southward propagation of the EAR over the plume head. Low factors (∼1.2) and thick lithosphere preclude a significant amount melt generation in the East African plume head beneath this part of the EAR.

The earliest volcanic activity in this part of northern Tanzania occurred between 8 Ma and 2 Ma and is represented by regional flood lavas, the Monduli volcanic centre and early activity at Kilimanjaro. These magmas are mildly alkaline and volatile-poor. Fractionated heavy rare-earth element ratios and relative depletions at Ti, Rb and K are consistent with melting of a phlogopite/amphibole-bearing garnet peridotite source. This early melting appears to have been initiated by conductive heating of H_2O-rich metasomatic veins in the basal lithosphere (at depths up to ∼150 km). Subsequent localised crustal extension at ∼1.2 Ma immediately precedes the generation of small-volume silicate melts (melilitites and melanephelinites), which are characterized by relatively high Zr/Hf. These melilitites are typically associated with the eruption of carbonatite tuffs. The most recent phase of volcanism (<0.2 Ma), on the eastern flank of the EAR in northern Tanzania, is represented by strongly alkaline magmas at Mt. Meru, and mildly alkaline magmas at Mt. Kilimanjaro. The Meru lavas are characterised by similar compositions to CO_2-rich glasses that occur in mantle xenoliths from the nearby Olmani cone.

The genesis of the Meru magmas requires wide-scale melting of CO_2-rich metasomatised lithosphere (∼100 km) to produce the large volume (>150 km^3) of erupted magmas. Conduction models show that conductive heating of the lithosphere by a mantle plume over the ∼10 Ma volcanic history of the region can produce the required melting of the lithosphere

V51C-1028 0830h POSTER

Helium Isotope Compositions in Springs From the Three Sisters Region, Central Oregon, USA.

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The Three Sisters region has recently come under increased scrutiny after the discovery by Satellite Radar Interferometry (InSAR) of a broad area of uplift centered approximately 5 km west of the South Sister volcanic edifice (Wicks et al., 2001). The bulge, which at its center reaches a maximum of 10 cm, formed between 1998-2000. The exact cause for the uplift is unknown, but observations from other volcanoes and results from numerical modeling imply that the most likely cause is the movement of magma up to mid-crustal (∼6.5 km depth) levels (Wicks et al., 2001).

The area of uplift coincides with an area where spring chemistry shows anomalously high levels of chloride and carbon emissions (Ingebritsen et al., 1994). These features pre-date the bulge by at least a decade and can also be indicative of a magmatic source. It is unclear if the bulge and the geochemical anomalies are directly related, but both point to the presence of magma below the Three Sisters area.

Within the scope of a monitoring project that has recently been initiated to study the development of the bulge and any accompanying changes in the fluid/gas chemistry of springs in the Three Sisters area, 10 gas samples were collected for noble gas analysis in July 2001. Two of these samples were taken from cold bubbling springs located close to the center of the bulge and the remaining 8 were obtained from well documented geothermal springs within the general area of Central Oregon.

Helium isotope ratios (reported as R_c/R_a where R_c = air corrected $^3He/^4He_{sample}$ and R_a = $^3He/^4He_{air}$) for these 8 samples range from 2.8 to 5.1 R_a which is in agreement with existing data reported in a study carried out by Unocal in the early 1980's of geothermal springs in this area. The data show a relationship with distance to the bulge/South Sister volcano: all samples within a radius of 30 km have helium isotope ratios in the range of 4.5 to 5.1 R_a, while samples that fall outside this radius have distinctly lower helium isotope ratios (<4 R_a).

The two samples from the center of the uplift area have helium isotope ratios that are significantly higher (7.4 and 8.6 R_a) than the data for the other springs. This clearly demonstrates the presence of a mantle derived magma at some depth below the bulge and the occurrence of permeable pathways to the surface for gas of magmatic origin.

At this time, due to a lack of literature noble gas data for the exact area of the bulge, it cannot be determined if the occurrence of these high ratios, which are a common feature in other Cascade Range volcanoes, coincided with the formation of the bulge or if they predate the uplift. This remains a subject for further study.

References: Wicks, C. Jr., Dzurisin, D, Ingebritsen, S. E., Thatcher, W., Lu, Z., and Iversen, J. (2001) Magmatic activity beneath the quiescent Three Sisters volcanic center, central Oregon Cascade Range, USA, abstract AGU Fall meeting, this volume.

Ingebritsen, S. E., Mariner, R. H., and Sherrod, D. R. (1994) Hydrothermal systems of the Cascade Range, North-Central Oregon. USGS Professional paper 1044-L 88p.

Acknowledgements: We acknowledge Unocal for granting permission to use helium isotope data collected by them during a regional study in the early 1980's.

