Kappel and Ryan, 1986). Off-axis sampling and observations made with the ROV Tiburon provide a unique perspective on the crustal evolution along this typical moderate spreading-rate ridge. The rift valley walls are comprised of a series of major bounding faults, separated by blocks of oceanic crust that exhibit little or no deformation. Unlike the present axis that is dominated by sheetflows, these blocks are almost entirely comprised of unfaulted, constructional pillow ridges, mounds and hornitos. These blocks conform to the mound-like areas identified by Kappel and Ryan (1984) based on Sea MARC I images and our EM300 data. There is observational evidence of small volumes of off-axis volcanism along eruptive fissures and from point-sources that appear related to the formation of rift-bounding faults. Other volcanic constructs seem to be related to the formation of the first series of abyssal hills, consistent with "volcanic growth faults" draped with syntectonic lava flows.

Off-axis samples are moderately to highly evolved N-MORB but also include ferro-andesites and a dacite with somewhat "transitional" chemical characteristics. The range of compositions is greater than that previously reported for the entire southern JdFR. In contrast, samples recovered from the south Cleft axis are moderately evolved N-MORB and exhibit little chemical variability. Lavas sampled in cross-axis traverses encompass the entire range of compositions with no readily discernable pattern of variation with distance from the axis nor are the chemical trends symmetric across the ridge crest; features which are inconsistent with the split-ridge hypothesis. Initial geological correlations suggest the less evolved flows form the outward-facing constructional mounds and hills, whereas the most evolved types (FeTi basalts) form the small hornitos and areas of extensive sheetflows and lava drainback that are perched on "benches" between faulted, pillowed walls. We suggest that the less evolved samples are related to axial volcanism while the more evolved samples were formed by post-axial or off-axis volcanism. The highly fractionated off-axis MORB could have been derived from the cooler, distal edges of a magma chamber. Most of the major and trace element chemical variability can be explained in terms of low-pressure fractional crystallization (up to 50%) of parental magmas with compositions similar to recently erupted axial MORB. Ferro-andesites recovered from an outcrop along the inner valley wall appear to be spatially related to the major axial bounding fault and to some extinct sulfide chimneys. These highly fractionated andesites (and the dacite from the RTI), require extreme amounts of fractional crystallization as well as additional processes (assimilation/mixing) to explain their unusual compositions.

## V12A-0957 1330h POSTER

### Eruption Recurrence Rates and Compositional Variability of Discrete Lava Flows on the S-EPR from $^{238}$U-$^{230}$Th-$^{226}$Ra-$^{210}$Pb$-^{232}$Th

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Quantification of the absolute ages and geochemistry of individual seafloor lava flows provides important constraints on the magmatic processes responsible for building the oceanic crust. Here we present new $^{238}$U-$^{230}$Th-$^{226}$Ra-$^{210}$Pb radioactive disequilibrium age constraints (decadal to millennial time scale) for 3 mid-ocean ridge lava flows at 17°26'S on the East Pacific Rise (EPR): Aldo-Kihi, Rehu-Marka, and a neighboring unnamed flow. Our continuing study using high-resolution surveys and manned-submersible sampling (NAUDUR, 1993, and STOWA, 1991, expeditions) has previously shown that Aldo-Kihi is compositionally variable, is probably one of the youngest axial lavas in the 17°-19°S region, and was most likely erupted from a series of fissures extending >18 km along the ridge axis (Sinton et al., JGR, in revision). Rehu Marka has a more trace element enriched and evolved composition. The strongest age constraints in our U-series data set are from the $^{210}$Pb-$^{226}$Ra (half-life = 22.3 yrs) and $^{226}$Ra-$^{230}$Th (half life = 1600 yrs) systems. $^{210}$Pb-$^{226}$Ra disequilibrium (as 5-7% Pb deficits) is common in lavas from our S-EPR study area and slightly lower than disequilibria we have measured in lavas erupted in 1991 and 1992 at 9°50'N EPR. Although we are still developing our understanding of how this disequilibrium arises in MORB (e.g., how the radioactive "clock" is set for this isotope pair) a number of features of our preliminary data support the idea that these lavas are very young and that geologically observed contact relationships in the field separate the products of chronologically distinguishable eruptions. Also, the extent of $^{226}$Ra-$^{210}$Pb disequilibrium in 3 Aldo-Kihi samples compared to that observed at 9°50'N indicates that the Aldo-Kihi lava probably erupted within the last 10-20 yrs, and the higher but still <1 ($^{210}$Pb/$^{226}$Ra) activity ratio in a lava sampled near to but outside the boundaries of Aldo-Kihi indicates it is slightly older, but probably only by a decade or so. Although the older lava's major element composition is very similar to Aldo-Kihi, it has distinct U-Th-Ra chemistry, indicating it is from a different parental magma. Finally, the compositionally very distinct Rehu Marka flow just to the north has no $^{226}$Ra-$^{210}$Pb disequilibrium, indicating it is likely older than the maximum resolvable age with this method (100-120 years). An age estimate (about 750 yrs) of the latter can be made from its $^{226}$Ra excess. Together, these preliminary age constraints provide insight into eruption recurrence rates and the processes that allow for preservation of compositional variability within proximally located (in space and time) lava flows along this magmatically robust segment of the EPR.

## V12A-0958 1330h POSTER

### Subduction of the Woodlark Spreading Center: Geochemical and Tectonic Effects

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The triple junction formed by the subduction of the Woodlark spreading ridge beneath the New Georgia Group (NGG) of the Solomon Islands is associated with unusual arc-related volcanic centers on the subducting Australia-India plate and a foreshortened arc-trench gap (30 - 90 km). Large calc-alkaline seamounts have grown along the north-trending Simbo ridge and the ESE-trending Ghizo ridge. These two features intersect the trench system at points separated by nearly 100 km, and the absence of a deep trench in this area and the lack of a strong Benioff zone beneath the NGG suggests that subduction is being stifled by the presence of the high-standing Woodlark ridge topography. The presence of numerous arcuate faults in the triangular region bounded by the ridges and the trench suggests the area is under extreme rotational stress due to this impingement. Rotation and faulting here may have allowed magmas to rise along the zones of weakness at the Simbo and Ghizo ridges, which are a Woodlark transform and a possible former spreading segment, respectively.

Arc-like volcanism to the south of the triple junction has been attributed to migration of calc-alkaline magmas from a source region under the Pacific plate. However, the mantle in this area was geochemically enriched by a previous episode of southerly subduction of the Pacific Plate. The impingement of the Ontong Java Plateau in the Miocene caused a subduction polarity reversal and initiated the current northerly subduction direction, placing mantle that was once in a back arc region under the NGG and Australia-India plate. This enrichment is observed in MORB and andesites acquired from the Woodlark spreading center up to 50 km from the triple junction, and increases with decreasing distance from the arc. We are testing the hypothesis that the anomalous lavas of the NGG and on the Australia-India plate are both generated in-situ and tap similar mantle sources that were enriched by the earlier phase of subduction.

Samples from seamounts on both sides of the trench in the triple junction area were collected during the 2000 CSIRO Franklin cruise (FR04/00) by dredge and rock grab. Major and trace elements, and Sr, Nd, and Pb isotopic compositions of the rocks are being compared in this study to constrain the geochemical characteristics of the mantle sources being sampled by these volcanic centers, to identify geochemical gradients in the region, and to evaluate any contributions by the subducted Australia-India slab to the NGG lavas.

## V12A-0959 1330h POSTER

### Mafic Clasts with Unusual REE Patterns in Felsic Volcanic Rocks: Evidence of Subsolidus Alteration of Mafic Rocks from Ascension Island, South Atlantic Ocean

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Incompatible trace element abundances and patterns, particularly those of the rare earth elements (REE), have traditionally been used in igneous petrogenesis as indicators of processes relating to crystal fractionation, partial melting, and characteristics of mantle source regions of ocean island basalt (OIB) suites. However, unusual features of REE patterns, e.g. negative Ce anomalies, have been reported from basalt (island arc and OIB) and even from mantle peridotite. Mafic clasts hosted in trachyte from Ascension Island show unusual distribution of REE.

