Tales of Two LIPs: Kerguelen/Broken Ridge (Indian Ocean) and Ontong Java (Pacific Ocean)

Millard F Coffin

Institute for Marine and Antarctic Studies, University of Tasmania, Australia

E-mail: mike.coffin@utas.edu.au

The Kerguelen Plateau and Broken Ridge (KPBR), and Ontong Java Plateau (OJP), are among the largest igneous provinces (LIPs) on Earth, with crustal volumes of 25 and 57 million cubic km, respectively. They represent episodic and massive mafic magmatism not clearly associated with plate tectonic processes. LIPs are significant in the Earth system both for underlying mantle processes and effects on the global environment. Investigations of the two features have revealed significant differences. The Kerguelen hotspot has produced mafic magmas since at least 120 Ma, perhaps the longest continuous hotspot record on Earth. KPBR contain microcontinental fragments. Upper crust of KPBR is structurally complex, and includes sag basins, rift zones, pull-apart basins, faulted flanks, and volcanic centers. Although dominantly tholeiitic basalt, the upper crust contains a wide range of basaltic to rhyolitic volcanic products. Nearly all of the drilled upper crust formed subaerially, and subsequently subsided beneath sea level at rates comparable to those of typical oceanic crust. In contrast to KPBR, OJP is entirely oceanic, includes no continental material, and cannot be unequivocally linked to any hotspot track or currently active hotspot. It appears to have formed instantaneously, in a geological sense, at approximately 120 Ma, together with flood basalts in the older neighboring Nauru, East Mariana, and Pigafetta Basins, and simultaneously with the Manihiki and Hikurangi plateaus. The upper crust of OJP is structurally relatively simple, although its flanks are faulted in places, and is homogeneously tholeiitic. To date, all igneous basement rocks drilled on the plateau and sampled from obducted OJP sections in the Solomon Islands formed in a submarine environment, and subsequent lithospheric subsidence was either minimal or erratic. OJP is characterized by a low velocity mantle root extending several hundred kilometers into the asthenosphere that is interpreted as chemically, not thermally, anomalous. This root appears to deflect normal Pacific Ocean asthenosphere around it, and thus seems to be rigidly coupled to OJP crust. Classic plume theory explains neither KPBR nor OJP. Plume models predict massive flood volcanism roughly coeval with continental breakup, yet the onset of voluminous KPBR magmatism post-dated separation of India and Antarctica by at least 10 million years. Plume theory also predicts short-lived (approximately 1 Myr) plume head volcanism followed by long-lived (10 to 100 Myr) plume tail volcanism, yet peak magma output of the Kerguelen hotspot lasted approximately 25 Myr. Plume models predict major lithospheric uplift approximately coeval with voluminous magmatism, and subsequent plateau subsidence at rates similar to normal oceanic lithosphere, but the main OJP was never above sea level and has experienced only slight or erratic ensuing subsidence. Alternatives to existing plume models are needed to explain both KPBR and OJP.

Crustal structure of the Ontong Java Plateau revealed from seismic surveys

Seiichi Miura[1], Millard F Coffin[2], Shuichi Kodaira[1]

[1]Japan Agency for Marine-Earth Science and Technology, Japan, [2]University of Tasmania, Australia

E-mail: miuras@jamstec.go.jp

The Ontong Java Plateau (OJP), one of the largest oceanic plateaus on Earth, lies in the western equatorial Pacific Ocean, and is mainly defined by the 4000 m bathymetric contour (Mahoney et al., 2001). The main part of the OJP, the so-called High plateau, is shallower than 2000 m, and includes several atolls. The OJP's eastern salient extends eastward and southeastward from the High plateau and lies deeper. Since the 1970s, geophysical investigations, including seismic surveys, have been undertaken to reveal the OJP's structure (e.g. Furumoto et al., 1976). Although shallow water depths suggest that OJP crust is thick, seismic and gravity analyses have produced significantly different crustal thicknesses. For example, the maximum Moho depth determined from the first seismic refraction data from the northern High plateau was 42 km (Furumoto et al., 1976), whereas that from gravity data was 25 km (Sandwell and Renkin, 1988). In 1995, a seismic refraction transect was undertaken from the southern OJP to the Australian plate (Miura et al., 2004), and showed the Moho depth to be about 35 km below sea level for the southernmost OJP. To reveal the structure of the OJP's High plateau, we conducted an active source seismic experiment utilising a 128 liter active seismic source, 100 ocean bottom seismometers, and an approximately 6000 m streamer in 2010 (Miura et al., 2011), the first investigation of such scale on the OJP. The new reflection and refraction data are of high quality and image both the shallow sedimentary sequences and deep crustal reflections of the OJP. In this presentation, we will review previous seismic work on the OJP, show initial crustal structure interpretations resulting from our new seismic data, and discuss potential models for formation of the OJP.

Post-emplacement alkalic volcanism on the Ontong Java Plateau revisited: Insights from Lyra Basin basalts

Maria Luisa G Tejada[1], Kenji Shimizu[1], Katsuhiko Suzuki[1], Takeshi Hanyu[1], Takashi Sano[2], Masao Nakanishi[3], Akira Ishikawa[4], Qing Chang[1], Takashi Miyazaki[1], Yuka Hirahara[1], Toshiro Takahashi[1], Sun'ichi Nakai[5], Ryoko Senda[1]

[1]IFREE, Japan Agency for Marine-Earth Science and Technology, Japan, [2]Dept. Geology and Paleontology, National Museum of Nature and Science, Japan, [3]Graduate School of Science, Chiba University, Japan, [4]Dept. Earth Sci. and Astronomy, The University of Tokyo, Japan, [5]Earthquake Research Institute, The University of Tokyo, Japan

E-mail: mtejada@jamstec.go.jp

Post-emplacement volcanism on the Ontong Java Plateau (OJP) is evident both on the islands of Malaita and Santa Isabel in the Solomon Islands, forming its southern margin, and on the plateau itself based on geophysical imaging and occurrence of several atolls, seamounts, and other features of igneous origin. In addition, similar late-stage alkalic seamounts are also identified on Manihiki and Hikurangi plateaus that presumably formed between 70-100 Ma, suggesting similarity with the OJP. The cause for such widespread alkalic volcanism across all three plateaus is poorly understood. Some insights into a possible origin in the case of the OJP may be derived from the alkalic basalts in the Lyra Basin, forming the western margin of the plateau. These lavas also post-date the main emplacement of the OJP by about 60 Ma. Based on our Pb-Nd-Sr-Hf-Os isotope investigation of the alkalic lavas recovered by dredging on the Lyra Basin, we confirm the existence of post-OJP extrusives that may have covered the older plateau lavas in the area. The Lyra Basin alkalic basalts possess Sr-Nd-Pb isotopic compositions that are distinct from those of the OJP tholeiites. They also have Os isotopic compositions that are similar to the range of values determined for the Kwaimbaita-Kroenke-type OJP lavas but their Hf isotopic values are lower. These isotopic compositions do not match any of the Polynesian hot spots well either. Instead, the Lyra Basin lavas have geochemical affinity and isotopic compositions that overlap with those of some alkalic suite and alnoites in the island of Malaita. Although not directly related to the main plateau volcanism at 120 Ma, our geochemical modeling suggests that the origin of the Lyra Basin alkalic rocks may be genetically linked to the mantle preserved in the thick lithospheric mantle root of the OJP.

Lithium isotope evidence for direct assimilation of hydrothermal fluid to magma beneath oceanic large igneous provinces

Takashi Sano[1], Yoshiro Nishio[2]

[1]National Museum of Nature and Science, Japan, [2]Japan Agency for Marine-Earth Science and Technology, Japan

E-mail: sano@kahaku.go.jp

Li isotopic compositions of fresh basalts from two oceanic large igneous provinces (LIPs), the Shatsky Rise and Ontong Java Plateau, fall within those of the mid ocean ridge basalt (MORB) and ocean island basalt (OIB). In contrast the basalts from the two oceanic LIPs show Li enrichment compared to the MORB and OIB; Li contents are obviously higher at a given MgO. Among basalts from the two oceanic LIPs, one fresh glass sample from the Shatsky Rise has a distinctly enriched composition with high K/Ti and Nb/Ti. The delta^{7} Li value of the enriched sample is near the highest end (+6 permil) of the MORB and OIB values, implying that the sample may have been affected by recycled mantle that metasomatized by slab-derived fluids. However, no clear systematic relationship between the delta^{7} Li and the enrichment components are found in the other basalts from the two oceanic LIPs. On the other hand, obvious linear relationships exist between delta^{7} Li and Yb/Li, Y/Li, and Dy/Li of samples from the Shatsky Rise. The linear relationships are explained by binary component mixture between pristine magma and hydrothermal fluid beneath the oceanic LIPs. The direct assimilation of hydrothermal fluid to magma is the best mechanism to explain the Li enrichment with little shift of delta^{7} Li in basalts from the oceanic LIPs.

Self-limiting chemistry, aerosol and climate effects of large-scale flood basalt eruptions

Thorvaldur Thordarson[1], Anja Schmidt[2], Marjorie Wilson[2], Kenneth S Carslaw[2], Stephen Self[3]

[1]Faculty of Earth Sciences, University of Iceland, Iceland, [2]School of Earth and Environment, University of Leeds, United Kingdom, [3]Department of Earth and Environmental Sciences, The Open University, United Kingdom

E-mail: torvth@hi.is

Flood basalt volcanism is typified by repeated effusion of huge batches of magma (about 1000 cubic km) in events lasting more than 5-15 years. Estimated mean eruption rates for these events are 10-100 million kg per sec. It would take 10 years of continuous activity at Laki 1783-1784 AD peak eruption rate (12 million kg per sec) to produce a lava flow field of flood basalt dimensions. Model estimates indicate fountain heights of more than 1 km and plume heights of 10-15 km. A typical flood basalt event releases about 10,000 million tons of sulfur dioxide into the atmosphere or 1000 million tons per year for a 10-year-long event. We use a state-of-the-art global aerosol microphysics model (GLOMAP) to simulate the atmospheric and climatic effects of large-scale flood basalt eruptions. Our standard eruption scenario is that of the Laki eruption, which injected around 100 million tons of sulfur dioxide into the upper troposphere/lower stratosphere over the course of eight months. Our GLOMAP aerosol model results for Laki compare well with volcanological and historical records and other modelling studies. Subsequently, we scaled the Laki standard scenario by factors of 10 and 100 for the amount of sulfur dioxide released. In addition we conducted series of model simulations in which several consecutive Laki eruptions, or their scaled equivalents, are simulated for up to ten years. We assume that the sulfur-release by one Laki x10 per year for ten years corresponds to a typical flood basalt eruption, such as the 14.7 Ma Roza Member of the Columbia River Basalt Group. Furthermore, sensitivity runs were carried out by changing the eruption location and introducing volcanically quiescent periods to quantify atmospheric recovery times. Our modelling results imply that the sulfate aerosol lifetime is quasi equal across the eruption scenarios no matter how much volcanic sulfur dioxide was injected. In sharp contrast, the sulfur dioxide lifetime increases significantly (albeit non-linearly) with increasing atmospheric sulfur-loading. Quantification of both the chemical and the aerosol microphysical processes driving these self-limiting effects also shows that the efficiency to form new particles drops with increasing sulfur-loading. This implies that climatic effects of flood basalt eruptions should not scale linearly with the amount of sulfur dioxide released. We will discuss these aerosol-chemistry-climate feedback mechanisms and the magnitude of the climatic effects as well as the potential environmental consequences.

Understanding geochemical diversity of CFBs: rift and rift-shoulder magmas in the Jurassic Karoo-Ferrar province

Arto V Luttinen, Jussi S Heinonen

Finnish Museum of Natural History, University of Helsinki, Finland

E-mail: arto.luttinen@helsinki.fi

Geochemical grouping of continental flood basalts (CFBs) aims at understanding genetic links and spatial-temporal evolution of compositionally diverse magma suites. Recently accumulated data for ca. 180 Ma CFBs in Africa and Antarctica show that the conventional division into Karoo and Ferrar provinces and further into low-Ti and high-Ti magma types is not optimal for petrogenetic discussions. Firstly, the Ferrar and Karoo magmas have been shown to be spatially intercalated and, secondly, many high-Ti magmas appear to be associated with low-Ti parental magmas.

A revised geochemical grouping founded on rare earth element (REE) characteristics divides the CFBs into two compositionally and geographically distinctive categories:

(1) CFBs that exhibit strongly fractionated Sm/Yb values (>1.9 x C1) indicative of deep sources are almost exclusively associated with the triple arms of the Limpopo rift system and their counterparts in Antarctica. The wide range of low-Ti to high-Ti compositions (e.g. eNd +9 to -16) can be modelled quite well by variable lithospheric contamination of parental magmas derived from the same overall DM source. The magma volumes were probably relatively small due to partial melting under high pressure conditions below or adjacent to the thick Kaapvaal craton.

(2) CFBs with mildly fractionated Sm/Yb (<1.9 x C1) are widespread around the Limpopo rift and only include relatively monotonous (e.g. eNd +3 to -4) low-Ti types. These can be divided into three geographically and geochemically distinctive subgroups (Ferrar, Karoo, Dronning Maud Land) all of which represent extensive low-pressure partial melting within distinct lithospheric thinning zones. They may have different principal magma sources, possibly within variably subduction-modified lithospheric mantle, although our models for the Antarctic CFBs infer a possibility of precursory magmas from DM sources.

We believe that the suggested rift vs. rift-shoulder grouping clarifies the relationships of geochemically different magma types and promotes better understanding of the sources and processes related to Gondwana breakup magmatism.

