iments of the subducting Ionian plate. The third component is represented by continental material (crust-derived fluids or partial melts) which are incorporated into mantle-derived magmas. This last component is acquired in the crust, probably at 8-10 km of depth where seismic tomography and other geophysical studies, as well as pressure estimates resulting from melt inclusion analyses, identify an horizontally extended low-velocity layer. This layer is interpreted as the top of the present magma reservoirs in the areas beneath Mt. Vesuvius and the Phlegraean Volcanic District. We have detected an eastward spatial variation in the isotopic characteristics of the volcanic rocks, from Procida and Ischia islands to the Campi Flegrei caldera and Mt. Vesuvius. This variation can be interpreted as the result of variable contribution of the slab-derived component to the mantle source, due to the variable position of the volcanoes with respect to the Ionian plate, presently sinking beneath the Southern Tyrrhenian sea. We speculate that within the crust there are multiple sill-like bodies where magmas stop, permeate and interact with the crust. This structure would consist of rocks permeated by various portions of melt, in such a way to individuate different reservoirs at different depths. The existence of different depths of cristallization (10-22 km) and the occurrence of discrete isotope values in the volcanic rocks strongly suggest that different magma batches, starting from the mantle source, stop at various depths during their ascent towards the surface. Such a condition would determine a large surface of contact between magma and whole rock which could favour contamination.

V31E-0987 0830h POSTER

Volcanic rocks from Somma-Vesuvius (Italy): Evidence from an extensive geochemical and Sr-isotopic database, diverse magma sources, and crustal contamination.

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An extensive database of rock compositions from Somma-Vesuvius now exists that spans the volcanic products from 25 ka to 1944 AD. The database was produced by the University of Napoli (Italy) Federico II and the US Geological Survey (in press as an Open File report) and includes newly acquired major-, trace-element and Sr isotopic analyses as well as a compilation of data produced over the last decade. New data were obtained mostly on pyroclasts and lava flows from the Older (25 to 17 ka), Protohistoric (3.5 to 2.8 kaP), Ancient (79 to 472 AD) and Medieval (472 to 1631 AD) interplinian events, and from Somma caldera lava ($>$ 25 ka) and selected plinian products (e.g. Ottaviano, 8 ka; Seggiari, 14 ka). The rocks are potassic to ultrapotassic, increasingly enriched in K (and Na-La-Nb) with decreasing age of the eruptions. Three main compositional trends are distinguished: 1) potassic rocks older than 8 ka; 2) Avellino, Pompei, Protohistoric and Ancient ultrapotassic products; 3) ultrapotassic rocks with age equal or younger than the 472 AD eruption. All rocks have low Mg numbers ($<$ 40), low Ni and Cr contents ($<$ 80 and 300 ppm), and a span for $^{87}Sr/^{86}Sr$ from $\sim$ 0.70628 to 0.70807. Major- and trace-element and Sr-isotopic variations of the ultrapotassic rocks reflect a complex interplay of contributions from mantle sources, and particularly from the enhanced effects of crustal contamination. Crystal fractionation and phenocryst entrapment as the magmas ascended and were stored in the crust are key processes accounting for the geochemical variations. In particular, phenocryst entrapment was a widespread mechanism that amplified the effects of crustal contamination, as crystal mush generated (and contaminated) during previous magma storage in the crust can be ingested by new rising magmas thus decreasing the mass of wall rock necessary to vary the Sr-isotope composition of magmas. Compositional, volcanological and geochronological data show that a critical transition links an older volcanic phase (characterized by the eruption of low porphyritic and moderate K-rich magmas) to a younger phase (characterized by the eruption of highly crystalline and high K-rich magma) and culminated during the Pollena eruption. The Pollena eruption reflects the progressive exhaustion of the shallow-level magma chamber and magma replenishment from deeper storage, perhaps exceeding 11 km.