Ascension Island lava flows and pyroclastic deposits are transitional to mildly alkaline and are a continuous fractionation series of basalt-hawaiite-mugearite-benmoreite-trachyte-rhyolite. The major element variations from basalt to trachyte conform to those expected from crystal fractionation of the observed phenocryst phases from basalt parent magma. The mafic clasts in trachyte have the same compositional range ( 47 to 55 wt.% SiO2) from basalt to hawaiite, mugearite, and benmoreite with the majority of the clasts collected having a mugearitic composition. The mafic lava flows and pyroclastic deposits have been divided into four distinct genetically identifiable groups based on trace element and isotopic characteristics: 1) high Zr/Nb (5.6 to 6.1) basalt; 2) Dark Slope Crater type (Zr/Nb of 4.9 to 5.4) hawaiite; 3) low Zr/Nb (4.1) hawaiite; 4) intermediate Zr/Nb (4.7 to 5.4) basalt-hawaiite-mugearite-benmoreite. The mafic clasts are geochemically heterogeneous with compositions varying from the high Zr/Nb basalt to the intermediate Zr/Nb hawaiite-mugearite-benmoreite.

Oblong shape and uniformly smooth nature of the mafic clasts point to mechanical abrasion. The felsic magmatism that brought the clasts to the surface could not have mechanically abraded them into such shapes. Hence the rocks the clasts were derived from must have been abraded by mechanical weathering.

Some of the mafic clasts also have extremely high abundance and anomalous distributions of rare-earth elements (REE) and yttrium (Y), whereas other incompatible trace element concentrations and O, Sr, Nd, and Pb isotopic ratios do not differ from those of mafic (basalt to benmoreite) flows. The possibility of inheriting the REE from the host trachyte is not likely as the REE enrichment is different in different clasts. Also, the REE enrichment in the mafic clasts is commonly much greater than in the host trachyte. REE and Y enrichment in the clasts with respect to the mafic flows is a post-magmatic alteration feature. This is supported by negative Ce anomalies in these mafic clasts, since decoupling of Ce from the other REE is restricted to oxidizing, low-temperature, aqueous environments. Similar Nd isotopic ratios between the clasts and the mafic flows preclude the possibility that additional REE and Y are derived from marine sediment or guano, but rather suggest an origin under subsolidus conditions perhaps from interaction of mafic rocks with meteoric water circulating through the volcanic edifice.

# V12B MC: Hall D Monday 1330h

## Hawaii Hotspot

***Presiding:*** **J Morgan,** Rice University

## V12B-0960 1330h POSTER

### Geochemical Structure of the Plume Beneath Maui Nui, Hawaii

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Lavas from West Maui volcano show a significant contribution from the Kea component, a mantle source for Hawaiian volcanoes characterized by depleted isotopic signatures. We analyzed shield-building stage W. Maui samples from a valley-exposed 300 m section, and

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from 200 m of well cuttings. We sampled stratigraphically in order to evaluate the temporal changes in the plume source with a decrease in magma supply rate near the end of the shield-building stage, and to assess the nature and variability of the Kea component in W. Maui magmas.

Our samples show no compositional correlation with stratigraphic height. Most have restricted [La/Lu]n (4.3-5), over a range of La concentrations (50-90x chond.). Pb, Sr and Hf isotope compositions define a limited range, and fall in the field of Kea-type compositions. $\epsilon_{Hf}$ varies from +11.5 to +13.1, increasing towards the bottom of the section. Pb isotopes display a restricted range (e.g., $^{206}Pb/^{204}Pb$ = 18.38-18.47), and do not correlate with $\epsilon_{Hf}$. $^{207}Pb/^{204}Pb$ - $^{206}Pb/^{204}Pb$ variability narrowly defines two linear, sub-parallel arrays. $^{87}Sr/^{86}Sr$ ranges from 0.703497 to 0.703631.

We can use the contemporaneous volcanoes of Maui Nui (the Maui Volcano Complex) to map chemical zonation of the plume at 1.5 Ma. Although the volcanic centers of W. Maui and E. Molokai are 40 km apart, they contemporaneously erupted Kea-type shield-building lavas that show minimal inter- and intra-volcano isotopic variation. In contrast, Lanai, a contemporaneous Koolau-type volcano, shows intra-volcano variability greater than the inter-volcano range of the Kea-type volcanoes. The region of the plume beneath Maui Nui dominated by the Kea component was either isotopically homogeneous over length scales of at least 40 km, or efficient mixing processes consistently produced magmas of limited composition. Conversely, the Koolau-dominated region of the plume is either heterogeneous within the melting region of a single volcano, or it contributes to magmas in proportions that vary widely over the life of the volcano. The contrasting heterogeneity of Kea vs. Koolau volcanoes may be a characteristic of the Hawaiian Plume.

## V12B-0961 1330h POSTER

### Geochemical Characteristics of Mantle Sources of North Arch Alkalic Volcanism, Hawaii

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The North Arch volcanic field is located on the seafloor between 100 and 390 km north of Oahu, and has an estimated total volume between 1000 and 1250 km$^3$ (Clague et al., 1990, 2000, 2001). The alkalic volcanism is located far from the axis of Hawaiian volcanism and is characterized by eruption of primitive, low-silica, alkali-rich magmas (Clague et al., 1990). We present new Pb and Sr isotope compositions and major and trace element contents of 17 North Arch alkalic lava samples collected from volcanic cones, sheet flows, and a pitcrater at water depths in excess of 4 km during two Shinkai 6500 dives. $^{87}Sr/^{86}Sr$ and $^{206}Pb/^{204}Pb$ isotope compositions of the samples vary from 0.70297 to 0.70313 and from 18.02 to 18.28, respectively, and show linear covariance. The samples have isotopic signatures similar to those reported for four North Arch lava samples and for Hawaiian rejuvenated stage lavas (Frey et al., 2000). Some of our new analyses extend lower in both Sr and Pb isotopes than previous North Arch analyses. The range of Sr and Pb isotope data suggest that the North Arch alkali lavas are derived from a mixed source consisting of depleted mantle and an enriched Hawaiian plume component. HFS element concentrations confirm that at least two mantle components are involved in North Arch volcanism.

## V12B-0962 1330h POSTER

### Large Pb Isotopic Variations in Pre-shield Stage Kilauea Magmas

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Volcaniclastic sediments found from a scarp below the mid-slope bench at water depths between 3,000 and 5,000m offshore south of Kilauea, Hawaii, contain abundant glass shards that represent submarine eruptions from an ancestral Kilauea volcano (Lipman et al., 2000; Sisson et al., 2001). Their major element compositions range from tholeiites/transitional basalts to alkali basalts to basanites and nephelinites. Pb isotopic compositions of the glasses were determined using a Cameca IMS 1270 ion microprobe at Woods Hole Oceanographic Institution. Replicate analyses of basalt glass stnadards show that $^{208}Pb/^{206}Pb$ and $^{207}Pb/^{206}Pb$ ratios could be determined in basalt glasses with external precisions better than 0.15% (1$\sigma$) in a spot of 30 $\mu$m across. Results show that: (1) a range of Pb isotopic compositions observed in the glasses are much greater than the entire spectrum of the Hawaiian volcanics. $^{208}Pb/^{206}Pb$ ratios vary from 2.099 to 2.004 and $^{207}Pb/^{206}Pb$ from 0.864 to 0.805. (2) There appear to be three distinct compositions, with each being represented by diverse magmatic compositions. There appears to be no significant mixing between them, and they form a linear array in a 208/206 vs 207/206 space, encompassing the entire Hawaiian Pb isotopic composition array. The least radiogenic composition ($^{208}Pb/^{206}Pb$=2.099, $^{207}Pb/^{206}Pb$=0.864) in on an extension of the Honolulu Volcanics array, whereas the most radiogenic composition ($^{208}Pb/^{206}Pb$=2.004, $^{207}Pb/^{206}Pb$=0.805) is far more radiogenic than any known Hawaiian magmas. The intermediate composition ($^{208}Pb/^{206}Pb$=2.041, $^{207}Pb/^{206}Pb$=0.827) is close to the "Kea" endmember composition proposed by Eiler et al. (1998). The ancestral Kilauea nephelinites are derived from two distinct sources with radiogenic compositions and are quite distinct from all other Hawaiian post-erosional nephelinites. It is evident that diverse sources were tapped during the pre-shield stage Kilauea magmatism, and that melts erupted without mixing one another as a crustal plumbing system beneath Kilauea was not yet fully developed.