Recycled material in magma sources of Shatsky Rise; noble gas evidence

Takeshi Hanyu[1], Kenji Shimizu[1], Takashi Sano[2]

[1]Japan Agency for Marine-Earth Science and Technology, Japan, [2]National Museum of Nature and Science, Japan

E-mail: hanyut@jamstec.go.jp

Early Cretaceous is a period that is marked by the emplacement of several gigantic oceanic plateaus in the Pacific Ocean. Shatsky Rise is one of those oceanic plateaus, consisting of three main massifs, Tamu, Ori, and Shirshov, that was constructed by intense volcanism around 140 Ma. In order to explore the sources of this oceanic plateau, we present noble gas compositions from fresh quenched glasses cored by ocean drilling at Site U1347 on the Tamu Massif and Site U1350 at the Ori Massif. The studied glasses are normal type basalts with relatively low incompatible element (e.g., U, Th, and K) concentrations. Noble gas compositions were determined by applying gentle crushing technique for gas extraction to minimize post-eruption radiogenic noble gases, and the validity of this technique for aged glasses is assessed by stepwise crushing and subsequent fusion. $^{3}He/^{4}He$ in glasses from Site U1347 are variously low relative to the atmospheric ratio, presumably owing to magma degassing coupled with radiogenic ingrowth of ^{4}He. In contrast, glasses from Site U1350 show very uniform $^{3}He/^{4}He$ (5.5-5.9 Ra) for all stepwise crushing fractions in each sample and for glasses from different lava units. Considerably uniform $^{3}He/^{4}He$ cannot be achieved if gases in glass vesicles have been affected by secondary contamination or post-eruption radiogenic ingrowth. Moreover, gases in glass matrix extracted by fusion show variously low $^{3}He/^{4}He$ relative to those in vesicles, precluding diffusive exchange of He between vesicles and glass matrix. Therefore, the uniform $^{3}He/^{4}He$ in the normal type basalts from Site U1350 is assigned as a feature for their source. The slightly low $^{3}He/^{4}He$ in these glasses compared to MORB values suggests the involvement of recycled slab material in the source of the normal type basalts. However, the depleted radiogenic isotope signatures are inconsistent with recycled slab being a distinct melting component. Our preferred model is that the source of the normal type basalts of Shatsky Rise is a heterogeneous mantle domain where subducted fertile material is dispersed in the mantle material. Such a source could exist either in the mantle transition zone or in the D" layer in the lower mantle.

Different styles of magma replenishment at Sierra Negra Volcano, Galapagos

Dennis Geist[1], William Chadwick, Jr.[2]

[1]University of Idaho, USA, [2]Oregon State University/NOAA, USA

E-mail: dgeist@uidaho.edu

Volcan Sierra Negra, in the western Galapagos, is one of the most actively deforming volcanoes on Earth and is monitored by a 10-station continuous GPS network. Its most recent eruption was in October 2005, which was accompanied by > 5 m of deflation at the center of the caldera floor. The volcano began re-inflating the day after the eruption at a rate that decreased exponentially over the next 6 years. For the first 6 months after the eruption, inflation proceeded at 2.6 m/y, and by the beginning of 2011 the rate of inflation had decreased to 4.4 cm/y. We attribute this to a steadily decreasing pressure gradient between the shallow subcaldera sill and the deeper source of the magma. In August 2011, the caldera began to deflate gradually, which was not related to eruption of Sierra Negra or any neighboring volcano. By June 2012, deflation had amounted to a total of 8 cm. On June 18, 2012, the gradual deflation ended abruptly and the volcano suddenly inflated 2.2 cm over just 4 days. No seismicity was detected by the global seismic network at the time of this change in behavior. The rest of 2012 and early 2013 are characterized by rather erratic behavior, including another rapid inflation event (3.5 cm in 25 days in July) punctuated by moderate inflation and deflation events amounting to < 2 cm of deformation.

Deformation at Sierra Negra is modulated by a sensitive feedback between a deep pressurized magma source and the shallow (2 km) subcaldera sill. The years it took for the two chambers to equilibrate indicates that they are connected by a narrow conduit, which controls the flux of viscous magma, or by a porous network that provides viscous resistance. The ending of one episode of magma influx (2005-2011) and the apparent beginning of another (2012-?), suggests that the magma supply from depth to Sierra Negra is episodic rather than constant.

Growth and evolution of the western Galápagos volcanoes: insights from space-geodetic observations.

Marco Bagnardi, Falk Amelung

RSMAS - University of Miami, United States of America

E-mail: mbagnardi@rsmas.miami.edu

Current understanding of the construction and evolution of basaltic shield volcanoes is largely based on studies of Hawai'i, however, the Hawaiian conceptual model is not sufficiently representative of basaltic shields elsewhere on Earth and other planets. For example, the volcanoes of the western Galápagos Islands generally lack well-developed rift zones, and eruptions occur from fissures oriented circumferentially to the summit on the upper portions of the volcanoes and radially on the flanks. The cause of the great difference between paths of magma transport or patterns of eruptive fissures at Hawaiian volcanoes and those of the western Galápagos Islands has long been a source of speculation, especially given the similar intra-plate hotspot origin for the two archipelagos. The application of space-geodetic techniques over the past 20 years has provided an unprecedented opportunity to study the sub-surface structure of the Galápagos volcanoes.

We use interferometric synthetic aperture radar (InSAR) measurements of surface displacements associated with eruptive activity as well as episodes of volcanic inflation and deflation that occurred between eruptions at Fernandina, the youngest and most active volcano in the Galápagos archipelago. The volcano is characterized by at least two hydraulically connected magma reservoirs, at ~1 km and ~5 km depth beneath the summit caldera. The deeper reservoir appears to be the source of large sill-like intrusions in 2006 and 2007 that are indicated by broad patterns of flank deformation, while the shallower reservoir feeds summit and flank eruptions. Displacements associated with eruptions in 1995, 2005, and 2009 are particularly instructive with regard to the origin of the pattern of eruptive fissures, since both radial (1995 and 2009) and circumferential (2005) fissure eruptions have been spanned by radar images acquired by multiple satellites. We show that magma transport at Fernandina is by means of subhorizontal intrusions, since both types of eruptions are initiated as subhorizontal sills, and not as subvertical dikes as would be expected by analogy with Hawai'i. A radar image acquired only two hours prior to the start of a radial fissure eruption in 2009 captures one of these intrusions in the midst of its emplacement.

The characteristic pattern of radial and circumferential fissures is best shown at Fernandina but is evident to varying degrees at all volcanoes in the western Galápagos, suggesting that the processes controlling intrusive and eruptive dynamics are common to all the edifices. These results suggest an alternative model for the internal growth of basaltic volcanoes that is contrary to the Hawaiian example. Furthermore, models of stress changes generated by sill intrusions at Fernandina suggest that it is possible to forecast the location and style of future eruptions based on deformation associated with previous events.

Magma injection process in monogenetic volcanoes: the El Hierro eruption, Canary Island, Spain: applications to eruption forecasting

Alicia Garcia[1], Jose M Marrero[2], Manuel Berrocoso[3], Angeles Llinares[4], Servando de la Cruz-Reyna[5], Ramon Ortiz[1]

[1]Geosciences Institute IGEO, CSIC-UCM. J. Gutierrez Abascal, 2, 28006 Madrid, Spain, [2]Self employed Researcher, Los Realejos, 38410, Canary Island,, Spain, [3]LAG-Faculty of Sciences, Cadiz University, Spain, [4]Department of Soils Science and Geology. University of La Laguna. Tenerife. Canary Islands, Spain, [5]Institute of Geophysics, UNAM, Mexico

E-mail: ramon.ortiz@csic.es

A new submarine eruption started in October 2011 on El Hierro, Canary island. The eruption was preceded by three months of seismic unrest related to internal magma movements. Several magma injection processes have been identified from the beginning of the unrest but only a few have culminated with a new vent opening. These successive injection processes are being monitored with the available high quality GPS deformation and seismic data.

An injection model (De la Cruz-Reyna and Yokoyama (2011), and a cumulative seismic energy model proposed by Yokoyama (1988) were adopted after the volcanic unrest was detected in July 2011. The former is used to assess the spatial susceptibility of new-vent formation, and the latter to forecast the probability of volcano-tectonic earthquakes exceeding magnitude 4 occurring as a consequence of the magma displacements.

Using the GPS deformation data in real time, a new pressure source is assumed using a Mogi model, and a conical region of likelihood for new vent opening is calculated from the abovementioned injection model as the surface of maximum shear stress resultant from the superposition of the Mogi pressure source and the lithostatic pressure. The intersection of the conical region with the known fracture system on the surface defines the points of maximum probability of vent opening. At the beginning of each injection process the volcano-tectonic seismic energy accumulates at a constant rate and is mostly released by earthquakes with magnitude lower than 2.0. However, when the volcano-tectonic cumulative seismic energy reaches about 1011 Joules, the injection process accelerates producing earthquakes with magnitudes higher than 4.5, thus increasing the probability of a new opening.

To the time of this submission, six distinct injection processes have been identified, but at least two opened vents to the surface of the crust. The first one produced a submarine serretian eruption south of the island. Another one produced a second deep-sea eruption north of the island which remained undetected on the surface except for the characteristic seismic tremor signal.

A multidisciplinary approach to the understanding of the magmatic and volcanic history of Heard Island, Kerguelen Plateau.

Jodi M Fox[1], Graeme E Wheller[2], Millard F Coffin[3], Timothy E Leser[4], Rebecca J Carey[5]

[1]ARC CODES and School of Earth Sciences, University of Tasmania, Hobart, Tasmania, Australia, [2]Volcanex International Pty Ltd, Tasmania Australia, Australia, [3]Institute for Marine and Antarctic Studies, University of Tasmania, Australia, Australia, [4]University of Tasmania, Australia, Australia, [5]ARC CODES, School of Earth Sciences, University of Tasmania, Hobart, Tasmania, Australia

E-mail: jmfox@utas.edu.au

Heard Island, a sub–Antarctic volcanic island in the southern Indian Ocean, is heavily glaciated and subject to high winds, snow, and wet conditions. It is the southernmost sub–aerial exposure of the Kerguelen Plateau and the source of its magma is believed to be the Kerguelen plume (Weis et al 2002).

Volcanic rock on the island overlies Paleogene Laurens Peninsula Limestone that is unconformably overlain by the Upper Miocene, predominantly volcaniclastic Drygalski Formation (Truswell et al 2005, Stephenson et al 2006). The lava–dominated volcanic sequences that overlie the Drygalski Formation are interpreted to be less than one million years old (Clarke et al 1983) and constitute most of the island's volume.

Big Ben, a stratovolcanic complex dominated by basanite, basalt, and trachybasalt lava, rises to 2745m and forms the main part of Heard Island (Kiernan & McConnell 1999, Stephenson et al 2006). Mawson Peak is at the summit of Big Ben and has been active as recently as 2012. The smaller centre, Laurens Peninsula, consists of three volcanic peaks. The tallest is Mt Dixon (775m), a volcanic dome that may have been active in the last several hundred years (Stephenson et al 2006). Laurens Peninsula lavas consist of older trachytic lavas overlain by recent basaltic lavas (Quilty & Wheller 2000).

Around the circumference of Heard Island are small scoria and tuff cones and some associated lava flows, these are thought to be younger than 10,000 years old (Stephenson et al 2006). The relationship of these cones to other volcanic features is unclear, although they have been thought to be parasitic in origin (Kiernan & McConnell 1999) and possibly monogenetic (Wheller pers com 2012). A recent bathymetric and seismic review (Leser 2012) has revealed concentrations of relatively low volume cones on the submarine Kerguelen Plateau around Heard and McDonald islands. Some of these may have erupted subaerially, and be contemporaneous with the scoria and tuff cones on Heard Island, implying a more regional, broad scale volcanism.

The Institute for Marine and Antarctic Studies, University of Tasmania is planning a scientific cruise to obtain detailed information about the topography of the seafloor and the interpreted submarine volcanoes of the Kerguelen Plateau, particularly those adjacent to Heard Island. Continuous swath mapping will be conducted using deep and mid–water multibeam sonar systems, a sub–bottom profiler, gravimeter and magnetometer. Back–scatter data will be used to identify which volcanic features may be hydrothermally active. Mapping will be followed by water sampling and rock dredging. Comparison will be made between these rocks samples and existing Heard Island samples with a view to placing the young sub–aerial scoria and tuff cones on the island in the overall context of young volcanism on the Kerguelen Plateau.

Geochemistry and eruption depths of volcanic glasses from the Louisville seamounts

Alexander RL Nichols[1], Christoph Beier[2], Philipp A Brandl[2]

[1]IFREE, JAMSTEC, Japan, [2]GeoZentrum Nordbayern, FAU Erlangen-Nuernberg, Germany

E-mail: nichols@jamstec.go.jp

The Louisville seamounts form a ∼4300 km-long trail in the south Pacific generally attributed to a mantle plume located at the south-eastern end of the trail until 1.11 Ma. IODP Expedition 330 (Dec. 2010-Feb. 2011) drilled five of the older seamounts (50 to 74 Ma) at the north-western end. Fresh glass samples were recovered from four of the seamounts and we present their major (microprobe), including F, S, and Cl, trace (LA-ICP-MS) and volatile (FTIR spectroscopy) element compositions. These allow us to test models regarding the origin of oceanic intraplate volcanism, how magmas evolve between and within seamounts, and infer the environment in which the magmas were emplaced.

Of the 61 glass samples so far analysed all but one are alkalic (SiO_2 44.5-50.2 wt%; Na_2O+K_2O 3.5-6.5 wt%; MgO 3.5-6.8 wt%), and fall in the basalt field with a few trachybasalts and basanites. There is minimal downhole variation in major and trace elements, even over the ∼500 m drilled in Hole U1374 on Rigil Seamount, and there is less variation in the drill samples than in previously collected dredge samples. Thus, there is still no evidence in the Louisville seamounts for the dominant tholeiite shield-building stage of Hawaiian volcanoes. Immobile, source sensitive trace element ratios, e.g., La/Yb, Zr/Nb, show less variation over 24 Myrs and 76 Myrs in the Louisville drill and dredge samples, respectively, than over 5-6 Myrs in Hawaiian samples. Thus it appears that the Louisville seamounts are derived from an extremely homogeneous source.

Volatile elements show that glasses from the volcaniclastics are degassed (H_2O 0.07-0.12 wt%; S 160-662 ppm; CO_2 below detection limits of 20 ppm), implying eruption near, or above, the sea surface. It is possible that the sequences have moved downslope due to flank instability or are flow-foot breccia formed as subaerial flows entered the sea. Less degassed glass (H_2O 0.37-0.58 wt%; S 890-1088 ppm; CO_2 below detection) are only found on the chilled margins of sheets that intrude into the degassed volcaniclastics in Holes U1376, Burton Seamount, and U1377B, Hadar Seamount. Intrusion ∼100 m below the surface can be inferred from the volatile contents. Even so, low H_2O/K_2O (0.26-0.58) suggest they have degassed, thus glass from the Louisville seamounts cannot be used to constrain source volatiles. Using inferred eruption and emplacement depths, the minimum subsidence that the seamounts have experienced since their formation can be estimated. Combining this with the expected subsidence of the oceanic lithosphere if no seamount was present, we find that the younger the seamount, the greater the subsidence exceeds that of normal oceanic lithosphere. This may reflect erosion of the seamount with age decreasing the rate of subsidence.

