Wills Memorial Building, Queens Road, Bristol, BS81RJ, United Kingdom

<sup>3</sup>Institut des Sciences de la Terre d'Orléans, UMR 6113 CNRS-UO, Orléans, France

Until recently models of magma reservoirs have typically involved a large body of magma instantaneously emplaced into the crust that slowly cools down, crystallizes and differentiates. However, magma intrusion into the crust is more likely to be incremental with accretion of successive smaller intrusions. The thermal evolution of an incrementally growing magma reservoir is fundamentally different from an instantaneously emplaced magma reservoir, which has implications on the mechanisms of magma differentiation and on the dynamics of magma chamber.

When a magma reservoir starts to grow by addition of sills, the first sills emplace in a relatively cold environment and rapidly cool down and crystallise. However each successive sill transfers its heat to the crust and the whole system progressively heats up. The most efficient way to generate large amount of differentiated, and geochemically diverse melts is to emplace mafic magmas in the deep crust where temperatures are high and H<sub>2</sub>O concentrates in the residual melts. After an incubation period, the system temperatures exceed the sill solidus temperature and each new injected sill retains a small amount of residual melt. These first melts are highly differentiated. With time and increasing temperatures the residual melts progressively become less differentiated. When the country rocks solidus is exceeded, more melts are produced by partial melting of the crust. The ratio of residual melt (mantle source) to partial melt (crustal source) evolves with time and depends on the fertility of the crust, on the mafic magma emplacement rate and if panels of crust are sandwiched between the mafic sills.

In the case of shallow magma chambers, an incremental growth also implies that an incubation time is needed before a significant volume of eruptable magma can accumulate. Heat transfer modelling shows that for the magma chamber of Mount Pelee (Lesser Antilles Arc), a minimum average accretion rate of 3 cm/yr is needed to build up a magma chamber persistent over the last 13 500 years, with characteristics that fit the data provided by experimental petrology, i.e. a temperature of 875-900° and a pressure of  $2 \pm 0.5$  kbar. In the upper crust, if the emplacement rates are lower than a few centimetres per year, the successive magma batches solidify and crystallise after emplacement and no large magma chamber grows. The Manaslu leucogranite (Nepal, Himalaya) provides an example of a slowly growing igneous body (over ca 5 Myr), where an average emplacement rate of a few millimetres per year has been inferred from the absence of convection and homogenisation in the body and from the small size of thermal aureole.

# Composition and evolution of parental melt of Karymsky volcano (Kamchatka) inferred from study of melt inclusions in olivine

Ivan Belousov<sup>1</sup> (ivanbelousov@mail.ru), M. Portnyagin<sup>1,2</sup>, N. Mironov<sup>1</sup>

<sup>1</sup>Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow, Russia <sup>2</sup>Leibniz Institute for Marine Sciences (IfM-GEOMAR), Kiel, Germany

Karymsky volcanic area is specifically known for appearance of two compositionally different magmas – basalts and andesites – on the distance of only 6 km one from another. Eruption of Karymsky volcano in 1996 was triggered by the introduction of new portion of basaltic magma into andesitic reservoir beneath Karymsky volcano (Izbekov et al, 2004). This basaltic melt also reached the surface and erupted in Karymsky Lake. So sampling of basalts from Karymsky Lake and andesites from Karymsky Volcano allowed us to compare compositions of two end-members and trace signs of differentiation, mixing and contamination.

Measuring major, trace element and volatile compositions of melt inclusions in olivine from Karymsky Lake basalts allowed us to calculate composition of parental melt and conditions of its evolution (1180-1110°C, 6-2.2 kbar, fO<sub>2</sub> around NNO buffer). Modeling of fractionation of basaltic melt at fO<sub>2</sub> around NNO buffer, 1 wt.% H<sub>2</sub>O and 2 kbar pressure, which corresponds to the location of andesitic reservoir beneath Karymsky volcano, reproduces precisely the composition of andesite. Degree of fractionation is estimated as 60%. Parental melt contained 0.14 wt.% S and 0.09 wt.% Cl, while groundmass glass in the rocks is substantially depleted in S (0.03 wt.%) and has nearly the same Cl content as estimated parental melts. Using this data and data on volcanic output from Karymsky center during last century, we calculated emission of sulfur and chlorine as 35000 and 8500 tons per year respectively, which is in good correlation with measurements by other methods (Fischer et al, 2002). Although magma mixing and crustal assimilation could play role in the origin of Karymsky volcano andesites, the main process responsible for the origin of the bimodal rock association is fractional crystallization.

## Magma Storage and Volatile Fluxes beneath Mount St. Helens, 1980-86

Jon Blundy<sup>1,2</sup>(jon.blundy@bris.ac.uk), Kathy Cashman<sup>3</sup>

<sup>1</sup>Dept. Earth Sciences, University of Bristol, Bristol BS8 1RJ, UK

<sup>2</sup>Dept. Earth and Planetary Sciences, Nagoya University, Nagoya 464-8602, Japan

<sup>3</sup>Dept. Geological Sciences, University of Oregon, Eugene, OR 97403-1272, USA

An enduring problem in volcanology is linking the petrological testimony of erupted rocks to the contemporaneous monitoring record. In an attempt to reconstruct conditions in the magma body that fuelled the 1980-86 eruption of Mount St. Helens (MSH) we analysed 187 rhyolitic melt inclusions and 25 groundmass glasses from for major and trace elements, CO2 and H2O, using a combination of electron- and ion-microprobes. Major and trace element concentrations of melt inclusions lie at the high-SiO<sub>2</sub> end of the array defined by late Quaternary MSH whole-rocks. For several major and trace elements, glasses define a trend that is oblique to the whole-rock trend, indicating a marked change in crystallising assemblage. We interpret the whole-rock trend as the result of fractional crystallisation of hydrous basaltic parents in the lower crust, while the glass trends were generated by closed-system crystallisation of phenocrysts and microlites at low pressures.

Dissolved H<sub>2</sub>O in melt inclusions ranges from 0 to 6.7 wt%, with the highest values from the Plinian phase of May 18, 1980. For the entire suite of inclusions H<sub>2</sub>O decreases, and incompatible trace elements increase, with increasing SiO<sub>2</sub>, indicative of decompression-driven crystallisation. Bubble-free inclusions contain  $\leq$ 400 ppm CO<sub>2</sub> and indicate that XH<sub>2</sub>O in the vapour phase was in the range 0.8 to 0.95, irrespective of H<sub>2</sub>O content, suggestive either of buffered volatile composition throughout the magma system or of disequilibrium degassing of CO<sub>2</sub>. Elevated contents of Li in melt inclusions from the cryptodome and post-May 18 samples are consistent with upward transport of Li in a magmatic vapour phase. Li enrichment attains its maximum extent at a pressure of ~150 MPa, which we ascribe to condensation of a single vapour phase to H<sub>2</sub>O-rich gas and dense Li-rich brine.

By converting calculated melt inclusion volatile-saturation pressures to depths, we have tracked changing magma extraction depths with time for comparison with the seismic record. The Plinian eruption of May 18, 1980 discharged magma stored pre-eruptively over a range of depths from 5-11 km below sea-level (bsl). The preceding eruptions, including the May 18, 1980 blast deposit, and subsequent 1980 episodes, involved withdrawal from shallower depths, from just below the edifice itself to  $\leq 10$  km bsl. Tapping of magma down to these depths stopped abruptly at the end of 1980, coincident with the onset of numerous shallow earthquakes. All post-1980 eruptive episodes were predominantly effusive and tap exclusively shallow-stored (~3 km bsl) magma. We interpret the change in behaviour as a consequence of diminishing magma supply rate from depth such that by late 1980 the shallow conduit system became choked by highly crystallised magma, which served as a barrier to further extraction of deeper magmas. Overall, the 1980-86 eruption is consistent with sequential evisceration of a vertically extensive column of magma. Gas fluxing from deeper to shallower levels was an important feature of this system.

# Implications from hafnium isotopes on subduction contributions and mantle heterogeneity in the eastern Trans-Mexican Volcanic Belt

<u>Yue (Merry) Cai<sup>1</sup></u> (cai@ldeo.columbia.edu), Steven L. Goldstein<sup>1</sup>, Charles H. Langmuir<sup>2</sup>, Arturo Gómez-Tuena<sup>3</sup>, Alexandra LaGatta<sup>1</sup>, Susanne M. Straub<sup>1</sup>, Ana-Lillian Martin Del-Pozzo<sup>4</sup>

<sup>1</sup>Lamont-Doherty Earth Observatory of Columbia University, 61 Rt. 9W, Palisades, NY 10964, USA

<sup>2</sup>Dept. of Earth & Planetary Sc., Harvard University, 20 Oxford Street, Cambridge, MA 02138, USA

<sup>3</sup>Centro de Geociencias, UNAM Campus Juriquilla, Querétaro, Mexico

<sup>4</sup>Instituto de Geofisica, UNAM Cuidad Universitaria, Circuito Inst. Mex., 04510, Coyoacan, DF, Mexico

Ouaternary volcanism at eastern Trans-Mexican Volcanic Belt (EMVB) is related to the subduction of Cocos plate. Despite the thick overlying continental crust (30~47km), near primitive basaltic and andesitic lavas erupt throughout the EMVB. In order to distinguish and better constrain subduction contributions on the mantle source of the EMVB and the effects of crustal contamination, we measured Hf and Nd isotope composition of the subducting sediments from DSDP Site 487 and relatively primitive Quaternary lavas erupted in stratovolcanoes and cinder cones in the EMVB. DSDP site 487 sediment column is composed of an upper layer (100m) of terrestrial sediments and a lower layer (70m) of hydrothermal sediments. The hydrothermal sediments display negative Ce anomalies, higher Fe, Mn and REE abundance, LILE/LREE and LILE/HFSE ratios, and lower Pb isotope ratios than the terrestrial sediments (e.g. <sup>206</sup>Pb/<sup>204</sup>Pb ~18.5 vs 18.8, respectively). Sr and Nd isotope ratios of both the hydrothermal and terrigenous sediments are similar and distinct from typical upper mantle values (~0.708-0.709, and  $\varepsilon_{Nd}$  ~-2 to -4). Hydrothermal sediments from DSDP 487 have EHf (<sup>176</sup>Hf/<sup>177</sup>Hf normalized to CHUR value) similar to Pacific hydrothermal sediments, falling on the Hf-Nd "seawater array" (Albarède et al., 1998). In contrast, the terrestrial sediments from DSDP 487 have lower EHf and fall on the "mantle-crust array" (Vervoort et al. 1999). All analyzed EMVB lavas overlap with the global "mantle-crust array" on Hf-Nd isotope plot. Basaltic lavas from a series of N-S trending scoria cones in Sierra Chichinautzin Volcanic Field (SCVF High-Nb lavas) show little LILE-enrichment and no Nb-Ta depletion. They have been suggested to represent primitive melts of the regional sub-EMVB mantle (Marquez et al., 1999; Verma, 1999). SCVF high-Nb lavas define a clear linear trend parallel to the "mantle-crust array". Lavas from the eastern most stratovolcano Pico de Orizaba (Orizaba) lavas define a linear trend with similar slope to SCVF high-Nb lavas, however they generally have lower Nd-Hf isotope ratios than other EMVB lavas, suggesting crustal assimilation effect. Therefore the trend defined by Orizaba and SCVF high-Nb lavas on the Nd-Hf isotope plot appears to represent the regional "EMVB Hf-Nd mantle-crust array". Toluca and Popo lavas do not follow the "EMVB mantle-crust array". Instead they generally have the higher (more depleted) EHf and ENd with limited range of variation, which suggest negligible crustal contamination effect.

Elevated Th/LREE and Th/Nb ratios of Toluca and Popo lavas indicate addition of subducted sediment melt to their mantle source. However, the depleted Nd isotope ratios of Toluca and Popo lavas require addition of low degree melt derived from the altered oceanic crust (AOC). On Zr/Hf and Lu/Hf vs. ɛHf plots Toluca and Popo lavas fall on mixing lines with negative slope. Addition of the modeled slab melt (mixture of low degree AOC melt and sediment melt) to the mantle wedge (represented by SCVF high-Nb lavas) could explain the observed chemical and isotope composition relationships in Toluca and Popo lavas. Thus, we conclude that Toluca and Popo compositions reflect mixing between the slab melt and the regional mantle, with minor crustal assimilation effect.

## The state of the art of measuring volcanic degassing from space

Simon A. Carn<sup>1</sup> (scarn@umbc.edu), Nickolay A. Krotkov<sup>2,3</sup>, Kai Yang<sup>2,3</sup>, Arlin J. Krueger<sup>1</sup>

<sup>1</sup>Joint Center for Earth Systems Technology (JCET), University of Maryland Baltimore County (UMBC), Baltimore, MD, USA.

<sup>2</sup>Goddard Earth Science and Technology (GEST) Center, UMBC.

<sup>3</sup>Laboratory for Atmospheres, NASA Goddard Space Flight Center, Code 613.3, Greenbelt, MD, USA.

Satellite measurements of sulfur dioxide (SO<sub>2</sub>) emissions during large volcanic eruptions have illuminated the abundance and distribution of volatiles in magmatic systems primed for eruption. However, most volcanoes emit a significant proportion of their volatiles in periods of relative quiescence through passive or non-eruptive degassing, which is poorly quantified in many volcanic regions. Recent advances in satellite sensor design now permit measurements of SO<sub>2</sub> emissions associated with a broader range of volcanic activity, including passive degassing. Here we focus on the capabilities of the Ozone Monitoring Instrument (OMI) on the polar-orbiting EOS/Aura satellite, launched in July 2004. OMI is providing the first daily, space-based observations of volcanic SO<sub>2</sub> emissions in the lower troposphere (e.g., Fig. 1).



**Fig.1.** OMI image of tropospheric SO<sub>2</sub> plumes from volcanoes in the SW Pacific on April 23, 2006.

appraisal of the strongest volcanic SO<sub>2</sub> sources, and will therefore improve estimates of the magnitude of global volcanic SO<sub>2</sub> emissions, and their temporal and spatial variability. By integrating daily data into weekly, monthly or annual average SO<sub>2</sub> maps we can detect weaker sources, and evaluate longer-term trends in degassing at local or regional scales. Some examples of OMI measurements actively at degassing volcanoes will be presented, and the assumptions involved in the retrieval of SO<sub>2</sub> concentrations and interpretation of the results will be reviewed. Over time, we expect OMI and similar instruments to provide a novel set of observations with which to test models of volcanic degassing at

These measurements allow a frequent

individual volcanic systems and in different tectonic environments, improve volcanic hazard mitigation, and collect valuable baseline emission data for many remote or unmonitored volcanoes. All OMI data collected to date are publicly available and can be accessed at http://disc.sci.gsfc.nasa.gov/data/datapool/OMI/.