V51C-1029 0830h POSTER

The Depleted Mantle Component in Kerguelen-Plume Related Magmas

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The Northern Kerguelen Plateau (NKP) and the Kerguelen Archipelago formed on the Antarctic plate after 43 Ma when Broken Ridge was split from the Kerguelen Plateau by spreading along the South-East Indian Ridge (SEIR). A depleted mantle component, similar to that of SEIR-MORB, is present in basalts from the NKP (Site 1140; 34 Ma) and from the Kerguelen Archipelago (26-29 Ma), but is absent in the youngest (<25 Ma) flood basalt sequences on the archipelago. This decrease in the depleted component appears to be correlated with time i.e., distance from the SEIR. We are investigating the oldest basaltic sections on the archipelago to constrain the origin of the depleted component in KA lavas.

Two of the oldest basaltic sections on the northwestern Kerguelen Archipelago (Ruches and Fontaine, 28 Ma) reveal the eruption of two isotopically different types of magmas within ∼1 myr. Their isotopic and trace element characteristics are between Kerguelen plume ($^{87}Sr/^{86}Sr_i$ ∼0.7052) and depleted SEIR-like ($^{87}Sr/^{86}Sr_i$ ∼0.703) compositions and show no simple magma mixing trends. The stratigraphically lower, isotopically depleted basalts ($^{87}Sr/^{86}Sr_i$ ∼0.7045) are overlain by transitional and isotopically heterogeneous ($^{87}Sr/^{86}Sr_i$ ∼0.7047-0.7056) high-MgO basalts. This transition reflects the increasing contribution with time of the Kerguelen plume source. The depleted component may represent contamination of plume-derived magmas by depleted upper mantle under the archipelago, similar to the source for SEIR-MORB. This could account for the geographical distribution of the depleted component in the northwest and central part of the Kerguelen Archipelago. It could also explain the absence of a depleted component in < 25 Ma alkali basalts that formed by deeper melting, when the Kerguelen Archipelago was further away from the ridge, and the lithosphere thicker. Alternatively, the depleted component could represent entrained upper mantle associated with the Kerguelen plume. There is no evidence for an intrinsic depleted component in the Kerguelen plume source.

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V51C-1030 0830h POSTER

A Lower Mantle Origin for the Worlds Biggest LIP? A High Precision Os Isotope Isochron From Ontong Java Plateau Basalts Drilled on ODP Leg 192

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Basalts drilled on ODP Leg 192 from the Earths largest igneous province, the Ontong Java Plateau (OJP) yield a Re-Os isochron age of 121.5+/-1.7 Ma and an initial $^{187}Os/^{188}Os$ ratio of 0.1295+/-0.0011. The basalts are from four ODP sites located over a 1000 km apart. The generation of such a high precision isochron using the Re-Os isotope system indicates the source of the OJP is remarkably homogeneous, with an Os isotope composition very similar to that of the primitive mantle. Their high Re contents (1000-1600 ppt) and relatively high Os contents suggest that they are produced by melting beyond sulphide-out in the mantle. Other trace element data support the conclusion that these basalts are derived by high degrees (25-30%) of partial melting of the mantle. Such high degrees of partial melting may assist in homogenising the Os isotopic signature of the source region. The Os isotope data indicate that there is no core signature in the source of the OJP basalts analysed in this study, but that they are more likely derived from entrained lower mantle.

V51C-1031 0830h POSTER

Mantle Evolution Associated With the Rio Grande Rift: Geochemistry of Upper Mantle Xenoliths

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Upper mantle xenoliths from three locales associated with the southern Rio Grande Rift have been investigated to determine lithosphere composition, chemical processes, and pre-eruptive pressure and temperature conditions. Sample locations, Potrillo and Elephant Butte within the rift axis and Adam's Diggings, located 50 km west of the rift axis, were specifically selected to evaluate spatial differences in mantle evolution. Xenolith suites from all locations included spinel lherzolites, harzburgites, and pyroxenites hosted in basanite and alkali basalt. Thin section, electron microprobe, and LA-ICPMS analyses were used to obtain detailed textural information, mineral compositions, and whole rock geochemistry.

Xenoliths are classified as protogranular, porphyroclastic, or equigranular texture types. Equigranular texture types occur in the off-axis site. Recrystallized olivine grains are larger in xenoliths from sites along the rift axis than from the rift shoulder. Geothermal gradients based on mineral compositions, utilizing two-pyroxene and olivine-spinel geothermometers and the Ca-in olivine geothermobarometer, indicate temperatures off the rift axis at Adam's Diggings that are 75^o-100^{o}C cooler for a given pressure than under the rift axis. Whole rock chemical data and mineral modes support an early depletion event affecting xenoliths from all locations: Al_2O_3, CaO, Na_2O, TiO_2, V, Sc, Yb, and clinopyroxene content decrease with increasing MgO. The average $(La/Yb)_n$ of clinopyroxenes are 12.37, 0.95, and 1.14 for Adam's Diggings, Elephant Butte, and Potrillo xenoliths, respectively. This LREE enrichment and the occurrence of phlogopite that is interpreted to be primary in xenoliths from the off-axis site indicate both cryptic and modal metasomatic events. Both LREE-enriched and -depleted lherzolites are present at rift axis sites. Differences in recrystallized olivine size, xenolith textures, composition, and pre-eruptive pressure-temperature conditions between rift axis and rift flank locations suggest that the upper mantle underlying the Rio Grande Rift has undergone partial melting and at least two metasomatic episodes by melt and fluid.