Dynamics of Kilauea's magmatic system imaged using a joint analysis of geodetic and seismic data

Christelle Wauthier[1], Diana Roman[1], Michael Poland[2], Andy Hooper[3], Asta Miklius[2], Yo Fukushima[4], Valerie Cayol[5]

[1]Carnegie Institution of Washington, USA, [2]Hawaiian Volcano Observatory, USGS, USA, [3]TUDelft, Netherlands, [4]Disaster Prevention Research Institute, Kyoto University, Japan, [5]Laboratoire Magmas et Volcans, Universite Blaise-Pascal, France

E-mail: cwauthier@dtm.ciw.edu

InSAR (Interferometric Synthetic Aperture Radar) provides high-spatial-resolution measurements of surface deformation with centimeter-scale accuracy. At Kilauea Volcano, Hawai'i, InSAR analysis shows complex processes that are not well constrained by GPS data (which have relatively poor spatial resolution). However, GPS data have higher temporal resolution than InSAR data, allowing for better imaging of time-dependent processes. The two data sets are thus complementary. To overcome some of the limitations of conventional InSAR, which are mainly induced by temporal decorrelation, topographic and orbital errors, and atmospheric delays, a Multi-Temporal InSAR (MT-InSAR) approach can be used to integrate multiple SAR acquisitions over the same area. Here, we apply conventional InSAR and the "StaMPS" ("Stanford Method for Permanent Scatterers") technique, which incorporates both persistent scatterer and small baseline approaches, to RADARSAT-1, ENVISAT and ALOS data spanning 2000 to 2010, to analyze subsidence of Kilauea's southwest rift zone (SWRZ). The SWRZ "background deformation" is characterized by broad subsidence of a few cm/yr, except during periods of magma accumulation in the subsurface. In addition to the broad subsidence, the rift zone hosts two linear subsidence features that are clear in interferograms spanning long time periods (usually several years). Based on daily GPS solutions, we define three "background deformation" periods, during which no abnormal eruptive activity or unrest influences the deformation behavior of the SWRZ. The first period spans July 2000 to September 2003 and is covered by a highly coherent RADARSAT-1 interferogram. The second background period spans October 2006 to March 2007, just a few months before an east rift zone intrusion and eruption in June 2007. The third period spans December 2009 to June 2010. We speculate that broad SWRZ subsidence is caused by the same processes that trigger subsidence of Kilauea's east rift zone - namely deep rift opening and basal fault slip - whereas narrow, linear subsidence features might be due to the stiffness contrasts between cracked areas in the SWRZ and old intrusions beneath the ground surface. A 3D Mixed-Boundary Element model including deep rift-zone opening (running from 3 to 9 km depth beneath Kilauea's east and southwest rift zones) as well as slip on the decollement fault that underlies the volcano's south flank (at 9km depth) can explain broad SWRZ deformation imaged from RADARSAT-1 data for the first background period. This model will be refined by inversions and compared to simpler kinematic analytical models involving distributed Okada, and tested against the other background deformation periods. In addition, we will include seismic data to help constrain the models.

Petrology and geochemical evolution of lavas from the ongoing and voluminous Puu Oo eruption of Kilauea Volcano, Hawaii

Michael O Garcia[1], Aaron Pietruszka[2], Andrew Greene[3], Jared Marske[4], Marc Norman[5], J. M. Rhodes[6], John Eiler[7], Dominique Weis[8]

[1]University of Hawaii, USA, [2]U.S. Geological Survey, Denver, USA, [3]Hawaii Pacific University, USA, [4]DTM, Carnegie Institution of Washington, USA, [5]Research School of Earth Sciences, Australian National University, Australia, [6]University of Massachusetts, USA, [7]California Institute of Technology, USA, [8]Dept. of Earth and Ocean Sciences, University of British Columbia, Canada

E-mail: mogarcia@hawaii.edu

The Puu Oo eruption reached its 30th anniversary in early 2013. Volumetrically, this is the most significant historical eruption of Kilauea having produced 4 km3 of lava from several sites along its east rift zone. Since its start in 1983, we have monitored the compositional and isotopic signatures of its lavas, which have shown remarkable variations resulting from diverse crustal and mantle processes including crystal fractionation, magma mixing and storage, assimilation of crust and melting of a heterogeneous plume source. Crystal fractionation is an important process in Puu Oo lavas based on their wide range of MgO contents (5-10 wt. percent) and normally zoned minerals. The effects of crystal fractionation are superimposed on magmas that initially (1983-85) were hybrids from mixing evolved, rift zone-stored magmas with new, mantle-derived magma. After 1985, lava erupted from two primary vents (Puu Oo and Kupaianaha) and did not have an evolved magma component. Lava erupted during two uprift episodes in 1997 and 2011 was, however, dominated by cooler, rift zone stored magma. Oxygen isotope exchange of Puu Oo magma with hydrothermally altered Kilauea lavas is indicated by the low O isotope values for matrix material and olivines, and the lack of correlation of O isotope values with other geochemical parameters. This exchange probably occurred within the shallow reservoir underlying the Puu Oo vent and has affected most of its lavas. Small, systematic variations in isotopes of Pb and Sr, incompatible trace element ratios and MgO-normalized major element abundances document rapid changes in the parental magma composition unrelated to crustal processes. Lavas erupted between 1985-1998 continued the post-1924 composition trend of Kilauea lavas towards more depleted compositions. This trend begain just after the collapse of summit crater during a period of low magma supply. From 1998-2003, Puu Oo lavas show a systematic temporal evolution towards historical Mauna Loa lava compositions. This trend reversed in 2003 and again in 2008 creating a cyclic pattern of geochemical variations. These reversals in composition are contrary to previous models for sustained basaltic eruptions. The cyclic variations of Pb isotopic and some trace element ratios during the Puu Oo eruption suggest melt extraction from a mantle source with thin strands of vertically-oriented source heterogeneities. These strands may be 0.6-2 km in diameter in order to explain the scale of isotopic variations for the Puu Oo eruption. The continuing Puu Oo eruption provides a dynamic laboratory for evaluating models of the generation and evolution of basaltic magmas.

Petrological interpretation of deep crustal intrusive bodies beneath oceanic hotspot provinces

Mark Richards[1], Eduardo Contreras-Reyes[2], Carolina Lithgow-Bertelloni[3], Mark Ghiorso[4], Lars Stixrude[3]

[1]University of California, Berkeley, USA, [2]Universidad de Chile, Santiago, Chile, [3]University College, London, UK, [4]OFM Research, Seattle, USA

E-mail: Mark_Richards@berkeley.edu

Seismic refraction studies of deep-crustal and upper mantle structure beneath some oceanic hotspot provinces reveal the presence of ultramafic bodies with P-wave velocities of Vp 7.4-8.0 km/s lying at or above the Moho, e.g., Hawaii, the Marquesas, and La Reunion. However, at other hotspot provinces such as the Galapagos, Nazca Ridge, and Louisville the lower crust is intruded by large volumes of gabbroic (mafic) rocks (Vp 6.8-7.5 km/s). Ultramafic primary melts formed beneath mature oceanic lithosphere at pressures of 2-3 GPa (60-90 km depth), and ponded at the Moho due to their relatively high density, can explain the observed ultramafic deep-crustal bodies. By contrast, plume melts formed at depths of 15-30 km beneath thin lithosphere crystalize assemblages that are more gabbroic. The velocity and density gradient is particularly strong in the pressure range 0.6-1.3 GPa due to the replacement of plagioclase by olivine as melts become more MgO-rich with increasing pressure (and degree) of melting. This anomalous density gradient suggests a possible filtering effect whereby plume melts equilibrated at relatively shallow depths beneath very young and thin oceanic lithosphere may be expected to be of nearly gabbroic (mafic) composition (6-10 wt. percent MgO), whereas ultramafic melts (MgO 12-20 wt. percent) formed beneath older, thicker oceanic lithosphere must pond and undergo extensive olivine and clinopyroxene fractionation before evolving residual magmas of basaltic composition sufficiently buoyant to be erupted at the surface. A survey of well-studied hotspot provinces of highly-varying lithospheric age at the time of emplacement shows that deep-crustal and upper mantle seismic refraction data are consistent with this hypothesis. These results highlight the importance of large-volume intrusive processes in the evolution of hotspot magmas, with intrusive volumes being significantly larger than those of the erupted lavas in most cases. Pyrolite melting can account, to first order, for the total crustal column of magmatic products, whereas alternative models such as selective melting of pyroxenite blobs probably cannot.

Intrusive breccia related to the alkaline-carbonatitic association of NW Fuerteventura (Canary Islands, Spain): a remnant of deep-seated parts of diatremes?

Cristina de Ignacio[1], Mercedes Munoz[1], Juana Sagredo[2], Angela Claro[1]

[1]Dpt Petrologia y Geoquimica, Facultad CC Geologicas, Universidad Complutense de Madrid, Spain,
[2]Instituto de Geologia Economica, CSIC, Facultad CC Geologicas, Universidad Complutense de Madrid, Spain

E-mail: cris@ucm.es

The island of Fuerteventura, in the eastern part of the Canary archipelago (Central Atlantic) is one of the few geological sites worldwide for oceanic carbonatites and related alkaline silicate rocks. This alkaline-carbonatitic association (ACA) represents the first magmatism occurring in the island, at 25-23 Ma (Munoz et al., 2005 and references therein) and comprises: perovskite-clinopyroxenite, ijolite, nepheline-syenite and calciocarbonatite (Munoz et al., 2003; de Ignacio, 2008). There is evidence that these intrusive rocks had their volcanic equivalents (Munoz et al., 2002), though the remnants of the latter are scarce in the island. In this work, small outcrops of intrusive breccias showing gradational relations to nepheline-syenites and ijolites in northwest Fuerteventura are described. These breccias are clast-supported, showing 3 to 5 cm long, subangular to subrounded, syenitic fragments (composed of K-feldspar and albite) and, 0.3 to 0.5 mm long, ijolitic fragments (composed of oxides, apatite and titanite). The matrix is formed by abundant, minute crystals of K-feldspar, albite, iron oxides, mica, apatite, and occasionally zircon, reflecting comminution of the syenitic and ijolitic country rock. Mineral chemistry of both the fragments and matrix compares well with composition intervals defined by de Ignacio (2008) for each mineral phase in the host rock nepheline-syenite and ijolite. The syenitic fragments contain K-feldspar (Or75-80) with 1-2 wt% BaO, a composition which falls inside the range for K-feldspar in nepheline-syenites (Or72-88). When it is fresh, mica forming part of the matrix is Phl75, with 2 wt% TiO_2, which falls inside the range for mica in the ijolites (Phl80-74). The small opaque fragments in the breccias comprise several types: 1) 1-4 mm oxide crystals associated with apatite aggregates; 2) 0.2 mm long, anhedral titanite enclosed by 0.8 mm long oxides and 3) 0.4 or less mm long, subangular, elongated oxide crystals marking, together with mica, a crude flow texture in the matrix. The first and third type of oxides are almost pure magnetite (Mt98-91 Usp2-9) with 3-5 wt% TiO_2, resembling oxides of ijolites (Mt92-94 Usp6-8), though the matrix ones are more altered (low analytical sums). The second type of oxides, surrounding titanite, are anatase (TiO_2) and an intermediate product between ilmenite and anatase. These oxides are the transformation products of perovskite, which is abundant both in clinopyroxenites and ijolites (de Ignacio, 2008). Considering their field, textural and mineral chemistry features, it is proposed that these breccias could represent the subvolcanic part of diatremes that once connected the ACA intrusives with volcanic edifices currently dismantled. No fragment of carbonatite has been observed in them and therefore, we propose that the propelling agent for fragmentation of ijolite and nepheline-syenite would have been CO_2 related to carbonatite magmas belonging to this rock association.

The phonolitic Cão Grande Plinian volcanism on Santo Antão, Cape Verde Islands: When, Where, How

Steffen Eisele[1], Armin Freundt[1], Steffen Kutterolf[1], Ricardo Ramalho[2]

[1]GEOMAR Helmholz Centre for Ocean Research Kiel, Germany, [2]Lamont-Doherty Earth Observatory, Columbia University, USA

E-mail: seisele@geomar.de

Santo Antão is an ocean island shield volcano in an early post-erosional stage. At this stage, mafic Strombolian volcanic activity had been replaced by Pleistocene highly explosive eruptions of evolved, phonolitic magmas. Two phonolitic tephra successions, Cão Grande Pumice units I and II (CGI and CGII) had been previously identified and described (Holm et al. 2006; Mortensen et al. 2009) but our tephrostratigraphic fieldwork on Santo Antão identified a third, older explosive phonolitic phase (CG 0) and two phonolitic domes. CG 0 comprises eight pumice fallout layers and two ignimbrites.

Using major and trace element glass compositions, mineral compositions and bulk rock analyses, we correlate Cão Grande Group units with ash beds in 14 sediment gravity cores from the ocean floor up to 400 km away from the island. These correlations demonstrate that CG0, CGI and CGII all comprised large magnitude Plinian eruptions that produced tephra blankets dispersed over more than 10^5 km².

While the exact source-vent locations on Santo Antão for CG0 and CGI remain unknown, we found that the Morro de Figueira dome has the same composition as the CGII tephra and thus marks the source vent of that youngest Cão Grande tephra, an interpretation supported by the observed lateral variations in thickness and grain size of the CGII fallout tephra.

Our combined on-land and marine tephrostratigraphy combined with geochemical and petrological analyses and ongoing 40Ar/39Ar-dating of sanidines will allow us to reconstruct in detail the post-shield history of evolved magma evolution and explosive eruptions of Santo Antão.

A geochemical window into the magmatic architecture of the Taney Seamounts, northeast Pacific Ocean

Jason P Coumans[1], David A Clague[2], Willaim Minarik[1], Nobumichi Shimizu[3], John Stix[1]

[1]McGill University, Canada, [2]Monterey Bay Aquarium Research Institute, USA, [3]Woods Hole Oceanographic Institute, USA

E-mail: jason.coumans@mail.mcgill.ca

The Taney Seamounts are a NW-SE trending linear, near mid-ocean ridge chain consisting of five submarine volcanoes located on the Pacific plate 300 km west of San Francisco, California. Taney Seamount-A, the largest and oldest in the chain, is defined by four well-exposed calderas which reveal previously infilled lavas. The calderas can be differentiated in time by their cross-cutting relationships, creating a relative chronology. The caldera walls and intracaldera pillow mounds were sampled systematically by a remotely operated vehicle (ROV) to obtain stratigraphically-controlled samples. Differentiating shallow and deep magmatic processes allows us to define the magmatic architecture of near-ridge seamounts. Deep magmatic processes at the Taney Seamounts are revealed by flat incompatible element ratios such as K_2O/TiO_2 and consistent LREE slopes indicating that the aggregate melts from the mantle source are geochemically similar over the formation of a single seamount. The lavas are change chemically as the seamounts become younger (Taney-A to Taney-C) from slightly enriched to transitional MORB (K_2O/TiO_2: 0.13 - 0.7). The progressive depletion in highly incompatible elements can be explained by a change in source composition, an increase in the degree of partial melting, or a combination of the two. Melts from the mantle source are entrained in anorthitic plagioclase megacrysts (An 82-88) as they are transported to the shallow magmatic reservoir. Using H_2O-CO_2 solubility relationships from melt inclusion analysis, the majority of calculated pressures, assuming vapor saturation, are approximately 300 MPa (12 km). These pressures imply entrainment at or slightly below the crust-mantle transition where a permeability barrier promotes melt pooling, homogenization and crystallization prior to ascent to the shallow system. However, if the melt inclusions are supersaturated in CO_2, then crystallization occurred in the crust and high CO_2 concentrations could drive explosive eruptions. Evidence for explosive eruptions at the Taney Seamounts includes volcaniclastic deposits on caldera rims, which may be coeval with a collapse event. Major element geochemistry of glassy basalt pillow rims indicate that lavas which infill a caldera collapse are chemically distinctive, and can be either more or less differentiated than pre-collapse lavas. The entire sequence of lavas on Taney Seamount-A represent various degrees of fractionation at shallow depths of a similar primitive source melt. This is due to the episodic formation of near-ridge seamounts where a magma pulse from the source results in reservoir formation and differentiation, effusive eruption, then catastrophic collapse of the chamber roof due to a large evacuation. Caldera collapse is followed by magmatic rejuvenation initiating a new cycle.