## V12B-0963 1330h POSTER

### Comparison of TIMS and MC-ICP-MS Analyses of Pb Isotopic Compositions on Prehistoric Mauna Loa Basalts: Implications for Plume Source Components

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Recent isotopic studies on Hawaiian lavas have shown the necessity of constraining fractionation for Pb isotopes. This isotopic system presents systematic variations reflecting the presence of different plume components in the source of Hawaiian basalts. We have analyzed a series of 23 tholeiitic Mauna Loa basalts ranging in age from 36,780 to 140 y for their Pb isotopic compositions by TIMS (Micromass Sector 54) and MC-ICP-MS (Nu Plasma) to directly compare results from the same, carefully leached, samples. These analyses indicate an internal precision better than 120 ppm for the MC-ICP-MS Pb ratios, while for the TIMS ratios, it is in the per mil range. This results in a more coherent dataset for the MC-ICP-MS analyses, with the range of $^{207}Pb/^{204}Pb$ variations decreasing by a factor of 3 and of $^{208}Pb/^{204}Pb$ ratios by a factor of 1.5.

The co-variations between the Pb isotopic data and other geochemical parameters for the Hawaiian lavas are now much stronger and better defined. There are clearly two groups amongst the prehistoric Mauna Loa basalts: one group with higher $^{87}Sr/^{86}Sr$ (>0.7038) and low $^{206}Pb/^{204}Pb$ (<18.15) that covers the entire range of Nb/Y (0.31 to 0.51) observed in this volcano, and the other group with low $^{87}Sr/^{86}Sr$ (<0.7038) and higher $^{206}Pb/^{204}Pb$ with Nb/Y<0.4. The second group is only present in basalts younger than 3,000 y or older than 24,000 y. The high $^{87}Sr/^{86}Sr$ group was not sampled in the HSDP I drill core, which covers an age range of 100,000 y. This either reflects a sampling bias, as the upper flow units (<10,000 y) were not sampled for geochemistry, or variations in magma supply. Altogether, Mauna Loa lava flows that are younger than 20,000 y show much more isotopic variation than older flows and there is a nearly continuous transition away from the Kilauea component. This may indicate that the transition between the Mauna Loa and Mauna Kea trends is not as sharp as previously documented. This study shows the importance of reducing the error associated with mass fractionation by measuring Pb isotopes by MC-ICP-MS to constrain plume components in the mantle source of oceanic basalts.

## V12B-0964 1330h POSTER

### Magmatic Processes at Loihi Seamount Inferred From 226Ra-230Th-234U-238U Disequilibria

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We have conducted a detailed study of the U-series isotope geochemistry of young tholeiitic, transitional and alkalic Loihi basalts to examine the melt generation process during the preshield stage of a Hawaiian volcano. A previous study (Sims et al. 1999; GCA, v. 63) of two dredged lavas from the deep flanks of Loihi found a higher (230Th/238U) activity ratio in an alkalic basalt (1.07) compared to a tholeiitic basalt (1.04). This difference suggests that the tholeiitic basalt may have formed at a higher rate of mantle upwelling than the alkalic basalt. Our samples were collected from surface lava flows at Loihi's summit and along the volcano's south rift zone by submersible. Analyses were preformed using high-precision plasma ionization mass spectrometry. The samples display a relatively large range in the amount of excess 226Ra (0-13%) that extends to much lower values than observed at Kilauea Volcano (11-12%). The low (226Ra/230Th) ratios of Loihi lavas probably result from post-eruptive decay of 226Ra and imply eruption ages of 0-12 kyr. All of the Loihi samples (including the 1996 lava) have small amounts of excess 234U (0.2-0.8%). The most likely source for (234U/238U)>1 at Loihi is seawater, which has (234U/238U)=1.14. Since all of the samples were fresh, hand-picked glasses, these elevated (234U/238U) ratios may have resulted from the assimilation of a seawater-derived component within Loihi's magmatic plumbing system rather than post-eruptive U addition. The range of (230Th/238U) that we measured is 1.01-1.07, which is larger than the previous range known for Loihi. Mass balance calculations using the measured (234U/238U) ratios suggest that 1-6% of the U in the samples that we analyzed is ultimately derived from seawater. Correcting the 230Th-238U disequilibria of the Loihi lavas for this seawater-derived U results in a narrower range in the amount of excess 230Th (6-9%) with no significant differences between tholeiitic, transitional or alkalic basalts. This calculation indicates that these lavas may have been produced at a constant rate of mantle upwelling, which is consistent with the idea that Loihi taps the margin of the Hawaiian plume.

## V12B-0965 1330h POSTER

### Petrogenesis of Trachyte Magmas at the Onset of Post-shield Alkalic Volcanism, Hualalai Volcano, Hawaii

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Trachyte magmas, including the Puu Waawaa cone and flow, trachyte blocks in maar deposits, and trachytes drilled in water wells, are abundant at Hualalai Volcano compared to other Hawaiian volcanoes. These evolved magmas mark the transition from tholeiitic to alkalic shield volcanism ca. 100,000 years ago. New geochemical, isotopic, and 40Ar/39Ar data were obtained to determine the conditions under which these trachytic magmas evolved. Hualalai exhibits the classic Daly Gap that allows the possibility that the trachytes are partial melts of older hydrated basalts (MORB crust or old shield). However, trachyte trace element and Nd-Pb isotopic compositions are all consistent with a fractional crystallization origin from an alkalic basalt parent. Puu Waawaa trachytes yield an Ar-Ar age of 118 ka +/- 8, whereas five blocks and drill core samples have younger ages of 108 +/-16 to 98 +/-8 ka. Puu Waawaa trachytes are also the least fractionated of the Hualalai trachytes, from which the later trachytes evolved by fractionation of anorthoclase, magnetite, zircon, apatite and acmite. Although Nd and Pb isotope ratios in trachytes are invariant within analytical error and overlap with Hualalai alkali basalt compositions, 87Sr/86Sr in acid-leached trachytes range from 0.70366 to 0.70422 and are more radiogenic than any basalt from Hualalai. Oxygen isotope ratios are distinctly higher in Hualalai trachytes (+6.5 to +7.9) than in Hualalai basalts (+5.3). We propose that Sr-poor trachyte magmas in a magma chamber interacted with altered basalts at depth and exchanged Sr and O with them. An alternative, post-eruptive isotopic exchange, is less likely given the size of the Sr isotopic shift in the trachytes and the lack of an oxygen isotope shift in surrounding basaltic lavas. The basaltic contaminant must be isotopically heavy, limiting potential contaminant rocks to the uppermost oceanic crust and submarine island edifice that were altered at low temperature. The xenolith population from Puu Waawaa also supports a shallow-level magma chamber. In contrast, evolved hawaiites through benmoreites from Mauna Kea are proposed to have fractionated from basaltic parents within the uppermost mantle or lower oceanic crust. At Hualalai, the magma chamber must have been of sufficient volume to allow the evolution of on the order of ten km3 of trachyte magma at the start of the post-shield alkalic stage.