V51D MC: 305 Friday 0830h

Conduit Processes During Explosive Basaltic Eruptions II *(joint with P, S, T)*

Presiding: **M Ripepe,** Universita di Firenze**; M Hort,** University of Kiel

V51D-01 0835h INVITED

Linking Surface Observations to Sub-Surface Processes in Basaltic Explosive Eruptions

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Along with magma volatile content, magma rise speed is the main control on the characteristics of explosive eruptions. Key issues are the extent to which gas bubbles are distributed non-uniformly in the magmatic liquid and the extent to which gas bubbles do not have a monodisperse size distribution. Larger, early nucleating bubbles overtake smaller, later nucleating

ones, producing a small number of large bubbles at the expense of a large number of small bubbles. At small enough magma rise speeds, a run-away situation can arise in which one giant bubble fills the vent. The resulting slug flow is one way to cause a series of discrete Strombolian explosions well-separated in time. The absolute speed of the magma, the initial bubble size distribution and the magma viscosity determine if fully-developed slug flow will occur or if, instead, a random pattern of various relatively large bubble sizes will ensue. The second option leads to unsteady, but not discontinuous, Hawaiian-style explosive activity at the surface vent. At very small magma rise speeds, even very small bubbles will rise through the magma to accumulate at its surface, which may be an exposed lava pond in a vent or the region beneath the upper tip of a dike not penetrating the surface. A foam layer can build up, thickening with time until it eventually drains. In a dike this will produce a connected gas pocket, the fate of which depends on the geometry: gas may leak out to the surface via fractures too narrow to allow magma escape but wide enough for significant gas flow. Alternatively, the gas pocket may migrate sideways along the top of the dike and reach the surface somewhere, to be released abruptly, forming a very gas-rich (and possibly juvenile magma-free) explosion. If the foam layer is present at the top of an open lava pond, foam collapse will also lead to an explosion, blasting away the cooled pond skin. The details of this explosion will depend on the chilled skin thickness and hence on the interval since the last time the surface was ruptured. If the skin is thin, this kind of explosion may appear similar to that resulting from the rise of a single large bubble through the magma; alternatively, if the skin is thick enough, it may have much in common with a vulcanian explosion. Measurements of the clast-to-gas mass ratio and clast ejection speeds should make it possible to distinguish between these various mechanisms.

V51D-02 0850h

Magma Ascent and Volcanic eruptions: An Analytical Solution of the Two Phases Fluid Flux Equations

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The understanding of the magma ascent mechanism has been investigated from early 70 and, up to now, the proposed models are based on a fluid motion in a porous medium driven by the pore compaction and dilation. The basic equation is the well known Darcys law: it states that the liquid flux through a permeable matrix is proportional to the pressure gradient in the liquid. Basically a complete description of the physics of the problem is given by means the equations of continuity and of energy and momentum conservation. The solution of such a system of equations in 1D is a soliton while in 2 and 3D it is a solitary wave (note that the only difference between solitary waves and solitons is that the first ones scatters while the second ones do not). Note that, while the shape of the waves may change, their existence depends only on the conditions that the matrix is permeable and viscously deformable. Except for the 1D case we have, for the other two, only numerical solutions are available. In the present paper we shall show that, in certain conditions, there exists an analytical solution in 3D. Such a solution depends on the possibility of transforming the two equations into a non linear Shroedinger equation which admit solitary waves solutions.

V51D-03 0905h

Timing of the Crystallization, Bubble Nucleation and Degassing during Magma Ascent in the Usu 2000 Eruption, Japan

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Crystallization, vesiculation and degassing (gas separation) during magma ascent change magma's physical properties. Although there have been studies on the cumulative result of each process in eruptives, little is known about how each process advanced at a certain moment during ascent. Products of phreatomagmatic eruption on 31 March, however, give constraints on timing of each process, as well as characteristics of magma ascent in the beginning of an eruption.Petrological examination of the essential material (pumice, and micropumice in ash) revealed homogeneity of the 2000 magma in reservoir. Water content in the melt (75.0 wt. percent SiO_2) was about 5 wt. percent, solubility at 2 kbar.

The essential fragments vary in vesicularity. The diversity resulted from whether or not magma had been quenched by the aquifer on the way to the surface. In contrast to the micropumices with water-quench feature, pumices may have been formed without interaction with water; further vesiculation even after passing aquifer led to high vesicularity. The water content in the groundmass glass of essential fragments decreases with increasing vesicularity, suggesting that variable vesicularity resulted from different degree of exsolution, not from different extent of degassing. Thus, essential material can be a clue to know the characteristics of phenomena induced by the water-exsolution around the depth of aquifer.

Individual microlite species are homogeneous in chemistry among essential fragments. This indicates that microlites had been crystallized under a similar physical condition and independently from quenching in aquifer. Water contents in groundmass glass are variable, but confirm the generation of enough decompression-induced undercooling for the crystallization. Constant microlite crystallinity among essential fragments with various vesicularities can be explained by the completion of crystallization before the final decompression.