Geological evidence of a post shield stage at the Juan Fernandez Ridge, Nazca Plate

Luis E Lara[1], Javier Reyes[2], Mirella Pina-Gauthier[3], Gabriel Orozco[1]

[1]Volcano Hazards Program, SERNAGEOMIN, CHILE, [2]Universidad de Chile, Andean Geothermal Center for Excellence, CHILE, [3]Minera Las Cenizas, CHILE

E-mail: luis.lara@sernageomin.cl

The Juan Fernandez Ridge (Eastern Pacific, Nazca Plate) is thought to be a classic hot spot trail because of the apparent age progression observed in K-Ar data. However, geological evidence and some thermochronological data suggest a more complex pattern with a rejuvenation stage in Robinson Crusoe Island, the most eroded of the Juan Fernandez Archipelago. In fact, a sharp unconformity separates the underlying shield-related pile from the post-erosional volcanic association. The latter is formed by partially collapsed scoria cones and small shield volcanoes together with a fissure-type complex. Ash fallout and tuffs at the base of the sequence describe an explosive behavior followed by a Hawaiian-style eruptive cycle. At least six vents can be recognized, roughly organized in a tangential pattern. The present volume of the erupted products is ca. 1 km3, which would be close to a half of the total erupted volume.

New 40Ar/39Ar data indicate ages ranging from 900 to 700 ka for the last eruptive event, which is more than 3 Ma younger than the shield stage in Robinson Crusoe Island. In addition, petrological data of the post-shield basanites indicate that erupted magmas are mostly alkaline (Ba/Yb=236.58; La/Yb=22.32; Ba/Zr=2.26; Nb/Zr=0.26) in contrast with the previous shield stage where tholeiitic to transitional magmas dominate.

Post-shield, post-erosional or rejuvenated volcanism is an outstanding feature of a number of oceanic islands and several processes have been invoked to explain such a feature. Here we hypothesize that a variation to a metasomatised HIMU type source are a plausible model for post-shield volcanism at Robinson Crusoe, although magma ascent and eruption triggering still deserve more research.

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Can Kick 'em Jenny submarine volcano emerge? A slope stability analysis as a tool of assesment for a potential emersion in the Lesser Antilles Volcanic Arc..

Frederic Jean-Yves Dondin[1], Jean-Francois Marc Dorville[2], Richard E. Robertson[1]

[1]Seismic Research Centre, The University of the West Indies, St Augustine, Trinidad and Tobago,
[2]Physic Department, Faculty of Sciences and Technology, The University of the West Indies, Mona, Jamaica

E-mail: fredericdondin@gmail.com

Volcanic islands are peculiar geomorphological reliefs generated in three volcanic contexts: (i) arc volcanism; (ii) rift volcanism ; (iii) hotspot volcanism. They represents the final result of a long sustained volcanic activity capable of overcoming the weathering condition (oceanic and atmospheric), and tectonic vertical movements. However the main factor of longevity of such type of island is their ability to remain stable. Indeed over the last three decades flank instabilities have been recognized as the main erosive factor of volcanic island arc since weak flanks affecting these islands can cause sector collapse events. In some cases one sector collapse can destroy not only the volcanic edifice of the island but also affect partially or entirely the island and can lead to its destruction. (e.g. Ritter volcanic island). In the Lesser Antilles Volcanic Arc, 47 evidences of sector collapse events have been recognized on almost all the 21 identified active volcanoes so far. On some islands (Dominica, Martinique, St-Lucia) some events were large enough to affect the island flank partially.

Kick 'em Jenny volcano is the only submarine active volcano of the Lesser Antilles Arc and one of its most active. This strato-volcano is located 8 km north of Grenada on the steep (slope ca. 22°) eastern flank of the Grenada Basin it culminates at -180 m u.s.l and the deepest sector within the vent is at -260 m u.s.l. In this study we focus on Kick 'em Jenny volcano since a recent study of Dondin et al., 2012 showed that the volcano during its eruptive history may have emerged above the sea level and formed an island before a large sector collapse destroyed the entire edifice. The associated slump deposit of ca. 4.4 km3 is located at the bottom of the remaining horseshoe-shaped structure and has a runout of 14 km. The edifice lies within this structure. Taking into account the current edifice relative proximity to the surface, its basement location upon a preexisting failure surface within a horseshoe-shaped structure on the steep eastern flank of the Grenada basin, one of the issue related to KeJ is to know if it can emerge and form an perennial island or collapse before reaching the surface.

To be able to answer to this question we present the first slope stability analysis for this volcano in order to assess its current level of stability and to evaluate its stability in case of future emersion due to a sustained eruptive activity. The Slope stability was performed using the open source Slope Stability Analysis Program (Borselli et al., 2011) based on the validated Limit Equilibrium Method. We investigate the potential tsunami hazard related to potential collapse of the volcano following two scenario a partial and a total collapse of the volcano.

The geology and geochemistry of Isla Floreana, Galapagos: A different type of late-stage ocean island volcanism

Karen S Harpp[1], Dennis Geist[2]

[1]Geology Department, Colgate University, USA, [2]Department of Geological Sciences, University of Idaho, USA

E-mail: kharpp@colgate.edu

Isla Floreana, the southernmost volcano in the Galapagos Archipelago, has erupted a diverse suite of alkaline basalts continually since 1.5 Ma. Because these basalts have different compositions than xenoliths and older lavas from the deep submarine sector of the volcano, Floreana is interpreted as being in a rejuvenescent or late-stage phase of volcanism. Most lavas contain xenoliths or their disaggregated remains. The xenolithic debris and large ranges in composition, including during single eruptions, indicate that the magmas do not reside in crustal magma chambers as do magmas in the western Galapagos. Floreana lavas have distinctive trace element compositions that are rich in fluid-immobile elements (e.g., Ta, Nb, Th, Zr) and even richer in fluid-mobile elements (e.g., Ba, Sr, Pb). Rare earth element (REE) patterns are light REE-enriched and distinctively concave-up. Neodymium isotopic ratios are comparable to those from Fernandina, at the core of the Galapagos plume, but Floreana has the most radiogenic Sr and Pb isotopic ratios in the archipelago. These trace element patterns and isotopic ratios are attributed to a mixed source originating from within the Galapagos plume, which includes depleted upper mantle, plume material rich in TITAN elements (Ti, Ta, Nb), and recycled oceanic crust that has undergone partial dehydration in an ancient subduction zone. Because Floreana lies at the periphery of the Galapagos plume, melting occurs mostly in the spinel zone, and enriched components dominate. Floreana is the only Galapagos volcano known to have undergone late-stage volcanism. Here, however, the secondary stage activity is more compositionally enriched than the shield-building phase, in contrast to what is observed in Hawaii, suggesting that the mechanism driving late-stage volcanism may vary among ocean island provinces.

Deep volatile-induced melting, crustal melt-peridotite interactions, and the origin of primary ocean island basalts in the Earth's ambient mantle

Rajdeep Dasgupta, Ananya Mallik

Rice University, Department of Earth Science, 6100 Main Street, MS 126, Houston, Texas 77005, USA

E-mail: Rajdeep.Dasgupta@rice.edu

Intraplate magmas are known to display large variability in terms of long-lived radiogenic isotopes, trace, major, and volatile element abundances and ratios. These differences and variability have been interpreted to reflect heterogeneities in the mantle compositions and temperature. However, the origin of intraplate magmas in general and that of alkalic ocean island basalts (OIBs) in particular remain matters of active debate. In particular, the relative contributions of excess mantle potential temperature (T_P) and mantle heterogeneity in terms of lithology and volatiles remain incompletely constrained for alkalic OIBs.

Here we present key constraints on OIB petrogenesis based on recent advancement on laboratory experiments on carbon-induced silicate melting of peridotite (1) and subducted crust-derived partial melt and mantle interactions (2,3). We show that either via redox melting or by carbonate-fluxed decompression melting, carbonated silicate melts akin to silica-poor, primary basanite, nephelinite, melilitite can form at depths spanning 70 to 150 km at a T_P of 1350 °C. Moreover, strongly carbonated, kimberlitic to melilititic primary melt is generated and may be present as deep as 150-250 km in the ambient mantle, influencing the seismic structure and electrical conductivity of the deep ocean island source.

Although most major element chemistry of near-primary, silica-poor OIB can be derived from a fertile peridotite with minor $CO_2 \pm H_2O$, a number of minor, trace (Ti, Ni, Mn, Zn, Mn/Fe), and isotopic compositions call for eclogitic lithologies in the source regions. Previous experimental studies, however, argued against MORB-like ocean crust in the source regions of alkalic magma production because the partial melts derived from the crust is silica-rich and Mg-poor. To evaluate how eclogite-derived melt evolves in reaction with peridotite, we conducted basaltic andesite and peridotite reaction experiments with and without CO_2. Our results show that reactive infiltration of eclogite-melt into peridotite leads to formation of orthopyroxene and garnet and dissolution of olivine, leading to silica and alumina depletion and MgO-enrichment in the reacted melt. Dissolved carbonates enhance these changes further and high-MgO (>14-16 wt.%) alkalic basalts can be generated at T_P of 1350 °C. The compositions of reacted eclogite-derived melt produce a reasonable match to near-primary alkalic OIBs. Our data, therefore suggest that production of OIBs can occur in an ambient mantle through fluxing of CO_2 and mantle hybridization via MORB-eclogite-melt-peridotite reaction.

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H2O distribution and signature in MORB glasses

Maxime MERCIER, Pierre SCHIANO, Estelle ROSE-KOGA, Abdelmouhcine GANNOUN, Ivan VLASTELIC

Laboratoire Magmas et Volcans, Blaise Pascal University, Clermont-Ferrand, FRANCE

E-mail: m.mercier@opgc.univ-bpclermont.fr

Many studies have investigated H2O content in MORB and demonstrated its important impact on the physical and chemical properties of oceanic mantle. Thus, the H2O content dissolved in MORB melt can bring new constraints on mantle composition, melting and evolution.

Here we report the global variation of H2O content dissolved in MORB glasses from worldwide locations (EPR, MAR, CIR and SEIR). This has been studied at different scales: global scale (inter- and intra-oceanic comparison), macroscale (within a population of melt inclusions trapped in olivine from FAMOUS zone) and microscale (concentration profiles into melt inclusions). H2O content was measured by microRaman spectroscopy. Simple sample preparation (one-side polishing) and high spatial resolution (1 micron) make microRaman spectroscopy a very appropriate technique for this study. The method has been improved in order to lower the detection limit, from around 3000 ppm in mafic glasses, down to 500 ppm, which is more appropriate to MORB glasses. H2O concentration data have been coupled with major, trace and isotopic analysis to study the effects of mantle source heterogeneity.

We identified large global H2O heterogeneity ranging from 0.14 to 0.47 (wt. percent) in both Atlantic and Pacific MORB samples with an average around 0.25 (wt. percent). However Indian MORBs samples are statistically more enriched with an average around 0.30 (wt. percent) and a more restricted range (from 0.20 to 0.38 wt percent). The analyses performed on melt inclusions yielded homogeneous H2O content at both macro and microscale. Hence the previously observed heterogeneity at global scale is not due to sampling artefact but reflect resolvable regional variations. Based on the positive correlations between water and incompatible elements (Rb, Th) and the solubility models into basaltic melts, we infer that H2O variations cannot result from degassing processes or seawater contamination, but must instead reflect magmatic processes. Furthermore, the observed positive correlation (R^2= 0.70) between H2O and 87Sr/86Sr led to suggest that the observed variations is likely due to mantle source heterogeneity rather to a variation of partial melting degree.

Using the H2O/Ce ratio as a mantle source tracer (H2O having the same behavior as Ce in MORB) we identified specific signatures for each ocean basin: high and homogeneous ratio for the Indian Ocean samples (average value of 260), low and homogeneous ratio for the Pacific Ocean samples (average of 176) and highly dispersed values for the Atlantic Ocean samples (from 150 to 350). While the spread of Atlantic data is probably due to the influence of mantle plumes along the ridge, the data show that Pacific and Indian mantle have contrasted H2O/Ce ratios, with little, if no overlap. High H2O/Ce, thus appears as a robust fingerprint of Indian mantle, in the same manner as its peculiar Pb isotope signature.

Icelandic zircon: investigating felsic magmatism in a unique oceanic environment

T L Carley[1], C F Miller[1], J L Wooden[2], I N Bindeman[3], R C Economos[4], A K Schmitt[4], C M Fisher[5], J M Hanchar[6]

[1]Vanderbilt U, Earth and Environmental Sciences, USA, [2]Stanford-USGS, Microanalysis Center, USA, [3]U of Oregon, Geological Sciences, USA, [4]U of California at Los Angeles, Earth and Space Sciences, USA, [5]Washington State U, Earth and Environmental Sciences, USA, [6]Memorial U, Earth Sciences, CAN

E-mail: tamara.l.carley@vanderbilt.edu

Iceland is home to the greatest-known concentration of silicic rock in the modern ocean. Abundant low-density material, coupled with the unusual thickness of the island's crust, hints at continental nucleation and permanent crust construction in an oceanic environment. Understanding Icelandic silicic petrogenesis may thus lend important insight into Earth's early history, as well as magmatic processes at large ocean islands.To investigate this silicic magma genesis, we have analyzed >700 zircons from 8 volcanoes, 4 intrusions, 6 rivers and 3 sedimentary units spanning Iceland's history (15 Ma to present) and tectonomagmatic settings (e.g., on and off rift). Our growing database includes high spatial resolution determinations of trace elements, U-Pb and U-Th ages, and O isotopes (SIMS) and Hf isotopes (LA-MC-ICPMS), and complementary data (host rocks, mineral assemblages).

