are poorly constrained because of experimental limitations; they are high on average, in the order of 2 % for the gabbros, and 5 % for the peridotites. Except for one site, in which the late alteration is marked by abundant talc, the density of serpentinite samples is inversely correlated to their bulk magnetic susceptibility. The slope of the correlation is different at each site, and may be related to the type of hydrothermal alteration reactions. As expected in a highly altered environment, the P-wave velocities in serpentinized peridotites and troctolites are very low (2.82 to 5.14 km/s, with a mean of 3.88 km/s), and lower than in the gabbros and diabases (3.41 to 5.86 km/s, with a mean of 5.13 km/s). Most gabbros have slightly lower velocities than those sampled earlier at MARK (ODP Leg 153). Peridotites and troctolites are similar to those sampled earlier, or have lower densities and velocities. Our data are compared to seismic profiles (J.A. Collins
R.S. Detrick, pers. com.) in the same region, and to velocity-depth profiles calculated for gabbros and variously serpentinized peridotites. The in-situ velocities are lower than the velocities in completely serpentinized rocks, suggesting that the uppermost crust contains large-scale fractures. The seismic velocities near the seafloor are consistent with a composite crust, composed of serpentinized peridotites and altered gabbros.

V11E-0546 0830h POSTER

Shallow mantle and crustal structure beneath the Mid-Atlantic Ridge (35°N): melt supply and crustal construction

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P-waves recorded during wide-angle refraction experiments provide a measure of crustal thickness and the velocity structure of the crust and uppermost mantle along the Mid-Atlantic Ridge near 35N. We use 29,605 crustal refractions, 14,682 reflections from the base of the crust, and 9322 mantle refractions to generate a three-dimensional anisotropic P-wave image of sub-ridge structure that extends 60 km along the ridge, 50 km across the ridge, and to 10 km depth. These data were compiled from six separate two- and three-dimensional experiments which, taken together, include 49 ocean-bottom instruments and 5118 airgun shots. This section of the Mid-Atlantic Ridge is bounded to the north by the Oceanographer fracture zone and to the south by a non-transform offset and previous studies suggest that more melt is supplied to the center of the ridge segment than the ends. Shallow isotropic velocities are generally low in a band that parallels the ridge axis and this band is punctuated by a series of small, 10-km-long, low velocity anomalies of up to -1 km/s magnitude. The variability of shallow crustal structure suggests strong spatial and temporal variability of the melt supply to the shallow crust. In addition, in the shallow crust we detect a small amount of azimuthal anisotropy that indicates the presence of vertically aligned cracks that are oriented parallel to the strike of the ridge. Such cracks indicate that the shallow crust is experiencing tensional forces generated by plate spreading. At the center of the ridge segment, where a line of seamounts intersects the ridge, a 10x10 km^2 low-velocity region (-0.6-0.8 km/s magnitude) extends downward through the crust and into the mantle where it widens to 20x20 km^2 in width. The seismic image is consistent with a region of high temperatures and perhaps a small amount of melt and thus indicates the current magma supply system of the ridge. Although the aperture of our imaging does not extend completely to the segment ends, the crust is generally thinner towards the segment ends (5 km thick) and thicker at the center of the segment (8.5 km thick). Our results indicate that mantle-derived melts rising beneath this ridge segment are focused at mantle depths towards the center of the segment resulting in a thicker crust and a high-temperature, partial melt zone near the segment center. Within the median valley, a volcanic ridge runs northward from the segment center, but is not underlain by low velocities in the lower crust nor mantle. Thus, this ridge may be similar to an Hawaiian type rift zone, with magma fed to it laterally from the ridge segment's center instead of from directly below.