## V12B-0966 1330h POSTER

### P-T Path and Nd-isotopes of Garnet Pyroxenite Xenoliths From Salt Lake Crater, Oahu

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Abundant garnet pyroxenite and spinel lherzolite xenoliths are found in Salt Lake Crater (SLC) in Oahu, Hawaii [Jackson and Wright, 1970]. The SLC pyroxenite suite xenoliths (olivine-poor type) have complex exsolution textures that were probably formed during a slow cooling. In this study, we used digital image software to obtain modal data of exsolved phases in the host pyroxene using backscattered electron images (BEIs). The abundances of the exsolved phases were multiplied by the phase compositions determined by electron probe micro-analyzer (EPMA) to reconstruct pyroxene compositions prior to exsolution. In order to evaluate the error in this calculation, we recalculated the reconstructed pyroxene compositions using the different pyroxene pairs. Reconstructed clinopyroxenes in each sample have almost no variations (MgO, CaO $\pm$1wt %, FeO $\pm$0.5wt % and the other oxides $\sim\pm$0.1wt %). Reconstructed orthopyroxenes are more variable in MgO, CaO ($\pm$2wt %) and FeO ($\pm$1wt %) than reconstructed clinopyroxenes, but the other oxides have only limited variations ($\sim\pm$0.5wt %). These compositions were used to calculate igneous stage (magmatic) P-T conditions based on the geothermometers and geobarometers of Wells [1977] and Brey and Kohler [1990] Following assumptions are made: (1) the reconstructed pyroxene compositions are the final record in the primary igneous stage, and (2) cores of the largest garnet grains in each sample record the primary igneous stage composition.. The recalculation using the different pairs of reconstructed pyroxenes show the uncertainty to be $\pm$ 30° C and 0.1 GPa. These appear to be small compared to the large intrinsic errors of geothermometer and geobarometers ($\pm$20°-35° C and $\pm$ 0.3-0.5 GPa). Estimated P-T conditions for garnet pyroxenites are 1.5-2.2 GPa, 1000°-1100° C in the final reequilibration stage and 2.2-2.6 GPa (at maximum), 1150°-1300° C (at minimum) in the igneous stage. The all samples show ca. 200° C cooling and 0.5 GPa decompression. This implies that the garnet pyroxenites cooled ca. 200° C to develop the observed complex exsolution and may have risen from about 70-80 km to 50-65 km depth. Glass pockets and fine minerals (olivine, pyroxene, spinel) occur in the SLC garnet pyroxenite xenoliths. Amphibole and phlogopite, which may have crystallized by metasomatism, are common accessory minerals in them. In order to study the nature of metasomatism as revealed by the glass pockets and fine aggregate of spinel and pyroxene, Nd-isotope study on the SLC xenoliths is under way.

## V12B-0967 1330h POSTER

### Long-lived but Discontinuous Hotspot Volcanism of the South Pacific Mantle

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Hotspots of the South Pacific have been operating since the Early Cretaceous. We present evidence that their heterogeneous geochemical character and, hence, their respective HIMU-EMI-EMII mantle sources, can be traced back into the West Pacific Seamount Province (WPSP) using plate tectonic reconstructions. This implies that the HIMU, EMI and EMII mantle components are enduring features within the Earths mantle, at least, for the last 140 Myr. These correlations are eminent on the scale of the WPSP and the South Pacific Thermal and Isotopic Anomaly (SOPITA) although the evolution of individual hotspots emerges notably more complicated. Hotspots in the WPSP and SOPITA mantle regions typically display intermittent volcanic activity, longevities shorter than 70 Myr, superposition of hotspot volcanism, and indirectly the motion of their mantle plumes through time.

In our plate tectonic reconstructions, we use $^{40}Ar/^{39}Ar$ seamount ages and Sr-Nd-Pb isotopic signatures to map out Cretaceous hotspot volcanism in the WPSP and to characterize its evolution with respect to the currently active hotspots in the SOPITA region. EM-type Magellan, Anewetak, Ralik and Ratak seamount trails can be traced back to the magmatic activity of the Macdonald, Rurutu and Rarotonga hotspots during the Cretaceous; the HIMU-type seamounts within the Southern Wake seamount trail (97-120 Ma) most likely originated from the Mangaia-Rurutu hot-line in the Cook-Austral Islands. The Typhoon and Japanese guyots terminated their volcanism during the Early Cretaceous and have no presently active hot spot. However, the currently active Samoan, Society, Pitcairn and Marquesas hotspots may be traced back only to about 30-70 Myr and lack long-lived counterparts in the WPSP. These hotspots may have become active over the last 30-70 Myr only. All in all hotspot volcanism in the South Pacific seems to be controlled by a superplume type of mantle convection giving rise to multiple weak mantle plumes, each with their own distinct isotope signature and only intermittently active over geological time. We pose that their resulting long-lived but discontinuous volcanism should be considered another end-member type of hotspot volcanism as opposed to the strong and continuous Hawaiian-type hotspots.

## V12B-0968 1330h POSTER

### New Hawaiian Bathymetric Data

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A collaborative effort between Japanese and US scientists sponsored by the Japan Marine Science and Technology Center (JAMSTEC) has studied marine volcanology and sedimentation off shore of the Hawaiian Islands. The focus of the cruises is to build a greater understanding of the Hawaiian Volcanoes through manned and robotic submersible diving programs, collection of piston cores and dredges, and the surveying of the seafloor with single channel seismic and a multibeam sonar mapping system. During the first leg of the 2001 effort, approximately 29,000 km$^2$ was surveyed using the multibeam sonar in addition to the previously collected 115,000 km$^2$. The broad coverage and moderate resolution of these maps provide the base necessary for further research.

The new data provide insights into several features that were partially mapped. The western end of the southernmost strand of the Molokai fracture zone were it is down warped beneath the Hawaiian Ridge shows a bifurcating structure. The structure may be due to either splaying of the fracture or involvement with an older seamount. A series of horst and grabens were mapped south east of the Island of Hawaii. These features appear to contradict the previous satellite-based gravity derived bathymetry for the area. The Waianae slide southwest of Oahu was also mapped in its entirety. A little studied volcanic field southwest of Oahu lies at approximately 159° 10' W and 21° 30' N. The volcanic field was first recognized using the GLORIA sidescan sonar surveys of the Hawaiian Exclusive Economic Zone by the USGS (J. Moore et al.,1989). The GLORIA surveys show that the area is characterized by a high sonar backscatter similar in nature to the South Arch and North Arch volcanic fields. Preliminary interpretation of the new sonar data reveal the shield-like nature of the Southwest volcanic field, numerous cones and a southwest/northeast trending lava flow originating from a cone.

## V12B-0969 1330h POSTER

### MBARIs 2001 Hawaii Expedition using the R/V Western Flyer and ROV Tiburon

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The MBARI research vessel Western Flyer with the Tiburon remotely operated vehicle (ROV) spent 36 days at sea doing mainly geologic investigations offshore the Hawaiian Islands during March to May 2001. During these operational days we conducted 57 dives at depths ranging from 150 m to 3820 m and collected 1198 volcanic and carbonate rock samples; 185 sediment samples using sediment scoops, push-cores and short vibracores; and assorted megafauna. We occupied 32 closely spaced heat flow stations, and collected 167 water filtration samples for radium analysis. We also recorded about 280 hours of digital beta format video of the bottom. Heat flow and in-situ thermal conductivity was measured on the northwest flank of Oahu. The radium samples were collected during all of the dives east of Oahu by filtering about 200 liters of seawater on the ROV using a new pump/filtration system. The dives addressed a range of research topics that can be roughly subdivided into four groups.

Volcanologic observations and petrologic sampling of constructional volcanic features were done on eruptive fissures on the Kohala terrace west of Hawaii, cones on Kilaueas Puna Ridge and the west rift of Kahoolawe, rejuvenated stage cones and flat-topped cones offshore Oahu, Kauai, and Niihau, and postshield stage cones offshore Niihau. The analyzed lavas from the Puna Ridge are tholeiitic basalts with 4.8-6.4% MgO. The samples from the west rift of Kahoolawe are submarine-erupted, high-SiO2, tholeiitic basalt and tuff. The analyzed rejuvenated and postshield stage lavas and tuffs are alkalic and submarine erupted.