Icelandic zircons form a distinct and coherent compositional population compared to zircons from other environments (cf. Grimes et al. 2009). They are clearly distinguishable from zircons from MORB and continental arcs but show some similarities to zircons from continental rifts (some overlap with Miocene Colorado River, close similarity to East African Rift). They are relatively high in Ti and Nb and low in Hf compared to typical continental zircons. Relative to MORB zircons, they have high U/Yb and low Yb/Nb. More subtly, elemental compositions can be used to distinguish zircons from Icelandic volcanoes in distinct tectonomagmatic settings.

Zircon Hf isotope compositions (114 analyses) range from 10-16 (eHf), spanning most of the variability observed in Icelandic basalts (Peate et al. 2010). Zircons from individual magmatic centers have relatively uniform eHf but zircons from distinct tectonic settings appear to be distinguishable by eHf (13-16 on rift, 10-13 off rift).

Icelandic basalts and rhyolites are known for d18O that is low relative to mantle values, a characteristic commonly attributed to hydrothermal alteration of source material by meteoric water. Zircon corroborates the importance of reprocessed hydrothermally altered crust in Icelandic felsic petrogenesis. Of 620 oxygen isotope analyses (averaging 2.9 permil), only 14 fall within or above the accepted range of d18O mantle values (5.3 +/- 0.3 permil). We observe increasing d18O from active (0-2 permil) through propagating (0-4) to off (3-5) rift settings at modern central volcanoes. Despite pronounced cooling and presumably falling d18O of meteoric water through Iceland's climate history (temperate through peak glaciation to the present), there is no evidence for changing d18O of zircon with time (15 Ma to present).

Compositions of Icelandic zircons distinguish their tectonic settings and petrogenetic histories. Overall, their common characteristics link their genesis and distinguish them from the global zircon record.

Geodynamic constraints of Canarian volcanism

Joan Marti, Adelina Geyer

Institute of Earth Sciences Jaume Almera, CSIC. Lluis Sole Sabaris s/n, 08028 Barcelona, Spain

E-mail: joan.marti@ictja.csic.es

The intimate relationship between tectonism and magmatism is evident in all volcanic environments, where magma production, magma ascent rate, loci of volcanic activity, and the style of volcanic activity, are directly dependent on the regional/local tectonic characteristics of the area. A good understanding of the geodynamic controls of volcanism is crucial to characterise its associated hazards and to forecast future volcanic eruptions. Unfortunately, very few active volcanic areas are well constrained in terms of their geodynamics, which are basically investigated at a regional scale in order to understand the origin of the related magmatism, but not at a more local scale trying to characterise the structural controls on magma evolution and eruption. In this contribution we investigate the geodynamic framework of Canarian volcanism, applying numerical modelling to determine the current distribution of regional and local stresses. On the light of the results obtained we discuss the structural controls of the Canarian volcanism, and propose a conceptual model that explains the interplay between volcanism and geodynamics as an effective way to forecast future volcanic activity in this area.

New evidence for a depleted Hawaiian Plume component in Cretaceous Emperor Seamounts

Kaj Hoernle, Maxim Portnyagin, Folkmar Hauff, Reinhard Werner

GEOMAR Helmholtz Center for Ocean Research, Germany

E-mail: khoernle@geomar.de

Depleted (MORB-like) geochemical compositions have been found at the Meiji and Detroit Seamounts, oldest in situ products of the Hawaiian Hotspot, located at the northwestern end of the Cretaceous Emperor Seamount chain. The origin of these depleted compositions is controversial. It has been proposed that the depleted component was derived either through melting of depleted (MORB source) upper mantle interacting with the Hawaiian plume near a spreading center (Keller et al. 2000, Nature 405), or through melting of a depleted component in the plume sampled due to enhanced melting beneath thin lithosphere (Huang et al. 2005, G-cubed 6: Q01L06; Regelous et al. 2003, J. Petrol. 44). During two of the R/V SONNE 201 cruises, relatively fresh shield stage tholeiites were recovered from the NW Emperor seamounts (Suizei, Tenji and Meiji). New major and trace element and isotope (Sr, Nd, Pb) investigations of whole rocks and major and trace element compositions of olivine phenocrysts provide new insights into the origin and evolution of the Hawaiian plume volcanism in the Late Cretaceous. The recovered samples range from enriched tholeiites on Meiji and Tenji Seamounts with high La/Yb (1.5 to 6.5) to depleted tholeiites at Suizei Seamount with low La/Yb (0.7 to 1.2), nearly indistinguishable from MORB tholeiites. Initial Pb and Nd isotope ratios from the seamount samples form a very tight inverse linear array, consistent with mixing of two mantle components. The enriched endmember, represented by a sample from Meiji, has, e.g., high initial 206Pb/204Pb (18.7), unradiogenic Nd (0.51295) and high La/Yb (6.5) and is similar to the Kea component in present day Hawaiian tholeiites (Abouchami et al., 2000, Chem. Geol. 169) and has also been found in Early to Mid-Cretaceous Hawaiian plume-related rocks in Kamchatka (Portnyagin et al., 2008, Geology 36). The more depleted endmember, represented by a sample from Suizei, has, e.g., low initial 206Pb/204Pb (17.6), radiogenic Nd (0.51302) and low La/Yb (0.7). An extension of the mixing array to less radiogenic Pb, however, does not intersect the Pacific MORB field (Nd isotope ratios in MORB being higher at a given Pb isotope ratio). Trace elements in olivine suggest that the melts were derived from mantle peridotite with only a minor addition of eclogite. Therefore, we believe that the Suizei endmember was a component in the Hawaiian plume: either a depleted component, e.g., recycled oceanic lithospheric mantle, (Regelous et al. 2003; Huang et al. 2005; Portnyagin et al., 2009, EPSL 287) or possibly ancient primitive mantle (Jackson et al., 2010, Nature 466; Jackson and Carlson, 2011, Nature 476). In conclusion, the new data from the NW Emperor Seamounts confirm the presence of both an enriched Kea type and a depleted or primitive mantle component in the Late Cretaceous Hawaiian plume.

Dynamics of mantle upwelling and outflow during Galapagos plume-ridge interaction

Sally A Gibson[1], Dennis J Geist[2], Mark A Richards[3]

[1]University of Cambridge, UK, [2]University of Idaho, USA, [3]University of California, Berkeley, USA

E-mail: Sally@esc.cam.ac.uk

The compositions of basalts erupted in the Galapagos archipelago and adjacent Galapagos Spreading Centre provide important constraints on the dynamic processes involved in transfer of deep-mantle-sourced plume material to mid-ocean ridges. Galapagos Islands are unusually widespread for such a tectonic setting and offer a unique broad aperture into mantle processes. Of particular interest are recent basalts from central and northeast Galapagos that are more isotopically depleted, and have lower volatile contents, than those at the nearby ridge. Paradoxically, these depleted basalts have higher Sm/Yb ratios than those on the adjacent ridge. We infer from this and also regional variations in isotopic ratios that the compositional differences of basalts erupted during plume-ridge interaction are influenced by factors other than lithospheric thickness variations and mantle heterogeneity.

We use published surface wave data (Villagomez et al., 2007) to calculate temperatures in the Galapagos mantle, at sub-anhydrous peridotite solidus depths. A depth slice at 100 km reveals a 200 km wide channel of highest-temperature (TP=1400 oC) mantle extending from the postulated plume stem towards the nearest section of ridge. Further independent support for this region of high-temperature mantle is provided by coincidence of its predicted intersection with the eastern Galapagos Spreading Centre with the location of the most enriched basalts, greatest crustal thickness and elevated topography. We propose that at this section of ridge (east of the 91 oW transform fault), combined plume-driven deep volatile-rich melting and plate-limited shallow anhydrous melting generate relatively large volumes of more enriched basalts than elsewhere on the Galapagos Spreading Centre. We further note that ridge-ward flow of plume mantle is unaffected by variations in lithospheric thickness of the Nazca Plate and suggest that these are too small to capture and cause confinement of Galapagos plume material flowing to the ridge.

Our geochemical and geophysical observations for Galapagos require a model that involves narrow channelling of highest temperature, low-viscosity mantle from the plume stem to the nearest section of the Galapagos Spreading Centre at depths below the anhydrous peridotite solidus (>80 km), together with sub-axial rather than radial plume flow. The physical parameters and styles of mantle flow that we have defined for Galapagos are poorly constrained for other well-known sites of plume-ridge interactions, such as Easter Island in the Pacific, the Azores, St Helena and Tristan in the mid-Atlantic, and Amsterdam in the Indian Ocean. In many of these cases the presence of a mantle plume is contested. Our findings permit realistic parameters and boundary conditions to be used in dynamical models of global plume-ridge interactions and therefore aid understanding of what drives the most currently active volcanism on the surface of the Earth.

A stratigraphic and structural reconstruction of a complex terrane in an Archean large igneous province: the Redeemer-Raroonga mine corridor, Agnew, Eastern Goldfields, Western Australia

Patrick C Hayman[1], Ray AF Cas[1], Ian H Campbell[2], Ngya Melissa[1], Pegg Ian[3], Squire J Rick[4], Thebaud Nicolas[5], Whitworth Anne[1]

[1]Monash Univerity, Australia, [2]Australian National University, Australia, [3]Agnew Mine Site, Gold Fields, Australia, [4]Deutsche Group Services Pty Limited, Australia, [5]University of Western Australia, Australia

E-mail: patrick.hayman@monash.edu

The Au-mineralised Redeemer-Waroonga mine corridor, situated near Agnew within the Kalgoorlie Terrane of the Eastern Goldfields, Yilgarn Craton, is part of a 2.7 Ga large igneous province (LIP). The stratigraphy has experienced at least one regional deformation event and been metamorphosed to greenschist facies. We examined 46 diamond drill holes spread evenly along the 15 km mine corridor to unravel the structure and stratigraphy in relation to the evolution of the LIP. We begin with the early stages of mafic and ultramafic magmatism, continue with the generation of felsic magmas and resultant uplift, erosion and sedimentation, and end with the later deformation and mineralising events.

The basal sequence is a 3 km thick package of mafic and ultramafic rocks and thin mudstones. The paleo-environment was subaqueous and distal to any major landmass, as judged from the thin mudstone beds, pillowed basalts and komatiites. The paucity of sediments also suggests that there were no significant time breaks between volcanic events, suggesting rapid emplacement, as expected from mantle-derived melts generated from one mantle plume. Unconformably overlying this is the sediment-dominated succession, which consists of a generally upward fining sequence of conglomerates, pebbly sandstones, sandstones, siltstones and mudstones. Thick beds of cross-bedded sandstone suggest that the paleo-environment was dominantly subaerial, although less common turbidites indicate that at least some of the stratigraphy was subaqueous and below wave base. There are several significant stratigraphic changes along strike, including: 1) the lithofacies underlying the sediment-dominated succession varies between basalt, dolerite and komatiite, 2) the conglomerate thickness ranges from 2 to 200 m, and 3) there are several thin intervals of basalt, komatiite and highly deformed equivalents, within the sediment-dominated succession. Based on lithofacies variations and geochemistry of lithic clasts, we show how the mafic-ultramafic succession was uplifted and tilted by diapiric felsic plutons (approximately 2665 Ma), which were sourced from crustal melts generated from plume-derived magmas. The thin ultramafic and mafic intervals within the sediment-dominated succession are located in the Waroonga Shear, a major regional structure and indicate that structural duplication plays a major role in the stratigraphy. Thus, it is difficult to assess whether lithofacies thickness changes have any depositional significance.

Gold is hosted in most of the sedimentary lithofacies and occurs along the Waroonga shear zone, thus lithology does not appear to be a first-order control on mineralisation. Recent teleseismic studies indicate that deep crustal structures link with the Waroonga Shear, providing a pathway for Au-bearing fluids. This research has application to reconstructions of complex volcano-sedimentary successions within LIPs where there is limited material for study.

Wide compositional range of enriched continental flood basalts derived from a long-term depleted mantle source: a case from the Karoo large igneous province

Jussi S Heinonen, Arto V Luttinen

Finnish Museum of Natural History, University of Helsinki, Finland

E-mail: jussi.s.heinonen@helsinki.fi

Continental flood basalt (CFB) provinces manifest anomalous large-scale mantle melting events that are associated with global mass extinction events and continental breakup. Characteristically, CFBs show considerable geochemical heterogeneity even within a single province. This heterogeneity has often been linked to heterogeneities in the mantle source, generally involving major contributions from the variably enriched subcontinental lithospheric mantle (SCLM).

The flood basalt formations of the Vestfjella mountain range represent an Antarctic extension of the Jurassic (180 Ma) Karoo CFB province that is mostly situated in southern Africa and was generated during the initial stages of the breakup of the Gondwana supercontinent. The Vestfjella CFBs and related intrusive rocks are locally well exposed and show notable variation in their chemical composition (e.g., initial ε_{Nd} from -15 to +8). Three major geochemical flood basalt types (CT1, CT2, and CT3) can be distinguished in the lavas, whereas the dikes also show rare lamproitic, ferropicritic, and MORB-like (initial ε_{Nd} = +8) compositions. The MORB-like dikes show indistinguishable Sr, Nd, Pb, and Os isotopic composition from Southwest Indian Ridge MORB, but their trace element compositions indicate melting at high pressures (below thick Gondwanan lithosphere).

Traditionally, the notable geochemical differences between the lavas have largely been attributed to variation in the subcontinental mantle source. Here we show that by selecting viable representatives for crustal and mantle contaminants (Archean and Proterozoic crust and SCLM-derived melt i.e. lamproite) and by using the energy-constrained assimilation and fractional crystallization (EC-AFC) modeling instead of traditional AFC in the case of crustal contamination, all three CT lava types can be produced from a high-pressure MORB-like parental melt with less than 5

We emphasize the following observations: 1) Vestfjella mountains are well-exposed and vegetation-free and reveal the CFBs of the area in their whole geochemical diversity. 2) The application of EC-AFC overcomes the shortcomings related to AFC modeling that often suggest superfluous degrees of crustal contamination. 3) The model parameters have not been adjusted to our needs, but present values that are representative of the geological system. Our study raises the important question whether most CFBs in other parts of Karoo and in other provinces evolved from highly depleted sublithospheric mantle melts (derived at varying pressures) that rarely reached the surface uncontaminated. The compositions of the parental melts may be difficult to assess in cases where such rocks are not known or exposed.