V11E-0547 0830h POSTER

The Lower Crustal Melt Distribution Within the East Pacific Rise, 9°30′N, from a Combined Study of Compressional-Wave Velocities and Seafloor Compliance Data

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Most of the melt within the fast-spreading East Pacific Rise (EPR) crust at 9-10°N sits within a 4-6 km wide and 2-4 km tall lower crustal partial melt zone detected by seismic and seafloor compliance studies. However, we do not know how much melt there is or how it is stored and/or transported, because different combinations of temperature, melt fraction, melt geometry and rock composition can have the same compressional-wave velocity. Whole-crustal compressional-wave velocity and seafloor compliance data have been collected and separately interpreted at 9°30′N on the EPR. The compressional-wave velocity data was interpreted to indicate up to between 10% and 38% melt in the lower crust, depending on the melt geometry and the importance of anelasticity [Dunn *et al.*, 2000], but this interpretation only takes into account a subset of the possible melt geometries and does not account for the sensitivity of melt generation to rock composition. We investigate the range of possible melt amounts and geometries by modeling as broad a range of melt geometries as possible and testing the effect of compositional and melt geometry variations with depth. We first determine the large model space fitting the compressional-wave velocity model of Dunn *et al.* [2000]. We then reduce this model space by comparing the low-frequency (0.01 Hz) shear modulus calculated for each model with the measured seafloor compliance. Seafloor compliance measurements are sensitive to the crustal shear modulus at frequencies between 0.003 and 0.03 Hz, and the relationship between this shear modulus and the compressional-wave velocity at seismic frequencies (10-15 Hz) depends on the rock composition, melt geometry and the importance of anisotropy. We present the new model space and discuss its implications for crustal accretion at the East Pacific Rise.

V11F MCC: 3008 Monday 1020h

Modern Trends in Petrography: Textural and Microanalysis of Igneous Rocks II

Presiding: **D A Jerram,** University of Durham; **J P Davidson,** University of Durham

V11F-01 1020h INVITED

Geochemical microanalysis: The link between textural and geochemical characterization of igneous rocks

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In this presentation I will review recent advances in microanalytical techniques that allow us to directly couple textural and geochemical information to the study of igneous rocks, particularly with respect to the analysis of silicate melt inclusions. Textural examination has long been a mainstay of the classification and petrologic study of igneous materials. The advent of the electron microprobe over 50 years ago allowed textural and geochemical observations to be coupled at small spatial scales and directly related to the physical and chemical conditions of formation and subsequent melt evolution. This resulted in a revolution in the petrological investigation and understanding of igneous rocks that continues today. Recent advances in geochemical microanalysis techniques are providing exciting access to new geochemical information at smaller and smaller spatial scales. These are enabling measurement of the abundances, and in some cases isotopic compositions, of a range of elements in correspondingly smaller sample volumes. A case in point is the study of silicate melt inclusions. Although melt inclusions have been recognized and studied for over a century, there has been a recent surge in interest directly tied to development of techniques capable of performing in-situ analysis of trace element and volatile components at small spatial scales. Melt inclusions allow direct sampling of melts present during crystal formation, and are particularly useful for relating crystal textures and compositions to those of their source melts. Chemical compositions of melt inclusions reveal the diversity of igneous compositions present in igneous systems, and may be combined with textural observations to constrain a wide range of igneous processes, including degassing, assimilation, fractional crystallization and mixing.

V11F-02 1035h

A multidisciplinary approach to understanding the origin of peridotite cumulates

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The key to understanding the origin of igneous cumulates is to determine the relative importance of the competing processes of cumulate formation. Crystal sedimentation and/or in-situ growth, compaction, porous media convection and textural equilibration may all contribute to the final textural and chemical configuration of the rock. Using an integrated approach encompassing quantitative textural analysis, geochemistry and relatively new electron backscatter diffraction (EBSD) techniques has allowed the nature and extent of postcumulus textural and chemical modifications to be quantified, and illustrates that the final rock texture still carries essential information concerning magma-chamber processes and the early evolution of the cumulate rock. Quantitative textural analysis has highlighted several distinct olivine morphologies within individual peridotite layers from the Rum Intrusion, Scotland, and has demonstrated that in-situ growth alone cannot account for the textural variation within the peridotites because transport of at least one crystal phase is required from elsewhere in the magma chamber. The combined use of quantitative textural analysis to determine shape preferred orientations (SPOs) and EBSD to determine crystallographic preferred orientations (CPOs) has shown that the SPO and CPO for each peridotite layer are essentially in agreement. This, together with the presence of mixed olivine morphologies within a single rock, indicates that significant postcumulus recrystalization cannot have taken place and furthermore compaction by pressure solution is unlikely to have occurred to any significant extent. Whole-rock geochemical analysis of several of these peridotite layers has highlighted positive Sr- and Eu- anomalies but no textural evidence for cumulus plagioclase, suggesting that interstitial plagioclase grew when melt was able to move through the crystal framework. However, in-situ ion microprobe analyses have shown that interstitial clinopyroxene formed from the final trapped melt fraction. This final melt fraction was heterogeneously distributed throughout the rock in a manner ultimately governed by the packing arrangement of the crystals which is itself controlled by primary magma chamber processes such as crystal transport.