# Insights into magma evolution of Unzen: Evidence from chemical and Sr isotopic study of the USDP-1 core of Unzen Scientific Drilling Project

Chang-Hwa Chen<sup>1</sup> (china@earth.sinica.edu.tw) and Setsuya Nakada<sup>2</sup>

<sup>1</sup>Institute of Earth Sciences, Academia Sinica, P.O.Box 1-55, Nankang, Taipei, Taiwan, ROC <sup>2</sup>Volcano Research Center, University of Tokyo, Tokyo 113, Japan

The Unzen volcano lies on the Shimabara peninsula of western Kyushu in southwestern Japan. It is within the Unzen graben, which began to undergo north-south extension at least 0.5 Ma and subsided to 1000 m below sea level. Although, the eruptive history of the Unzen volcano can be divided into four major stages: Fugendake (0-125 Ka), Kusenbudake (100-175 Ka), Takadake (175-275 Ka) and pre-Takadake (230-580 Ka) from the surface study, the deep drilling will contribute the best way to inspect the eruptive history and magma variations with time. The Unzen Scientific Drilling Project (USDP) finished the first pilot-drilling down to 750 m on March, 2000. This paper shall show the preliminary isotopic results of USDP-1 samples and discuss the magma variations of Unzen volcano.

The silica contents of USDP-1 samples obviously show the five zigzag shapes with depth (Akimasa et al., 2000). Ten samples for isotopic study covered four periods from 138 m to 535 m were chosen. With respect to isotopic variations, they did not show any positive or negative correlation with the silica contents. The trend of Sr isotopic values displays single arch with depth. Comparison the chemical and isotopic data of the core samples and the historical and pre-historical eruption materials (Chen et al., 1993,1999), the data distribution of core samples always falls into that of previous studies. A general AFC model can interpret this phenomenon; moreover, three arrows show the FC process that affects the silica content gradually increasing in samples having similar Sr isotopic value. Other major elements (CaO and MgO) and trace elements (Rb and Sr) also exhibited the similar trend with isotopic values. These individual FC processes in the magma evolution can be cogitated, as the magmas in different eruption events have themselves independent sources and processes. There are consistent with the suggestions from phenocrysts and matrix isotopic study (Chen et al., 2000).

## Major- and trace-element abundance of apatites as an indicator for granitoid petrogenesis

<u>Mei-Fei Chu</u><sup>1, 2</sup> (meifei@ntu.edu.tw), Sun-Lin Chung<sup>2</sup>, William L. Griffin<sup>3</sup>, Norman J. Pearson<sup>3</sup>, Yoshi Iizuka<sup>1</sup>, Kuo-Long Wang<sup>1</sup>

<sup>1</sup> Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan

<sup>2</sup> Department of Geosciences, National Taiwan University, Taipei, Taiwan

<sup>3</sup> Australian Research Council National Key Centre for Geochemical Evolution and Metallogeny of Continents (GEMOC), Department of Earth and Planetary Sciences, Macquarie University, Sydney, Australia

Among accessory minerals in igneous rocks, apatite has been preliminarily documented that its remarkable variation in major- and trace-element compositions show high potential as tracers of petrogeneses. In this study, *in situ* geochemistry of apatites from Transhimalayan igneous rocks, including the I-type Gangdese granite suite, S-type granites in the northern belt, and collisional type adakites, are assessed for such application. The results demonstrate that F, Mn, Sr and REEs compositions of apatites generally well correlate with their host magmas and thus have high potential to be utilized as petrogenetic indicators. More specifically, F and Mn contents in apatites are covariant with the aluminosity (or ASI values) of the host rocks so that can be used as an indicator for magma differentiation. Combining with Sr and REE data, which show significant variations in apatites of different rock types, these elements may be furthermore used to construct "discrimination diagrams" for more detailed investigations of complex petrogenetic processes such as magma mixing and compositional heterogeneity.

# Process of the Mesozoic magmatic activity in the costal area of the Yangtze river in Anhui province: evidence from igneous suites and xenoliths

Yang-Song Du (duys5510@cugb.edu.cn), Shun-Ting Li, Yi Cao, and Xin Lu

State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Beijing 100083, P. R. China

The costal area of the Yangtze River in Anhui Province situated in the middle segment of the Yangtze River Deep Fault Belt is structurally located in the foreland of the Dabie Orogenic Belt. In this area are widely exposed a set of post-collisional to postorogenic associations formed in the Late Jurassic to Early Cretaceous.

The beginning and end of major post-collisional episodes are remarked by formation of gabbroic xenoliths and pyroxene cumulates in intrusions in Tongling and A-type granitoids along either bank of the Yangtze River, respectively. The post-collisional association formed in this period includes peraluminous silicic rocks (137~139 Ma) and metaluminous mafic-felsic igneous suites, ranging from medium-K to high-K calc-alkaline (133~143 Ma) to shoshonitic (128~140 Ma) to ultrapotassic (125~128 Ma). The peraluminous silicic rocks are distributed from Guichi to Xuanzhou. The medium-K to high-K calc-alkaline suite consists mainly of intrusive rocks in Tongling and volcanic rocks of the Zhongfencun and Chisha Formations in the Fanchang Basin (FB), the shoshonitic suite is composed of volcanic rocks of the Longmenyuan and Zhuanqiao Formations in the Lujiang-Zongyang Basin (LZB), and the ultrapotassic suite is dominated by A-type granitoids distributed along either bank of the Yangtze River.

The beginning and end of major postorogenic episodes are remarked by formation of gabbro with spinel lherzolite xenoliths in the Nanjing-Wuhu Basin (NWB) and phonolite with feldspathoid phenocrysts in NWB and LZB, respectively. The postorogenic association formed in this period ranges from sodic alkaline (115~125 Ma) to peralkaline (105~115 Ma). The sodic alkaline suite consists mainly of intrusive rocks with gabbroic composition in NWB, volcanic rocks with garnet of the Kedoushan Formation in FB, and volcanic rocks of the Shuangmiao Formation in LZB, and the peralkaline suite is composed of volcanic rocks of the Fushan Formation in LZB and the Niangniangshan Formation in NWB.

The geological, petrological, and geochemical data obtained through this study are consistent with the gradual deepening of the Yangtze River Deep Fault caused by lithospheric extension combined with asthenospheric upwelling during the Late Jurassic to Early Cretaceous, and support the partial melting of the middle to lower crust or lithospheric mantle owing to lithospheric decompression and asthenospheric heating. It is inferred that a series of complex middle to lower crustal interactions with the underplated basaltic magma derived from metasomatized plagioclase, spinel or garnet lherzolite are responsible for the formation of the igneous suites and xenoliths in the area.

# Composition and genesis of clinopyroxene and feldspar megacrysts from alkaline basalts of Mongolia

Vera Egorova (verae@uiggm.nsc.ru), Valery Kalugin, Roman Shelepaev

Institute of Geology and Mineralogy of SB RAS, Novosibirsk, Russia

A large diversity and abundance of megacrysts of pyroxene, amphibole, garnet, mica, feldspar, ilmenite, etc., are typically for alkaline basalts from many volcanic localities all over the world. Different hypotheses have been proposed concerning their origin. They have been considered as high-pressure phases crystallized from liquids parental to their host rocks or as disaggregated inclusions of upper mantle and crust rocks. In eastern Asia Neogene-Quaternary intraplate alkaline basalts are located from Northern Mongolia to Southern Vietnam. These basalts made up of huge lava flows with various safety domes. Basalts are basanites with high TiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, alkaline and low MgO. Megacrysts of clinopyroxene and K-Na feldspars were studied from alkaline basalts of Tarjat, Orkhon-Selenga, Dolinoozernii and Dariganga volcanic fields in central and south-eastern Mongolia.

Clinopyroxenes (CPx) are Al-augites with high contents of Al<sub>2</sub>O<sub>3</sub> (6.6-9.6 wt.%), Na<sub>2</sub>O (1.7-3.4 wt.%), TiO<sub>2</sub> (1-2.1 wt.%) and with no chromium. CPx composition examination show dependence between composition of CPx megacrysts and host basalts. Most magnesia CPx megacrysts are found in most magnesia basalts. This dependence is found in other components (Ca, Na, Al). For example, most alumina, sodium and calcium CPx were found in Tarjat basanites with high content of these elements as compared with Dariganga basalts. Pressure estimates for CPx can be obtained by using the structural geobarometers of Nimis [1]. Estimated pressures for CPx megacrysts are 1.45-1.55 GPa. According to experimental data CPx similar to CPx megacrysts in composition can be crystallized from alkaline basaltic melt at 1.4-1.6 GPa and 1200°C.

K-Na feldspar (Fsp) megacrysts from alkaline basalts of Mongolia are anorthoclase ( $Or_{22-40}$ ) and sanidine ( $Or_{41-78}$ ). Fsp megacrysts are subdivided into two groups. One group of Fsp is characterized high Rb, Cs, Ba, Sr content correlated with high K<sub>2</sub>O (9.4-12 wt.%). Another group have low K<sub>2</sub>O (5-6 wt.%) and LIL elements content. Such variety is due to different genesis of Fsp megacrysts. Depleted in these elements Fsp crystallize from residual melt after clinopyroxene, amphibole, ilmenite crystallization. Enriched Fsp were formed as a result of interaction between basalt melt and lower crustal rocks.

By our researching megacryst composition depends on chemistry features of host alkaline basalts. This is one more evidence of cognate relation basalts and megacrysts. Cpx megacrysts are a result of crystallization of alkaline basalts in intermediate magmatic chamber at pressure 1.45-1.55 GPa (about 50 km) at depth levels close to the mantle-crust boundary in Eastern Asia.

[1] Nimis, P. (1999) Clinopyroxene geobarometry of magmatic rocks. Part 2. Structural geobarometers for basic to acid, tholeiitic and mildly alkaline magmatic systems. Contribution to Mineralogy and Petrology, 135, 62-74.

#### Volcanic Gas Emissions: Sources, Variations and Implications

Tobias Fischer (fischer@unm.edu)

Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131-1116, USA

Magma ascent towards the surface results in the release of volatiles to the atmosphere. The composition of these volatiles as they discharge from active volcanoes is dominated by H<sub>2</sub>O, CO<sub>2</sub> and S species. Trace components include the noble gases, HCl, HF, N<sub>2</sub>, H<sub>2</sub>, CH<sub>4</sub> and CO. At high temperature fumaroles (>700°C) concentrations of Be, Rb, Sr, Ru, Rh, Pd, Cd, W, Re, Pt, Pb, Bi, Se, Sc are in the 5 - 1300 ug/L range. Systematic variations of gases (CO<sub>2</sub>, N<sub>2</sub>, He) and isotopic compositions ( $\delta^{13}$ C,  $\delta^{15}$ N,  $\delta$ D,  $\delta^{18}$ O) with tectonic setting show that gas emissions are strongly influenced by varying contributions of volatiles from the crust, the mantle and the subducting slab. In particular, time-series data of  $\delta D$  and  $\delta^{18}O$  values of discharging steam shows that H<sub>2</sub>O in arc volcanoes is a mixture of magmatic water (from the mantle and subducted slab) and surface derived meteoric water with varying contributions depending on the volcano's current state of activity. Changes in volcanic activity can also result in distinct changes in the major gas composition, such as the CO<sub>2</sub>/HCl ratio. An increase in this ratio may be due to new magma addition into the volcanic edifice, releasing low solubility CO<sub>2</sub>. A ratio decrease may result from the boiling of an HCl-rich hydrothermal fluid due a temperature increase of the system. At Poas Volcano, Costa Rica, changes in gas ratios from 2001 to 2006 suggest addition of new magma coupled with a temperature increase of the volcano-crater lake system.

Although direct sampling of fumaroles provides the most complete record of gas compositions, other methods, including remote sensing (ground based and satellite based) and analyses of ash leachates (for volatiles adsorbed by the ashes in the plume), are often utilized to investigate volcanic processes. At Karymsky, Kamchatka, for example, almost continuous monitoring of SO<sub>2</sub> flux by COSPEC showed short term (minutes to hours) variations in the amount of SO<sub>2</sub> released from the erupting volcano. These fluctuations seem to be strongly controlled by vent sealing processes while gas supply from the magma remained constant. At Galeras, Colombia, longer-term (weeks to months) gas flux variations, correlate with seismic events recorded at the volcano and suggest pressure build-up and vent sealing processes that can lead to explosive eruptions. In the Marianas Islands, ash leachates collected immediately after the first historical eruption of Anatahan volcano, in May 2003 showed that the eruption was likely triggered by either gas pressure build-up in the hydrothermal system.

Future volcanic gas studies may benefit from on 1) development of instrumentation and methods for obtaining continuous records of gas emissions (composition and fluxes), 2) direct comparisons with petrologic studies, in particular volatiles measured in melt inclusions and studies of short-lived radiogenic isotopes and 3) integration of gas emissions into global element cycling models.

# Temporal Controls on the Release of Mantle and Crustal Volatiles from Cold Fluid Seeps at Monterey Bay, California, USA

Evelyn Füri (efueri@ucsd.edu), David Hilton, Mike Tryon, Kevin Brown

Geosciences Research Division, Scripps Institution of Oceanography, La Jolla, CA 92093-0244, USA.

We report  ${}^{3}\text{He}/{}^{4}\text{He}$  ratios,  $\delta^{13}\text{C}$  values as well as He and CO<sub>2</sub> abundances for cold seep fluids issuing at ~ 1km depth in Monterey Bay, California. Fluids were collected in copper coils attached to Chemical and Aqueous Transport (CAT) meters [1] and an Optical Tracer Injection System (OTIS) [2] deployed for 2-3 weeks in 2004. The systems allow serial sampling of fluids and their preservation at ambient pressure. Thus, specific times of interest (e.g. immediately prior to and/or following a crustal event) can be targeted for detailed, follow-up analytical work.

All samples are supersaturated in He and CO<sub>2</sub> with respect to seawater indicating addition of extraneous volatiles. The main features of the results are: (1) air-corrected <sup>3</sup>He/<sup>4</sup>He ratios vary between ~ 1R<sub>A</sub> and 2.4 R<sub>A</sub>, i.e., between values expected for mantle-derived He (8 R<sub>A</sub>) and radiogenic He produced in crust and/or sediments (0.02R<sub>A</sub>). Using a simple 2-component mixing model, up to ~25% of the total He is mantle-derived. (2) For most samples, the CO<sub>2</sub>/<sup>3</sup>He ratios are significantly greater than anticipated mantle values (MORB ~ 2 × 10<sup>9</sup>). (3) There is a large range in  $\delta^{13}$ C values, from -5‰ to ~-25‰. This is consistent with an input of both organic-derived ( $\delta^{13}$ C ≈ -30‰) and mantle-derived CO<sub>2</sub> ( $\delta^{13}$ C ≈ -6‰). However, perhaps the most significant finding of our deployments is temporal variability in both the isotopic and concentration systematics of the dissolved He and CO<sub>2</sub>. The data demonstrate remarkable changes over days/weeks in the volatile content of the cold seep fluids.

Subsequent to our initial analytical effort, we refined our laboratory procedures and constructed a dedicated extraction system which can be interfaced directly to the mass spectrometer. In this way, we can obtain He-CO<sub>2</sub> results on significantly smaller quantities of fluid (< 1 cm<sup>3</sup>) thus dramatically improving our time-resolution on the dissolved gas analyses. Using different sections of the same Monterey coils, we have now obtained a total of 10 combined He-CO<sub>2</sub> analysis which cover a total time period of 1 day (i.e. sampling was achieved with a frequency of ~2.5 hours), an unprecedented level of sampling frequency for submarine cold seeps. Corrected <sup>3</sup>He/<sup>4</sup>He ratios vary between 1.4 and 3.4R<sub>A</sub> over a single day, and show a clear correlation with helium concentration.  $\delta^{13}$ C values range from -14‰ to -40‰, suggesting additional input of CO<sub>2</sub> derived from methane oxidation. The results are consistent with external regulation of the release of one or both (mantle or crustal) volatile components.