Changes in bubble size distribution with vesicularity in micropumices show two bubble nucleation events; the secondary nucleation of bubbles and their growth generated the diversity in vesicularity. In this eruption, geophysical observations showed that magma reached below West Nishiyama, the western foot of Usu volcano, after passing through below the summit. The first nucleation may have taken place around the depth of 2 kbar. The secondary nucleation occurred after passing below West Nishiyama. The H_2O exsolution during magma ascent down to West Nishiyama is expected to have occurred in an equilibrium condition, according to both magma's ascent speed estimated by geophysical observation and results of decompression experiments.

Disequilibrium in H_2O exsolution is easily achieved by the increase in magma ascent speed. Considering the situation before the beginning of an eruption, pressure drop of magma head by the crater opening can be a cause to accelerate magma ascent. Thus magma ascent in this eruption can be divided into two periods in speed; up to 1-2km depth below West Nishiyama, and the remaining period up to the aquifer.

The closed-system vesiculation model requests degassing before secondary decompression. The degassing may be enhanced by a low ascent speed in this period. Two-stage magma ascent in the beginning of an eruption was also found in the Futatsudake eruption(1). These indicate that magma ascent in this stage is preceded by slow and deeply seated intrusion of magma, which is followed by high-speed ascent due to the vent opening.

(1) Suzuki Y. and Nakada, S., 2000, EOS, 81, 233.

V51D-04 0920h

Preference between the Summit and Flank Eruptions: Controlling Factors and Actual Volcanic Features

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Volcanic eruptions happen sometimes at the preexisting summit crater and sometimes from new fissures generated on the flank. A simple criterion that describes the preference between the summit and flank fissure eruptions is proposed comparing the pressures that enable magma to flow into an established conduit and a new fissure, respectively, from the common magma chamber. This criterion involves as controlling factors the summit height, the magma density in the conduit, the lithostatic pressure at the chamber, and the pressure enhancement to open fissures. The criterion is applied to some volcanoes along the Izu volcanic chain, Japan to interpret their various eruptive features.

The preference for a summit or flank fissure eruption depends on the tectonic stress that determines the pressure enhancement for fissure opening. The Higashi-Izu group of monogenetic volcanoes is considered to have formed with a strong extensional stress under which magma can readily move and stay in fissures. It is predicted that the preference may change with growth of a polygenetic volcano because summit and flank eruptions contribute mainly to its vertical and horizontal growth, respectively. In fact, Fuji volcano has had periods with dominant summit or flank eruptions by turns every 1,000 to 3,000 years. In some eruptive activities of Izu-Oshima and Miyake-jima volcanoes, a summit eruption immediately follows a flank eruption and vice versa, suggesting that the first event may induce the second. Such sequential occurrence of two eruptions is explained by change of the magma density during the preceding event.

V51D-05 0935h

Rapid Ground Deformations at the Miyakejima Volcano, Central Japan Detected by 30-sec Kinematic GPS Analysis on June 26-27, 2000

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Miyakejima volcano located about 180 km south of Tokyo, Japan on the volcanic chain of Izu-Ogasawara experienced strong earthquake swarm started in the evening of June 26, 2000 and it continued through the beginning of September. In order to explain crustal deformation at the beginning of Miyakejima volcano activity, we analyzed GPS data at twelve stations observed on June 26 to June 27 using kinematic analysis every thirty-second time interval, and discuss only the earliest part of the Miyakejima 2000 eruption process. As a result we distinguish three major phases in the initial stage of the Miyakejima activity (from 7 p.m. on June 26 to 4 a.m. on June 27). In the first phase estimated that first ground deformation toward east and uplift was observed in the southeastern part of the volcano around 7 p.m. on June 26 (JST). At 9 p.m. horizontal deformation toward southwest and northeast was observed at GPS stations in the southwest and northwest parts, respectively. Ground deformations were detected at all GPS stations in Miyakejima volcano, at 11 p.m. Model of the GPS data indicate that first ground deformation was caused by dike intrusion with 0.5 km depth and during the phase 2 (from 9 p.m. to 11 p.m. on June 26) the crack was opening in the western part of Miyakejima island. We suggest that pressure source of the volcano was migrated rapidly from south to west within few hours.

V51D-06 0950h INVITED

Listening to Stromboli Volcano as a tool into its Volcanic Conduit

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Breaking of metric bubbles at the top of a magma column is observed during most basaltic eruptions: it is called "gas-piston" activity during hawaiian eruptions or explosions for strombolian volcanoes. Because these bubbles are the trademark of basaltic activity, one needs to understand their behaviour both when they arrive at the surface and when they formed at depth. By combining acoustic measurements at Stromboli with a model for sound generation, the bubble length and radius as well as its overpressure have been estimated at the vent. Because bubbles are significantly overpressurised when they break at the top of the magma column, they are also overpressurised when they leave the shallow magma chamber.