V11F-03 1050h

A History of one Olivine Crystal: Microsampling Melt Inclusions by Wire Saw

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Melt inclusions record magma composition, magma volatiles and magma depth (from volatile saturation pressures), but multiple melt inclusions are difficult to study within a single crystal. Often the sample geometry and preparation requirements (e.g. FTIR wafer) limit sampling density to one melt inclusion per crystal. Thus suites of crystals are studied but the relationship between multiple crystals and their melt inclusions

must be inferred. Crystal mass has been used as a temporal constraint for melt inclusions (EPSL 187 p.221), but questions remain about crystal growth mechanisms, growth rates and possible hybridism. This study uses microsampling to investigate the melt inclusion record preserved within a single phenocryst. A large euhedral olivine crystal (2.2 x 4.5 mm) from the 1999 eruption of Cerro Negro volcano, Nicaragua has been sectioned with a wire saw to isolate multiple melt inclusions. The size of the host crystal and the wide spatial distribution of the melt inclusions indicate that inclusion formation occurred repeatedly throughout the crystal's growth history rather than during a single event. The crystal was first photographed to record melt inclusion position and then sectioned to recover 22 individual melt inclusions and several gas inclusions. The host phenocryst is unzoned (Fo_{82}) except for slight zoning at the rim (Fo_{77}). Locally the rim is resorbed or displays unsealed hourglass inclusions. Most melt inclusions have a single vapor bubble and the volume, as percentage of total volume, is lowest near the core of the crystal (1.8%) and shows an apparent increase outward (3-4%). All seven identified gas inclusions, containing little or no silicate glass, occur near the outer crystal edge consistent with the observed bubble volume trend in silicate inclusions. Melt inclusion compositions are restricted (all but four 0.18 to 0.26 wt.% K_2O, others 0.41 to 0.43 wt.% K_2O) relative to those found in more common, small to moderate-size phenocrysts from the same eruptive unit (0.18 to 0.72 wt.% K_2O). The melt inclusions with elevated K_2O (> 0.40 wt.%) are located near the core of the crystal and are also distinguished by high S and low Cl relative to melt inclusions in small to moderate-size phenocrysts. This compositional pattern apparently records an early perturbation (decreased K_2O, S and moderate Cl increase) followed by relatively stable conditions. The variation can be explained by fractional crystallization and repeated magma recharge. The high K_2O and sulfur within interior melt inclusions is interpreted as due to early closed-system enrichment, although low Cl requires previous gas loss. Later recharge events produced relatively constant K_2O, sulfur and chlorine. FTIR measurements on microsampled melt inclusions are currently under investigation and will be compared to associated small and moderate-size phenocrysts hosting compositionally similar melt inclusions. It is expected that the results for the large phenocryst will exceed volatile saturation pressures (H_2O and CO_2) of associated small and moderate-size phenocrysts (~1.5 to 3 kb) indicating deep magma storage and movement prior to the 1999 earthquake and eruption sequence.