[1] (Tryon et al., 2001) [2] (Labonte et al., 2006)

## Long-lasting degassing activity at basaltic volcanoes: the bearing of U-series isotopes

<u>Pierre-Jean Gauthier</u><sup>1</sup> (P.J.Gauthier@opgc.univ-bpclermont.fr), Kenneth WW Sims<sup>2</sup>, and Séverine Moune<sup>1,3</sup>

<sup>1</sup>Laboratoire Magmas et Volcans – Observatoire de Physique du Globe de Clermont-Ferrand (CNRS, UBP) – 5 rue Kessler – 63000 Clermont-Ferrand, France

<sup>2</sup>Department of Geology and Geophysics – Woods Hole Oceanographic Institution – Woods Hole, MA 02543, USA

<sup>3</sup>Institute für Mineralogie – University of Hannover – Callinstrasse 3 – 30167 Hannover, Germany

Degassing is probably the most common manifestation of volcanic activity, including at quiescent volcanoes that produce almost no lava at the surface. It obviously raises questions about the origin of gas fluxes at such persistently degassing but non-erupting volcanoes. It is generally admitted that gas fluxes are mostly sustained by the exsolution of volatiles that were initially dissolved in the magma at depth. However, it remains unclear whether these gases originate either from small ascending magma batches (ultimately recycled at depth once degassed) or large magma reservoirs beneath active volcanoes. Setting constraints on magma residence times in shallow degassing reservoirs and/or feeding systems is of obvious interest to distinguish between these two models. Radioactive disequilibria between short-lived <sup>238</sup>U-series isotopes (<sup>210</sup>Pb, <sup>210</sup>Bi, and <sup>210</sup>Po) in volcanic gases have proved helpful in constraining shallow magma dynamics, as exemplified at Stromboli, Italy [1].

Here, we present unpublished data on radioactive disequilibria in Masaya's (Nicaragua) gases collected since 2000. These disequilibria are best explained by the degassing of a magma body having a much longer residence time (between 3 and 150 years) than at Stromboli (tens to hundreds of days at most [1]). Noteworthy, (<sup>210</sup>Po/<sup>210</sup>Pb) activity ratios are lower in gases from Masaya than in volcanic emanations from other basaltic volcanoes, which is best explained by <sup>222</sup>Rn enrichment and subsequent decay in gas bubbles. We present here as well as in a companion paper [2] new unpublished data on <sup>222</sup>Rn-<sup>210</sup>Pb disequilibria in gases emanating from Masaya that support this hypothesis. Furthermore, radioactive disequilibria in Masaya's gases display significant variations through time that are correlated with observed activity and gas fluxes at the surface. Taken together, it suggests that degassing occurs at Masaya in a large magma reservoir beneath the active Santiago crater and that input of deep pristine magma in this reservoir controls the eruptive activity at the surface.

[1] Gauthier P-J., Le Cloarec M-F. and Condomines M., 2000, Degassing processes at Stromboli Volcano inferred from short-lived disequilibria (<sup>210</sup>Pb-<sup>210</sup>Bi-<sup>210</sup>Po) in volcanic gases, J. Volcanol. Geotherm. Res., 102-1/2, p. 1-19.

[2] Sims K.W.W. and Gauthier P-J., 2007, From Source to surface: U-series constraints on the processes and timescales of magma generation, evolution and degassing, MAG2007, Taipei, April 22-27, 2007.

# Silicic Ignimbrites of El Valle Volcano, Panama: Comparison With Silicic Ignimbrites of the Central American Volcanic Arc

Paulo J. Hidalgo (hidalgop@msu.edu), Thomas A. Vogel and Ryan M. Currier

Michigan State University, Department of Geological Sciences, East Lansing, MI 48824-1115, USA

El Valle Volcano is located in Panama on the easternmost extent of the Central American Volcanic Arc, where volcanism is related to subduction of the Nazca Plate. In contrast, volcanoes northwest of Panama in the Central American Volcanic Arc are related to subduction of the Cocos plate.

The most recent volcanic activity on El Valle Volcano occurred between 1.5 Ma - 0.9 Ma (Defant et al., 1991), with the emplacement of silicic pyroclastic flows and domes. The El Hato formation represents the eruption of an extensive silicic ignimbrite sheet (approximately 300 km<sup>2</sup>), which resulted in a 20 km<sup>2</sup> caldera. This caldera collapse was followed by emplacement of resurgent dacitic domes (0.9 Ma).

The recent silicic volcanism found at El Valle volcano is distinct from silicic volcanism at volcanic centers associated with the Cocos plate. The eruptive products of El Valle contain little chemical variation (SiO<sub>2</sub> 69.5% S.D. 3.2, MgO 1.26% S.D.0.8, CaO 4.50% S.D. 1.20, etc), whereas those from the Cocos plate contain a relatively large variation.

There are major chemical differences between El Valle silicic deposits, and similar deposits associated with the Cocos plate. The El Valle deposits have lower alkali  $K_2O/Na_2O$ , Y values and higher Sr/Y values. The Ba/La ratios from El Valle Volcano are among the lowest found along the arc. In addition, the HREE are extremely depleted.

These differences indicate a different source for the silicic volcanism on the Panama portion of the arc compared to those associated with the Cocos plate. The high alkalis and K<sub>2</sub>O/Na<sub>2</sub>O ratio and relatively high REEs in most ignimbrites associated with the Cocos plate requires an evolved rock source with medium to high-K basalt as starting compositions (Vogel et al., 2006). The values in the El Valle Volcano deposits, along with HREE depletion requires a lower K source and a more primitive garnet bearing rock. Our detailed studies on the geochemistry of El Valle Volcano points out the uniqueness of these silicic ignimbrites compared to the ignimbrites from the Cocos plate. Further studies on silicic deposits from other volcanoes in Panama are required to determine if El Valle deposits are representative of the silicic volcanism in Panama.

# Results of recent helium isotope studies in seismically-active regions: the San Andreas Fault Zone, California and the North Anatolian Fault Zone, Turkey

<u>David Hilton</u><sup>1</sup> (drhilton@ucsd.edu), Diana De Leeuw<sup>1</sup>, Nilgun Gulec<sup>2</sup>, Halim Mutlu<sup>3</sup>, Evelyn Füri<sup>1</sup> and Justin Kulongoski<sup>4</sup>

<sup>1</sup>Scripps Institution of Oceanography, La Jolla, CA 92093-0244, USA.

<sup>2</sup>Middle East Technical University, Ankara, Turkey

<sup>3</sup>Osmangazi University, Eskişehir, Turkey

<sup>4</sup>U.S. Geological Survey, Water Resources Division, San Diego, CA 92123, USA

Monitoring helium isotope variations in crustal fluids (groundwaters and geothermal fluids) have shown great potential as a predictive tool in earthquake studies. Prior work has demonstrated that the balance between high <sup>3</sup>He/<sup>4</sup>He magmatic gas and low <sup>3</sup>He/<sup>4</sup>He crustal volatiles can be disturbed by crustal perturbations, e.g., magma movement by dike injection. Permeability changes induced by crustal disturbance can also lead to release of stored radiogenic He which can affect the He-isotope ratio. Here, we present new He isotope data (and associated carbon data) from two of the world's great fault systems - San Andreas Fault, California (SAF) and the North Anatolian Fault Zone, Turkey (NAFZ) - to further investigate the potential of He isotopes as a tracer of mantle-crust interaction in seismically-active regions.

Following the catastrophic earthquakes along the NAFZ in 1999, we initiated a periodic monitoring program targeting geothermal fluids (from boreholes and natural springs) for their chemical and dissolved gas characteristics. Sampling was undertaken 3 times/year for the years 2002-04 and helium (and carbon) data have been produced for 9 locations along an 800-km transect of the fault - from Yalova on the Sea of Marmara to Resadiye in eastern Anatolia. <sup>3</sup>He/<sup>4</sup>He ratios vary between 0.29 R<sub>A</sub> (Yalova, Gozlek) and 2.2 R<sub>A</sub> (Mudurna) (R<sub>A</sub> – air <sup>3</sup>He/<sup>4</sup>He) indicating a discernable contribution of magmatic He throughout the length of the fault. There were no large earthquakes in the region over the monitoring period, and there is little variation in <sup>3</sup>He/<sup>4</sup>He values at individual sampling localities. However, there are significant changes in the CO<sub>2</sub>/<sup>3</sup>He ratio and especially  $\delta^{13}$ C. We report these changes with respect to the regional stress pattern in Turkey.

We have also targeted groundwater systems in close proximity to the SAF in order to understand the influence of fault distribution on the release of mantle-derived volatiles. Mantle-derived He is pervasive in the vicinity of the SAF (to within 50 -100 km) - with the Mojave River Basin in southern California having <sup>3</sup>He/<sup>4</sup>He ratios up to 0.11 R<sub>A</sub> whereas the nearby east Morongo Basin has <sup>3</sup>He/<sup>4</sup>He ~ 0.32 R<sub>A</sub>. Higher <sup>3</sup>He/<sup>4</sup>He ratios appear correlated with locations of faults in each basin. In the Monterey Bay region, we have measured <sup>3</sup>He/<sup>4</sup>He ratios up to 3.4 R<sub>A</sub> in submarine seeps. The whole region adjacent to the SAF, therefore, is leaking mantle-derived He to the surface albeit heavily diluted with radiogenic He produced in the crust.

## Volcanic emissions of gas and particles in sustained tropospheric plumes.

Evgenia Ilyinskaya (ei213@cam.ac.uk), and Clive Oppenheimer

Department of Geography, University of Cambridge, Cambridge CB3 3EN, UK.

Volcanoes are one of the principal natural sources of reactive aerosol in the atmosphere. Even between large explosive phases, volcanoes can be constantly degassing through the main crater, fumaroles and soil cover. Significant quantities of numerous gas and particles species are added to the troposphere by quiescent but sustained emissions. In fact, averaged over time, their magnitude exceeds the amount added by rare explosive eruptions.

Emissions of volcanic aerosol can result in local and regional perturbations in the atmosphere; its deposition has significant effect on terrestrial ecology, agriculture and human health. Detailed observations of the emissions can be used to predict and quantify the impacts on the atmosphere and surrounding ecosystems; and evaluate potential health hazards. Equally, the data can provide information about the sub-surface magmatic conditions that power the volcanic system.

Aerosol consists of liquid and solid particles suspended in a gas. The size range of volcanic aerosol particles is from few nanometers to tens of microns. Important chemical species include  $SO_2$  and derived  $SO_4^{2^-}$ ; halogens (F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>); metals (including cations such as Na<sup>+</sup>, Ca<sup>2+</sup>, K<sup>+</sup> and Mg<sup>2+</sup>); trace metals; and REE. There are several gas species that are theoretically possible but have not yet been detected, such as halogen oxides of IO and BrO (except in Masaya volcano).

The objective of this project is to carry out detailed measurements of both gas and particle phases in plumes of several constantly degassing volcanoes. Work has been carried out on Mt. Erebus (Antarctica), Masaya (Nicaragua), Poas and Arenal (Costa Rica). Further work is planned in Hawaii and Vanuatu islands, in addition to re-visiting previous fieldsites.

Gas phases in the plume are constrained using a variety of UV and IR spectroscopic equipment, including DOAS spectrometer. The aerosol optical thickness can be quantified using MICROTOPS sunphotometer. Particle samples are collected using a ground-based cascade impactor, MOUDI. The impactor has 14 stages, which segregate the particles into different size bins. The last three stages allow detection of nano-sized particles, with the lowest detection limit of 10nm. This is the first time that the nano-MOUDI is applied on the fieldsites in question; it is anticipated to yield original information about the particles on the ultra-fine end of the size-spectrum.

The analysis of the particle samples will characterise the geochemical composition of emissions, and interactions between gas and particles in the dynamic plume. The composition of the plume is progressively changing as particles react with gases and with each other; are scavenged; and/or deposited. It is also necessary to evaluate the effect of the background meteorological conditions. While it is vital to characterise the chemical composition and concentration in the plume, it is equally important to study the size-resolved chemistry of the particles; their distribution in time and space; and their morphology. This will allow speculations on the future evolution and fate of the plume, as well as its impacts on the surroundings.

# A comparison of ultraviolet and thermal infrared retrievals of SO<sub>2</sub> in the cloud produced by the 2003 Al-Mishraq state sulfur plant fire

<u>Courtney Kearney</u><sup>1</sup> (c.kearney@bristol.ac.uk), I. Matthew Watson<sup>1, 2</sup>, Gregg J.S. Bluth<sup>2</sup>, Simon Carn<sup>3</sup> and Vincent J. Realmuto<sup>4</sup>

<sup>1</sup>Department of Earth Sciences, University of Bristol, Bristol, UK

<sup>2</sup>Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI, USA

<sup>3</sup>Joint Center for Earth Systems Technology (NASA/UMBC), University of Maryland Baltimore County, Baltimore, Maryland, USA

<sup>4</sup>Jet Propulsion Laboratory, Pasadena, California, USA

It is estimated that volcanoes emit 7.5-20 x  $10^{12}$  g yr<sup>-1</sup> of sulfur (as SO<sub>2</sub>) per year, which accounts for approximately 7.5-20 % of the total global sulfur budget. Although the detection of SO<sub>2</sub> plumes by space-based sensors has been demonstrated in the ultraviolet (UV) and thermal infrared (TIR), these estimates are based mainly on UV remote sensing because of the recent introduction of the TIR technique. It is necessary to combine the two methods in future studies to increase the accuracy of the contribution of volcanoes to the total S budget; however, the relationship between the two retrievals is poorly constrained. In this study, we compare near-coincidental data from the UV Earth Probe Total Ozone Mapping Spectrometer (EP TOMS) and TIR MODerate resolution Imaging Spectroradiometer (MODIS) of a near-pure SO<sub>2</sub> plume from the Al-Mishraq State sulfur plant fire on 29 June 2003.

On 24 June 2003 a fire started at the Al-Mishraq State sulfur plant near Mosul, Iraq and lasted for approximately one month. The combustion of elemental sulfur to SO<sub>2</sub> produced the largest anthropogenic plume detected to date by the EP TOMS and MODIS. Previous studies indicate a total of 400 kt of S-bearing product from the plant was consumed and 98% was assumed to be elemental sulfur. On 29 June, EP TOMS and MODIS images were acquired at 0752 and 1010 UTC respectively. A previous EP TOMS retrieval estimated the plume contained 102 kt SO<sub>2</sub> compared to the 138 kt detected by MODIS. The resampling of the MODIS-based retrieval to the coarser spatial resolution of EP TOMS results in a decrease in the MODIS total mass by 9% and reveals a range from zero agreement to agreement within error between EP TOMS and resampled MODIS at the pixel scale. These variations are likely the result of differences in spatial resolution of the EP TOMS and MODIS measurements, sensitivity of the SO<sub>2</sub> estimates to atmospheric absorption and scattering and solar illumination, and variations in plume height with distance from the fire and time of data acquisition.