V31F MCC: 3006 Wednesday 1020h

The Origins of Hot Spots, LIPs, Seamount Chains, and Volcanic Ridges V *(joint with OS, T)*

Presiding: **G R Foulger,** University of Durham**; D C Presnall,** Carnegie Institution of Washington

V31F-01 1025h INVITED

Low Temperature Origin of Oceanic Ridges and Associated Hot Spots

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In the absence of melting, the small amounts of H_2O (100-300 ppm) in the MORB mantle would be totally dissolved in nominally anhydrous minerals and no hydrous phases would occur. These amounts of H_2O would lower the solidus only an insignificant amount. In contrast, the solidus temperature is a very weak function of the mount of CO_2, and even the smallest amount would reduce the solidus at P$>$1.9 GPa by $>$300°C. The consistent occurrence of vesicles in MORBs and the strong dominance of CO_2 in these vesicles indicates that at least some CO_2 exists in all or almost all of the mantle beneath ridges. The seismic low-velocity zone (LVZ) closely follows the ocean ridge system, and with rare exceptions (Iceland, Afar, and possibly a few other localities), it does not extend to depths greater than $\sim$250 km. The minimum potential temperature (Tp) required for the generation of basalts is $\sim$1240°C, a Tp that could not avoid producing carbonatitic melts at very low melt fractions in the depth range of $\sim$65-300 km. This confirms earlier conclusions that partial melting occurs in the LVZ. For a Tp of 1240-1260°C, both the depth range of melting and depth of maximum melting ($\sim$70 km) predicted by the phase relations closely match the observed S velocity variations that define the LVZ beneath oceanic ridges. This supports the presence of CO_2 as the cause of melting and a low Tp range for almost all ridges. Here the carbonated lherzolite solidus is extrapolated to higher pressures in a way that minimizes the solidus-adiabat intersection and thereby maximizes the viability of high Tp values. Even with this conservative extrapolation, melting models that involve strongly variable potential temperatures ranging up to $\sim$1450-1500°C (McKenzie and Bickle, 1988; Langmuir *et al.*, 1992) imply melting at depths extending into the mantle transition zone for a carbonated lherzolite. For almost all ridge segments, shear wave tomography does not support melting at these extreme depths and is consistent only with low potential temperatures. If the Azores, Galapagos, and Tristan "hot spots" are hot, their broad topographic swells extending over $>$2000 km suggest the existence of deep and broad low shear velocity anomalies that should be easily visible by global seismic tomography. The absence of such anomalies supports low potential temperatures also for these near-ridge "hot spots".

V31F-02 1045h

No Core Contribution in Mantle Plumes: New Evidence From Tungsten Isotopes

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Os isotope ratios provide major constraints on the sources of ocean island basalts, but are currently interpreted in two dramatically different models. One implies interaction with the outer core, and as a corollary of coupled ^{186}Os-^{187}Os anomalies requires early inner core formation, whilst the other involves a source of recycled oceanic crust. Tungsten isotope data on the same set of picrites used to establish ^{186}Os-^{187}Os anomalies for Hawaiian picrites have ϵW= -0.06 to 0.04 with errors of $\pm$0.11 to $\pm$0.31. Similarly a suite of selected South African kimberlites, which have also been proposed to contain a core contribution, have ϵW= -0.07 to 0.03 with errors of $\pm$0.10. The isotope budget of tungsten in the Earth is well characterised. Given that bulk Earth is chondritic (ϵW = -2) and the silicate Earth has ϵW = 0 (by definition), then the core ϵW = -2.1. Tungsten is siderophile during core formation and incompatible during mantle melting, which leaves it depleted in the mantle (1.9-15 ppb) but strongly enriched in the core ($\sim$500 ppb) and the crust (850-1100 ppb). Thus, tungsten is a sensitive tracer of core contributions in the source of mantle melts. We explore two different models of simple core-mantle mixing where mantle W-depletion and inner core crystallisation history are the two most important parameters. None of the samples analysed have the negative W-isotope values of -0.2 to -0.6 ϵW predicted from our preferred core contribution model. Extreme combinations of all critical input values have to be assumed to achieve any overlap between modelled and measured ϵW. Hence a simple core-mantle mixing scenario appears to be ruled out, and other explanations need to be sought. Mn-nodules have high $^{190}Pt/^{188}Os$ $\sim$0.2-0.5, low Re/Os $\sim$0.1-0.5 but high [Os] $\sim$1-3 ppb and $^{187}Os/^{188}Os$ $\sim$0.5-1. $\sim$2% of recycled Mn-nodule in the peridotite source reproduces the observed Os isotope trends and it would be associated with an increase of just $\sim$0.5 wt% Mn.