The subsidence history of the islands and paleoclimatic history were addressed by sampling old shoreline feature such as drowned coral reefs and drowned beaches. Dives with this objective were done on six terraces on the Kohala terrace, one on East Kohala, four south and southwest of Lanai, one north of Molokai, one south of Oahu, one on the Kaena Ridge, and one northwest of Niihau. We recovered corals from most of these locations and reef limestone from all but the Kaena Ridge dive.

We explored the origin of submarine canyons northeast of Oahu, north and south of Molokai and east of Kohala. A related objective was to examine several deep plunge pools that occur at the base of the steep slope below the break-in-slope that marks old shorelines. These topics are covered in other abstracts at this meeting.

The structure of the flanks of the volcanoes, mainly associated with the headwalls of giant landslides, was investigated during dives on the south Kona slide, east of Kohala, north of Molokai, west of Oahu on a block in the Waianae landslide, and on the northwest flank of Niihau. The analyzed samples are mostly pillow breccia and hyaloclastite composed of subaerially-erupted tholeiitic basalts, although submarine-erupted lavas occur at the base of the Waianae slide block and the slope of Molokai.

Video highlights of the dives and preliminary results will be presented.

## V12B-0970 1330h POSTER

### Observations on the Origin of Submarine Volcanic Cone Morphologies in Hawaii

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Our recent models for the formation of flat-topped and pointed volcanic cones on the submarine flanks of the Hawaiian islands were based on 30 kHz multibeam bathymetry and backscatter data and the few existing samples [Clague et al., Bull. Volcanol. 62, 214-233, 2000]. During MBARI's Hawaii expedition in April-May 2001, we used the ROV TIBURON to further investigate the origins of volcanic cones.

Pointed cones have steep, symmetrical, smooth slopes with no discernible summit platform. We proposed that these were monogenetic cones constructed of a uniform type of fragmental volcanic products in the manner of cinder cones on land; major differences are that submarine pointed cones are taller and do not have summit craters. Observations from dives on three such cones on the NW flank of Ni'ihau showed that the smooth acoustic character of the slopes cannot be attributed either to sediment cover or to the specific nature of volcanic products on the cones' surfaces (e.g., volcaniclastics vs. talus vs. pillow lava), but instead to a uniform distribution of these products. One of the cones is partly dissected and eroded, exposing bedded volcaniclastics in both interior and exterior, but near the summit its surface is mantled by pillow lava. The other two are located 600m apart and are composed of geochemically similar hawaiites, suggesting that they represent two vents from the same eruption. These observations are consistent with our proposal that these pointed cones were constructed by vigorous eruption of fragmental ejecta, and this gives them their steep, pointed shape. The pillow lava is a thin veneer extruded at lower effusion rate during the waning stage of eruptions. New samples from these three pointed cones are vesicular hawaiite similar to Ni'ihau's subaerial postshield alkalic lavas, and confirm that pointed cones form by eruptions of gas-rich alkalic lavas.

Flat-topped volcanic cones are found on the tholeiitic submarine rift zones of all mature Hawaiian volcanoes, and are also abundant on the submarine flank of Ni'ihau. They have the form of truncated cones. We modeled them as monogenetic constructions formed by an inflating and overflowing lava pond during protracted, steady eruption of gas-poor, low-viscosity lava. Previous dive observations on flat-topped cones at Mahukona and Kohala showed that the outer slopes are covered by pillow lava flows (and talus), consistent with overflows from a lava pond, but observations on the flat tops were thwarted by heavy sediment cover. The recent TIBURON dives investigated five flat-topped cones on Ni'ihau. As before, elongated pillow lavas were observed on the outer slopes. On the flat tops, the lava flow forms protruding through the sediment were primarily hackly sheet flows, folded sheets, tumuli (which form on inflated sheet flows), and lobate lavas. Submarine hackly sheet flows indicate unusually fast-moving, well-insulated lava. Existence of these flow forms on a low-grade slope is consistent with crust forming on an actively circulating lava pond, and suggests that the crust forms over large areas of the pond at once, rather than gradually accumulating at the edges as the cone grows. The lobate flows may represent lava extruded through cracks in the crust. The flat-topped cones on Ni'ihau are confirmed to be submarine equivalents of the rejuvenated stage Kiekie Volcanics on the island. The new samples have low vesicularity, supporting the model of flat-topped cones as sustained eruptions of gas-poor, low-viscosity lava.

## V12B-0971 1330h POSTER

### Deciphering the Thermal and Rheological Evolution of Deep Submarine Lava Flows Using the HAWAII MR-1 Mapping System

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The North Hawaiian Arch Volcanic Field is a 24,000 km3 region of young submarine volcanic landforms located 100-390 km north of Oahu and Kauai, centered on the flexural arch created by the Hawaiian Islands. The lavas are emplaced on Cretaceous seafloor at a depth of approximately 4000 m, and the relative youth of the field is indicated by GLORIA backscatter imagery [Holcomb et al. 1988]. Alkalic lavas sampled from the flow field yielded inferred ages of 0.5-1.5 Ma based on palagonite thickness and thickness of overlying sediment. The lavas range in composition from nephelenite to alkalic basalt, with low volatile contents [Frey et al. 2000].

We used the HAWAII MR-1 seafloor imaging system to obtain acoustic imagery and bathymetry of the southern part of the volcanic field. Individual lava flows are resolvable in our data set due to the large backscatter contrast between the young lavas and the pelagic sediments they overlie. This backscatter contrast permits precise resolution of flow boundaries, and supports the measurement of morphological parameters such as flow width and minimum length. The bathymetric data provide information on the regional slope of the seafloor upon which the lavas were emplaced. We can compare these measurements with those of well-studied subaerial lava flows to model the thermal and rheological evolution of the flows of the North Hawaiian Arch.

FLOWGO, a thermo-rheological numerical model used to predict lava flow lengths for rapidly moving channelized lava flows in the subaerial regime, is in the process of being modified for the submarine environment, allowing the measured lava flow parameters to help constrain the model. Preliminary applications of the FLOWGO model suggest that if these long individual flows were emplaced in a rapid, channelized thermal regime, they would have had effusion rates and channel velocities close to an order of magnitude higher than have been observed historically, with the exception of the 1783 Laki eruption. With initial parameters of a channel width of 50 m, assumed depth ranges of 20-30 m and measured length of 35 km, the resulting effusion rates range from 3760 to 12840 m3/s and the channel velocities range from 4.7 to 10.7 m/s.

## V12B-0972 1330h POSTER

### Perception of Lava Flow Hazards and Risk at Mauna Loa and Hualalai Volcanoes, Kona, Hawaii

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The island of Hawaii is composed of five sub-aerially exposed volcanoes, three of which have been active since 1801 (Kilauea, Mauna Loa, Hualalai). Hawaii has the fastest population growth in the state and the local economy in the Kona districts (i.e., western portion of the island) is driven by tourism. Kona is directly vulnerable to future lava flows from Mauna Loa and Hualalai volcanoes, as well as indirectly from the effects of lava flows elsewhere that may sever the few roads that connect Kona to other vital areas on the island. A number of factors such as steep slopes, high volume eruptions, and high effusion rates, combine to mean that lava flows from Hualalai and Mauna Loa can be fast-moving and hence unusually hazardous. The proximity of lifelines and structures to potential eruptive sources exacerbates societies risk to future lava flows.

Approximately $2.3 billion has been invested on the flanks of Mauna Loa since its last eruption in 1984 (Trusdell 1995). An equivalent figure has not yet been determined for Hualalai, but an international airport, several large resort complexes, and Kailua-Kona, the second largest town on the island, are down-slope and within 15km of potential eruptive Hualalai vents. Public and perhaps official understanding of specific lava flow hazards and the perceptions of risk from renewed volcanism at each volcano are proportional to the time lapsed since the most recent eruption that impacted Kona, rather than a quantitative assessment of risk that takes into account recent growth patterns. Lava flows from Mauna Loa and Hualalai last directly impacted upon Kona during the notorious 1950 and circa 1801 eruptions, respectively.

Various non-profit organizations; local, state and federal government entities; and academic institutions have disseminated natural hazard information in Kona but despite the intuitive appeal that increased hazard understanding and risk perception results in increased hazard adjustment adoption, this assumption is not always justified (Burger and Palmer, 1992).