## Evidence of Mantle Source Volcanism in the Adriatic region

<u>Goran Kniewald</u><sup>1</sup> (kniewald@irb.hr), Ladislav Palinkas<sup>2</sup>, Sibila Borojevic<sup>2</sup>, Delko Barisic<sup>1</sup> and Vladimir Bermanec<sup>2</sup>

<sup>1</sup>Department of Marine and Environmental Research, Rudjer Boskovic Institute, POB 180, 10002 Zagreb, Croatia

<sup>2</sup>Institute of Mineralogy and Petrology, Faculty of Science, University of Zagreb, Horvatovac bb, 10000 Zagreb, Croatia.

The broader region of the Adriatic sea is characterised by a sequence of magmatism-related events from the (pre)-Mesozoic through Cenozoic age. The triassic magmatism and jurassic ophiolites formed at the margins of the Adria plate promontory. The cenozoic tectono-magmatic evolution of the central-western Mediterranean produced the migration of an inter-arc basin system and variations in the mode of subduction, and a subsequent cenozoic within-plate volcanism and lithospheric mantle evolution in the same areal.

The triassic rift-related magmatism in the peri-Adriatic region resulted in an intrusive gabbro-diorite-syenite-granite formation and an extrusive basalt-andesite-dacite formation with an abundance of pyroclastic rocks. These formations have a spatial and genetic relationship with the late permian (through norian) rift-derived sedimentary formations of the Adriatic Carbonate Platform (ACP). Associated volcanic rocks are altered due to the strong oceanic hydrothermal metamorphism, and strontium and oxygen isotopic ratios indicate their upper mantle origin. The ophiolitic associations found along the western flanks of the Dinaride and Albanide ranges represent the westernmost relics of the alpine Tethys. The variations in the composition of spinels associated with these ultramafics reflect substantial lithological variability. With respect to the wider circum-Adriatic region, the distribution of gravity anomalies and topography suggests that the mantle is rising beneath the main topographic bulge of the Apennines and that this flow is maintained by buoyancy forces, rather than being driven by movement of the subducted slab.

Local evidence of mantle volcanism in the Adriatic region is found in the form of igneous rocks from the islands of Vis, Jabuka and Brusnik (central part of the eastern Adriatic sea). Less proximal facia consist, i.e. in the northern part of Croatia, consist of pillow lavas with "peperitic hyaloclastites", belonging to dismembered ophiolitic sequences derived from rift-magmatism. Analysis of fluid inclusions in these rocks, with monophase and multiphase inclusions presents a strong indication of their complex formation and alteration history.

# Invasion of Mantle-Derived Fluids into I-Lan Plain, NE Taiwan from Southwest Part of the Okinawa Trough: Evidence of Helium Isotopes in Soil Gases

<u>Tefang Faith Lan</u><sup>1</sup> (f92224105@ntu.edu.tw), Tsanyao Frank Yang<sup>1</sup>, Yuji Sano<sup>2</sup>, Hsiao-Fen Lee<sup>1</sup> and Ching-Chou Fu<sup>1</sup>

<sup>1</sup>Department of Geosciences, National Taiwan University, Taipei 106, Taiwan <sup>2</sup>Ocean Research Institute, The University of Tokyo, Tokyo 164-8639, JAPAN

The I-Lan Plain is located in northeastern Taiwan and is famous for its hot and cold springs. With subsidence rate of 126 mm/y, the I-Lan Plain is considered to be the westward extension of the Okinawa Trough on land. An active volcanic islet, Kueishantao, is located at the most southwestern part of the Okinawa Trough and only ca. 10 km east to the Plain. The helium isotopic ratios of bubbling gases from submarine hot springs around Kueishantao are up to 8.3 Ra, where Ra is the <sup>3</sup>He/<sup>4</sup>He ratio of air. It implies that a primordial mantle component is degassing in the region. Moreover, elevated <sup>3</sup>He/<sup>4</sup>He ratio can also be found in the gas and fluid samples from hot/cold springs in the Plain. In order to better understand the distribution/migration of possible mantle fluids in this region, we systematically conducted the soil gas survey in the Plain. Helium and carbon isotopes were also analyzed to examine their gas sources. The results show that most samples exhibit both excess 3He and 4He and progressively decrease from east toward west of the Plain. It infers that the mantle-derived fluids may have invaded into the I-Lan Plain through the westward extension of the Okinawa Trough. Furthermore, the distribution of excess helium isotopes can be helpful to delineate the surface trace of possible deep faulted-structure in central part of the Plain.

### The Variations of Fumarolic Gas Compositions in Tatun Volcano Group, Northern Taiwan

<u>Hsiao-Fen Lee<sup>1</sup></u> (d94224006@ntu.edu.tw), Tsanyao Frank Yang<sup>1</sup>, Tefang Faith Lan<sup>1</sup>, Sheng-Rong Song<sup>1</sup>, and Shujung Tsao<sup>2</sup>

<sup>1</sup>Department of Geosciences, National Taiwan University, Taipei 106, Taiwan

<sup>2</sup>Central Geological Survey, MOEA, Taipei 235, Taiwan

Hydrothermal activity is commonly found in northern Taiwan. Helium isotopic compositions of fumarolic samples show that more than 60% mantle source was involved in its gas sources. Carbon and nitrogen isotopic results also show significant mantle signature. It infers that a magma reservoir may exist underneath northern Taiwan. For monitoring purpose, therefore, we systematically analyze the compositions of representative fumarolic gases from Tatun Volcano Group (TVG) by utilizing the Giggenbach-bottle technique. The results show that the dry gas compositions of the gas samples are typical compositions of low temperature fumaroles, which dominated with  $CO_2$  (65~85%) and  $H_2S$  (>10%) and low  $SO_2$  (<4%) contents.

The time series results show that the major gas composition and helium isotopic ratios did not show significant variations since 1999. It implies that the degassing system in studied area was quite steady in last few years. However, since August 2004, there is not only a progressive increase of HCl concentrations but an increase of SO<sub>2</sub>/H<sub>2</sub>S ratio in fumaroles from Da-You-Keng (DYK), where has the highest helium isotopic ratio been analyzed in this area. The outlet temperature of fumaroles in the TVG is also higher than that in the past, especially in DYK. Both HCl concentration and SO<sub>2</sub>/H<sub>2</sub>S ratio fluctuate with temperature. We propose two possible processes to explain observed phenomenon. One is more magmatic gases were released from recent opened fractures; another is magma ascending. These two processes can cause the similar variations of gas compositions. The present surface temperature of fumaroles in DYK is around 116°C and does not show much rising in last few months so that we consider these variations may be related to the local volcanic activity. Although the GPS monitoring results show that there is a continuous uplifting of ground in this area (Lin, C.H. unpublish data), we need to closely watch the variations of fumaroles and hot springs to check/clarify the possible relationship between the possible local magma activity with other parameters, e.g., seismicity, and flux of fumarolic steams etc.

#### An experimental study to determine the solubility of C-H-O-S volatiles in basaltic melts

Priscille Lesne (lesne@cnrs-orleans.fr), Bruno Scaillet

Institut des Sciences de la Terre d'Orléans, UMR 6113 CNRS - Université d'Orléans, 1A rue de la Férollerie, 45071 Orléans Cedex, France

Arc volcanism is known for his dangerousness, because of his high content of volatiles. Major volatiles present in magmatic liquids are C, H, O, S, forming the major gases emitted by volcanoes: H<sub>2</sub>O, CO<sub>2</sub>, and SO<sub>2</sub> and/or H<sub>2</sub>S, depending on f<sub>O2</sub>. A significant amount of work has been done to define the solubility laws of H<sub>2</sub>O, CO<sub>2</sub> and S in silicic melts. However, such data are still scarce for basaltic liquids. To remedy this gap, we are conducting experiments on basaltic liquids at 1050°C and 1200°C, at pressures varying between 250 and 2000 bar in oxidized (NNO+2) or reduced (NNO-1) conditions, using an IHPV equipped with a system of rapid quench. Basaltic compositions from Vesuvius, Etna and Stromboli are equilibrated with H<sub>2</sub>O, H<sub>2</sub>O+ CO<sub>2</sub>, H<sub>2</sub>O+S and H<sub>2</sub>O+CO<sub>2</sub>+S rich fluid phase. After a rapid quench, H<sub>2</sub>O and CO<sub>2</sub> dissolved in the glasses are analyzed using both KFT and FTIR. Major elements and sulphur contents are determined by electron microprobe analyses. The comparison of our results with studies carried out on MORBs (Dixon et al. 1995) or on other basaltic compositions (Berndt et al., 2002), shows that there is no significant effect of composition on water solubilities under these experimental conditions. In contrast, the CO<sub>2</sub> content of basaltic melts is strongly dependent on its composition, and this dependence increases with pressure (at 2kbar basalt from Vesuvius (7,39% Na<sub>2</sub>O+K<sub>2</sub>O) dissolves 3900 ppm of total carbon whereas a basalt from Etna (5.38% Na<sub>2</sub>O+K<sub>2</sub>O) or from Stromboli (4.20% Na<sub>2</sub>O+K<sub>2</sub>O) dissolves less than 2000 ppm). Microprobe analyses show that, at near H<sub>2</sub>O saturation, sulphur contents increase strongly with pressure (from 2500 ppm at 250 bar, to 6700 ppm at 2000 bar for Etna and Stromboli compositions at NNO+2). Basaltic melts dissolve more S under oxidized conditions than under reduced conditions. First results obtained on basaltic liquids equilibrated with an H<sub>2</sub>O+CO<sub>2</sub>+S rich fluid phase show that the C/S ratio increases strongly with pressure and alkalies content of the melt.

# The high- $\delta^{18}$ O signature of High-Mg andesites: evidence of high- $\delta^{18}$ O subduction fluids or crustal signatures at Mt Shasta, California

Erwan Martin<sup>1</sup> (ermartin@uoregon.edu), Ilya Bindeman<sup>1</sup>, Tim L. Grove<sup>2</sup>, John M. Eiler<sup>3</sup>

<sup>1</sup>Geol Sci, University of Oregon, Eugene, OR, USA <sup>2</sup>MIT, Cambridge, USA

<sup>3</sup>GPS, Caltech, Pasadena, CA, USA

The oxygen isotopic composition of subduction zone fluids has been hypothesized to have high- $\delta^{18}$ O derived from the high- $\delta^{18}$ O upper portions of the slab's top and sediments. We report oxygen isotope analyses of olivine and other phenocrysts from Mt Shasta that appears to have unusually large fluid contributions (ca >8-10wt%). A.T. Anderson (1973, 1974) reported up to 12wt% of water in melt inclusions within orthopyroxene phenocrysts in high-Mg andesites. We correlate  $\delta^{18}$ O value of phenocrysts with reported water concentrations and with published fluid-sensitive trace elements and elemental ratios (e.g. Ba/La, Sr/Y), and we use mass balance approaches to constrain the amount of fluid added. We use Grove et al. 2002 model of flux melting in an attempt to estimate the oxygen isotopic effect of flux melting of initially-depleted hartzburgitic compositions. We also test the alternative and popular hypothesis that high  $\delta^{18}$ O signature is related to the assimilation of the Cretaceous ultramafic Trinity ophiolite complex in the area. Xenocrystic olivine contamination is present in several localities.

Basalts and mantle-derived high-Mg andesites from Mt. Shasta have olivine  $\delta^{18}$ O values ranging from 5.06-5.83‰ only moderately elevated above mantle values. The  $\delta^{18}$ O value of subduction fluids may not be universally high as evidenced by examples from other primitive arc samples worldwide. In some places, where fluid signature is strong, it can also be variable but have  $\delta^{18}$ O not much higher or lower (i.e. ±2-3‰) than the mantle. This result corroborates our recent result that slab-derived melt components also cluster around mantle  $\delta^{18}$ O values. Examples of significant departures from this rule: high  $\delta^{18}$ O olivines in Trans-Mexican volcanic belt and Kamchatka, and low- $\delta^{18}$ O (e.g. Kamchatka, Fisher and Okmok calderas, Aleutians) are explained by crustal contamination. However, in the case of Mt Shasta high  $\delta^{18}$ O fluids could be due to the subduction of the Blanco fracture zone off the coast of California. We explore petrologic possibilities of high fluid, high- $\delta^{18}$ O fluxing of the depleted mantle and the role of adiabatic melting.

## Chemical and morphological characterisations of Mt. Etna aerosols

<u>Robert Martin<sup>1</sup></u> (rsm45@cam.ac.uk), Tamsin Mather<sup>2</sup>, David Pyle<sup>2</sup>, Andrew Allen<sup>3</sup>, Matthew Power<sup>4</sup>, and Edmund Ward<sup>5</sup>

<sup>1</sup>Department of Earth Sciences, University of Cambridge, UK

<sup>2</sup>Department of Earth Sciences, University of Oxford, UK

<sup>3</sup>Department of Public Health, University of Birmingham, UK

<sup>4</sup>Camborne School of Mines, University of Exeter in Cornwall, UK

<sup>5</sup>Department of Materials, University of Cambridge, UK

Previous studies of the aerosols from Mt. Etna have invariably taken three distinct but complimentary approaches: plume photometry, soluble ion plume chemistry and particle microscopy. These techniques are able to offer particle size distributions, particle chemistry and particle morphology but particle-by-particle correlations between these different aspects of the aerosol phase were previously impossible. Recent developments in the understanding of the radiative, chemical and health properties of volcanic aerosols have shown that a unified understanding of the chemical and morphological character of aerosols is vital for assessing the role and impact of these species

In this study, aerosols were sampled from the plume of Mt Etna in 2004-2005 using filter packs and subsequently analysed using the QEMSCAN instrument. The instrument allows the chemical and morphological properties of many hundreds of particles to be retrieved and cross-correlated to determine if chemistry and particle morphology are independent. In addition, size-selective impaction (MOUDI) and filter pack samples were also analysed for soluble ion chemistry and thermophoretic precipitation (TP) samples were analysed for particle size distribution in the 10nm-100nm range.

# Peculiarities of island arc volcanism on different mantle-crust substrata (Pacific and Indian Oceans)

Yury Mironov (mironov@sgm.ru)

Vernadsky State Geological Museum RAS, Moscow, Russia

We have tried to assess an impact of mantle-crust primary heterogeneities on variations in compositions of volcanic complexes along island arcs belts in the Pacific and Indian oceans. The mantle-crust heterogeneities are proved with both geophysical data and according to the ratio isotopes Sr, Nd, and Pb. Modified Zindler-Hart's «mantle tetrahedron» was used for isotope systematization. It is characterized with important role of the component F ("focal") together with conventional end-members (DM, HIMU, EM1, and EM2). It is an average characteristic of well-known intratetrahedron components (FOZO, C, PREMA, and others), improved with multivariate statistic. Three main isotope types of volcanites were detected. These types are divided in space, forming extensive belts of island arcs. The Sumatra-Sunda-Banda belt is characterized with intensive enrichment of melts by continental crust substance (type F+EM2). Volcanites of the inner Western Pacific belt (Kyushu, Ryukyu, Luzon, Halmahera) correspond to the mixture F+ EM1. Ensimatic arcs prevail within the outer belt (Kuriles, Izu-Bonin, Mariana, Tonga-Kermadek). General dispersion of their rock's composition is determined by F and DM. Volcanites of some short segments within this belt, formed on the ancient continental crust (New Zealand, Honshu), are enriched with EM2). Magmas melted from different isotope reservoirs differ systematically from each other both for primary composition and differentiation peculiarities. Primitive basaltic melts from reservoir EM1 (and more from EM2) as a whole are enriched by all high-incoherent elements (La, Ce, Nd, Sm, Eu, Gd, K, Rb, Th, U, Ba, Sr, Cs, Pb, Zr, Hf, Nb, P) in comparison to the melts from reservoirs DM and F. Nevertheless, these distinctions are gradually decreased during magma differentiation. Some elements (Tb, Lu, and Y), which are middle-incoherent in all other cases, begin accumulate rapidly in melts from reservoir F. since andesitic stage of differentiation. The compositions of different isotope types of volcanites cross each other on the main classification diagram SiO<sub>2</sub> vrs Na<sub>2</sub>O+K<sub>2</sub>O within the area of normal alkalinity. Nevertheless, total alkalinity as a whole increases consecutively in the series of reservoirs F+DM – F+EM1 – F+EM2. The most reliable indicators of ensimatic arcs are: 1) presence of low-alkalinity boninite-marianite-dacite-rhyolite complexes, which prevail on the earliest stages of the evolution; 2) weak (mainly basalt-andesite) differentiation of normal alkalinity complexes; 3) virtually total absence of high-alkalinity complexes. Strong differentiated normal-alkalinity and high alkalinity complexes prevail on all stages of evolution in the ensialic arcs. If continental crust substance is involved in magmagenesis alkaline high-potashium complexes can originate together with the named above ones. Hence, the primary heterogeneities of mantle-crust substrata are a very important factor of island arc magmatism, which detects not only peculiarities of compositions and differentiation of melts but some features of the general magmatic evolution. This work is supported by program of RAS Presidium "The World Ocean".