V31F-03 1100h

Noble Gas Partitioning Behaviour During Mantle Melting: A Possible Explanation for 'The He Paradox'?

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New UVLAMP measurements of experimental noble gas crystal/melt partitioning values (including He) suggest reasonably incompatible behaviour for both olivine and cpx and no significant fractionation of noble gases relative to one another. This is consistent with models of noble gas incorporation at crystal lattice sites in both crystals (1). However the determined D values of approximately 8 x10-4 for cpx and 5 x10-3 for olivine suggest a small but significant amount of noble gas might be retained in the mantle after melting. It is also apparent that He is three orders of magnitude less incompatible than U and Th in olivine. As opx is predicted to show similar characteristic to olivine, melting to produce a highly depleted harzbugitic (low-cpx) mantle would involve the preferential removal of U+Th relative to He. This in turn would allow a relatively undisturbed primordial/radiogenic 3He/4He ratio to be retained in association with low He abundance. Thus, recycling of previously depleted mantle into the source region of 'hot spots' provides one possible explanation for the paradox of high 3/4 He ratios previously thought to indicate an undegassed, primordial lower mantle reservoir, with low He abundance indicating a degassed source (2). Preliminary UVLAMP depth profiles for noble gas diffusion in mantle minerals confirm that although sub-solidus diffusive removal of He relative to other noble gases from a gas-rich mantle plum is theoretically possible, the short distances involved are unlikely to produce an effect that can be sustained though a hot spot melting event. The slow diffusion rates and lack of fractionation of noble gases in our partitioning experiments suggests that low He/Ar (and Ne/Ar) ratios observed at hot spots are most likely to be features inherited from the source, or subsequently imposed by some shallow level process. In our partitioning experiments, it proved surprisingly difficult to grow olivine crystals that are free of bubbles, even from volatile undersaturated melts. These bubbles nucleate on the crystal surface and can become included as the crystals grow. Although inclusions can be avoided using our micro-analytical technique, their bulk effect is to produce high crystal+bubble/melt D values and fractionation of light from heavy noble gases due to decreasing solubility in the melt for the latter. If such bubble capture occurs in nature as suggested by (3), the cumulative crystal rock would show enrichment in light noble gases and the residual melt will be depleted. This effect is similar to degassing but may be independent of saturation and depth of emplacement and decoupled from other volatile behaviour. The removed volatiles will also be retained in the cumulate rock rather than degassed. Differences in crystal growth processes and bubble trapping during MORB and IOB emplacement could contribute towards different He/Ar and Ne/Ar ratios. 1. R.A. Brooker et al., Nature 423, 738-741.

2003 2. D.L. Anderson, Proc. Natl. Acad. Sci. USA 95, 4822-4827. 1998 3. J.H. Natland, J. Pet. 44, 421-456. 2003

V31F-04 1120h

Motion of Hotspots Relative to the Paleomagnetic Axis

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Southward motion of the Hawaiian hotspot plume relative to the paleomagnetic axis has been observed (Tarduno et al.,2003), and this can be explained by either motion of the Hawaiian hotspot relative to other Pacific hotspots, or motion of the group of hotspots relative to the paleomagnetic axis. First, we examined whether inter-hotspot motion is essential or not for the explanation of observed data of seamounts in the Pacific basin. We found that both the Polygonal Finite Rotation Method (Harada and Hamano, 2000) and the Hotspotting Method (Wessel and Kroenke, 1997) can successfully be used to develop models of the Pacific and the Nazca plate motion relative to hotspots. This indicates that no inter-hotspot motion is needed to explain ages and positions of hotspot tracks in the Pacific basin. Second, combining the Pacific plate motion relative to hotspots and Pacific paleomagnetic poles (Acton and Gordon, 1994, Johnson, 2000), we calculated the motion of Pacific hotspots relative to the paleomagnetic axis (Pac-PWP). Based on this analysis, southward drift of the Hawaiian hotspot is predicted and it is quite in harmony with the newly observed southward motion of paleolatitude for the Emperor seamount chain. Similarly, we constructed a model of the African plate motion relative to African hotspots, and calculated the motion of African hotspots relative to the paleomagnetic axis (Af-PWP). Pac-PWP and Af-PWP are quite similar and we conclude that there is no significant relative motion between Pacific hotspots and African hotspots since 70 Ma.