Here, simplified equations for the rise of an overpressurised bubble show that such a bubble oscillates while rising. The change in volume of the rising bubble pushes the magma column up and down, vigourously enough to produce sound waves of low frequency (bubble volume mode around 0.5 Hz). Furthermore, the initial oscillations of strombolian bubbles are strong enough to produce gravity waves at the surface of the magma column (sloshing waves of 1-3 Hz), which can be detected acoustically.

The model for bubble rise predicts that a precursory peak in acoustic pressure, i.e. ahead from the explosion itself, should occur simultaneously both around 0.5 Hz (bubble volume mode) and 2 Hz (sloshing modes) when the bubble starts its rise in the conduit. First, the amplitude of the precursory peak in acoustic pressure measures the initial overpressure in the bubble ($\approx$ 11 MPa). Second, the time delay between the precursory peak and the explosion itself corresponds to the time

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needed for a bubble to rise from the magma chamber to the surface. Its depth is then estimated around a few hundred meters at Stromboli. A mechanism for the origin of bubble overpressure at the base of the conduit will be proposed.

V51D-07 1025h

Source Mechanism of Strombolian Explosions Determined From Moment Tensor Inversion of Very-Long Period Data

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During September-October 1997, 21 three-component broadband seismometers were deployed on Stromboli Volcano at radial distances of 0.3-2.2 km from the active crater to investigate the source mechanism of Strombolian explosions. In the 2-50 s band, the very-long period (VLP) signals associated with explosions are nearly linear and point to a source centroid located at shallow depth beneath the northwest flank of the volcano. To determine the source centroid location and source mechanism we minimize the residual error between data and synthetics calculated by the finite difference method for a point source embedded in a homogeneous elastic medium that includes the topography of Stromboli. The observed waveforms are well reproduced by our inversion with a residual squared error of 3.7%. The source centroid that best fits the data is located at an elevation of 600 m, approximately 100 m below and 80 m northwest of the crater. The source mechanism includes both moment tensor and single force components. The principal axes of the moment tensor have amplitude ratios 1:1:2, which can be interpreted as representative of a crack if one assumes a Poisson ratio $\nu = 1/3$ at the source. This value of ν is appropriate for hot rock. The imaged crack dips 63° to the northwest and strikes northeast-southwest along a direction parallel to the major axis of the crater. The crack azimuth is fully consistent with azimuthal directions of exposed dikes and with a known zone of weakness in the edifice. The volume change estimated from the moment is 150 m^3 for the largest explosion in our dataset. The observed rate of eruptions represents an overall volume emission rate of $1500 - 2000\ m^3$/hr. The source-time functions of the moment components show a characteristic sequence of inflation-deflation-inflation of the source. The initial inflation phase is consistent with a pressurization of the dike associated with the formation and release of a plug of gas. A stronger deflation follows, which reflects mass withdrawal from the conduit during the eruption. The third phase points to a repressurization of the dike associated with the influx of liquid drawn into the source to fill the void left by the escaping gases. Together with this volumetric source is a dominantly vertical force which is initially directed downward, then upward. The downward force is synchronous with the initial dilation of the source volume, and the following upward force is synchronous with the deflation of the source volume. These downward and upward forces are consistent with upward and downward mass movements, respectively. The forces may be explained by upward movement of the perched column of liquid above the gas plug in response to the piston-like motion of the plug, coupled with the upward movement of liquid drawn from below, followed by a downward flow of liquid between a core of gas and the conduit wall as the plug nears the surface. The jet recoil during the eruption may also contribute to the observed downward force component. Unfortunately, the individual source-time functions of vertical force components produced by mass movements and the jet recoil can not be separated because our inversion only resolves the combined contributions from all these forces.

V51D-08 1040h

Quantitative Discrimination of Vent Explosions at Stromboli Volcano, Italy

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As part of the multidisciplinary STROBE Experiment (STROmbolian BEhaviour) of May 2001, we deployed a broad band seismo-acoustic array around the summit craters of Stromboli Volcano, Italy. Three broadband instruments and five short period stations were each equipped with infrasonic microphones to measure the acoustic wave field from the nine events that were active over a period of 10 days. Explosion activity during the deployment was especially intense with numerous vents erupting with repose times of a few minutes. Several of the vents have consistent seismic and acoustic source signatures which allows us to distinguish between explosions based on cross correlation cluster analysis and frequency response of the multivariate time series. For example, the northeast crater consistently exhibited long period waves, greater than 10 s in wavelength, although the southwest crater does not contain this response. In spite of the broad band deployments we did not record any local tectonic earthquake activity. The variety of source activity suggests a complicated near surface conduit system where the dynamics of energy transfer to the atmosphere is controlled by vent structure and geometry. The activity at Stromboli differs considerably from observations at single vent systems like Karymsky, Russia or Sangay Volcano, Ecuador.

V51D-09 1055h

Thermal, Seismic and Infrasonic Time Delays for Modeling Conduit Process at Stromboli volcano.