# Evolution, entrap and release of magmas: a case study from the northern part of Harrat Rahat volcanic field, Saudi Arabia

Mohammed Rashad Moufti (mmoufti@kaau.edu.sa), Syed Ali and Mustafa Hashad

Faculty of Earth Sciences, King Abdulaziz University, P.O. Box 80206, Jeddah 21589, Kingdom of Saudi Arabia

About 310 km long, late Cenozoic (< 10 Ma) intraplate Harrat Rahat lava field that developed as a result of plume-related magmatism and northward propagating continental rifting provides a typical example of evolution, entrap and release of magmas. The Quaternary (1.7–Recent) Al-Madinah volcanic field, which forms the northern part of Harrat Rahat near the city of Al-Madinah is characterized by the presence of olivine trasitional basalt (OTB), alkali olivine basalt (AOB), hawaiites and their differentiates: mugearites, benmoreites and trachytes. Petrographic, geochemical and isotopic data suggest that the magmas that ascended rapidly on surface with little residence time appeared as OTB lavas, whereas the trapped magmas after open-system fractionation released as AOB and hawaiite lavas. The late stage release of mugearite, benmoreite, and trachyte lavas in the form of domes indicate the longer residence time and advance fractionation of the trapped magmas in the crustal chambers with little or no magma replenishment.

In most of the early OTB lava flows only olivine was fractionated from magma prior to eruption. In the AOB and hawaiite, olivine+plagioclase and olivine+plagioclase+clinopyroxene were fractionated, respectively, prior to eruptions. Major and trace elements data show the consistency with magma evolution dominated by fractional crystallization of phenocrysts phases with evidence of polybaric processes that occurred in the middle (mantle-crust boundary) and shallow crustal reservoirs. However, crustal contamination probably played a minor role in the evolution of OTB, AOB and hawaiite lavas. Some OTB and AOB lavas displayed near-primary magma compositions, indicated that some portion of the magma did not reside in the crustal chamber en route to the surface.

The OTB, AOB and hawaiite lavas of the Harrat Al-Madinah display chemical signatures of upwelling mantle plume or OIB-type source with strong enrichment in Cs, Rb, Ba, Th, U, K, Nb, Ta and LREE's relative to mid-ocean ridge basalt (MORB) and enriched or E-MORB and a distinct pattern, similar to average OIB-type basalt. The <sup>87</sup>Sr/<sup>86</sup>Sr (0.702985-0.705186), <sup>143</sup>Nd/<sup>144</sup>Nd (0.512922-0.513033), and <sup>206</sup>Pb/<sup>204</sup>Pb (18.623-19.382), <sup>207</sup>Pb/<sup>204</sup>Pb (15.530-15.717) and <sup>208</sup>Pb/<sup>204</sup>Pb (38.362- 38.947) ratios of the AOB and hawaiite rocks are almost identical to those of the OIB-type plume source basalts. They show the isotopic similarity with the Afar plume material exposed at the Gulf of Aden 46°E anomaly and the Manda-Inakir axial range of Afar depression in Djibouti. The highly evolved trachytes of Harrat Al-Madinah with very high <sup>87</sup>Sr/<sup>86</sup>Sr ratios of 0.707472-0.707485 display longer residence time of entrapped magma accompanied with fractionational crystallization, magma mixing and crustal assimilation.

## Continuous thermal monitoring of fumarolic vents at active volcanoes in Nicaragua

<u>Sophie Pearson</u><sup>1</sup> (spearson@mail.usf.edu), Charles Connor<sup>1</sup>, Peter Young<sup>2</sup>, Ward Sanford<sup>3</sup>, Wilfried Strauch<sup>4</sup>

<sup>1</sup>Department of Geology, University of South Florida, 4202 E Fowler Ave, Tampa, Fl, 33620

<sup>2</sup>Center for Research on Environmental Systems and Statistics, Lancaster University, UK

<sup>3</sup>US Geological Survey, Reston, USA

<sup>4</sup>Instituto Nicaraguense de Estudios Territoriales, Managua, Nicaragua

Changes in volcanic activity are often reflected by surface temperature variations. Mass flux causes gases to flow through fractures in a volcanic edifice, transferring heat towards the surface. Changes in temperature at quite distal fumarolic vents can therefore reveal changes in a volcanic system. Dataloggers installed in Nicaragua and Ecuador recorded temperature, atmospheric pressure, electrical self-potential, seismicity and rainfall. At Masaya volcano in Nicaragua, 5°C changes were measured in fumaroles 3.5 km from the active crater, corresponding to an increase in RSAM seismic readings. The activity culminated in lava extrusions three days later. Statistical analysis suggests some changes in temperature, barometric pressure, rainfall) and are therefore interpreted to be due to changes in mass flow from the volcano. Finite element modeling allows these temperature variations to be extended laterally and vertically and can be used to assess pressure changes at depth. These pressure changes give an indirect measure of mass flow within the system. This relatively cheap equipment therefore shows good potential to reveal changes in volcanic activity prior to any manifestations within the crater.

#### Mechanisms and time scales of crustal assimilation: a review

David W. Peate (david-peate@uiowa.edu), Ingrid Ukstins Peate, and Jay Thompson

Department of Geoscience, The University of Iowa, 121 Trowbridge Hall, Iowa City, IA 52242, USA.

In this presentation, we will review some of the recent progress that has been made in understanding the nature of crustal assimilation, and outline some approaches that our group are taking to provide some fresh insights into the mechanisms and time scales of assimilation processes. Key advances in recent years have included the development of more sophisticated and realistic quantitative compositional models that include energy conservation and/or kinetics of mineral dissolution (e.g. [1-3]), and crystal forensics – the interpretation of mineral-scale elemental and isotopic data (e.g. [4] and references therein). High-precision Pb isotope data also show great potential (better than Sr or Nd) in constraining assimilant compositions as any assimilation binary mixing process will lead to linear trends on Pb-Pb isotope plots.

Our philosophy is to focus on the simplest magmatic systems - monogenetic eruptions - and select young examples (suitable for U-series disequilibria studies) that show compositional variations consistent with assimilation and that contain partially-melted crustal xenoliths (potentially representative of the assimilant). For example, the 660 BP Ice Springs flow (SW Utah) is a primitive lava (c. 8 wt% MgO), and samples from one of the flow lobes show elevated SiO<sub>2</sub> (51% vs. 49%) and K/Ti (1.3 vs. 0.8) relative to the other samples, indicative of crustal assimilation. Intact partially-melted crustal xenoliths are only found in the low-Si flow lobes, which is consistent with the suggestion of Dungan [5] that assimilation can be a rapid process, such that complete digestion of crustal xenoliths during the early stages of the eruption could have generated the contaminated 'high-Si' samples, without requiring a zoned magma chamber. The potential of olivine-hosted melt inclusions to provide a window into the early stage of crustal assimilation has been demonstrated by Kent et al. [6], and we will present preliminary results from olivine-hosted melt inclusions in the Ice Springs flow. While the interpretation of major element data in melt inclusions is complicated by the effects of post-entrapment equilibration issues, ratios of incompatible elements (e.g. K/Ti, Ba/Nb) should be minimally affected and can be used to assess the extent and type of assimilant involved. Variations in inclusion composition relative to the host Fo content and bulk rocks should allow us to investigate the predicted association of high rates of assimilation linked specifically to crystallisation of olivine [e.g. 1, 6].

- [1] Reiners et al., 1995. Geology, 23, 563-566.
- [2] Edwards & Russell, 1998. Geology, 26, 1103-1106.
- [3] Spera & Bohrson, 2001. Journal of Petrology, 42, 999-1018.
- [4] Davidson et al. 2005. Journal of Volcanology & Geothermal Res., 140, 157-170.
- [5] Dungan 2005. Journal of Volcanology & Geothermal Research, 140, 193-203.
- [6] Kent et al. 2002. Earth & Planetary Science Letters, 202, 577-594.

# Products of Lamongan volcano (Java, Indonesia): indication of gradational magmatic changes from continental to subduction-related system

Bambang Priadi<sup>1</sup> (bpriadi@gc.itb.ac.id), Jhonny<sup>1</sup> and Rosgandika Mulyana<sup>2</sup>

<sup>1</sup>Department of Geology, Institut Teknologi Bandung, Bandung, Indonesia <sup>2</sup>Volcanological Survey of Indonesia, Bandung, Indonesia

Lamongan Volcano is a small volcano situated between Bromo-Tengger and Iyang volcanic ranges in East Java (Indonesia), recently is part of an island arc setting. This volcano is supposed to be Plio-Pleistocene in age and it is characterized by the occurrence of maar-lakes in its surroundings.

Petrographic and geochemical (of major and trace elements) study on data from this volcano indicate lithology of basalt, basanite, basaltic-andesite, trachv-andesite, absarokite, and shoshonite having magmatic affinity in transition from alkaline to calc-alkaline. Based on MgO and TiO2 contents, volcanic products can be subdivided into 4 volcanic groups. Group-I (TiO2>1.3%; MgO>6%) and Group-II (TiO2>1.3%; MgO<6%) indicate gradational modification in chemical compositions from continental to subduction systems. Variations on Ba vs K/Rb contents indicate the contribution of lower crust in forming magma of Group-I. This process tends be influenced by continental magmatic system. These volcanic groups are also characterized by the presence of silicate undersaturated rocks (basanite and trachy-andesite) as well as petrographic textures representing the magma mixing process. Group-3 (TiO2<1.3%: MgO>6%) and Group-4 (TiO2<1.3%: MgO<6%) indicate characters of subduction related magmatism with variations in Mg contents.

Lacking of age data in volcanic products of Lamongan Volcano lead to the interpretation volcanic succession as follows : Magmatism of continental type was formed in the area and resulting magma chambers filled with magma of continental characters. The area then was affected by subduction activity producing magmas of subduction characters. As the latters were introduced to already formed magma chambers they might cause mixing of two kinds of magmas, and the volcanic products would present a gradation of mixing represented by Volcanic Group-1 and 2. As subduction continues the following magma characters tend to be more of subduction related system (Volcanic Group-3 and 4) rather than the continental system.

In point of view of the East Java geodynamic system, basement of Lamongan Volcano may represent micro-continent coming from somewhere in southeast of Sundaland and a has already had volcanism of continental character. As the micro-continent approached and embedded in Sundaland, it was then affected by north trending subduction to give 4 groups of volcanic products.

## Degassing fluxes from subduction zone volcanoes

David M. Pyle<sup>1</sup>, Tamsin Mather<sup>1</sup>, Melanie Witt<sup>1</sup> and Genevieve Millard<sup>2</sup>.

<sup>1</sup>University of Oxford, Department of Earth Sciences, Parks Rd, Oxford, OX1 3PR UK <sup>2</sup>University of Cambridge, Department of Earth Sciences, Downing Street, Cambridge, CB2 3EQ

One outstanding challenge which remains in subduction zone studies is understanding the partitioning of material fluxes between subsurface and surface volcanism. Here we critically review what is, and what is not, known about the fluxes of volatile elements and magmas returned to the crust and atmosphere in arc volcanism; and speculate on the links between the magma supply at depth and the escape of the fugitive constituents at the surface.

In active subduction zones, the output of volcanic gases must reflect the integrated effects of exsolution and gas loss from cooling and decompressing magmas throughout the crust, modified by interactions on the way to the surface. The relative inertness of some tracers (e.g. He), and ease of measurement of others (SO<sub>2</sub>) makes this a relatively tractable problem, at least in principal, and there have been a number of valiant attempts to solve arc-scale to global-scale volcanic emissions budgets on this basis. Such work is, however, severely constrained by questions of the relationship between sparse sampling and variable fluxes; and by the limitations of the materials available to be sampled. Some measurement techniques (e.g. for He) have only ever been made on fumaroles, sampled so that contamination from external air is excluded. While the ratios between conservative species in such fumaroles may shed light on the compositions of deeper magmatic fluids, it is far from obvious that it is wise to scale up to estimate global emissions of trace gas species from such measurements. Additionally, not all active volcanoes have appropriate high-temperature fumaroles. With the development of portable ground-based remote-sensing instruments, and the application of direct sampling techniques to measure gas and aerosol emissions from high temperature, open-vent systems, it is now possible to develop arc-scale budgets for the high-temperature release of reactive volcanogenic trace gases; and thereby to constrain at least to some extent the quantities of subterranean magmas releasing gases at that moment. Such studies also allow an assessment of the relative balance between subduction-fluxes of volatile species, and their eruptive fluxes - a question which remains very poorly constrained, at least for the most significant species (e.g. S and the halogens).

Our recent re-evaluation of the degassing fluxes from the Central American arc illustrates many of the questions which remain to be solved: while the eruptive and degassing flux of Cl may be approximately in balance with the subduction flux of Cl, the current subduction flux for C is substantially in excess of that returned by degassing volcanoes; and the budgets for S and H are essentially unconstrained, due to our incomplete knowledge of what goes in (S), or comes out (H).

#### VolcanoGasML: A format to exchange geochemical volcanic gases data

Eric Reiter (ereiter@free.fr).

2, rue des abeilles, F-57440 Algrange, France

Chemical analyses of volcanic gases consist of: location of sampling, date of sampling, identification of the sampling, physical and/or chemical data. Nowadays, these data are generally represented in different formats. All of them are inflexible and machine dependent.

XML is a markup language for documents. A markup language is a mechanism to identify structures in a document. XML becomes the most important method of transferring data between computers. VolcanoGasML is a new format, based on XML, for the chemical analyses of volcanic gases. Its definition is divided into several layers: the first one describes the general information concerning the sample, the second, which is organized in several sublayers, contains the chemical data. . In recent years, the World Wide Web Consortium (W3C) has developed numerous standards and recommendations for data representation and handling. They reflect the increasingly recognized needs for easy and flexible data exchange. Basically, XML is the center point of these technologies. It is not only a meta-language to describe object-oriented data representation designed for the use in the Internet. It is more: XML is probably the most flexible data representation.