V31F-05 1135h

Transform Control on Ridge Propagation and Hotspot Formation

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Large extensional stresses at ridge-transform intersections provide a mechanism for both the propagation of mid-ocean ridge segments and the formation of hotspot seamounts at ridge-transform intersections (RTIs). I propose that extensional stress is increased at ridge-transform intersections when slip along transforms is impeded. Thus, the inability of transforms to slip may cause either ridge-propagation and/or the formation of hotspot seamounts at RTIs. Extensional stress at the ridge-transform intersection may result in decompression melting and a change in the physiographic and thermal gradient in the upper mantle. Under these conditions excess magma at or near the ridge would result in the formation of a hotspot seamount at the ridge-transform intersection rather than in the segment center. Conversely, ridge propation may occur when the magma supply is lower and the stress concentration is high enough. Because transform slip can be impeded by a number of factors ranging from hydrothermal alteration to plate motion changes, the coupling of ridge-propagations to transform slip does not decouple the propagation of ridges from changes in plate motion. Rather, in addition to providing an alternative means of propagation during plate motion changes, the coupling of ridge-propagation to transform slip provides a mechanism for ridge-propagation during steady-state plate motions. Thus, a simple lithospheric mechanism is proposed, under certain conditions, to be responsible for the propagation of mid-ocean ridge segments and the location of hotspot seamounts at RTIs. To test the viability of this proposal a three-dimensional finite element grid of a series of three ridges and 2 transforms was constructed. Slip along the transforms was impeded by changing the strength of the transform and by varying plate motions. Large extensional stresses were concentrated at ridge-transform intersections when slip along the transform was impeded. Changes in the stress of the mantle were also observed when slip along the transform was impeded. Large concentrations of extensional stress at transforms may result in either the propagation of the ridge or, when magma supply is high, the formation of a hotspot. Thus, a lithospheric element is suggested as a mechanism for ridge propagation and hotspot formation.

V31F-06 1150h

Mantle Dynamics beneath the western United States

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Much uncertainty still exists with respect to the state of the mantle beneath the western United States and the dynamical activity that created this current state. Three end-member dynamical agents may be at work. First, input of heat from below is often used to explain: the Yellowstone Hotspot track (a plume), the high standing elevation of the northern Basin and Range (a plume head), the petrology and geochemistry of southern Nevada young basalts (a plume), and the late-Cenozoic uplift and rifting of the southern Rockies (unspecified source of heat). Second, many publications note the correspondence between the volcano-tectonic activity of the western US and pre-existing lithospheric structures (sutures). For example, the low velocity body imaged beneath the Jemez volcanic lineament (from the CD-ROM project) shows clear mantle velocity layering within the low velocity body suggesting that this velocity anomaly is lithospheric, not asthenospheric in origin. Third, both lithospheric and asthenospheric modes of small-scale convection may be ongoing today. If our understanding of the dynamical parameter space for small-scale convection is correct, then the low upper mantle viscosity ($<10^{19}$ Pa-s) and thin Basin and Range lithosphere demands that small-scale convection is occurring. Yet, the abundance of seismic imaging beneath this region cannot presently constrain the planform and modes of small-scale convection. In particular, the magnitude of the thermal anomalies are poorly constrained due to uncertainties in the Q operator and hence the magnitude of the anelastic velocity-temperature derivative. Also, the numerous short term (<1-2 year) PASSCAL deployments in the western US, while providing unparallel spatial coverage, generally lacks a sufficient distribution of SKS events to constrain dipping anisotropy. This undersampling problem is unfortunate because dipping anisotropy is probably our best proxy for small-scale convective flow beneath this region Comments on the seismic imaging challenges, that will face the deployment of the USarray component of Earthscope, will conclude this talk.