V11F-04 1105h

Crystal- and fragment- size distributions of quartz and zircon in pumice: growth and fragmentation conditions in large and small-volume magma chambers

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I describe an acid (HF and HBF4) technique to extract phenocrysts from individual vesiculated pumice clasts, coupled with camera- and computer-assisted measurements of phenocryst length, width, 3D shape, and vol abundance. CSDs of quartz and zircon are presented for several well-known voluminous ash-flow tuffs and small-volume lavas: Bishop, Lava Creek, Lower Bandelier, Toba, Katmai, and Timber Mt. Measured CSDs of quartz and zircon from these clasts provide a quenched "snapshot" view of growth conditions in preclimactic magma chambers. A common feature of CSDs of unfragmented phenocrysts is a concave-down, lognormal shape in contrast to the reported linear CSDs in more mafic systems.In addition, there are no crystals smaller than a threshold size. These features in silicic magmas are interpreted to be a general result of surface-controlled crystal growth (with growth rate dispersion) by layer nucleation. CSD slopes on log-linear frequency- size graphs in large volume tuffs, and smaller volume intracaldera lavas are similar, and do not simply correlate to the eruptive volume, or SHRIMP-determined zircon ages. CSDs of quartz in clasts with known stratigraphic positions document single evolving reservoir, fingerprint different magma batches (L Bandelier and Lava Creek), and overgrowth and gravitational redistribution (Bishop). Fragment size distributions (FSDs) in the same clasts document fragmentation due to 1) decrepitation of melt inclusions decompression- and heating-induced), and 2)syneruptive breakage. FSDs are treated with lognormal, Weibull, and fractal distributions. Among studied clasts, asymptotic and fractal FSDs are found to be more common. However, the genesis mechanisms (e.g. fractal, scale-invariant vs. size-dependent lognormal) inferred from CSD or FSD should be treated with caution. Decrepitation results in a smaller number of fragments (2-6) than crushing and in shapes that can be distinguished on perimeter/area vs. length diagrams. CSD and FSD have potential implications as fingerprinting tools to identify/correlate different magma batches in ash-flow tuffs. FSD serves as a novel tool for trace elemental and isotopic exchange in magma chambers.

V11F-05 1120h

Mineral-Scale Sr and Pb Isotopic Variations as Recorders of Magma Differentiation Processes in the Fish Canyon Magmatic System, San Juan Volcanic Field, U.S.A.

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The use of crystal isotope microstratigraphy, through microanalysis for Sr and more recently Pb isotopes, shows that inter- and intra-crystalline isotopic and compositional heterogeneities exist within many volcanic rocks. Here we report preliminary Sr and Pb isotope data for sanidine, plagioclase and biotite (Sr only) crystals separated from representative samples of the 5000km^3, 28Ma Fish Canyon Tuff and the pre-caldera Pagosa Peak Dacite, from the La Garita Caldera, San Juan Volcanic Field, U.S.A. Age-corrected whole-rock $^{87}Sr/^{86}Sr$ values define a small range (0.7063 to 0.7065), whereas plagioclase values range from 0.7063 to 0.7072 and sanidines define a more limited range 0.7063 to 0.7067. These ranges in $^{87}Sr/^{86}Sr$ cannot be solely attributed to radiogenic ingrowth during residence in the Fish Canyon magma reservoir, as the $^{87}Rb/^{86}Sr$ values (plagioclase; 0.003 to 0.011, sanidine; 0.30 to 0.73) are too low to significantly affect $^{87}Sr/^{86}Sr$ over magmatic timescales. Biotites exhibit a much greater range in initial Sr isotope ratios (0.7202 to 0.7295), but with even higher $^{87}Rb/^{86}Sr$ ratios of 8 to 12, more than 50 Myrs would be needed to evolve such ratios from the whole-rock ratio. Similarly, large ranges of Pb isotope ratios in sanidines and plagioclase, cannot be produced given the U/Pb ratios of these phases on any geologically reasonable timescale. We interpret the isotopic variations to represent open system processes in the generation of the Fish Canyon magma either by 1) crystallisation from heterogeneous isotopically modified (ultimately mantle-derived) magmas during interaction with old, heterogeneous crust, and/or 2) the direct incorporation of xenocrystic phases from the crust to produce an isotopically heterogeneous magma (and rock) at the mineral scale. Small but significant variations in $^{39}Ar/^{40}Ar$ total fusion ages for each of the studied phases, are consistent with the latter interpretation, suggesting that the crystal population is a mixture of newly-crystallised and old xenocrystic, incompletely degassed crystalline products.