The VolcanoGasML definition, described in the XSD schema language, is divided into several layers:

• Layer 1 describes the general information concerning the sample: the volcano name, the country where the volcano is located and/or geographical coordinates of the volcano (necessary when two volcanoes around the world have the same name), the identification number of the sample, the date when the sample was taken, a location for the sample (e.g. northern part of the crater rim), a GPS location, the sampling method. Two of these data are required: the volcano name and the identification number. The rest is optional.

• Layer 2 describes the chemical data. It is organized in several sub-layers:

- General information such as temperature and pH.
- Chemical content which is subdivided into two other sub-layers:
  - Major species according to quantity such as H<sub>2</sub>O, CO<sub>2</sub>, HCl, SO<sub>2</sub>, etc.
  - Trace species for the minor elements such as He, Ar, NH<sub>3</sub>, PH<sub>3</sub>.
- Isotopic analyses
- Ratios for some calculated ratios, e.g. Gas/Steam

All the information for this layer is optional.

The advantages of XML and VolcanoGasML are:

• Missing data in catalogs of historic geochemistry causes problems when using fixed-column formats. In VolcanoGasML, any information except the volcano's name and the sample's identification is optional and can be extended by error information of any length and precision

• Any XML definition can be extended in two ways, either by including additional user specific fields (tags) or by including itself into another XML definition. VolcanoGasML files can be included in any given XML file or can reference pictures which could be easily inserted in a target format.

# Volatile History in the Ongoing Mount St. Helens Eruption as Recorded by Amphibole and Feldspar Phenocrysts

Michael C. Rowe<sup>1,2</sup> (rowem@mail.utexas.edu), Adam J.R. Kent<sup>2</sup>, Carl R. Thornber<sup>3</sup>

<sup>1</sup>University of Texas at Austin, Department of Geological Sciences, 1 University Station C1100, Austin, TX 78712

<sup>2</sup>Oregon State University, Department of Geosciences, Corvallis, OR 97331

<sup>3</sup>U.S. Geological Survey, Cascade Volcano Observatory, Vancouver WA 98683

Amphibole and feldspar phenocrysts from Mount St. Helens, erupted between October 2004 and December 2005, record systematic variations in lithium and copper concentrations despite a large variation of major- and trace-element concentrations in these phases during the same time interval. Li and Cu are of interest in that both elements will strongly partition into a fluid/vapor phase at low pressures, and as such, have the potential for tracking volatile migration within shallow magmatic systems.

Prior studies have identified a lithium enrichment in feldspar phenocrysts in erupted dacite at the initiation of both the 1980-86 and 2004 eruptions of Mount St. Helens ([1,2]). This enrichment has been interpreted as recording a flux of volatiles derived from deeper in the magmatic system to shallowly stored magma. In contrast to the enrichment in feldspars, amphibole phenocrysts record relatively low initial Li and Cu concentrations, increasing by over an order of magnitude (up to 1139  $\mu$ g/g and 94  $\mu$ g/g, respectively) as the eruption has progressed (Fig. 1). Li<sub>amphibole</sub>/Li<sub>feldspar</sub> ranges from 1 to 50, despite similar mineral/melt



## Figure 1: Li variations in amphibole and feldspar from 2004-2005 Mount St. Helens dacite.

partition coefficients. The opposing trends in Li concentration in coexisting feldspar and amphibole grains cannot result from a single volatile enrichment event and are likely recording multiple processes. Several models to explain trends in Li and Cu, accounting for

multiple variables including timing of crystallization and/or diffusion, eruption rates, and volatile fluxing, are potentially feasible. However, all models are dependent on diffusion rates and partitioning of Li and Cu in amphibole.

1 K. Berlo, J. Blundy, S. Turner, K. Cashman, C. Hawkesworth, and S. Black, Geochemical precursors to volcanic activity at Mount St. Helens, USA, Science, 306, 1167-1169, 2004.

2 A.J.R. Kent, J. Blundy, K. Cashman, K.M. Cooper, C. Donnelly, J.S. Pallister, M. Reagan, M.C. Rowe, and C.R. Thornber, Vapor transport prior to the October 2004 eruption of Mount St. Helens, Washington: Insight from Li and <sup>210</sup>Pb systematics, Geology, *in press*.

#### Volcanic gases and their effects

#### Oybek Rustamov (oybeck1984@mail.ru)

#### Gulistan State University, Uzbekistan

Volcanic gases undergo a tremendous increase in volume when magma rises to the Earth's surface and erupts. Volcanic eruptions can enhance all three of these the ozone, greenhouse, and haze effects variable degrees. They contribute to ozone depletion, as well as to both cooling and warming of the earth's atmosphere. Influence on the ozone effect: the halide acid HCl has been shown to be effective in destroying ozone; however, the latest studies show that most volcanic HCl is confined to the troposphere. Thus, it never has the opportunity to react with ozone and it appears that volcanic eruptions can play a significant role in reducing ozone levels. However, it is an *indirect* role, which cannot be directly attributed to volcanic HCl. Eruption-generated particles, or aerosols, appear to provide surfaces upon which chemical reactions take place. The particles themselves do not contribute to ozone destruction, but they interact with chlorine- and bromine-bearing compounds from human-made CFCs. Fortunately, volcanic particles will settle out of the stratosphere in two or three years, so that the effects of volcanic eruptions on ozone depletion are short lived. Influence on the greenhouse effect: Volcanic eruptions can enhance global warming by adding  $CO_2$  to the atmosphere. However, a far greater amount of  $CO_2$  is contributed to the atmosphere by human activities each year than by volcanic eruptions. Volcanoes contribute about 110 million tons/year, whereas other sources contribute about 10 billion tons/year. The small amount of global warming caused by eruption-generated greenhouse gases is offset by the far greater amount of global cooling caused by eruption-generated particles in the stratosphere. Influence on the haze effect: Volcanic eruptions enhance the haze effect to a greater extent than the greenhouse effect, and thus they can lower mean global temperatures. It was thought for many years that the greatest volcanic contribution of the haze effect was from the suspended ash particles in the upper atmosphere that would block out solar radiation.

## Gas emissions from Nyiragongo volcano, D.R. Congo

Georgina Sawyer<sup>1</sup> (gms26@cam.ac.uk), Simon Carn<sup>2</sup>, Clive Oppenheimer<sup>1</sup>, Vitchko Tsanev<sup>1</sup>

<sup>1</sup>Department of Geography, University of Cambridge, Downing Place, Cambridge, CB2 3EN, UK

<sup>2</sup>Joint Center for Earth Systems Technology, University of Maryland Baltimore County, Baltimore, MD, USA

Nyiragongo volcano (Democratic Republic of Congo; alt. 3500 m), located 18 km north of the city of Goma (pop. 500,000), is currently considered among the world's largest point sources of pollutants to the atmosphere. Since mid-2002, substantial volumes of toxic gas and aerosol have been emitted as a result of persistent degassing from a lava lake contained within the summit crater, with significant short- and long-term implications for human health, water quality and crop production in the region.

We report the composition and flux of gas from Nyiragongo volcano during May 2005 and January 2006, obtained using ground-based remote sensing techniques. Scattered zenith solar light DOAS measurements performed in May 2005 indicate average SO<sub>2</sub> emission rates of 38.5 kg s<sup>-1</sup> whilst those collected in January 2006 suggest a reduced flux of 22.6 kg s<sup>-1</sup>. In combination with open-path Fourier transform infrared spectroscopic measurements, recorded during the same periods, from the summit of Nyiragongo, we calculate H<sub>2</sub>O, CO<sub>2</sub>, CO, HCl, HF and OCS fluxes of 171, 131, 3.2, 1.3, 0.3 and 0.01 kg s<sup>-1</sup> respectively in 2005 and H<sub>2</sub>O, CO<sub>2</sub>, CO, HCl and OCS fluxes of 96, 86, 2.0, 0.8 and 0.006 kg s<sup>-1</sup> in 2006 (column amounts of HF were below detection limits during this period). It is hoped that these measurements will assist in the future evaluation and mitigation of risks associated with living in close proximity to the volcano.

#### Mafic dyke swarms of the Deccan Traps: Key to magma transport and stratigraphic development

Hetu Sheth (hcsheth@iitb.ac.in)

Department of Earth Sciences, Indian Institute of Technology (IIT) Bombay, Powai, Mumbai 400 076 India

Continental flood basalts (CFBs) exhibit dense mafic dyke swarms, many of which arguably represent the feeder dykes. The ~65-million-year-old Deccan CFB of India (with a present-day area of 500,000 km<sup>2</sup>) is best developed in the Western Ghats (Sahyadri) region, where it is almost flat-lying with a stratigraphic thickness of 3 km. The province has three major dyke swarms: (1) The Narmada-Satpura-Tapi swarm, in the north-central Deccan, with a ENE-WSW strike, (2) the Konkan swarm, on the coastal plain, with a NNW-SSE strike, and (3) the Western Ghats swarm northeast of Mumbai, without as strong a preferred orientation as the other two [1]. The longest single, en echelon dyke encountered so far is 79 km long, in the Tapi swarm [2]. Which dykes fed the huge Deccan lava flows? This question can be answered with detailed field, petrographic, geochemical (major and trace element and isotopic) and palaeomagnetic studies of individual dyke swarms in the province, followed by statistical comparisons of the geochemical data to well-characterized lava packages. Once the most probable feeder dykes of a particular lava sequence are thus identified, bounds can be placed on the distances of magma transport, whether in the crust, or after eruption on the surface. Dykes are thus important to understand magma transport in CFBs and also their progressive stratigraphic development. Here, I will be summarizing recent and ongoing geological and geochemical-isotopic studies of the Deccan dyke swarms [1-3]. A substantial (1000 km<sup>3</sup> or larger) lava flow could have formed at low, Kilauea-like eruption rates of 1 m<sup>3</sup>/sec per metre length of fissure, from a 50-km-long dyke with consecutively active 5-km-long segments, in only about 7 years [2,4]. Focussed field, petrographic and geochemical (element and isotopic) studies of Deccan dyke swarms have the potential to answer many long-standing questions about the volcanological, stratigraphic, structural-tectonic and geochemical evolution of the Deccan province and similar CFBs elsewhere.

- N. R. Bondre, W. K. Hart, H. C. Sheth, Geology and geochemistry of the Sangamner mafic dyke swarm, western Deccan volcanic province, India: Implications for regional stratigraphy. J. Geol. 114 (2006) 155-170.
- [2] R. Ray, H. C. Sheth, J. Mallik, Structure and emplacement of the Nandurbar-Dhule mafic dyke swarm, Deccan Traps, and the tectonomagmatic evolution of flood basalts. Bull. Volcanol. 69 (2007) 537-551.
- [3] L. Vanderkluysen, J. J. Mahoney, P. R. Hooper, H. C. Sheth, Location and geometry of the Deccan Traps feeder system inferred from dyke geochemistry. Eos Trans. AGU, 87(52), Fall Meet. Suppl., Abstract V13B-0681
- [4] H. C. Sheth, The emplacement of pahoehoe lavas on Kilauea and in the Deccan Traps. J. Earth Syst. Sci. 115 (2006) 615-629.

# Recycling of atmospheric argon concurrent with pore water subduction in the Izu-Ogasawara arc

<u>Aya Shimizu</u><sup>1</sup> (aya@eqchem.s.u-tokyo.ac.jp), Hirochika Sumino<sup>1</sup>, Keisuke Nagao<sup>1</sup>, Kenji Notsu<sup>1</sup>, Naoto Hirano<sup>2</sup>, Shiki Machida<sup>3</sup> and Teruaki Ishii<sup>3</sup>

<sup>1</sup>Laboratory for Earthquake Chemistry, Graduate School of Science, University of Tokyo <sup>2</sup>IGPP, Scripps Institution of Oceanography, University of California

<sup>3</sup>Ocean Research Institute, University of Tokyo

The Izu-Ogasawara arc is located at an intra-oceanic convergent margin between the Pacific and Philippine Sea plates. This arc is suitable to investigate the origin of fluid, which is released from the subducting materials and plays an important role in arc magma generation. This is because we can neglect the contribution of the continental crustal component in arc magma genesis. How noble gases subduct and are recycled to Earth's surface via arc volcanism is an important issue in the understanding of the behavior of fluids in the subduction system. Here we report the recycling of volatiles concurrent with the subduction process, based on the behavior of the different noble gas species.

We measured noble gas isotopic composition of subducting sediments, basalts and gabbros as input materials, serpentine in the Izu-Ogasawara forearc as a mantle wedge material, and volcanic products in the northern part of the Izu-Ogasawara arc as output materials. The volcanic products show  ${}^{3}\text{He}/{}^{4}\text{He}$  ratios of ca. 8 R<sub>A</sub> (R<sub>A</sub> denotes the atmospheric  ${}^{3}\text{He}/{}^{4}\text{He}$  ratio of  $1.4 \times 10^{-6}$ ), which are in the range of the MORB value (8 ± 1 R<sub>A</sub>). The  ${}^{40}\text{Ar}/{}^{36}\text{Ar}$  ratios of these samples range from 300 to 620, which are significantly lower than that of the MORB source (up to 40000). The  ${}^{40}\text{Ar}/{}^{36}\text{Ar}$  ratios of input materials range from 360 to 1000, some of which are higher than those of the volcanic products. These observations revealed that subducted pore water dissolving atmospheric argon ( ${}^{40}\text{Ar}/{}^{36}\text{Ar} = 296$ ), rather than the subducted sediments or basalts, affects the isotope signature of noble gases in arc magma. The serpentine, which is formed by the hydration of wedge mantle peridotite with pore water, may play an important role to transport sea water components in pores and fractures of sediment and/or crust to the mantle beneath the volcanic arc. However, the possibility of direct transportation of pore water to deeper place cannot be excluded.

A simple mass balance calculation of argon isotopes revealed that at least 7% of the subducting atmospheric argon-bearing pore water in the slab is recycled back to Earth's surface through arc volcanism. This suggests that subducting atmospheric argon is effectively introduced into the mantle wedge at least beneath the volcanic arc accompanying the subducting slab.

# Continuous Degassing Caused by Magma Convection in a Conduit: Constraints and Consequences

## Hiroshi Shinohara (shinohara-h@aist.go.jp)

Geological Survey of Japan, AIST, Central 7, Higashi 1-1-1, Tsukuba 305-8567, Ibaraki, Japan

Non-erupting continuous degassing, such as at Etna, Stromboli, Masaya, Sakurajima, Miyakejima etc, discharges huge amount of volcanic gases, whose global sum is more than half of the global volcanic gases discharged from subaerial volcanoes. The large volcanic gas discharge rate implies degassing of a large volume magma; e.g., 2000 t/d SO<sub>2</sub> discharge requires degassing of ~0.1 km<sup>3</sup>/y basaltic magma or ~0.5 km<sup>3</sup> of andesitic magma, that corresponds to VEI=4 eruption once a year. This comparison indicates that the continuous degassing is the major magmatic process on the Earth.

The continuous degassing occurs at many volcanoes with various situation, magma type and activities, but has common features of large gas discharge rate (>300 t/d SO<sub>2</sub>), long-term and continuous activity and magma head at near surface. The plume measurements indicate that the volcanic gases discharged by the continuous degassing has H<sub>2</sub>O-rich composition similar with high-temperature fumarolic gases. Comparison of the volatile composition of melt inclusions, matrix glasses and the plume also indicates that the degassing occurs at near surface pressure. These constraints require that the volatiles need to be transported from a large magma chamber to top of a magma column together with magma and degassed at the low pressure, implying magma convection through a volcanic conduit.