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During several experiments we have monitored the eruptions at Stromboli with infrared sensors. Infrared emission during the explosions were recorded in parallel to the infrasonic and seismic signals by the same multichannel acquisition system. We detected each strombolian explosion as a sudden spike in the thermal signal seen by an infrared radiometer pointed at the vent. This occurs as soon as the hot gas and entrained ejecta reaches the visible top of the conduit, which is at height h above the level of the free surface of the magma within the conduit. If the gas rises at a speed U then this occurs at a time that is later than the bursting of the gas slug by h/U. It will then be detected effectively instantaneously by the radiometer. On the other hand, the onset of the infrasonic pulse generated by the arrival of the gas slug at the free surface will not be observed until the pulse has had time to travel up the conduit and then through the air to the detector. We assumed that the infrared onset is representative for the explosion onset at the surface. Time delays between infrared and infrasound changes with the explosions in a range from 0.5 to 3.5 seconds. This indicates that infrasonic waves are not produced outside the vent when the gas-fragments mixture hits the atmosphere, but inside the volcanic conduit and indicates that infrasound inside the conduit propagates faster than gas jet, which lead us to conclude that gas jet is subsonic also inside the conduit. Independently from the model we use to explain the origin of infrasound, time delay with respect to the infrared emission, will depend i) on depth where gas-fragments mixture separates from the magma column and accelerates towards the surface and ii) on the gas jet velocity changing as the system moves from one degassing state to another. Time differences between seismic, infrasound and infrared onsets provide strong constraint for modeling the explosive dynamics of open-vent volcanoes.

V51D-10 1110h

Conduit Convection Insights from Thermal Measurements of Gas Puffing at Stromboli and Etna

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Degassing at persistently active vents often proceeds in a puffing fashion. During 3 field experiments at Stromboli (1999, 2000 and 2001) we used thermal infrared thermometers along with infrasonic sensors to gain statistics for such puffing behavior. We found that the puffing cycled between periods of high (30 puffs per minute) and low (18 puffs per minute) frequency puffing, each cycle lasting 10s of minutes. These periods correspond to changes in the eruption frequency. This declined from 4-13 per hour to 1 per hour during the high-to-low transition observed during 1999. We propose a model whereby the supply of mass and gas to this persistently active system is variable in the short term. Within this model we explain puffing by the ascent of bubble bands in the conduit. Periods of high supply are related to high frequency puffing and eruption frequencies, and low supply periods are related to low frequency puffing and eruption frequencies. During 2001 we applied the experiment over a 3-day period to Etna's S.E. Cone. Strong thermal and infrasonic pulses were observed, which in turn could be related to puffing from vents within the S.E. Cone. At the same time, we observed variations in the level and velocity of lava flowing in the master channel of a persistent lava flow from the S.E. Cone. Correlation between puffing cycles and lava flow surges may imply pulsed supply to the eruption over a time scale of hours. Lack of correlation will imply that short-term channel flow variations are due to some other mechanism (e.g. back-up behind blockages).

V51D-11 1125h

Monitoring volcanic eruption velocities in three dimensions: First results from Doppler radar measurements at Stromboli volcano, Italy

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The proper detection and monitoring of volcanic eruptions is the most essential information that is provided to public authorities in an event of an eruption. Here we report on a new method to resolve the temporal and spatial variation of clast movement during volcanic eruptions. During September 2000 we monitored the eruptive activity at Stromboli volcano, Italy, for a total of about 10 days. For eruption monitoring we used VErDeMoS (Volcanic Eruption Detection and Monitoring System), a new volcano monitoring system recently developed at GEOMAR. The core of the system are up to three frequency modulated Doppler Radar instruments. For a total of about 2 days during our field measurements in September 2000 the three instruments, located at different positions along the old crater rim of Stromboli, were pointed towards the same eruptive vent. The instruments were aligned in such a way that the radar beams intersected above crater 2. Having measurements of the eruption velocity projected onto each of the three radar beams, one can in principle calculate the true direction of the main blast. We recorded nearly 50 events using this technique. However, as the three measurements are just enough to determine the true eruption velocity vector (i.e. the system is not overdetermined), small errors in positioning and data processing make it difficult to process some of the recorded data sets. The main findings are that the direction of the eruptive jet is quite variable in space and time and at least during our observational period almost never vertical but somewhat inclined. Initial blast velocities are found to vary between 35 and 10 m/s. In addition the data suggest that between eruptions the position of the main jet moves somewhat inside the crater, as the proportions of the backscattered electromagnetic energy between the three instruments varies from eruption to eruption.

V51D-12 1140h

Simultaneous Monitoring of Three Active Craters at Stromboli/Italy: Time Series and Eruption Signatures Derived From Doppler Radar

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During May 2001 we simultanously monitored the eruptive activity of three active vents on Stromboli volcano, Italy using 3 Metek MVR 3 Doppler Radars. Within 10 days, more than 1200 eruptions were recorded. Radar data are used to estimate eruption intervals, activity duration, velocity distribution and the reflected radar power of each event. Typical clast sizes of the events are estimated from clast sinking velocities. A semi-empirical law generally used for rain drop settling forecast converts mean sinking velocities into typical particle diamters. Daily averages of these data are used to infer typical eruption signatures. The reflected radar power allow a qualitative approximation of erupted masses. Crater 3 showed the highest reflected radar power and the most regular activity with typical eruption intervals of 400 s and a mean particle rising velocity of 16 m/s. Craters 1 and 2 showed interval lengths of about 700 s and rising velocities of about 17 m/s. Mean eruption lengths are 7 s for crater 1, 17 s for crater 2 and 13 s for crater 3. Mean particle diameters are13 mm for crater 1, 9 mm for crater 2 and 12 mm for crater 3 to but they vary strongly with time from about 5 to 30 mm. For crater 3 they show a significant diurnal variation with big diamters during night and the smallest around noon. Currently we are working on the statistical analysis of the whole data set, which we wish to present at the conference.