V11F-06 1135h

The Crystal Stratigraphy of Ontong Java Plateau Plagioclase Pegacrysts: New Insights into the Evolution of LIP Magmas.

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The Ontong Java Plateau (OJP) is the world's largest LIP made up of 2 isotopically distinct lava types that comprise the Singgalo and Kwaimbaita formations (Tejada et al., 2002, J.Pet 43:449). Some Kwaimbaita basaltic flows contain plagioclase-rich cumulate xenoliths. As plagioclase is stable over a range of magmatic conditions, microanalysis of this phase allows the evolution of the parent magma(s) to be constrained (cf. Davidson & Tepley, 1997, Science 275:826). This crystal stratigraphy approach has been applied to cm-size plagioclase megacrysts from three basaltic units (5B, 6, and 7) recovered at ODP Leg 192 Site 1183. Core-to-rim trace element variations were quantified by LA-ICP-MS, major elements by EPMA, and compositional backscatter SEM imaging was used to investigate the subtle compositional zoning and textural features within the plagioclases. All 5 OJP megacrysts sampled show little core-to-rim anorthite variation (82 mol % An +/- 5%); An-rich plagioclase crystals are resistant to re-equilibration and are more likely to retain magmatic trace element signatures (Blundy & Wood, 1991, GCA 55:193). The Unit 7 (oldest) plagioclase contains a relatively Sr, Ga, REE, and Ti poor core bounded by a resorption surface and a relatively Sr, Ga, REE, and Ti rich zone suggesting this crystal was exposed to 2 compositionally distinct magmas. The Unit 6 plagioclase contains a relatively Sr, Ga, REE, and Ti poor core with increasing abundances toward the rim, consistent with evolution through fractional crystallization. This megacryst also contains a distinct resorption surface bounded by a core-like Sr, REE, and Ti poor zone. The three Unit 5B plagioclases display core-to-rim Sr and Ba increases with little core-to-rim REE and Ga variations. The uppermost Unit 5B crystal (youngest) exhibits a core-to-rim decrease in Ti, while the lower 2 crystals display the opposite relationship. We suggest the textural and trace element variations seen in OJP plagioclase megacrysts are again evidence of magma mixing. Reconstructed liquids suggest at least two distinct mixing end members: an enriched end member, similar to Singgalo-type lavas, and a depleted end member, similar to Kwaimbaita type lavas. As the Singgalo- and Kwaimbaita-type basalts are isotopically distinct (I(Sr) = 0.7041 and 0.7038, resp.), Sr isotope determinations of the different plagioclase zones through microdrilling is planned for the near future to test this hypothesis. If correct, it suggests that both the Kwaimbaita and Singgalo sources were active at the same time, which is in contrast to the stratigraphy determined by whole-rock compositions.

V11F-07 1150h

Feldspar Zonation in Andesites from Monogenetic Cones and Long-lived Stratovolcanos (Andagua and El Misti, S. Peru) : Constraints for Eruption Triggers