We are nearing completion of a survey among high school students, adult residents, and tourists in Kona to evaluate hazard understanding, risk perception and adjustment adoption. The findings should serve as a foundation for the development of future lava flow hazard education and mitigation initiatives. An evaluation of demographic, infrastructure, and land-use planning issues is also being performed to assess vulnerability and societal resilience in future eruptions.

## V12B-0973 1330h POSTER

### Mass Fluxes Attending the Palagonitization of Sideromelane in Hyaloclastites From the HSDP-2 Core Hole

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Isovolumetric conversion of sideromelane to gel palagonitized glass releases components to solution because the latter is hydrated and less dense. In hyaloclastites from the HSDP-2 core, development of gel palagonitized glass is accompanied by the precipitation of secondary minerals, chiefly smectite, phillipsite, and chabazite, but also thaumasite, apophyllite, gyrolite, and gypsum. We have calculated mass balance among these major phases using a combination of electron microprobe analyses (for major elements) and laser ablation microprobe-inductively coupled mass spectrometry (for trace elements), in conjunction with density determinations and petrographic point counts. Our reconnaissance data indicate that most major elements are elutriated from sideromelane during conversion to gel palagonitized glass, except FeO which remains constant, and TiO2 which is somewhat enriched (by more than passive accumulation) in the gel palagonitized glass. Conversely, precipitation of secondary cements in pores requires addition of major elements to the whole rock, chiefly SiO2, Al2O3, K2O, MgO, and MnO. One unexpected initial result is that the REE patterns of sideromelane and associated gel palagonitized glasses are nearly identical. Differences in absolute abundances reflect change in density.

## V12B-0974 1330h POSTER

### Fractionation Correction and Rare Earth Element Inverse Modeling of HSDP Basalts

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In an effort to understand the evolution of the Hawaiian plume over the lifetime of an individual volcano, the Hawaiian Scientific Drilling Project (HSDP) cored over 3000 meters of basalt near Hilo, Hawaii. We have analyzed 120 whole rock samples from the core, comprising both Mauna Loa and Mauna Kea lavas, for their rare earth element (REE) concentrations. These basalts are then corrected to parental magma compositions by accounting for crystal fractionation (generally of olivine, but with clinopyroxene becoming important near the top of the Mauna Kea section). The fractionation-corrected REE data show strong variations throughout the core, but with the most pronounced changes at the end of the Mauna Kea eruptions. Inverse modeling of the REE data is done in subsections throughout the core to observe if variations in geochemical data correlate with changes in the mineralogy of the plume source.

## V12B-0975 1330h POSTER

### Ilmenite Exsolution in Xenolithic Garnets From the Hawaiian Hot Spot: Evidence for the Existance of High-titanium Garnets in the Earth's Mantle

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Oxide inclusions in a pyrope host were discovered in a single garnet clinopyroxenite xenolith (sample 115954-20 B; Jackson Collection, Smithsonian) from Salt Lake Crater, Oahu, Hawaii. These inclusions, $\sim$ 5-6 $\mu$m thick and 10 $\mu$m long, appear to radiate from

a point, rather than align along the <111> direction, as found previously by other authors (e.g., Haggerty, 1991b). In the same section there are other garnet grains that have ilmenite of the same morphology but along <111>. Electron microprobe analysis and Raman spectroscopy show that both types of inclusions are ilmenite ($FeTiO_3$) with a large geikelite ($MgTiO_3$) component, and minor amounts of $Al^{3+}$, $Cr^{3+}$, and $Fe^{3+}$. Note that ilmenite does not occur as a discrete phase in the xenolith. Inclusions of ilmenite and rutile, have previously been found in host garnets from eclogitic and lherzolitic xenoliths in kimberlites and ultra-high pressure terrains. This is the first report of such occurrence from an oceanic hot spot source. Based on texture, we suggest that the ilmenite inclusions in garnet in the Hawaiian xenolith are of exsolution origin as opposed to an origin by epitaxal precipitation (as proposed by Wang et al, 1999). At the present time, because of the lack of appropriate experimental study it is difficult to speculate on the P,T conditions under which ilmenite exsolved from the garnet host. However, Van Roermund et al (2000) have hypothesized on crystal chemical grounds that such inclusions are the result of the break down of a high P,T super-titanic garnet to a lower P,T pyrope with exsolved ilmenite, in a similar fashion to the breakdown of super-silicic or majoritic garnet to pyrope with exsolved pyroxene.

## V12B-0976 1330h POSTER

### Explosively Erupted Gabbro From Kilauea Volcano's Summit Magmatic System

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Gabbro clasts up to 13cm in diameter were blasted to the surface of Kilauea volcano by a powerful pyroclastic eruption 1500-1000 years b.p. They occur in the Kulanaokuaiki 3 tephra and as sparsely distributed lag lithics over 70 square km of the volcano's south flank where the tephra has been eroded away. These holocrystalline and glass-bearing gabbros make up about 12 per cent of the 1100 lithic clasts studied. Some are enclosed in cored bombs, but most occur as monolithologic clasts. Lag-lithic isopleths from an array of 110 south-flank sites suggest that this eruption emanated from the volcano's summit.

The gabbros are remarkably fresh and consist chiefly of plagioclase + clinopyroxene + opaque oxides with varying percentages of olivine and rare orthopyroxene. Plagioclase and clinopyroxene crystals range up to 5 mm in length in the coarsest examples. Interstitial glass comprises as much as 25 modal per cent of the rock. In some samples this glass is moderately vesicular, reflecting an abrupt pressure drop accompanying eruption. The interstital glass contains 2.0 to 0.5 wt. per cent MgO and some has locally abundant apatite needles. Major element compositional trends of interstitial glass and glass melt inclusions in olivine suggest that the gabbros formed by crystallization along multiple liquid lines of descent.

Whole-rock XRF compositions of 11 samples suggest that the gabbros are of two distinct types. Nine have 11 to 15 wt. per cent MgO and are samples of magma bodies that were crystallizing or had crystallized at depth. Two gabbros contain 6 wt. per cent MgO; these probably originated as segregation veins in as yet unknown parent bodies. All of the gabbros texturally resemble segregation veins from Kilauea Iki and other Kilauean lava lake deposits, but only the two low-MgO samples likely had such an origin.

Most of the gabbros are fragments torn from partially to entirely crystallized bodies adjacent to the Kulanaokuaiki 3 parent magma body. We infer that the extremely energetic eruption necessary to disrupt these bodies and to project their shattered remnants as far as 15 km from the summit originated deep within the volcano, perhaps within or beneath the volcano's 2 to 6 km deep summit magmatic system.

## V12B-0977 1330h POSTER

### Submarine Structure and Stratigraphy of the South Kona Slump, Hawaii: Results from the MBARI 2001 Hawaii Expedition

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As part of the MBARI 2001 Hawaii Expedition on board the R/V *Western Flyer*, the ROV *Tiburon* was used to carry out several highly successful dives upon the little studied submarine South Kona slump, southwest Mauna Loa, Hawaii, offering a rare opportunity to look inside the broken flank of Mauna Loa volcano. Four dives transected a scarp marking the southern lateral detachment of the Alika debris slide, which cut through the South Kona slump more than 100,000 years ago.