Olivine-hosted melt inclusions in Mg- and Fe-rich magmas: Tracing mantle source and crustal processing in the Paraná-Etendeka LIP

Eleanor S Jennings, Sally A Gibson, John Maclennan

University of Cambridge, United Kingdom

E-mail: esj26@cam.ac.uk

Magmas erupted in continental flood basalt (CFB) provinces have the potential to provide a unique insight into the nature and composition of the Earth's convecting mantle. In CFB provinces, early-phase mantle melting is restricted to relatively high pressures and lower fractions, so any 'streaks' of readily fusible material are likely to make a greater contribution to the final aggregate melts. However, the perceived geochemical complication of crustal and lithospheric mantle contamination during CFB genesis, and rare occurrence of primitive magmas, means that studies of mantle heterogeneity have usually been based on oceanic basalts.

This study examines low 87Sr/86Sr, high 143Nd/144Nd MORB-like picrites and rare ferropicrites from the Early-Cretaceous Parana-Etendeka LIP in order to assess composition and heterogeneity of their contributing mantle source regions, as well as subsequent crustal storage and contamination. These primitive melts were erupted as part of the main 132Ma CFB pulse. While the compositions of the picritic melts are consistent with their derivation from high-temperature melting of peridotite, petrological and experimental studies suggest that the ferropicrites with their distinctive major-element (FeO >13 wt%, low Al2O3) and trace-element (fractionated HREE, [Gd/Yb]n = 2-3.5) chemistry formed by melting of a garnet pyroxenite source. Isotopic ratios suggest low levels (<15%) of upper crustal and lower crustal contamination for the picrites and ferropicrites, respectively.

Our study focuses on olivine-hosted melt inclusions from the picrites and ferropicrites. These provide a 'snapshot' of the compositions of trapped mantle melts before significant crystallisation, contamination and mixing. We have combined major- and trace-element analyses of fully-homogenised melt inclusions together with mineral chemistry to make a preliminary assessment of the nature of contributing melt source regions and also the level and style of contamination. Elevated concentrations of incompatible trace elements, such as Rb, Sr and K, in a subset of the picrite melt inclusions are evidence of upper crustal contamination. Ferropicrite melt inclusions show enrichments in Ba along with a striking depletion in Nb, which may be indicative of lower-crustal contamination. Ferropicrite melt storage at the base of the crust is also indicated by the presence of clinopyroxene phenocrysts, and may be due to the high melt density. Concentric zonation of these phenocrysts indicates a pulsed magma supply to these deep, but most likely small volume, crustal magma chambers.

Variations in trace-element ratios of olivine-hosted melt inclusions in ferropicrites and picrites indicate a fundamental difference between their contributing melt source regions. The small length-scales of lithological heterogeneity in the upwelling proto-Tristan plume head are most readily identified in the compositions of early high-pressure ferropicrite melts.

Lead isotopic record of Barremian-Aptian marine sediments: Implications for large igneous provinces and the Aptian climatic crisis

Junichiro Kuroda, Katsuhiko Suzuki, Naohiko Ohkouchi

Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan

E-mail: kurodaj@jamstec.go.jp

We present initial isotopic ratios of lead for Early Cretaceous (Barremian-Aptian) sections from Shatsky Rise (Pacific) and Gorgo a Cerbara (Italy). These sedimentary sections track an interval representing Oceanic Anoxic Event (OAE)-1a, which is characterized by quasi-global deposition of organic carbon-rich black shale. Pb isotopic compositions of sediments from Shatsky Rise decrease at the end of Barremian time, from radiogenic continental values to unradiogenic values, and subsequently remained less radiogenic until the end of early Aptian time. We explain the isotopic shift by a significant increase in supply rate of unradiogenic Pb, most likely due to massive volcanism. In contrast, the Pb isotopic compositions from the Italian section, which was situated at the western end of Tethys, are mostly identical to those of upper continental crust, showing no significant change in supply rate of unradiogenic Pb. The discrepancy between two sites is attributed to quiescent deep-submarine eruptions of Pacific large igneous provinces (LIPs) such as the Ontong Java Plateau (OJP), which severely limited dispersion of Pb-carrying particles out of the Pacific Ocean. Published Os isotopic data from the Italian section indicate two episodes of massive eruptions of OJP or contemporaneous Manihiki and Hikurangi plateaus starting from earliest Aptian time, slightly later than that indicated by the sedimentary Pb isotopic record from Shatsky Rise. Differences in isotopic variations between Pb and Os likely reflect differences in their chemical behaviors in the oceans, i.e., Pb isotopic compositions would have varied in response to local or regional changes in sediment provenances, whereas large-scale changes in Os inputs are required to explain variations in seawater Os isotopic compositions. Our Pb isotopic data, together with the published Os isotopic record, provide new evidence for the eruptive history of OJP together with contemporaneous Pacific plateaus and its environmental consequences, starting from end-Barremian time and extending through early Aptian time.

Is there a genetic relationship between the Dead Sea Transform and the western Arabia LIP?

Yishai Weinstein

Bar-Ilan University, Israel

E-mail: weinsty@biu.ac.il

The western Arabia Neogene-Quaternary volcanic fields are part of the Afro-Arabian LIP. The volcanism here is mainly related to the opening of the Red Sea rift, which is evident by its occurrence along the eastern flanks of the Red Sea, its age (ca. 30 Ma to present), which is concurrent with the Red Sea rifting, and the dominant directions (NW, sub-parallel to the Red Sea). However, the volcanism also shows spatial relations with the nearby Dead Sea transform (DST) fault. The latter is manifested in fields or lineaments of volcanic structures aligned N-S, sub-parallel to the DST, and the high occurrence of volcanism along the northern part of the DST, 500 to >1,000 km away from the Red Sea.

In this study, it is shown that the DST often functioned as a magma plumbing system. This includes the concentration of large volumes of magmas in pull-apart basins (e.g. south of the Sea of Galilee), the channeling of magmas away of the center of activity along DST segments (north of the Sea of Galilee) and the emplacement of magmas with distinct compositions (e.g. basanites vs. alkali-basalts) on opposing sides of the DST. It is also suggested that due to the 105 km sinistral displacement along the DST, it may form a sharp boundary between lithospheric domains with different composition, as reflected in certain cases in the magmas derived from these domains.

The possible existence of genetic relationship between the DST and magma generation (namely: partial melting due to DST-related extension) is studied through basalt composition on- and off-transform. It is shown that the composition of magmas that erupted along the DST does not differ from that of off-transform magmas (e.g. northern Israel). Furthermore, in cases (e.g. northern Syria), magmas that erupted along the DST are more enriched than magmas that erupted tens to hundreds of km away from the transform, which is in opposite sense to the common on-axis/off-axis petrogenetic comprehension. This, together with the lack of volcanism along the southern part of the DST and the concentration of northern DST fields in association with off-DST fields, doubt the existence of genetic relations between the DST and magmatism.

New insights into composition and source, single or multistage emplacement, and relationship to eruption cycles from first drilling of volcanic island landslides, offshore Montserrat

Peter Talling[1], Sebastian Watt[1], Michael Cassidy[1], Kyoko Kataoka[2], Daisuke Endo[3], Akihiko Fujinawa[4], Molly McCanta[5], Adam Stinton[6], Robert Hatfield[7], Maya Coussens[1], Osamu Ishizuka[3], Anne LeFriant[8], Martin Jutzeler[9], Debra Wall-Palmer[10], IODP Expedition 340 Scientific Party[11]

[1]National Oceanography Centre, UK, [2]Niigata University, Japan, [3]Geological Survey of Japan (AIST), Japan, [4]Ibaraki University, Japan, [5]Tufts University, USA, [6]Montserrat Volcano Observatory, Montserrat, [7]Oregon State University, USA, [8]Institut de Physique du Globe de Paris, France, [9]University of Otago, New Zealand, [10]Univeristy of Plymouth, UK, [11]Various, Various

E-mail: Peter.Talling@noc.ac.uk

Volcanic island landslides can pose a significant hazard due to the landslide itself, and through generation of far travelling tsunamis. The potential tsunami magnitude is highly controversial, and depends on where material originates, and how the landslide is emplaced. It is also important to know whether landslides are preceded or post-dated by major eruptions, and whether landslides play a role in initiation of new volcanic centres. IODP Expedition 340 recovered the first cores through volcanic island landslides, located offshore Montserrat and Martinique. Here we analyse two landslides offshore Montserrat, where we also have unusually comprehensive seismic data and shallow cores. The younger Deposit 1 (1.8 km^3) contains chaotically distributed blocks and was emplaced as a granular avalanche. The older and larger volume (9 km ^{3}) Deposit 2 contains blocks in its proximal part, but generally has a smoother surface. Cores from IODP Site U1395 (25 km from the volcano) contain a spectacular 7 m thick stack of massive, graded turbidite sands associated with Deposit 2. For comparison, the 1995 to recent eruption on Montserrat only produced a 20 cm thick deposit at this location. The stacked turbidites lack intervening mud suggesting emplacement by pulses in a single event. Deposit 2 is 100 m thick at Site 1394, where it comprises flat-lying turbidite sands and hemipelagic mud, and thin intervals of homogenised muddy sand. Most turbidites contain a significant (20 to 90 percent) bioclastic component. The surprising composition of Deposit 2 can be explained by two hypotheses. First, the flat-lying turbidites and hemipelagic muds are in-situ and record episodic failure over a prolonged period of time. Second, emplacement of material from the volcano caused failure of sea floor sediment, and the turbidite sand and hemipelagic muds are flat-lying blocks of seafloor sediment incorporated into the landslide. Shear was concentrated on the homogenised muddy sand. The latter hypothesis is most likely, as it is corroborated by IODP site U1399 offshore Martinique, where flat-lying strata with thin zones of muddy sand occur within landslide deposits. Deposit 2 is directly overlain by a basaltic fallout deposit at Site U1394 suggesting it was followed by a major eruption, which could represent the start of the basaltic South Soufriere Hills centre. Although drilling of Deposit 1 was unsuccessful, run-out deposits associated with Deposit 1 were recovered at Sites U1394 and U1395. The most powerful event since Deposit 2 produced a mixed bioclastic-volcaniclastic turbidite at 14 ka, suggesting that Deposit 1 includes carbonate platform material. Mud intervals in the 14 ka turbidite indicate 5 stages of emplacement. Alternatively, emplacement of Deposit 1 is recorded by turbidites at 2 ka or 6ka, coeval with formation of Englishs Crater on land. However, the magnitude of Deposit 1 favours correlation with the larger 14 ka turbidite.

Edifice collapse processes and the volcano-magmatic response to collapse

Sebastian F.L. Watt[1], Michael Cassidy[1], Peter J. Talling[2]

[1]University of Southampton, U.K., [2]National Oceanography Centre, Southampton, U.K.

E-mail: sebastian.watt@noc.soton.ac.uk

Recent advances in geophysical imaging and direct sampling have led to an improved understanding of large-scale flank-collapse processes at island volcanoes. On ocean islands, such as the Canaries and Hawaii, such events are among the largest mass movements known on Earth. They rapidly transport large volumes of sediment to ocean basins, are capable of generating substantial (even ocean-basin scale) tsunamis, and, via magma system unloading, may be directly associated with volcanic eruptions or exert an influence on the subsequent evolution of volcanoes. Such processes are not limited to ocean islands, but occur in island arcs and can affect any composite volcanic edifice. They are therefore of fundamental importance in understanding volcanic systems, both in terms of hazard generation and in long-term changes in the style and frequency of volcanic activity at individual centres.

Here, we report on recent work that demonstrates the complexity of collapse dynamics around island volcanoes. Collapses frequently occur in multiple discrete phases, and their volume can be significantly increased by the incorporation of seafloor sediment. Both processes are significant for a correct interpretation of tsunami hazard associated with such events. We also summarise recent results on interpreting the diversity of landslide parameters at different volcanoes, in an effort to draw general observations on collapse processers. We go on to show that the magma system may respond in different ways following collapse, with variations in bulk composition, crystallinity and eruption frequency. All of these responses are, however, potentially consistent with the process of magma system unloading, though dependent on local variation in the storage system.

Deformation processes before, during, and after the March 2011 Kamoamoa fissure eruption, Kilauea Volcano, Hawai'i

Paul Lundgren[1], Michael Poland[2], Asta Miklius[2]

[1]Jet Propulsion Laboratory, California Institute of Technology, USA, [2]Hawaiian Volcano Observatory, U.S. Geological Survey, USA

E-mail: paul.lundgren@jpl.nasa.gov

We examine surface deformation of Kilauea Volcano surrounding the March 5, 2011, Kamoamoa fissure eruption along the volcano's east rift zone (ERZ). The Kamoamoa eruption followed several months of magma accumulation beneath Kilauea's summit. In addition to inflation of a shallow (1.5-2 km depth) source near Halema'uma'u Crater, precursory deformation at Kilauea's summit is attributable to sources distinct in space and time from previously identified zones of magma storage and faulting. Differential interferometric synthetic aperture radar (InSAR) data from the COSMO-SkyMed (CSK) and TerraSAR-X (TSX) satellites, combined with GPS data, show evidence for two additional sources active during the inflation prior to the Kamoamoa eruption: 1) progressive inflation of a triangular-shaped area extending from the southern edge of Kilauea Caldera and west of the ERZ, and 2) a nearly vertical, mostly extensional feature beneath the western edge of Kilauea Caldera. The shallow Halema'uma'u source appears to have gained in volume during the entire pre-eruption period, while the source of the triangular deformation in the south caldera became active in the final month prior to the Kamoamoa eruption. Following the eruption, GPS and satellite InSAR time series (from CSK and TSX data) over ten months, along with individual airborne interferograms from the NASA UAVSAR instrument over an eight-month interval, show inflation of the area surrounding the fissure eruption. To model the sources, we use a Markov chain Monte Carlo (MCMC) Bayesian approach. Preliminary pre-eruptive models show a set of shallow (upper 4 km) sources: mostly tensile opening along the west caldera margin shallower than 1 km, and pressurization of magma storage areas beneath the central part of the caldera and south of the caldera. Preliminary post-diking models suggest deeper opening of the ERZ beneath the Kamoamoa dike, similar to deformation patterns observed during previous ERZ intrusions and fissure eruptions (for example, in 1997). We will compare models for the pre- and post-diking surface deformation observations with the co-eruptive intrusion and to observations of Kilauea's magmatic and structural system. Finally, we will compare the 2011 observations with the present-day spatiotemporal deformation sequence to ascertain whether or not the pre-Kamoamoa summit deformation represents a recurring pattern that is characteristic of a magma system that is about to rupture.