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Recharge, mixing, and degassing are generally thought to be the major triggers for volcanic eruptions. Mixing can involve (1) newly injected magma, (2) mixing of magmas coexisting in a (zoned) magma chamber) or (3) mixing of magmas of similar composition but different temperatures, e.g. from thermal plumes originating at the interface to mafic magma underplating. We use high-resolution imaging of plagioclase zonation and quantitative analysis by electron microprobe to investigate these scenarios for andesites from the Central Andes of S. Peru. El Misti stratovolcano and the monogenetic Andagua centers are well-suited because they are similar in terms of (1) lava major element compositions (SiO2 from 57 - 65 wt. per cent (El Misti) 56 - 67 wt. per cent (Andagua) and (2) size (100 to 500 microns). An vs. Fe-systematics on feldspar zonation have been applied on lavas from the El Misti stratovolcano and from the Andagua monogenetic field (S. Peru). They allow distinction between these triggering processes: Large and correlated An-Fe contrasts indicate chemical mixing related to recharge, mixing and complete overturn. By contrast, repeated and correlated An-Fe at low compositional contrast may indicate intra-chamber mixing. Thermal mixing leads to variable An content at constant Fe. Despite the similarities in lava compositions, zonation patterns in plagioclase differ strongly between El Misti and Andagua lavas: While Andagua lavas show largely homogeneous Ab-rich cores sharply overgrown only by a 10-30 microns thick An-rich rim, El Misti lavas comprise complexly zoned plagioclases with multiple events of mixing. Growth rate estimates for the largest crystals suggest less than 100 years of growth even for very slow rates. Clearly, many mixing events occurred without ensuing eruption, because the average time in between eruptions at El Misti is much longer than 100 yr. Andagua plagioclase zonations indicate that once the mafic second batch intruded the reservoir, an eruption was always and immediately triggered. This is in agreement with the relative volume of the magma systems. While Andagua eruptions are fed from small volume reservoirs that are filled and erupted only once. The Andagua reservoirs apparently cannot accommodate a second batch and the system reacts against the additional pressure with an eruption. By contrast, a large magma chamber in the upper crust feeds El Misti volcano. El Misti can easily accommodate a new batch, the large system is buffered. These relations are clearly imaged in the feldspar zonation patterns. Hence, recharge and mixing will trigger eruptions especially in small systems, large systems record many mixing events and may need an additional process as an eruption trigger.

V

V11F-08 1205h

The Protracted History of Magmatic Evolution Recorded by Zoning in Allanites

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Compositional zoning in crystals provides a detailed but nevertheless ambiguous record of melt differentiation in magma chambers because the duration and absolute timing represented by the zoning stratigraphy are essentially unknown. Using a novel marriage of *in situ* compositional and isotopic analyses of zoning in allanite, we unravel the magmatic history recorded by single crystals and resolve the duration and ages of differentiation in the voluminous rhyolitic magma chamber that produced the 75 ka Youngest Toba Tuff (YTT), Indonesia. Detailed electron probe traverses reveal that allanites from the most-evolved portion of the YTT magma chamber (75 wt.% SiO_2) are strongly zoned in composition and single crystals may zone to compositions that match those for allanites from the *least-evolved* (69 wt.% SiO_2) rhyolite reported by Chesner and Ettlinger (1989). Low MnO/MgO, high La/Nd, and greater concentrations of Mg, La, & Ce are characteristic of less-evolved allanite zones, and normal zoning produces trends to higher MnO/MgO, lower La/Nd, and higher concentrations of Mn & Th. Most allanites have similar patterns of oscillatory zoning punctuated by resorbed boundaries and mantled by a near-rim section of normal zoning recording episodic mixing with hotter, less-evolved melts and subsequent growth from more-evolved melts. The core-to-rim differentiation history revealed by these single allanites represents a time scale of up to 150 ky that continued up to the time of eruption, as determined by ion probe ^{238}U-^{230}Th dating. Nonetheless, no single allanite composition is associated with a specific time interval in the magmatic evolution. In fact, compositional variability increases by up to a factor of three within ca. 35 ky of eruption, suggesting an episode of increased crystal and/or melt mixing relatively close to eruption. The magnitude of MnO/MgO and La/Nd variations, as well as parental melt compositions predicted by the zoning, fall within the ranges reported for erupted YTT glasses, suggesting the allanites record interactions between a diversity of melts related by the 40-50% fractionation calculated by Chesner (1998). Our results demonstrate that minerals like allanite can record a complex differentiation history of fractionation and episodic mixing, which in the case of the YTT allanites represents protracted residence and crystallization in a voluminous magma chamber.