The magma convection in a conduit is driven by degassing, because the degassed magma has larger density than undegassed magma. The degassed magma will sink through the less-dense undegassed magma back to the deep magma chamber, and the convection can continuously supply the undegassed magma as long as the magma column is stable and the magma chamber will not be completely degassed. Since the magma loses eruptive potential by the degassing, the continuous degassing process can be regarded as a formation process of plutonic magma body, implying that the degassing induced magma convection is also a controlling mechanism of intrusive/extrusive ratio of the magma in the crust.

Vulcanian and strombolian eruptions are commonly associated with the continuous degassing activity, and the amounts of gases discharged by these eruptions are small compared with the rate of the continuous degassing. Therefore, these eruptions should be regarded as the processes occurring during the continuous magma convection, and observations or eruption mechanisms of these eruptions need to be interpreted considering the dynamic convecting magma column as the background condition rather than a static magma column, as commonly assumed. Although earthquakes and crustal deformation are the common indication of magma movement in the shallow crust, the continuous degassing associated with the rapid magma movement in the volcanic conduit does not causes significant volcano tectonic earthquakes and deformation with shallow sources.

# From Source to surface: U-series constraints on the processes and timescales of magma generation, evolution and degassing

Kenneth W. W. Sims<sup>1</sup> (ksims@whoi.edu) and Pierre-Jean Gauthier<sup>2</sup>

<sup>1</sup>Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA, 02543 USA

<sup>2</sup>Laboratoire Magmas et Volcans, OPGC - Univ. Bl. Pascal - CNRS (UMR 6524), 5, rue Kessler, 63038 Clermont-Ferrand Cedex, France

Measurement of U- and Th- decay series isotopes in volcanic lavas and gases can place important constraints on the timescales of both deep and shallow magmatic processes.

The longer-lived daughter isotopes <sup>230</sup>Th and <sup>226</sup>Ra of the <sup>238</sup>U -decay series, and <sup>231</sup>Pa of the <sup>235</sup>U -decay series have half-lives which bracket the time-scales over which melting and melt extraction are thought to occur (75.4 Kyr, 1.6 Kyr, and 32.8 Kyr respectively). Because their half-lives are appropriate, and there are large differences in their solid/liquid partitioning, departures from ( $^{230}$ Th/ $^{238}$ U), ( $^{226}$ Ra/ $^{230}$ Th) and ( $^{231}$ Pa/ $^{235}$ U) equilibrium provide unique information on the depth and extent of melting, the velocity of the upwelling (solid) mantle, the rate of melting, the melt velocity, the dispersivity associated with melt migration.

In contrast, most of the other U– and Th– decay series isotopes have much shorter half-lives, many of which are comparable to the timescales of shallow magmatic processes (e.g.  $^{222}$ Rn- 3.85 days;  $^{210}$ Pb-22.1 yrs;  $^{210}$ Po-138 days;  $^{228}$ Ra- 5.77 yrs;  $^{227}$ Ac-22 yrs). Many of these short-lived daughter isotopes also have starkly contrasting gas/liquid partition coefficients. Because of their much shorter half-lives and degassing characteristics, measurement of disequilibria among these shorter-lived systems {e.g. ( $^{210}$ Pb/ $^{226}$ Ra), ( $^{210}$ Po/ $^{210}$ Pb), ( $^{227}$ Ac/ $^{231}$ Pa), ( $^{228}$ Ra/ $^{232}$ Th)} provide unique information on magma storage and differentiation times, and magma recharge and magma degassing rates.

In this talk we present an overview of the application of U– and Th– series disequilibria for estimating the timescales of deep and shallow magmatic processes. Constraints from both longer-lived disequilibria {e.g.  $(^{230}\text{Th}/^{238}\text{U})$ ;  $(^{226}\text{Ra}/^{230}\text{Th})$ ;  $(^{231}\text{Pa}/^{235}\text{U})$ } and shorter-lived disequilibria {e.g.  $(^{210}\text{Pb}/^{226}\text{Ra})$ ;  $(^{227}\text{Ac}/^{231}\text{Pa})$ ;  $(^{228}\text{Ra}/^{232}\text{Th})$ } will be discussed. We also present new  $(^{222}\text{Rn}/^{210}\text{Pb})$  data in volcanic aerosols from Masaya volcano and discuss its implications for previous models of magma degassing rates.

### Sniffing for Clues to the Dinosaurs Demise: Measurement of Osmium Isotopes Composition and Platinum Group Element Abundances in Volcanic Emissions

<u>Kenneth W. W. Sims</u><sup>1</sup> (ksims@whoi.edu), Bernhard Peucker-Ehrenbrink<sup>2</sup>, Tamsin Mather<sup>3</sup>, Dave Pyle<sup>3</sup>, Robert S Martin<sup>3</sup>, Robert Pierre-Jean Gauthier<sup>4</sup>, Alessandro Aiuppa<sup>5</sup>.

<sup>1</sup>Dept of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole MA, USA

<sup>2</sup>Dept of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole MA, USA

<sup>3</sup>Dept of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, UK

<sup>4</sup>Laboratoire Magmas et Volcans, OPGC - Univ. Bl. Pascal - CNRS, Clermont-Ferrand Cedex, France

<sup>5</sup>Dip. CFTA, Via archirafi 3690123 PALERMO

Platinum Group Elements (PGE: Os, Ir, Rh, Ru, Pt, Pd) and osmium isotopes measured in marine and terrestrial sediment, snow and ice records are important paleo-tracers of riverine, hydrothermal, extraterrestrial, volcanic and anthropogenic inputs into the global surficial environment. For instance, the marine Os isotope record across the Cretaceous-Tertiary Boundary (KTB) indicates that the onset of the main phase of Deccan volcanism and the transient late Maastrichtian warming preceded the large extraterrestrial impact and the related KTB mass extinction by several hundred thousand years [Ravizza and Peucker-Ehrenbrink, 2003]. Distinguishing extraterrestrial from volcanic PGE sources has been difficult due to the similarity in Os isotopic compositions, complex PGE fractionations, and our lack of knowledge of the Os isotopic composition and PGE abundances in volcanic aerosols. These difficulties have fueled vigorous debate about extraterrestrial vs. volcanic triggers of mass extinctions in the geologic record.

To assess volcanic contribution to the global Re-Os-PGE cycle we have initiated a study to measure Os isotopic compositions and PGE abundances in volcanic emissions from volcanoes around the globe. Here we report preliminary data on PGE abundances and Os isotopes measured in gas and aerosol filter samples from Vulcan Masaya, Nicaragua and Mt Etna, Italy. Samples were analyzed by ID-ICPMS at WHOI. Osmium isotope compositions of the filters are unradiogenic ( $0.1272\pm0.0011$  to  $0.187\pm0.009$ ,  $2\sigma$ ). Osmium concentrations range from 28 to 97 pg/m<sup>3</sup>. Normalized PGE abundance patterns are fractionated relative to carbonaceous chondrites and two important features distinguish these patterns from other important PGE sources: 1) the Os/Ir is much higher than that of the continental crust, the mantle and extraterrestrial matter; and 2) the Pt/Pd is much lower than that of the continental crust, mantle, extraterrestrial matter and catalytic converters.

If these PGE patterns from Masaya and Etna are typical of volcanic emissions worldwide they indicate that volcanic emission PGE patterns are distinct from integrated KTB patterns [Tredoux et al. 1989; Evans et al., 1993] and that a volcanic source is not the cause of the elevated PGE abundances across the KTB. The PGE pattern of volcanic emmisions is also different from catalytic converters enabling us to distinguish between volcanic sources and contamination from catalytic converters in places such as the Greenland Ice sheet [Barbante et al., 2001].

While these data have important implications for understanding the contribution of volcanic emissions to the global Re-Os-PGE cycles they need to be augmented with further analyses from other volcanoes. It will also be critical to establish the extent to which PGE are being carried in volcanic emissions as aerosols, or as gaseous species, and to assess PGE fractionation during atmospheric transport.

## Quaternary Volcanisms of Taiwan

## Sheng-Rong Song (srsong@ntu.edu.tw)

Department of Geosciences, National Taiwan University, P.O. Box, 13-318, Taipei 106, Taiwan

Based on the tectonic frameworks, the distributions of volcanic rock in Taiwan can be distinguished into three volcanic provinces. They are the West, East and North volcanic provinces. The West, distributed in the western Foothills and Penghu Islands, was the intra-plate basalts which the eruptions were older than 8.5 Ma. The East, predominantly distributed in the east Coastal Range and offshore islands, the Lanshu and Lutao, was produced by the oceanic arc volcanism which the South China Sea plate was subducted into the Philippine Sea plate. Their activities ranged from 29.3 Ma to 0.02 Ma. The North, occurred in the northern Taiwan and the Kueishantau, was the products of arc volcanism of the Philippine Sea plate being subducted beneath the Asian continental margin. Most of the volcanic activities occurred in late Quaternary. Summarizing the published dating data, therefore, the Quaternary volcanism in Taiwan was predominantly distributed in the North volcanic province with partly in the East one.

Volcanoes in the North volcanic province consist of the Tatun and Keelung Volcano Groups, the Kuanyinshan and Tsaolinshan volcanoes, and five offshore islets, the Chilungtao, Huapinghsu, Mienhuahsu, Penghiahsu and Kueishantau. All of those volcanoes erupted in late Quaternary and are predominantly composed of andesitic rocks. Among them the Tatun Volcano Group (TVG) is the biggest and spans a longer duration. Two periods of volcanism can be distinguished in the TVG, 2.5~2.8 Ma and 1.5~0.2 Ma, respectively. Although the dated last eruption may be older than 0.2 Ma and was considered as an extinct volcano, the fumaroles and hot springs are still very active. Meanwhile, the micro-tremors or earthquakes related to the fluids or magmas and high <sup>3</sup>He/<sup>4</sup>He ratio can also be detected frequently. The TVG, therefore, should be considered as an active volcano on the basis of phenomenological definition. The Kueishantau can also be considered as another active volcano in Taiwan based on the empirical and phenomenological definitions. Evolving from the low-Mg to High-Mg andesites was recognized in the volcanic sequences from the field outcrops and drilling cores of the Kueishantau volcano infers that the volcanism of tectonic setting changed from the arc to rifting.

# Major and trace element and Sr-Nd-He isotope signature of the mantle beneath Central Lau Basin

Liyan Tian (11tian@ucsd.edu), Paterno R. Castillo, David R. Hilton and James W. Hawkins

Scripps Institution of Oceanography, Geosciences Research Divison, University of California at San Diego, La Jolla, CA, 92093, USA

A major question concerning back-arc magmatism is how material released from the adjacent subduction zone affects the composition of the mantle source for back-arc basin magmas. It is widely accepted that extension-related melting within a back-arc results from the same basic processes responsible for the production of mid-ocean ridge basalts, but with the involvement of components from the subducted slab. The Central Lau Basin in the southwest Pacific is an ideal place to investigate the role of added subduction components to the mantle source of back-arc basin magmas. In the Lau Basin, the active spreading centers are at varied distances from the active volcanic arc and trench, e.g., the Eastern Lau Spreading Center (ELSC) lies closer to the Tonga arc than does the Central Lau Spreading Center (CLSC).

We have analyzed basalts from both CLSC and ELSC for major elements, trace elements including B, LILE, REE, and HFSE, major volatiles (such as CO<sub>2</sub>), and isotopes of Sr, Nd and He. Our objective is to determine (1) the presence and nature of subduction components in the Central Lau Basin lavas, and (2) compositional differences between CLSC and ELSC lavas to quantify the varied amounts of subduction components in mantle sources as a function of distance from the arc. Basaltic lavas from both CLSC and ELSC are mainly tholeiitic, and generally similar to MORB. Their trace element contents are also broadly similar to those of normal-MORB; <sup>3</sup>He/<sup>4</sup>He ratios are consistent with a depleted mantle source like that for MORB. In detail, however, both the CLSC and ELSC lavas have higher ratios of fluid mobile/fluid immobile elements such as Ba/Th, Ba/Nb, Ba/Zr, and Pb/Ce than average normal-MORB. The Lau Basin lavas also have higher B and CO<sub>2</sub> contents. Our data suggest that the mantle beneath Central Lau Basin was modified by slab-derived components. Moreover, compared to CLSC lavas, ELSC lavas have lower Na<sub>2</sub>O but higher Si<sub>2</sub>O at a given MgO. The latter also show slightly more depleted HFSE and greater enrichment in fluid mobile elements and thus higher Ba/Th, B/Nb, B/Zr, etc. than the former. Thus, with increasing distance rearward from the arc. the subduction components in the mantle source of Lau Basin lavas diminish. The high <sup>87</sup>Sr/<sup>86</sup>Sr ratios combined with lower <sup>143</sup>Nd/<sup>144</sup>Nd suggests that ambient mantle beneath the Central Lau Basin is more akin to Indian Ocean rather than Pacific Ocean mantle. However, the elevated Sr isotopes of the CLSC and ELSC lavas may indicate an important role for recycling of altered ocean crust or hydrothermal fluids deep in a sub-Pacific mantle domain.

# Role of the fluid phase during multiple intrusions in felsic magma chambers and ore generation

Jean Louis Vigneresse (jean-louis.vigneresse@g2r.uhp-nancy.fr)

Nancy-Université, UMR 7566 G2R, BP 23, 54501 Vandoeuvre Cedex, France

The generation of granitic plutons is highly discontinuous, from its source to its emplacement, resulting in having a pluton built from successive magma inputs, with different temperature and composition. The magma also includes an important fluid phase (water, carbon dioxide, sulphur, halides, light elements as Li, Be, B) that incorporates many metals as complex compounds. Fluid exsolution occurs during the ascent, as first boiling, due to magma decompression, but also during crystallisation, as second boiling, due to melt shrinkage. The effects of the successive intrusions are examined in terms of sudden variations of the physical properties of the magma. Temperature contrasts between mafic and felsic magmas induce changes in the diffusion characteristic lengths, partition coefficients and redox conditions of the magma and fluid phase. Those variations have been estimated and quantified when a mafic, or felsic, magma enters a felsic, or mafic, magma chamber. The two types of boiling differ in that first boiling, that occurs at constant temperature, but decreasing pressure, does not affect too much metal solubility in the fluid phase. Conversely, second boiling, that takes place at constant pressure and decreasing temperature, also decreases metal solubility, resulting in metal precipitation. The specific role of S and halides is examined through the differential release of F, retained into the melt, and Cl that enters into micaceous minerals.