The seaward regions of the submarine flank, characterized by bathymetric ridges and troughs indicative of faulting and block detachment, revealed angular breccias and cohesive talus aprons that form low slopes, and indurated volcaniclastic sandstones and turbidites that define steep, high cliffs incised by dramatic erosional channels. Outcrops were consistently fractured and jointed, and occasionally intensely sheared, particularly in regions marked by bathymetric lows interpreted as block faults. Surface fractures occasionally exhibited "jig-saw puzzle" textures, often associated with rock avalanche deposits. The recovered sandstones were commonly fine-grained, particularly in the distal regions of the flank. Many were variably altered, often with zeolite pore filling, and exhibited sheared matrix and/or clasts. Most appear to be monolithic breccia samples derived from coarse flow interiors, although several samples were dominated by altered olivine sands. The interior of the proximal edifice consisted of thick units of fractured and broken pillow basalts, well preserved in cross-section in cliff faces, and interbedded with ledges of coarse fragmental basalts and breccias. Glass analyses of the flow units yielded from 5.76 to 6.80% MgO, and 51.8-52.9% SiO2. SiO2 contents are lower than modern Mauna Loa basalts, although the low ranges of TiO2 from 2.25% at 6.6% MgO to 2.6% at 5.8% MgO, are typical for Mauna Loa lavas. Sulfur contents <230 ppm, indicate that the proximal lavas were degassed or erupted subaerially prior to quenching in seawater. The contact between the primary basalt core, and the more seaward broken rock units, is buried by lobes of relatively fresh submarine pillow lavas, surrounded by thin beds of glassy basalt gravels, presumably derived from recent shoreline crossing lava flows from Mauna Loa.

The units traversed by the four dives appear to define a nearly complete stratigraphy of the southeast flank of Mauna Loa, which may allow us to unravel the dramatic growth and collapse history of the giant volcano. The abundance of fine grained sandstones, siltstones, and mudstones within 10 km of the Mauna Loa shoreline is surprising, but implies that Mauna Loa was built upon extensive distal turbidite deposits derived from mass wasting from older, distant volcanoes in the Hawaiian chain. These sediments were subsequently accreted to the toe of Mauna Loa as the young volcano grew, and ultimately collapsed by catastrophic landsliding forming the broken South Kona slump terrain. Young lava flows derived from subaerial eruptions appear to have infilled the slump scar, smoothing the submarine topography.

## V12B-0978 1330h POSTER

### Evolution of Jasper Seamount: Plume-Lithosphere Interaction?

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Ocean islands go through distinct evolutionary stages, with respect to the partial melting process and the isotopic characteristics of their source regions. Their main body typically consists of products of large degree melts (tholeiitic, or mildly alkalic). Later stages are often preceded by a period of volcanic quiescence and typified by fewer extrusives from smaller degrees of melting. The main shield of many ocean islands (Hawaii, Pitcairn, Society and Marquesas) is characteristic of a more "enriched" source, while the late stages are more depleted. Jasper seamount from the Fieberling seamount chain (30°27'N, 122°44'W; NW Pacific) shows similar petrologic trends, including a documented period of volcanic quiescence between shield and rejuvenated volcanism. Thus small seamounts may display similar petrological evolutions as very large islands like Hawaii. Bulk rocks and glasses of the two major magmatic phases of Jasper seamount were studied for trace element and radiogenic isotope characteristics (Nd-Sr-Pb-Hf) including. Late stage lavas are rich in xenoliths that provide a complete lithological section through the deeper seamount, the ocean crust and underlying oceanic lithosphere/mantle. We studied trace element characteristics for these xenoliths and the glasses by Ion Probe.

The Sr isotopes display the clearest distinction between the shield and late stage volcanics of Jasper Seamount ($^{87}Sr/^{86}Sr$: 0.703613-0.703818 versus 0.702976-0.7032270). Other isotope systems are consistent with these systematics, but ranges overlap to some extent.

The two stages display some characteristic differences in trace element ratios, whereby the late lavas are slightly more LREE enriched relatively to the shield (late stage La/Sm is higher, 5.1-7.0 vs. 2.9, indicating smaller melt fractions). The sources also differ slightly, e.g. La/Ce = 0.49-0.52 and Zr/Nb = 4.26-4.75 (late) versus La/Ce = 0.47 and Zr/Nb = 6.53 (shield).

Shield trace element patterns are similar to the equilibrium melt composition for pyroxenes in a spinel lherzolite xenolith providing a potential source composition for shield lavas.

## V12B-0979 1330h POSTER

### Mapping Dislocation Densities in Olivine Crystals of Hawaiian Picrites

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The nature of olivine crystals in Hawaiian picrites has been paid much attention because it is related to the estimation of primary magma compositions. Herz [1986] studied picrites from the 1959 Kilauea Iki summit eruption and found that olivine crystals with kinkbanding are dominant. Kink banded olivine crystals are commonly found in picrites in HSDP [Garcia et al., 1995] and those in submarine ridges [Garcia, 1996]. Takeguchi and Takahashi [2001] studied picrites from Koolau Volcano, and concluded that more than 90% of olivine crystals are xenocrysts because they exhibit dislocation densities higher than $10^6$ $cm^{-2}$, which is comparable to those in the upper mantle peridotite [Toriumi, 1980]. They showed that both kinkbanded olivines have high dislocation densities, implying that kink-banding is not a crieterion for identifying xenocrysts. In this study, we report the dislocation density and dislocation structure in olivine crystals in picrites from Loihi seamount and Kilauea Volcano. In order to observe dislocation in olivine crystals, the oxidation decoration method [Kohlstedt et al., 1976] was applied. Three types of olivine crystals were recognized in picrites from Loihi and Kilauea: Type-1, crystals with cellular structure with high dislocation density ($>10^6$ $cm^{-2}$); Type-2, crystals without cellular structure but with high dislocation density ($>10^6$ $cm^{-2}$); and Type-3, crystals with lower dislocation density($10^4$-$10^6$ $cm^{-2}$). Both the cellular structure and dislocation density of Type-1 crystals are similar to those formed experimentally under steady-state creep conditions equivalent to earthfs mantle [Toriumi and Karato, 1978], these are considered to be xenocrysts. The Type-2 crystals may be also xenocrysts because of their high dislocation density but may correspond to those under transient creep conditions. Only the Type-3 olivine crystals may be true phenocrysts crystallized from the host magma. According to this classification, xenocrystic olivine crystals are dominant (>90%) in studied picrite samples from Loihi (5 rock samples from its south rift zone and east flank). On the other hand, picrite samples from Kilauea (summit calderas, Puna ridge 4000-4500 m water depth) show coexistence of the Type-1, Type-2 and Tgype-3 crystals. Even in the Kilauea samples, the amount of xenocrystic crystals (Type-1 and Type 2) is always greater than true phenocryst (Type-3). Our study indicates that the nature of olivine crystals in Hawaiian picrite is complex and the amount of xenocrysts may be larger than previously thought.

## V12B-0980 1330h POSTER

### Susceptibility of Mid-Ocean Ridge Volcanic Islands to Landsliding

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Major landslides in volcanic islands on old oceanic lithosphere, such as in the Canaries, are revealed by deep embayments in their subaerial slopes, and below sea level by chutes and broad debris lobes at the base of their edifices. With a view to addressing whether volcanic islands growing on young oceanic lithosphere show a different character or incidence of landsliding to those on old lithosphere, a database was created

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from hydrographic soundings, radar images and multibeam and sidescan sonar data from Ascension, Bouvet, Guadalupe, Jasper Seamount and several of the Galapagos and Azores islands. The data suggest the following: 1) Major landslides on these islands are less common and are not obviously associated with multiple cycles of island growth and collapse as they are in the Canaries. 2) Landslides appear different from analogous Canary Island landslides, for example they do not clearly exhibit extensive chutes. 3) Landslides range in size from minor submarine slope failures (e.g., Ascension), to failures involving lower subaerial slopes (e.g., Tristan da Cunha), and only rarely to extensive events affecting the volcano summit or caldera (e.g. Guadalupe). 4) The Azores islands of Terceira, Flores, Corvo and Sao Jorge reach no more than 2500 m above the surrounding seafloor and show no landslides of significant size. This presentation will review the data and discuss possible origins of the contrasting incidence and character of landsliding between islands on young and old lithosphere.