V11G MCC: 3006 Monday 1020h

The Growth and Collapse of Hawaiian Volcanoes II *(joint with OS, T)*

Presiding: **B Eakins,** U.S. Geological Survey**;** **E Takahashi,** Tokyo Institute of Technology

V11G-01 1020h

Spreading Flanks of Ocean-Island Volcanoes: Similarities and Differences at Mauna Loa and Kilauea, Hawaii

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Submarine-flank deposits of Hawaiian volcanoes are widely recognized to have formed largely by gravitationally driven volcano spreading and associated landsliding. Observations from JAMSTEC submersibles (Japan Marine Science and Technology Center) show that prominent benches at mid-depths on flanks of both Mauna Loa and Kilauea consist of volcaniclastic debris derived by landsliding from nearby shallow submarine and subaerial flanks of the same edifice. Both volcanoes have mid-slope benches that record the same general processes of slope failure on varying scales, followed by modest compression during continued volcano spreading, even though they record development during different stages of edifice growth. Massive slide breccias from the mature subaerial tholeiitic shield of Mauna Loa underlie the frontal scarp of its South Kona bench. Outboard of the South Kona bench are large slide blocks, containing mixed subaerial and submarine Mauna Loa rocks, that appear to constitute a distal facies of the same large landslide event(s). The dive results also suggest that volcaniclastic rocks at the north end of the Kona bench, interpreted by others as distal sediments from older volcanoes that were offscraped, uplifted, and accreted to the island by far-traveled thrusts, alternatively are a largely coherent stratigraphic assemblage deposited in a basin behind the South Kona bench. In contrast, the Hilina bench developed as Kilauea volcano has spread seaward, in part riding piggyback on the still active south flank of Mauna Loa. The Hilina bench is underlain by coarse volcaniclastic sediments derived largely from submarine-erupted pre-shield alkalic and transitional basalts of ancestral Kilauea. The south flank of Kilauea is thus far not associated with any massive slide deposits comparable to the distal blocks of the South Kona slide complex.

V11G-02 1040h

North Kona Slump: a Recent Giant Submarine Landslide in Hawai'i

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Four Giant Submarine Landslides (GSLs) scar the west flank of Mauna Loa and adjacent Hualalai, two volcanoes of the Big Island of Hawai'i. Other than the Alika 2 slide (120 ± 10 ka), the ages of the GSLs are only poorly known. From sidescan sonar and multibeam bathymetry the South Kona GSL is older than Alika 1, and Alika 1 older than Alika 2, but where North Kona fits into this sequence is unclear. Because Alika 2 levees appear to cross the North Kona debris field, North Kona has been assumed to be more than 130 ka. More recent mapping, however, suggests that the apparent right levee of the Alika 2 debris avalanche may actually be the deformation front at the base of North Kona. Farther north, the North Kona Slump truncates the entire sequence of drowned terraces (18–430 ka) descending the submarine slope of Hualalai. A shallower terrace, previously undescribed, traverses the slope of Hualalai between 100 and 150 m depth. The terrace is probably the drowned reef from the 4 to 6 ka Holocene high stand; whether it has been disrupted by the North Kona Slump is unclear. Morphologically, the North Kona Slump is very similar to the currently-active Hilina Slump of Kīlauea. Indeed, a magnitude 6.5 earthquake in 1929 may indicate that the North Kona Slump is itself still active. The initial North Kona failure apparently occurred near the beginning of the Holocene Transgression, a timing supporting the hypothesis that large flank failures of oceanic island volcanoes have a climate trigger.