URL: http://www.geomar.de/~rseyfrie/index.html

V51E MC: 304 Friday 0830h

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

Presiding: **C H Langmuir,** Lamont-Doherty; **K Mezger,** Universitaet Muenster

V51E-01 0830h INVITED

Osmium Isotope Compositions of Komatiite Sources Through Time

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Extending Os isotopic measurements to ancient plume sources may help to constrain how and when the well-documented isotopic heterogeneities in modern systems were created. Komatiites and picrites associated with plume-related volcanism are valuable tracers of the Os isotopic composition of plumes because of their typically high Os concentrations and relatively low Re/Os. Re-Os data are now available for a variety of Phanerozoic, Proterozoic and Archean komatiites and picrites. As with modern plumes, the sources of Archean and Proterozoic komatiites exhibit a large range of initial $^{187}Os/^{188}Os$ ratios. Most komatiites are dominated by sources with chondritic Os isotopic compositions (e.g. Song La; Norseman-Wiluna; Pyke Hill; Alexo), though some (e.g. Gorgona) derive from heterogeneous sources. Of note, however, two ca. 2.7 Ga systems, Kostomuksha (Russia) and Belingwe (Zimbabwe), have initial ratios enriched by 2-3% relative to the contemporary convecting upper mantle. These results suggest that if the ^{187}Os enrichment was due to the incorporation of minor amounts of recycled crust into the mantle source of the rocks, the crust formed very early in Earth history. Thus, the Os results could reflect derivation of melt from hybrid mantle whose composition was modified by the addition of mafic crustal material that would most likely have formed between 4.2 and 4.5 Ga. Alternately, the mantle sources of these komatiites may have derived a portion of their Os from the putative ^{187}Os - and ^{186}Os -enriched outer core. For this hypothesis to be applicable to Archean rocks, an inner core of sufficient mass would have to have crystallized sufficiently early in Earth history to generate an outer core with ^{187}Os enriched by at least 3% relative to the chondritic average. Using the Pt-Re-Os partition coefficients espoused by our earlier work, and assuming linear growth of the inner core started at 4.5 Ga and continued to present, would yield an outer core at 2.7 Ga with a gamma Os value of only +1.2 and a $^{186}Os/^{188}Os$ enrichment relative to the contemporary upper mantle of only +13 ppm. Greater isotopic enrichments could have been achieved by 2.7 Ga if either the inner core comprised >2.8% of the mass of the core by 2.7 Ga, or if Re and Os solid metal-liquid metal D's for core crystallization were greater that those applied in the initial calculation.

V51E-02 0845h

Undersaturated Volatile Contents in MORB, Evidence for Re-Melting Episodes

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We present here the first report of undersaturated volatile contents for one of the most primitive suites from the EPR, the picritic lavas from the Siqueiros intra-transform spreading centers. We studied olivine-hosted (Fo 90-91) primary melt inclusions and their host glasses from lavas erupted at approximately 3900 meters below sea level. The study of melt inclusions and deep erupted glasses allows us to determine the primary volatile contents of the Siqueiros lavas, avoiding the effect of degassing occurring during eruption. The melt inclusions and glasses have refractory major and trace element compositions, with the most depleted compositions having strong enrichment in Sr content compared to elements of similar compatibility. The primitive-mantle-normalized trace element patterns of these depleted inclusions resemble those of plagioclase-rich cumulates occurring in the lower oceanic crust and in massif peridotites. The Siqueiros glasses and olivine-hosted melt inclusions are undersaturated in H_2O-CO_2, Cl and F, and range from barely saturated to undersaturated in S contents. The undersaturation in volatile contents of these glasses and melt inclusions is consistent with the low vesicularity of the Siqueiros picritic lavas (<0.1%). The refractory major, trace and volatile compositions of the Siqueiros melt inclusions and glasses can be explained by low extent of melting (1-5 %) of residual peridotite, left after the extraction of MORBs, and Associated veins of plagioclase-rich cumulates generated during MORB differentiation and interaction with the residual mantle. Our results have important implications for our interpretation of MORB geochemistry. For example, melting of young (<10,000 years) depleted peridotite left after the extraction of MORB with associated plagioclase-rich cumulate can give an alternative explanation to the extreme 226Ra excess found in MORBs.