## V12B-0981 1330h POSTER

### A Newly Recognized Shield Volcano Southwest of Oahu Island, Hawaii

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During the 2001 Hawaiian cruise of the JAMSTEC research ship Kairei (with ROV-Kaiko; P.I.: E. Takahashi, Co P.I.: T. Kanamatsu), Seabeam mapping revealed a previously unidentified volcanic edifice (submarine shield) located about 100 km southwest of Oahu. The volcano (centered at 21°35'N, 158°45'W) is approximately 100 km in diameter and 0.5 km high with its summit at 4200 m depth. Near the top of the volcano, a lava flow field with high reflectivity in the GLORIA image has been previously reported (Moore et al., 1989) but the presence of the shield volcano was not known. The low submarine shield is studded with numerous flat top cones typically less than 100m in height and several km across (similar to those described by Clague et al, 2000). In addition, more than 30 steep cones (circular to irregular in shape; typically 300 to 500 m in height) are distributed over the submarine shield volcano. Much of the east side of the volcano is mantled by thick sediment probably due to landsliding of Waianae volcano. The maximum thickness of such material is more than a few hundred meters. Accordingly, the flat top cones are not visible (if present) and only some steep cones are exposed on the east side.

ROV dive K203 (20°40.0'N, 158°51.5'W) collected samples from the high-reflectivity lava flow shown on the GLORIA image as well as from one of the steep cones. Judging from the thin sediment and the thickness of the Mn-coating (1-2 mm), the high-reflectivity lava flow may be similar in age to the North Arch alkalic lavas (0.5 to 1.5 Ma, Clague et al., 1990). The steep cone consists of vesiculated pillow lava and hyaloclastite and is apparently older than the flow judging from the thick sediment cover and the Mn-coating (up to 6 mm) similar to that on the north slope of the ca. 3 Ma old Koolau volcano (Shinozaki et al., 2001). The high vesicularity of some of the lavas (collected at depths of 4000 m) indicates a high volatile content and almost certainly an alkalic basalt composition. Dive K206 (20°39.0'N, 158°47.5'W) on one of the flat top cones imaged and sampled dense aphyric pillow lava (also with thick Mn-coating) cascading down the steep flank. Preliminary data collected from the recently completed cruise indicates that this newly mapped submarine Hawaiian shield volcano (2000-4000 km$^3$) is similar in age to those on Oahu island (Waianae and Koolau), and apparently grew during several stages of magmatic activity.

## V12B-0982 1330h POSTER

### A Distal Record of Large Hawaiian Submarine Landslides: the Lithology of Sediments Obtained From the Deep-sea Floor Adjacent to the Hawaiian Islands, KR01-K12 Cruise.

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To understand the timing and emplacement processes of giant Hawaiian submarine landslide, a series of piston coring was performed in the adjacent area of Hawaii islands by R/V KAIREI, JAMSTEC in the summer of 2001. Long-distance volcaniclastic sediment transport generated by Hawaiian submarine landslides has been suggested by several previous studies (e.g. Garcia and Hull, 1994). Stratigraphical, sedimentological, and geochemical studies on the cores obtained by systematic sampling will make to understand for origins and ages of volcaniclastics emplacement to the ocean-floor.

Nine cores were collected from the north of Oahu, the southwest and south of Hawaii Island, the south of Oahu. The major lithology is brown pelagic clay with abundant volcanic sand layers. Off Hawaiian Arch of the north of Oahu, pelagic clay with distinct 195cm-thick volcanic sand layer was recovered. The thick sand should be related to Nuuanu landslide, which debris avalanches were derived from Oahu Island. In the north of Haleakala rift, the alternation of brown colored clay and volcanic sand layer were obtained. Haleakala rift and Kohala slump are possible origins for these frequent occurrences of volcanic sand. In the south of Hawaii Island, we recovered alternations of volcanic sand and pelagic clay. The previous study suggested that volcaniclastic material in this area were derived from the Kilauea and older volcanoes of Hawaii Island. The obtained cores will provide stratigraphic information for volcanic history of Hawaii Island. The lower sequence below the alternation consists of radiolarian ooze, suggest the age of Eocene by on-board inspection. Two piston cores were obtained in the front of Waianae Landslide. The lithology of cores shows that the much volcaniclastics are interbeded in the upper sequence, and the massive clay in the lower.

## V12B-0983 1330h INVITED POSTER

### Plunge Pools in Hawaiian Submarine Canyons

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Many submarine canyon systems include well-defined intra-canyon depressions. Often, these depressions are found at the base of scarps along the canyon thalweg, with morphologic characteristics similar to subarial plunge pools formed at waterfalls. One plausible mechanism for the origin of these features is scouring during submarine debris flows. Other processes which can plausibly contribute to the formation of reentrants and depressions in submarine canyons include erosion by spring sapping, slumping, collapse following gas expulsion or subsurface dissolution, and channel damming by mass wasting of canyon walls.

The Monterey Bay Aquarium Research Institution conducted ROV dives around the Hawaiian Islands during a spring 2001 expedition of the R/V Western Flyer and ROV Tiburon. Three ROV dives investigated submarine canyons on the north (windward) sides of Molokai and Hawaii that exhibit well-developed intra-canyon depressions. These depressions ranged from 10 m deep and 150 m across to 90 m deep and 750 m across. The headwall scarps ranged from 20 m to 350 m. ROV video observations combined with rock and sediment sampling allowed us to characterize the depressions' detailed morphology, relate the morphology to the underlying geology, and view the genesis of these features in the context of the origin and evolution of the canyon systems as a whole. Our observations support the hypothesis that these intra-canyon depressions, or plunge pools, are formed through scouring during submarine debris flows. In all cases the down-canyon depression sills are dams composed of debris piles, with angular rubble exposed on the depression side and sand covering the down-canyon side. The Molokai plunge pool is draped with mud and silt, suggesting no recent activity. However, the Kohala plunge pools show clear signs of recent scour and no sediment cover. The headwalls above the plunge pools expose layered volcanoclastic and lava flow units, with more resistant layers frequently forming vertical or overhanging walls. We interpret these canyons as being largely formed through retrogressive (headward) erosion and slope failure. Periodic rockfalls and debris flows following undercutting of the headwalls scours the depressions, builds the pool dams, and both lengthens and deepens the canyons.

URL: http://www.mbari.org/education/cruises/Hawaii/

## V12B-0984 1330h POSTER

### The Waianae Slump Southwest of Oahu Island, Hawaii

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During August-September 2001, we mapped and sampled the Waianae Slump offshore southwest Oahu using Seabeam, single-channel seismic reflection and ROV diving with the JAMSTEC research ship Kairei and ROV-Kaiko. The Waianae landslide was identified as a slump-type landslide based on GLORIA data (J.G. Moore et al. 1989). The bulk of the slump is believed to consist of material from Waianae volcano, although the 130-km-wide slump may comprise material from Kaena ridge to the west and possibly Penguin bank to the east.

Our new Seabeam map shows that the Waianae slump consists of at least three major coherent blocks about 25-45 km long elongate parallel to the slump's arcuate toe, separated by transverse scarps. The major blocks are a series of ridges and troughs that are laterally continuous for 5-20 km and probably represent individual smaller slumps. The toe of the slump is irregular with many small embayments in the slope. Single-channel seismic data shot with a 150 in$^3$ GI gun show a landward-tilted block at the toe of the slump with a 1.8 km-wide basin behind filled by $<$100 m of sediment. Basin width increases upslope to 4-6 km and the sediment fill increases upslope to about 200m. The basin-filling sediment is tilted landward with dips progressively increasing with depth. A line parallel to the slope at a water depth of 3000 m images a landslide block 4.5 km wide and 100-200 m thick overlying dipping strata.

Kaiko dive 205 traversed 400 m up the steep basal slope. Only volcaniclastic rock outcrops were encountered during the dive; no primary lava was found. The base of the slope is mud littered with small loose rock chips. The first 80 m of upslope travel encountered mud and sand covered slopes with increasing amounts of blocks, some grouped to form vague outcrop-like areas. Eight samples at four locations range from volcanic breccia to mudstone. Below 4300m, jointed and fractured outcrops alternated with talus. Above 4300m, slope mantling sediment predominated. In addition, rocks were severely cemented with MnO coating. The rock outcrop on the main portion of the scarp face is highly fractured and undergoing continuous sloughing, as evidenced by relatively sediment-free talus at the base of the steeper outcrops.