V11G-03 1055h

Development of the Waianae slump and Kaena Ridge, Hawaii

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New ROV and submersible dives offshore of Waianae volcano, Oahu, provide evidence pertaining to the size and shape of the volcano's edifice as well as timing of its collapse to form the Waianae slump. Two JAMSTEC dives, K205 and S707, ascended the base of the slump and collected volcaniclcastic sandstones and pillow lavas that are relatively unfractionated (5.5 to 8.6 wt% MgO in glass), low-S (<300 ppm) tholeiites. These magmas likely erupted subaerially early during the volcano's shield stage, and correlate with subaerial Lualualei Member lavas. The dives are 70 km apart and their samples' compositional similarities suggest that the entire Waianae slump was derived from a single volcano. A single hyaloclastite sample from dive K205 contained abundant moderate-S (220 to 520 ppm) transitional basaltic glass grains, indicating shallow submarine eruption perhaps early during or before the volcano's shield stage. These transitional compositions do not overlap with the volcano's well-studied post-shield alkalic phase. MBARI dive T326, on a shallow portion of the slump, collected tholeiitic hyaloclastites, but glass grains are systematically higher in alkalis (2.7 to 3.8 wt% Na_2O + K_2O) and are more fractionated (5.5 to 6.7 wt% MgO) than glasses found at the slump's base. These shallow samples correlate compositionally with late shield-stage subaerial Kamailaenu lavas. None of the collected slump samples correlate with subaerial post-shield lavas. We suggest that the lower, largest portion of the slump formed during or just after the volcano's main shield building stage. A second mass-wasting event could have occurred during or after the latter portion of the shield stage, forming the upper, rotated block ascended by dive T326. MBARI dive T325 ascended a small shield atop the submarine Kaena Ridge northwest of Oahu, and encountered abundant basaltic beach cobbles and a single aa flow, all tholeiitic. Kaena Ridge may have formed as the subaerial northwest rift zone of Waianae volcano. Two additional MBARI dives along the northern flank of Kaena Ridge (T327 and T328) collected hyaloclastite fragments that contain rare alkalic glasses; these may be derived from late-shield or post-shield Waianae.

V11G-04 1110h

Rethinking the Standard Model of Kilauea's South Flank Deformation

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Over the last two decades, a standard model of deformation at Kilauea's south flank has emerged. Consisting of two main structures, the model includes a 9 to 10 km deep basal decollement, which slips steadily at 10 to 20 cm/yr, and a deep east rift zone, which opens at an equal rate. The two parts of the model are fundamentally interdependent in that they represent Kilauea's south flank as a large, mobile block that is, in the long run, decoupled from the rest of the island. Several recent papers have taken this model at more or less face value. Thus, the conclusions of these papers are conditional on whether or not the model is correct. Evidence is accumulating that it is not. First, a deep, rapidly opening east rift zone predicts significant subsidence within the rift zone and significant uplift on Kilauea's south flank. Continuous GPS receivers in these areas observe neither. Second, a recent pressurization of the east rift zone in early 2002 produced a deformation field inconsistent with a deep source. Either there are two, decoupled magmatic systems in the east rift zone, or there is a single system that extends to only a few kilometers depth. Third, a recent seismic tomography experiment sought to resolve the deep magmatic system in the east rift zone. It was unable to do so. Fourth, two episodes of aseismic fault slip have occurred in the last three years (the first in November 2000, the second in July 2003). These "silent earthquakes," which are unmistakable in the continuous GPS record, are occurring on a structure that is no more than 4 or 5 km deep. If this structure is the so-called decollement, then the decollement is much shallower than previously thought. A much shallower decollement requires significantly lower slip rates to explain observed secular deformation. Lower slip rates eliminate the need for a deep east rift zone as a "decoupler." Fifth, the standard model of south flank deformation fails to explain - indeed, even to address - the two most strikingly active structures on Kilauea: the Hilina and the Koa'e fault systems. We offer an alternative model of south flank deformation consisting of persistent creep on a hypothesized listric extension of the Hilina normal fault system. Not only is this model much simpler than the standard model, but it seems to make more sense mechanically. In the long term, we argue, the Hilina fault system behaves as a gravity-driven mass transport system, which moves both aseismically and in large earthquakes. We do not suggest that our alternative model for south flank deformation is a panacea or that it completely explains magmatic-tectonic interactions on Kilauea. Rather, we argue that our model is a more realistic starting point for future discussion about the origin of south flank deformation.

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The Hilina Slump: Consequences of Slope Failure and Volcanic Spreading Along the Submarine South Flank of Kilauea Volcano, HI

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