Investigating the formational mechanism of the Nīnole hills on Mauna Loa, Hawaii, through gravity surveys

Jeffrey M Zurek[1], Glyn Williams-Jones[1], Frank Trusdell[2]

[1]Department of Earth Sciences, Simon Fraser University, Canada, [2]Hawaiian Volcano Observatory, United States Geological Survey, United States of America

E-mail: jmz3@sfu.ca

Mauna Loa´s high eruption rates have extensively repaved its surface with over 90 % of its surface younger than 4000 years. This creates problems when attempting to understand the evolution of Hawaiian volcanoes as features that once existed have been buried under younger lavas. To obtain a window into Mauna Loa ´s past, it is necessary to locate fault scarps, anomalous structural features, or drill. One anomalous topographic feature, the Nīnole hills, protrudes from the flank of Mauna Loa and is the oldest exposed subaerial rocks on the edifice (100-300 ka).
There has been much discussion as to what the Nīnole Hills are and how they formed. The first proposed formation mechanism of the hills was a proto-volcanic edifice. This interpretation is based on the slope of the lavas in the Nīnole hills pointing to a source which is offset from the summit or the Southwest Rift Zone. This interpretation is problematic as rotation due to rift zone migration or faulting can change the slope of the ground. Later studies showed that the basalt that makes up the hills are geochemically identical to those of Mauna Loa suggesting that the Nīnole Hills are not a separate volcanic edifice. Rather, it has been proposed that erosional valleys due to gravitational slumping and mass wasting are a more reasonable mechanism to explain the morphology of the hills. Recently, seismic tomography studies have suggested that the Nīnole Hills are the remnants of a failed rift zone likely active before Kilauea buttressed Mauna Loa ´s south flank.
In order to address these disparate formation mechanisms, we present Bouguer gravity collected in April, 2013 and 3D gravity inversions. To remove the effect of density anomalies that are too deep or outside the Nīnole Hills, a regional gravity data is used through a two-step inversion process. Removal of the regional field enables high resolution images of density contrasts at depth which can be used to directly test the three different formational mechanisms. If the series of hills and ridges are created by a proto-Mauna Loa, then one would expect a central, somewhat shallow (less than 4 km depth), gravity high due to dense intrusions somewhere within the hills. If created by an active rift zone, we would expect to see a shallow, roughly linear, gravity high tracing out the highest point of the ridges similar to what is observed for Kilauea; corresponding to dense intrusions along the ridge axis. If created by a combination of fault zones, mass wasting, and erosion, then the gravity data will show no significant shallow signal but rather just the regional field.

Olivine crystallization pressures within Kilauea's lower east rift zone: the use of rehomogenized melt inclusions to interpret magma transport, storage, and energetic fountaining

Robin M Tuohy[1], Paul J Wallace[1], Donald A Swanson[2]

[1]University of Oregon, USA, [2]Hawaiian Volcano Observatory, USA

E-mail: rtuohy@uoregon.edu

The classic model of Kilauea's eruptive and deformation behavior is based on observations made by the Hawaiian Volcano Observatory during the 1959–1960 eruptions. Although the 1959 Kilauea Iki eruption produced the highest lava fountain observed at Kilauea (580 m), the 1960 Kapoho eruption on Kilauea's lower East Rift Zone (ERZ) produced fountains greater than 400 m in height. A possible explanation for high fountains on the lower ERZ is that they involve a component of undegassed, CO2 rich magma that has bypassed the summit reservoir and shallow rift system. Alternatively, they may involve rapid supply of magma to the rift zone from the summit magma chamber. The goal of this project is to determine if any of the energetic mid 20th century Kilauea eruptions on the lower ERZ were fed by deeply sourced magmas, with high CO2 concentrations, that had bypassed the summit and shallow rift systems. We are investigating this hypothesis by determining crystallization pressures for melt inclusions in olivine from the 1840, 1955 Puna, and 1960 Kapoho eruptions on the lower ERZ. The 1959 Kilauea Iki summit eruption, previously investigated by Anderson and Brown (1993) will represent a summit eruption site. Melt inclusions analyzed for this study were experimentally reheated to 1400℃ for 15 minutes to redissolve the CO2 lost to shrinkage bubbles after entrapment. Our results show that some hydrogen diffusive loss occurs from small inclusions, and we are running additional experiments at lower temperatures and shorter durations to quantify the extent of hydrogen loss. We will also compare our data to Raman measurements of CO2 in bubbles to see if they yield comparable results. Data for natural and reheated Kapoho melt inclusions suggest 50–60% of original CO2 is lost to the shrinkage bubbles, with reheated inclusions ranging from 200 to 1200 ppm CO2, and one value of 2400 ppm compared to 100 to 300 ppm CO2 for natural melt inclusions. The H2O and CO2 contents allow us to calculate the pressures at which the inclusion-bearing olivines formed, and thus infer the pressures of magma storage. Kapoho olivines crystallized between 1 and 10 km depth, and one value at 19 km, with a significant number of olivine having crystallized in the deep rift. The Kapoho olivines are typically Fo89, in contrast to Kilauea Iki olivines (Fo87), many of which have shallower crystallization depths (>1 to 6 km). Therefore, the Kapoho eruption may be more complicated than previously realized. If Kapoho was a simple extension of the Kilauea Iki summit eruption, there should be more overlap in Fo content and crystallization depth. The higher pressures of some reheated inclusions may suggest a source for some olivines that is deeper than the summit reservoir and shallow rift zone.

Kilauea's magma plumbing system

Michael P. Poland[1], Asta Miklius[1], Emily K. Montgomery-Brown[2]

[1]USGS - Hawaiian Volcano Observatory, USA, [2]University of Wisconsin, USA

E-mail: mpoland@usgs.gov

We propose a conceptual model of the magma plumbing system at Kilauea Volcano, Hawai'i, that we hope will provide an improved framework for studies of eruptive and intrusive activity at the volcano. The model is built upon a foundation defined by decades of previous work, with refinements based on geophysical, geochemical, and geologic data collected during recent eruptive activity. These datasets allow us to resolve two levels of magma storage and transport within Kilauea.

The deeper part of Kilauea's magma system is centered on the largest (about 10 km^3) magma reservoir, 3 km beneath the south caldera. This reservoir is connected to the volcano's rift zones, which radiate to the northeast and southwest and define the structural boundary between the volcano's stable north and unstable south flanks. Magma occasionally accumulates in those parts of the rift zones that are adjacent to the summit caldera, especially during periods when the main reservoir is highly pressurized. The more active east rift zone is continuously molten from the summit to at least its subaerial tip (about 60 km in length). Both rift zones contain small, isolated pods of magma that are relicts of past intrusions, can be highly differentiated, and are trapped in the crust above the continuous molten core (as indicated by deformation, seismicity, petrologic data, and geothermal drilling). The Koa'e fault zone, which structurally connects the east and southwest rift zones south of the summit caldera, occasionally can be intruded by magma and may connect the rift zones independent of the summit reservoir system.

The shallower magma system is rooted in a smaller (about 1 km^3) reservoir at 1 to 2 km beneath the east margin of Halema'uma'u Crater, near the center of the caldera. From this shallow reservoir, secondary magma pathways branch at 1 km depth or less, as indicated by historic eruptive fissures and fracture systems that extend to the east and west from Halema'uma'u Crater. These pathways may represent the former locations of the structural rift zones before they migrated to the south due to due to seaward motion of the Kilauea's south flank. Whether magma accumulates within the deep rift zones, below 3 km depth, is uncertain. Magma storage is suggested by a lack of earthquakes and by deformation that indicates rift opening, while gravity highs and fast seismic velocities argue for the presence of dense cumulates.

The duration of the shield stage of Hawaiian volcano; unspiked K-Ar dating of the submarine tholeiites from Koolau volcano

Seiko Yamasaki[1], Takahiro Tagami[2], Eiichi Takahashi[3]

[1]Geological Survey of Japan, AIST, Japan, [2]Kyoto University, Japan, [3]Tokyo Institute of Technology, Japan

E-mail: yamasaki.seiko@aist.go.jp

The determination of the duration of the shield-stage volcanism of Hawaiian volcanoes has a great importance to evaluate the size of the plume conduit. The duration of shield stage has estimated to be ∼0.7 Ma by volcano growth model. However, no studies have ever determined the onset of the shield stage because of the difficulty of approaching the submarine shield stage lavas. We report unspiked K-Ar ages for lava samples collected from the submarine flank and offshore landslide block of the Koolau volcano, Hawaii. The K-Ar dating results suggest that the onset of Koolau shield-stage volcanism was no later than ∼3.3 Ma. Since the end of the shield stage is regarded to be 2.1 Ma by dating the subaerial lavas, the duration of the shield stage is at least 1.2 m.y.

Signals of volcanic collapses in the centralwest part of the island of Fuerteventura (Canary Islands, spain) and their relationship with the intrusive complexes.

Angela Claro, Cristina de Ignacio, Mercedes Muñoz

Dpt Petrologia y Geoquimica, Facultad CC Geologicas, Universidad Complutense de Madrid, Spain

E-mail: aclaro@geo.ucm.es

It is known that the island of Fuerteventura (the easternmost one of the Canary archipelago) is the result of three large Miocene stratovolcanoes: Jandia, Gran Tarajal and Tetir Edifices, from south to north respectively (Ancochea et al., 1996). The Central and North edifices have associated intrusive rocks that represent their roots (Muñoz and Sagredo, 2004). In the study area these roots consist of olivine gabbros and melanogabbros in the lower parts that grade into gabbros s.s. and layered leucogabbros in the upper parts. The leucogabbros and associated dikes show a 40-44°trend with subvertical 60-70°dips to the NW. This trend, which probably controls intrusive emplacement, is consistent with the main extension direction affecting Fuerteventura in Miocene times (Ancochea et al., 1996). Although some authors have studied the growth and collapse history of the Miocene Volcanic Edifices (Ancochea et al., 1996; Stillman 1999) there is yet no study trying to describe the meso-scale structures associated to these collapse events and how they might have affected the different levels of the volcanic-subvolcanic systems. Los Molinos ravine, in centralwest Fuerteventura, dissects the upper parts of the intrusions, volcanoclastic materials and dikes that have been described as belonging to the Gran Tarajal Edifice. For this reason it has been selected in order to study the cross section which is presented in this work. In the north part of the cross section, the most important structure is a normal fault showing listric geometry implying detachment to the NW and putting into contact layered leucogabbros and dikes with volcanoclastic materials. In the footwall, the dip of the dikes mimics the listric geometry and the layered leucogabbros occur as wedge-shaped, rotated blocks among the dikes. The hangingwall is composed of 36-44°trending dikes with volcanoclastic materials (Salinas breccia) between them. The south part of the Los Molinos ravine is occupied by the Salinas breccia and associated dikes which are in turn affected by another, NE-SW listric fault dipping approximately 23°to the NW. In the footwall the Salinas breccia is more compact and the dikes again mimic the listric fault geometry, whereas in the hangingwall the breccia resembles an agglomerate and its associated dikes show more pronounced dips. The different parts of the above described cross section have been interpreted as different depth levels of the Central Volcanic Edifice that have been placed into contact by collapse processes affecting not only the volcanic materials and dikes but also the shallowest parts of their intrusive roots.

Depths of magma reservoirs at oceanic island volcanoes: the magmatic system of El Hierro (Canary Islands) during the 2011-2012 eruption inferred using satellite geodesy

Pablo J. Gonzalez[1], Sergey V. Samsonov[2], Susi Pepe[3], Kristy F. Tiampo[1], Pietro Tizzani[3], Antonio G. Camacho[4], Francesco Casu[3], Jose Fernandez[4], Eugenio Sansosti[3]

[1]Department of Earth Sciences, University of Western Ontario, 1151 Richmond Street, London, ON, Canada, [2]Canada Centre for Remote Sensing, 588 Booth Street, Ottawa, ON, Canada, [3]Istituto per il Rilevamento Elettromagnetico dell'Ambiente (CNR), Via Diocleziano 328, Naples, Italy, [4]Instituto de Geociencias, CSIC-UCM, Fac. Cc. Matematicas, Plaza de Ciencias, 3, 28040-Madrid, Spain

E-mail: pabloj.glez@gmail.com

Starting from July 2011, anomalous seismicity was observed at El Hierro Island (Canary Islands, Spain). During the following three months, seismic activity increased both in number of events and in magnitude, while expanding over a larger area. In early October 2011 the process led to a submarine eruption, with some uncertainty about the location and timing of the opening of the vent(s). The site of the eruption was approx. 15 km from the initial and main earthquake loci, indicative of significant lateral migration. The submarine eruption finished in early March 2012. However, several additional pulses of magma seemed to occur in June-July, 2012; September 2012; and January 2013 as indicated by an increase in seismicity and intense ground deformation. The additional pulses has not yet produced an eruption, and seemed to follow different migration paths with respect to the previous periods. Here, we conduct a multi-frequency, multi-sensor interferometric analysis of space-borne radar images acquired using three different satellites (Radarsat-2, ASAR-ENVISAT and COSMO-SkyMed). Radar interferometry is used to measure the deformation that occurred from December 2009 to January 2013.

InSAR data fully captures both the pre-, co- and post-eruptive phases. Elastic modeling of the ground deformation is employed to constrain the dynamics associated with the magmatic and eruptive activity. Results indicate that El Hierro Island magmatic plumbing system is a much more complex system that previously thought. It is composed with at least three main stagnation levels, i) a petrologically-constrained level at 20-26 km depth, ii) a level at the moho, base of the oceanic crust at 8-12 km depth, and iii) a 4 km depth level at the base of the volcanic edifice, coinciding with the typical seafloor depth at El Hierro region. The existence of a dual crustal magmatic reservoirs seems a recurrent/representative feature at other (basaltic) oceanic island volcanoes. Our preliminary interpretation is that the depth of the "dual" shallow system might be controlled by the mechanical properties of the underlying lithosphere and the magma supply rates. In addition, this study represents one of the first geodetically-constrained active magmatic plumbing system model for any of the Canary Islands volcanoes, and one of the few examples of geodetic measurement of submarine volcanic activity to date.

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Temporal succession, intensities, and magmatic evolution of large-magnitude Plinian eruptions from Fogo and Brava, Cape Verde Islands

Steffen Eisele, Armin Freundt, Steffen Kutterolf, Stefan Reissig, Dirk Nuernberg

GEOMAR Helmholz Centre for Ocean Research Kiel, Germany

E-mail: seisele@geomar.de

Eleven sediment gravity cores of up to 6 m length have been collected from the ocean floor around the southern chain of the Cape Verde Archipelago. These cores contain ash layers that we were able to correlate between cores using glass and mineral, major and trace element compositions. These correlated ash layers represent five basanitic/tephritic eruptions from the island of Fogo and four phonolitic eruptions from the adjacent island of Brava. Correlations with these islands are supported by on-land fieldwork and analyzed samples. Our tracing of these layers along the seafloor up to 240 km distance from the islands proves that all nine eruptions were high-intensity, large-magnitude Plinian events.