V51E-03 0900h

Determining the Mineralogy of the MORB Source Through Nd-Isotope Analyses of Abyssal Peridotites

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Interpreting the chemical and isotopic systematics of MORBs in relation to details of the melting process and the physical conditions under which melting takes place hinges on the assumption of compositional similarity or regularity between all MORB sources. For example, the interpretations of regular variations in Na8 and Fe8 versus axial ridge depth, thought to reflect a deeper initiation of melting and higher extents of melting beneath shallow ridges, are only valid in the context of chemically and mineralogically homogeneous source mantle. The presence of garnet-bearing mafic compositions with enriched signatures in the mantle has long been discussed. Garnet-bearing eclogite or pyroxenite blobs or veins in the MORB mantle would likely be associated with plume material and thus, would tend to correlate with the degree of “enrichment” in the MORB source. If residual during melting, garnet pyroxenite can further contribute to the chemically enriched character of derivative basalts by trace element fractionations that are characteristic of residual garnet. It has been shown that, in general, the mineralogical, major element and trace element variations abyssal peridotites are consistent with the major and trace element variations observed in MORB. We have examined the variations in Sr and Nd-isotopic and trace element composition of abyssal peridotites from two ridge segments, the segment near the Atlantis II Fracture Zone (AII FZ) and the 10^o to 16^oE section of the south east Indian ridge (10-16E) and compared these variations with the Sr and Nd-isotope variations in the basalts. Basalts from the AII FZ show a normal MORB chemistry and have $^{143}Nd/^{144}Nd$ ratios as low as 0.5130, while basalts from the 10-16E section show an anomalous enriched character and have $^{143}Nd/^{144}Nd$ ratios ranging from 0.51284-0.51302. The REE pattern of diopsides in the AII Fracture zone peridotite show a strongly light REE depleted pattern indicating they are residues of MORB genesis. In comparison, the REE patterns of the diopsides of the 10-16E area are flat to only slightly light REE depleted and the most enriched REE patterns can be in equilibrium with MORB. The Nd-isotopic composition of the diopsides in the abyssal peridotites comfirm the trace element chemistry. Clionpyroxenes from peridotites from the AII FZ have Sr and Nd-isotopic compositions that overlap with those of the basalts and $^{143}Nd/^{144}Nd$ ratios range from 0.513077 to 0.513409, and $^{87}Sr/^{86}Sr$ ranges from 0.70255 to 0.70305, while at the 10-16E section $^{143}Nd/^{144}Nd$ ratios vary from 0.513031 to 0.513194 and $^{87}Sr/^{86}Sr$ varies from 0.70260 to 0.703025. These data show that the Sr and Nd-isotopic composition of abyssal peridotites from both ridge segments have a MORB-source signature. Therefore at the 10-16E segment in which the isotopically “enriched” basalts occur the peridotites only overlap with the deplete endmember and the enriched signature requires the presence of a component other than peridotite. A mafic component in the MORB source of the 10-16E section is the most likely candidate.

V51E-04 0915h

Water concentrations in enriched mantle components in the north Atlantic: Evidence for efficient dehydration of recycled crust and sediments

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A major uncertainty in the earth's water cycle is the amount of water that enters the deep mantle through subduction and recycling of hydrated oceanic lithosphere. We measured H_2O and CO_2 in north Mid-Atlantic Ridge (MAR) glasses dredged by between 33.2 and 40.5°N (FAZAR expedition) between 926 and 3900 m depth. Two distinct geochemical anomalies occur within this region, a long wavelength anomaly associated with the intersection of the Azores archipelago and the MAR at ∼38-39°N (Azores Platform) and a short wavelength anomaly centered at 35°N (Great Meteor anomaly). Sr-Nd-Pb isotopic compositions show evidence for mixing of 3 mantle components: (1) depleted MORB mantle (DMM), (2) a common plume source (C) and (3) an enriched mantle component (EM) thought to represent recycled crustal materials. Azores Platform basalts form a linear mixing array between DMM and C. In contrast, basalts from the Great Meteor anomaly form a mixing array between C and EM. Dissolved water concentrations in the poorly vesicular Azores Platform samples correlate positively with K_2O and have H_2O/Ce ratios (253±33) consistent with previously reported values for the north Atlantic. Estimated bulk H_2O/Ce for the highly vesicular samples (247±54) are similar to the values for the nonvesicular samples for all but the shallowest dredge (17), which may have suffered some gas loss. Great Meteor samples have dissolved and bulk water concentrations at a given K_2O ∼30% lower than the Azores Platform samples (Bulk H_2O/Ce = 168±29). Extrapolation from C through the Great Meteor H_2O/Ce data yields a value of <100 at a $^{87}Sr/^{86}Sr$ of >0.705. Thus, EM components in north Atlantic are depleted in water relative to similarly incompatible elements. The results of this study are consistent with results from the south Atlantic (Leist et al., this volume) and previous work on Hawaii, where the Koolau (EM1) component was found to be depleted in water (Dixon and Clague, 2001, JPet, 42: 627-654; Hauri, 2001, Chem. Geol., in press). We suggest that relatively dry EM components are common and result from >92% extraction of water from crustal materials during the subduction process and their recycling through the deep mantle.

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