## Identifying End Members Involved in Magma Recharge at Unzen Volcano, Japan: Polytopic Vector Analyses

Thomas A. Vogel<sup>1</sup>, <u>Paulo J. Hidalgo</u><sup>1</sup> (hidalgop@msu.edu), L. C. Patino<sup>1</sup>, B. L. Browne<sup>2</sup>, J. C. Eichelberger<sup>3</sup>

<sup>1</sup>Michigan State University, Department of Geological Sciences, East Lansing, MI 48824, USA

<sup>2</sup>California State University, Department of Geological Sciences, Fullerton, CA 92834, USA

<sup>3</sup>University of Alaska Fairbanks, Geophysical Institute, Fairbanks, AK 99775, USA

The occurrence of chilled mafic enclaves in a silicic host has widely been interpreted to form by mingling of coexisting magmas with contrasting physical properties. At Unzen volcano, Browne et al, 2006 have documented two types of mafic enclaves in a dacitic host: a porphyritic enclave (P-enclave) and an equigranular enclave (E-enclave). Both have interacted with the dacitic host to various degrees. The P-enclaves contain host plagioclase and the dacitic hosts contain plagioclase from the enclaves. However, the E-enclaves do not contain host plagioclase. The P-enclaves formed from the intrusion of a porphyritic mafic magma into the dacitic host with abundant mingling of the two magmas. The lava that was erupted on the surface in 1663 is similar, both chemically and texturally to the P-enclaves. The E-enclaves are interpreted to have formed from the mafic magma that was ponded below the dacitic host magma, cooled slowly, developing a coarser texture, and was entrained by convection into the host magma.

A major problem in petrology has been the identification of end members involved in magma mingling and/or mixing events. Polytopic Vector Analysis (PVA) is a technique that uses all of the chemical constituents (major elements and trace elements) in all the samples to determine: (1) the number of end member compositions present in the system, (2) the chemical composition of each end member, and (3) the relative contribution of each end member in each sample. Each sample in the dataset is described as the sum of some fraction of each end member; therefore each sample is uniquely described by a specific amount of each of the end members. Graphical analysis of the output allows the recognition of trends either due mixing of separate magma batches, as samples form discrete clusters or trends with different variations in end member proportions. Mixing of discrete magma batches is immediately apparent, because samples representing mixed magmas plot between the parent magmas.

At Unzen two distinct mafic magmas are identified –one is relatively enriched in REE's and other incompatible elements and the other is not. This requires two separate sources for the melts. The E-enclaves contain a mixing trend which ranges from about 70\% non-enriched end members to about to less than 10\%, whereas the P-enclaves are dominated by the enriched end member and show only minor mixing with the non-enriched magma. Some E-enclaves are chemically similar to P-enclaves. Our interpretation is that the enriched magma ponded at the base of the dacitic magma body, while at the same time was injected into the dacite, forming the P-enclaves. The non-enriched magma injected into this ponded mafic magma, mixed and cooled slowly and was entrained into the overlying, convecting dacitic magma, forming the mixed E-enclaves.

# Olivine hosted melt inclusions from mafic small eruptive centers, Central Southern Volcanic Zone, Chile – an approach for characterizing primitive arc magma compositions

Susan Wacaster, Rosemary Hickey-Vargas, Murong Sun

Department of Earth Sciences Florida International University, Miami, FL, USA

Basaltic lavas and scorias having about 6-9 wt. % MgO are common throughout the Central Of two chemically distinct basalts identified, the Southern Volcanic Zone (CSVZ). predominant type is primarily associated with large composite volcanic centers, whereas another is found exclusively at small eruptive centers (SEC), especially those located along the north-south trending Liquine-Ofqui Fault Zone (LOFZ) (Lopez-Escobar et al., 1995). The latter is characterized by higher LREE/HREE abundances, lower relative abundances of fluid-mobile elements (FME) and lower 87Sr/86Sr ratios compared with the dominant basalt type (Hickey-Vargas et al., 1989; Lopez Escobar et al., 1995). These observations led to the concept that the magmas erupted at SEC form by smaller extents of partial melting that those erupted at composite volcanic centers, due to lesser input from the hydrous subduction component (Hickey-Vargas et al., 1989; Lopez Escobar et al., 1995). Further investigation showed that while the SEC basalts have typical subduction magma characteristics, such as LILE enrichment and HFSE depletion, U-series isotopes are near equilibrium and they have smaller, although measurable, amounts of 10Be (Hickey-Vargas et al., 2003, Sun, 2001). This contrasts with the composite volcano basalts, which have significant 238U excesses, higher 10Be/9Be and higher abundances of fluid mobile elements, like boron. Based on the collective major element, trace element, and isotopic characteristics of the two basalt types, Hickey-Vargas et al. (2003) and Hickey-Vargas and Sun (2004) proposed that the SEC basalts form by decompression melting of aged, subduction-imprinted mantle wedge, and that the composite volcano basalts form by flux melting with input from the active subduction system.

This work is a study of the major, trace, and volatile element contents of melt inclusions in olivines from to determine whether melt inclusions in Fo-rich olivines from geochemically distinct mafic SEC basaltic scoria are also distinct. If so, this would lend support to the hypothesis that the two magma types, defined on the basis of bulk rock geochemistry, are formed by mantle, rather than crustal processes. Another objective of the work is to estimate primary volatile contents, especially H2O and CO2, in the basaltic magmas, and to test the hypothesis of decompression melting versus flux melting for the SEC and composite centers.

Hickey-Vargas, R., Sun, M., López-Escobar, Leopoldo, L., Reagan, M., Morris, J., and López-Escobar L, Cembrano J, Moreno H (1995) Geochemistry and tectonics of the Chilean Southern Andes basaltic Quaternary volcanism (37-46°S). Rev Geol Chile 22: 219-234

Sun, M., 2001, Geochemical variation among small eruptive centers in the CSVZ of the Andes: an evaluation of subduction, mantle and crustal influences.

### Petrogenetic processes recorded by clinopyroxene megacryst geochemistry

### Shou-Cheng Wang (singerproncku@gmail.com)

Megacryst suites that have been reported within limited continental alkali basalts are the products of crystal fractionation. This study obtains a record of variations in major, trace elements and Sr-Nd isotope compositions that evaluate the local scale geochemical heterogeneity of Penghu volcanic province and physical constraints on megacryst genesis.

Analyzed clinopyroxene megacryst samples are collected from Yandunshan, Chap-po, in the north and Wang-an in the south of Penghu islands. Decreases of Si and Mg with increases of Ca, Fe, Al, Ti, and Na of cpx megacrysts are according with pMELTS modeling outcomes during isobaric cooling. It is concluded that cpx megacryst with high Al and Na in Wang-an represent products of highly evolved alkali basalt, otherwise, megacrysts in Yendunshan, Cha-po are less evolved products. Base on P, T estimates from Putirka(1997, 1999), the cpx saturation pressure of alkali basalt is about 9 kbar matching Moho discontinuity depth in this region, about 30 km, may related to magma underplating events.

Pairs of megacryst and host rock have similar Sr-Nd isotopic composition but are disequilibrium in major and trace elements, result to mechanism of parental magma mixed with less differentiated melts. Low 143Nd/144Nd ratios with high Nb, Ta, and LILE evaluate HIMU component involved into magma chamber recording in rim potion of cpx and core potion of feldspar during later stage of crystal fractionation. HIMU signal may result from low degree partial melting of paleo-subducted oceanic crust.

Crystal grow rate of cpx megacryst approximate 10-8 cm/sec, evaluated from heat balance model, pMELTS and correlation between mineral volumes and crystal temperatures. Time-scale of megacryst grow is less than 10 year, comparatively, time scale of high degree crystal fractionation is extend to 102 year which consistent with time scale of hydraulic fractures reactivation, Phenocrysts and megacrysts provide beneficial chemical signatures to explore intraplate basalt or LIP (Large Igneous Province) evolution processes and physical constraints within Moho discontinuity.

# Low- $\delta^{18}$ O magmas in the Late Miocene Heise volcanic field, Idaho: implications for the fate of the Yellowstone hotspot calderas

Kathryn E. Watts<sup>1</sup> (kwatts@uoregon.edu), Ilya N. Bindeman<sup>1</sup> and Axel K. Schmitt<sup>2</sup>

<sup>1</sup>Department of Geological Sciences, 1272 University of Oregon, Eugene, Oregon 97403, USA <sup>2</sup>Department of Earth and Space Sciences, UCLA, Los Angeles, California 90095, USA

We report oxygen isotope compositions of phenocrysts and U-Pb ages of zircons in four large caldera-forming ignimbrites and post-caldera lavas of the Heise volcanic field, a nested caldera complex in the Snake River Plain that preceded volcanism in Yellowstone. Early eruption of normal- $\delta^{18}$ O voluminous rhyolites with  $\delta^{18}O_{Qz} = 6.4\%$  started at Heise around 6.6-5 Ma, and was followed by a sudden 2-3‰ <sup>18</sup>O depletion in the subsequent 4.45 Ma Kilgore caldera cycle that includes 1,800 km<sup>3</sup> Kilgore ignimbrite, and >100 km<sup>3</sup> post-Kilgore intracaldera units. The Kilgore ignimbrite with  $\delta^{18}O_{Oz} = 4.3\%$  and  $\delta^{18}O_{Zircon} = 1.5\%$  represents an extremely voluminous low- $\delta^{18}$ O magma unit, in fact the largest single known low- $\delta^{18}$ O magma in the Snake River Plain, and worldwide. Post-Kilgore volcanism and resurgent doming was relatively short-lived (4.4-4.1Ma), small volume, and produced Kilgore-type magmas that share its depletion in <sup>18</sup>O and other geochemical characteristics. The post-caldera volcanism likely represents the waning stages of silicic magmatism at Heise during cooling of a batholith-sized Kilgore intrusion, prior to the re-initiation of silicic volcanism 100 km to the NE at Yellowstone. The low- $\delta^{18}$ O Kilgore cycle, the forth in the Heise sequence, represents remelting of hydrothermally altered volcanic and/or shallow intrusive rocks, similar to the process advocated for Yellowstone. The occurrence of low- $\delta^{18}$ O magmas at Heise and Yellowstone hallmarks a mature stage of individual volcanic cycles in each caldera complex. Sudden shifts in  $\delta^{18}$ O of silicic magmas erupted from the same nested caldera complexes argue against any inheritance of the low- $\delta^{18}$ O signature from mantle or crustal sources. Instead, oxygen isotope trends indicate systematically higher abundances of low- $\delta^{18}$ O hydrothermally altered intracaldera rocks in progressively younger magmas from individual cycles. This trend may be generally applicable to older caldera complexes in the Snake River Plain that are poorly exposed.

### Volcanic emissions of mercury to the atmosphere

<u>Melanie Witt</u><sup>1</sup> (melanie.witt@earth.ox.ac.uk) Alessandro Aiuppa<sup>2</sup>, Emanuela Bagnato<sup>2</sup>, Tamsin Mather<sup>1</sup> and David Pyle<sup>1</sup>.

<sup>1</sup>Department of Earth Sciences, University of Oxford, Oxford, OX1 3PR, UK <sup>2</sup>Dipartimento CFTA, Università di Palermo, Palermo, Italy

Mercury is a toxic metal which has a long lifetime in the atmosphere of around one year. This long life time enables it to be carried vast distances and the metal is found in elevated concentrations in remote regions of the world. There is some debate at present regarding the quantity of mercury naturally released by volcanoes and its relative significance to the natural Hg budget. In order to better assess this value, a number of field campaigns have been carried out to measure the gaseous mercury flux from Masaya in Nicaragua and Vulcano and Etna, Italy. A Lumex 915+ portable mercury vapour spectrometer was tested to record real-time gaseous mercury concentrations in the volcanic emissions. These measurements were carried out in parallel with the collection of gaseous elemental mercury on gold coated sand traps. While there is some uncertainty regarding the absolute values recorded by the Lumex the peaks in the Hg data correlate well with those of CO<sub>2</sub> and SO<sub>2</sub> enabling variations in the Hg/SO<sub>2</sub> ratios to be observed in volcanic gases. Speciation was also investigated with the collection of reactive gaseous and particulate mercury for subsequent analysis. A portable sensor box was developed to simultaneously record SO<sub>2</sub>, H<sub>2</sub>S, CO<sub>2</sub>, humidity, temperature and pressure. The Hg/SO<sub>2</sub> ratio was used in combination with the known SO<sub>2</sub> flux of the volcanoes to determine the Hg emissions at each location.

## Noble Gas Isotopic Ratios of Volcanics and Xenoliths from northern Taiwan-Luzon Arc

<u>Tsanyao Frank Yang</u><sup>1</sup> (tyyang@ntu.edu.tw), Mark D. Kurz<sup>2</sup>, Jun-ichi Matusta<sup>3</sup>, Takuya Matsumoto<sup>3</sup> and Cheng-Cheng Wang<sup>1</sup>

- 1. Department of Geosciences, National Taiwan University, Taipei 106, Taiwan
- 2. Department of Marine Chemistry & Geochemistry, WHOI, MA 02543, USA.
- 3. Department of Earth and Space Science, Osaka University, Osaka 560-0043, Japan.

The Taiwan-Luzon Arc, which was generated in response to the subduction of the South China Sea Plate, is currently colliding with the eastern margin of the Eurasian continental plate at the arc's southern and northern ends. Systematic temporal and spatial variations in the geochemistry of the magmas erupted along the arc are ascribed to the involvement of the subducted continent-derived sediments or crustal slivers close to the collision zones.

Three  ${}^{3}\text{He}/{}^{4}\text{He}$  ratios of hornblende, biotite and pyroxene separated from the arc volcanics near the collision zone were obtained. The ratios of Hsiaolanyu lava from northern arc are less than 2.3 and 1.3 times atmospheric ratios (Ra). The other is 3.0 Ra of Mt. Arayat lava from southern part of the Taiwan-Luzon arc. This implies that the crustal component played an important role in the petrogenesis of the arc magmatism, at least near the collision zone, to the lower down the  ${}^{3}\text{He}/{}^{4}\text{He}$  ratios of the lavas.

The helium isotopic ratios of olivines from xenoliths of Lanyu, Batan and Diogo island fall in a range from 8.1 to 10.1 Ra. They are close to the value of the average MORB ratio. However, the co-existing amphibole from the same nodule of Batan Island (8.4 Ra of olivine) shows a much lower ratio of 4.7 Ra, which are similar with the ratios of the arc lavas. In addition, pyroxenes and amphiboles from gabbroic xenoliths of the arc lavas exhibit a wide range from  $2.3 \sim 7.6$  Ra. It infers that they are cumulates in origin at different stages of fractionation in former magma chamber.

Combined with the Sr-Nd-Pb and helium isotopic data, we can conclude that at least two components, i.e., crustal component (Ra<1) and MORB component (Ra $\sim8$ ), are necessary for the generation of Taiwan-Luzon arc magmatism.

### Porphyritic lava domes generated by remobilization of igneous protoliths from arc crust

Georg F. Zellmer (gzellmer@earth.sinica.edu.tw)

Institute of Earth Sciences, Academia Sinica, 128 Academia Road, Section 2, Nankang, Taipei 11529, Taiwan, R.O.C.

While volcanic explosivity may largely be a function of magmatic water content and volatile exsolution, differences in the style of effusive volcanism can mainly be attributed to variations in magma viscosity. However, the controls of petrogenetic processes on the style of effusive eruptions at subduction zones have so far not been constrained on a global scale. Here, 238U-230Th and other geochronological and geochemical data from young arc volcanics are combined with information on eruptive style to show that porphyritic lava domes are commonly generated by remelting of previously intruded young igneous protoliths that are in or close to U-Th equilibrium. Surface heat flux estimates at continental and transitional arcs indicate that crustal temperature plays a significant role in this process and therefore influences eruptive style (Figure 1). The data suggests that remobilization of young igneous intrusions is a common phenomenon in cool arc crust.





MAG 2007 Conference Abstract