The alternation of basanitic/tephritic and phonolitic layers shows that highly explosive volcanism on both islands overlapped completely in time. Detailed Mg/Ca and δ18 O studies of planktonic and benthic foraminifera combined with radiocarbon ages from one core (M80/3-43) suggest that huge explosive eruptions from either Fogo or Brava took place about every 21 ka during the last 160 ka. Our ongoing geochemical, petrological and stratigraphic studies aim to reveal the conditions of magma storage and evolution as well as triggering of eruptions for both the Fogo and Brava systems, and may elucidate possible links between these simultaneously active magma systems.

Explosive volcanism from the galapagos hotspot: evidence from Miocene marine tephras found during IODP Expedition 334 and 344

Steffen Kutterolf[1], Julie C Schindlbeck[1], Susanne Straub[2], Nicole Stroncik[3], 334 and 344 science parties[3]

[1]GEOMAR Helmholtz Center for Ocean Research Kiel, Germany, [2]Lamont-Doherty Earth Observatory, USA, [3]Texas AM University/IODP, USA

E-mail: skutterolf@geomar.de

The Central American Volcanic Arc (CAVA) has generated numerous Plinian eruptions along its 1200 km NW-SE extension, evident as ash layers in marine sediments of the Pacific, downwind from the eruption centers. Such deposits are not known to exist from the Galapagos Hotspot. During IODP expeditions 334 and 344, offshore and near Costa Rica, a total of 81 and 37 tephra layers have been recovered at Sites U1381 and U1414, on top of and at the rim of the Cocos Ridge, respectively.

Within the first 56 (meters below seafloor) at Site U1381, eighteen tephra layers are intercalated with hemipelagic Pleistocene sediments of Unit I, associated with a near trench depositional environment. In contrast, the 63 tephra layers recovered from Unit II (>56 mbsf) are embedded, after a >9 my hiatus, in a succession of Miocene silicic and calcareous ooze dominated sediments. Plate reconstruction shows that these sediments may have been deposited in proximity to the Galapagos Islands.

Individual tephra layers range in thickness from 1 to 41 cm. The 81 tephra layers are compositionally variable. Gray to whitish layers show dacitic and rhyolitic compositions (predominantly Unit I; fresh, transparent glass shards, common plagioclase, amphibole and pyroxene) and gray to brown black layers show basaltic compositions (predominantly Unit II; dark to light brown sideromelane glass shards, rare tachylitic particles, and minor plagioclase and traces of pyroxene). Dark black tephra beds account for ca. 27% of the total tephra bed assemblage of Unit I, but are more abundant in Unit II (ca. 72%). Grain sizes range from fine to medium ash, getting coarser in Miocene Unit II (up to mm size). Generally, tephras from the older Miocene sequence have a lower crystal content than the tephras of the younger ones.

At Site U1414 a continuous sedimentary succession was recovered that encompasses the whole Holocene to the Middle Miocene. Tephra layers from U1414 are predominantly felsic in composition (>90%) and mafic tephras are less abundant than at Site U1381. Despite this difference, the appearance of the individual tephra layers and their glass shard and mineral inventory reflect the same variability as at Site U1381.

A first provenance analysis based on major and trace elements suggests that most of the tephra layers within the Pleistocene unit of Sites U1381 and U1414 are derived from Central American volcanic arc eruptions. In contrast, Miocene mafic and felsic tephras of Sites U1381 and U1414, respectively, show a Hotspot signature (Nb,Ta enrichment in spider diagrams and high Nb/La).

Both IODP sites constrain the occurrence of an important amount of large explosive volcanism at the Galapagos Hotspot, which is not evident from onshore data. How, where, when and to what extent this volcanism took place in the Miocene will be investigated in the future with more trace element analyses and Ar/Ar ages.

Petrology and thermochronology of the Juan Fernandez Ridge (Nazca Plate)

Javier Reyes[1], Luis E. Lara[2]

[1]Universidad de Chile-Andean Geothermal Center of Excellence (CEGA), CHILE, [2]SERNAGEOMIN, Volcano Hazards Program, CHILE

E-mail: luis.lara@sernageomin.cl

The Juan Fernandez Ridge on the oceanic Nazca plate is thought to be a classic hot spot trail because of the apparent age progression. However, geochronological data is still scarce and only a few anchor points are available to support this hypothesis. A 40Ar/39Ar total fusion age of ca. 9 Ma was previously obtained for the OHiggins seamount (115 km from the Chile-Peru trench) as well as K-Ar ages of ca. 3-4 Ma in Robinson Crusoe island (580 km from the trench) and ca. 1 Ma in Alejandro Selkirk (180 km further west). Taken together, they indicate a westward displacement of Nazcla plate at ca. 6-8 cm/yr, which is in good agreement with plate models and modern GPS data. On the other hand, new 40Ar/39Ar and geological reconnaissance suggest a post-shield stage in Robinson Crusoe, which is ca. 3 Ma younger than the main shield stage.

Petrological evidence also supports a typical hotspot evolutionary pattern. In fact, the partially altered older sequence in Robinson Crusoe island is tholeiitic (Ba/Yb=64.79; La/Yb=10.70; Ba/Zr=0.76; Nb/Zr=0.16). The shield stage (ca. 1-3 Ma) is transitional from tholeiitic to alkaline (Ba/Yb=107.42; La/Yb=13.69; Ba/Zr=1.07; Nb/Zr=0.16) and the younger post-shield stage (ca. 1 Ma) is mostly alkaline (Ba/Yb=236.58; La/Yb=22.32; Ba/Zr=2.26; Nb/Zr=0.26).

A fixed deep-mantle plume origin for Pacific hot spots has been widely debated and concurrent phenomena arise as a possible explanation for non-linear age progressions and/or long-lived volcanic activity. In fact, intraplate regional tectonics, plume displacement, and mantle heterogeneities could be the main factor of the ridge architecture or the mask for a first-order linear trend. An ongoing mapping and dating effort is aimed to understand the evolution of the Juan Fernandez Ridge.

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Evolution of silicic magmas at Icelandic central volcanoes during rift relocations

Tenley J. Banik[1], Calvin F. Miller[1], Ármann Höskuldsson[2], Tamara L. Carley[1]

[1]Dept. of Earth and Env. Sciences, Vanderbilt University, Nashville, TN 37240, USA, [2]Institute of Earth Sciences, University of Iceland, 101 Reykjavik, Iceland

E-mail: tenley.banik@vanderbilt.edu

The Iceland hot spot has been linked with the Mid-Atlantic Ridge (MAR) for about 25 Ma, which has had direct consequences for the magmatic and tectonic evolution of the island of Iceland. The MAR axis moves northwest about 1-3 cm/yr, resulting in the surface expression of the Iceland plume moving first under the MAR axis and then progressively east of it (Lawyer and Müller 1994). However, the plume periodically recaptures the terrestrial rift on Iceland by instigating rift relocation, which effectively moves the rift eastward (Jóhannesson 1980; Hardarson et al. 2008; Hey et al. 2010). Rift jumps have occurred several times throughout Iceland's history. One of the most notable features of Icelandic rift zones is the development of volcanic complexes consisting of a central volcano and associated fissure swarms (e.g., Carmichael 1964). Central volcanoes are the only places in Iceland with exposed silicic rocks, which compose about 10 percent of the exposed rock in Iceland (e.g., Walker 1966). Previous research at several silicic centers (e.g., Sigmarsson et al. 1991; Jónasson et al. 1992; Jónasson 2007; Martin and Sigmarsson 2010; Carley et al. 2011; Martin et al. 2011; Padilla et al. 2012) has indicated the common occurrence of the mineral zircon. However, no studies have been conducted that use zircon to obtain precise U-Pb ages or detail geochemical changes in central volcano magmas as they–and their host rift systems–evolve. Our work compares the evolution of three magmatic systems at different rift axes in the Westfjords and along the west coast of Iceland. The Árnes caldera formed at the Fenrir rift zone (Benediktsdóttir 2012) potentially as early as 13-15 Ma (Jordan et al. 2008; Hey et al. 2010) while the rift was juvenile. This area has well-documented, abundant silicic rocks, but they have undergone little petrologic or geochemical examination. The Nónfjall caldera was also formed during the Fenrir rift propagation around 10 Ma, but is undescribed in the petrologic literature. The Hafnarfjall-Skardsheidi central volcano in west-central Iceland was mapped in detail and examined by Franzson (1978), but emphasis was on the origin of the mafic rocks and not on the petrogenesis of the prominent felsic volcanic and intrusive units. This volcanic system–active from roughly 6-4 Ma (e.g. Moorbath et al. 1968) during the A-A′ rift jump (Hey et al. 2010)–formed from the juvenile Reykjanes-Langjökull rift axis. Since all central volcanoes in Iceland dated thus far appear to have lifespans of roughly 2 Myr, a comparison of the geochemical changes in each system over its lifetime will elucidate: a) the timing and diversity of silicic magma development; b) the processes active in facilitating these changes; and, c) the role that rift evolution and relocation plays on silicic magma genesis. Here we present preliminary findings from fieldwork and initial analytical results.

Volcanic activity history of Io To Island in Ogasawara Archipelago estimated by the terrace chronology and crustal deformation observation

Takayuki Nakano[1], Tetsuro Imakiire[1], Mamoru Koarai[1], Shinzo Ooi[1], Kosei Otoi[1], Keiichi Sasaki[2]

[1]Geospatial Information Authority of Japan, Japan, [2]Kanazawa Gakuin University, Japan

E-mail: t-nakano@gsi.go.jp

Io To Island in Ogasawara archipelago (hereafter referred as "Io To Island") is a volcanic island located at 141°17' 14" E longitude and 24°45' 29" N latitude, where uplift and volcanic activity are currently ongoing. Io To Island consists of Motoyama volcano making the main body of the island, Suribachi Yama lateral volcano, Kangoku Iwa rock (which is caldera rimb off the northwestern coast of the island) and so on. A few detailed studies about geoscience phenomena in this island were kept. We have conducted survey of topography and geology and observation of crustal deformation using GPS in order to interpretate a detailed uplift activity history, volcanic chronology and recent crustal deformation. This works was supported by MEXT KAKENHI (21510193). Primary results of this study were reported on Ooi and Yarai (2007) and Imakiire et al. (2010). In this presentation, we report the result of radioactive dating and component analysis about the samples extracted in Io To Island, and volcanic evolution history in Io To Island reached by making use of those results is suggested.

The volcanic activity history for 3,000 years past in Io To Island estimated by these results and existing results is as follows: (1) a great volume of lava and pyroclastic material (Motoyama tuff) spewed out about 2,700 years ago, and old Io To island covered thickly with it, (2) a submarine volcano erupted around Kangoku Iwa rock about 1,600-2,000 years ago, and the peperite was generated, (3) a large scale eruption of the volcano occured around Suribachi Yama lateral volcano about 1,400 years ago, and pumice drifted in Okinawa Islands, (4) Suribachi Yama lateral volcano erupted with a uprifting rapidly Motoyama volcano about 500 years ago, and Suribachi Yama volcano was connected with Motoyama volcano by a large amount of pumice, (5) a small scale eruption occured in Suribachi Yama lateral volcano about 200-400 years ago, and the scoria hill was formed on southern edge of the crater of this volcano, (6) a small eruption and phreatic explosion occured at the northeast coast of the island and along Asodai fault, where lie down the western part of island, during the past 100 years, and an eruption with magma occured at the sea bed off the southern coast of Motoyama volcano after the second World War.

It was confirmed that the uplift velocity past of Io To Island (Motoyama volcano) was intermittent and fastest in about 500 years ago by terrace chronology. On the other hand, the average uplift velocity during the past 100 years by a reference point and GPS observation is 15cm/yr (Hiraoka et al., 2009), and maximum uplift velocity was recorded in the 1950s-1960s and from late 2006 to 2010, about 56cm/yr (Tsuji et al., 1969) and about 50cm/yr (GSI, 2012) respectively. These recent uplift velocity is comparable to it in about 500 years ago, when Suribachi Yama lateral volcano erupted with a uprifting rapidly Motoyama volcano.

Is Ryukyu Subduction Tectonic Activity Driving Intraplate Volcanism in Korea?

Marco Brenna[1], Shane J Cronin[1], Jan Wijbrans[2], Young Kwan Sohn[3], Gabor Kereszturi[1], Gwang H Lee[4]

[1]Massey University, New Zealand, [2]VU University Amsterdam, The Netherlands, [3]Gyeongsang National University, Republic of Korea, [4]Pukyong National University, Republic of Korea

E-mail: m.brenna@massey.ac.nz

The driver(s) of volcanism in intraplate settings and its relationship to plate tectonic processes are themes of broad debate in the geological and geophysical community. Several Quaternary intraplate volcanic centres are located in and around the Korean peninsula, beyond the reach of modern subduction-related fluids as drivers of magmatic activity. The reason for their existence is enigmatic and controversial. They have been linked to mantle plume activity, or to local mantle upwelling and decompression driven by the sudbucting Pacific and Philippine Sea tectonic plates. We present a new dataset of Ar/Ar ages from Jeju Island and integrate these with the existing database of ages of Jeju rocks. We use these data to construct a temporal volumetric model for the construction of Jeju Island. The data show that the locus of volcanism was initially in the western half of the island and moved eastward over time. This eastward migration is controlled by lithospheric extensional structures likely related to splays from the Tsushima Fault Zone and gave the Island its elliptical shape. A magmatic trend starting from early eruption of High-Al alkali at c. 1.8 Ma, followed by transitional alkali, and finally contemporaneous Low-Al alkali and subalkali magma occurred in the western locus, and was entirely repeated at the later eastern region. The latter (post c. 400 ka) locus was volumetrically most important, building the bulk of the Island. A twofold increase in magma output rate from c. 400 ka at Jeju is coincident with other tectonic and magmatic events in the Korean region. A sudden increase in magma output rate is also observed in the Abu Monogenetic Volcano Group in southwestern Honshu at c. 400 ka, and two large basaltic lava flows erupted in central Korea soon after 500 ka. Additionally, volcanic activity in the Ryukyu Arc became increasingly explosive in the last 500 ka producing a higher density of large caldera structures compared to the previous 1.5 Ma. The onset of these volcanic events is temporally linked with a doubling of the extension rate of the Okinawa trough, which lies behind the Ryukyu subduction zone. This increase in extension rate is likely responding to a change in the subduction/convergence rate, which in turn changed the crustal stress regime in the Korean area, including Jeju. We therefore suggest that rates of volcanism on Jeju Island are linked with crustal stress that is influenced by changes in the subduction rate at the Ryukyu subduction zone.