V31F-07 1205h

Post-Laramide Volcanism and Upper Mantle Dynamics in the Western US: Role of Small-Scale Convection

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Seismic tomography in the Western U.S. reveals ubiquitous small-scale (200-600 km wavelength) seismic velocity variations at 100 km depth. Many slow anomalies lie beneath recent volcanic fields and exhibit a magnitude that is difficult to explain on the basis of temperature variations alone, implying the presence of partial melt in the asthenosphere. Two- and three-dimensional numerical convection simulations, including the effects of melt and residual composition changes, show that these effects add buoyancy to the system and increase both the vigor and temperature contrast in the resulting small-scale convection relative to cases in which no melting occurs. In our models, the viscosity contrast between lithosphere and asthenosphere is regulated by the activation energy for temperature-dependent viscosity. A high viscosity contrast results in small horizontal temperature anomalies and involves only small portions of the lithosphere (the "compact mode"). A lower viscosity contrast gives rise to larger temperature anomalies by involving a greater portion of lithosphere in the convection, resulting in substantial thinning of the lid by erosion in the form of detached drips (the "drippy mode"). Because the drippy mode occurs for small viscosity contrasts, it is consistent with a weak lithosphere that might arise due to the presence of volatiles. A temporal transition from a "wet" drippy mode (resulting in substantial lithospheric thinning and melt production) to a "dry" compact mode (following volatile removal in melts) may provide an explanation for the observed diachronous character of tectonic and volcanic events in the Western U.S. geologic record. This process would have initiated with the mid-Tertiary ignimbrite flare-up following removal of the flat (and presumably volatile-rich) Farallon slab, and continued through the Miocene when much of the volcanism became basaltic and effusive in character. Such a model is consistent with numerous observations, and perhaps importantly involves only basic small-scale convection processes without requiring the presence of deep-seated mantle plumes. In addition, by experimenting with various imposed strain rates in a moving lithosphere, we have also been able to produce time-progressive volcanism generated by small-scale convection in the form of Richter rolls that presents a viable alternative to the hot spot idea.

URL: http://geodyn.ess.ucla.edu/~hernlund

V31G MCC: 3008 Wednesday 1020h

Eruptive Behavior of Hazardous Volcanoes I

Presiding: **S L de Silva,** University of North Dakota**; A Clarke,** Arizona State University

V31G-01 1020h

Eruption Dynamics and Conduit Processes of the Circa 240 A.D. KS1 Eruption of Ksudach Volcano, Kamchatka, Russia

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The 240 A.D. KS1 eruption of Ksudach volcano formed a 6-7 km3 caldera and dispersed 18-19 km3 of material over much of the Kamchatka peninsula. Previous workers have shown that the deposit consists of 15 km3 of tephra falls and 3-4 km3 of pyroclastic flows. Current studies of deposit stratigraphy and componentry, rock textures, compositions, and volatile contents give insight into dynamics and conduit processes of the eruption. KS1 deposits consist of interbedded white pumice falls and ash layers overlain by gray pumice fall and flow deposits. Two lithic-rich fall layers are present at the transition from white to gray pumice and ash. We interpret the changing character of the deposits with distance and height as a reflection of changing eruptive conditions. Early stages of eruption were dominated by buoyant (fall) behavior. During the main stage, falls and flows (non-buoyant behavior) were simultaneously erupted. The final stage involved caldera collapse followed by buoyant eruption of gray material. Column heights calculated from lithic distributions show that the column was highest and eruption most vigorous during the main stage of eruption, just prior to caldera collapse. Occurring just after collapse and at the shift from fall and flow to fall-dominated deposition, the white to gray transition provides an important timeline in the eruption. Whole-rock and microprobe analyses show the two pumice types to be nearly identical. Similarly, magnetite-ilmenite geothermometry shows that both types were erupted at 895 degrees C. FTIR analyses of melt inclusions in phenocrysts indicate that both white and gray pumices had water contents of 4 wt% prior to eruption and completely degassed during eruption. These data indicate that the difference between the white and gray pumices may be solely textural. Ongoing studies of textural differences between white and gray pumices, particularly with regard to bubble sizes, shapes and distributions, may reveal important differences between pre- and post-collapse eruptive processes.

V31G-02 1035h

Pre-eruptive volatile contents of the 26.5 ka Oruanui magma, Taupo Volcanic Zone, New Zealand

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