V22C MCC: Level 1 Tuesday 1330h

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

Presiding: **M L Coombs,** U.S. Geological Survey**; J R Smith,** Hawaii Undersea Research Laboratory, University of Hawaii

V22C-0592 1330h POSTER

Pyroclastic Fragmentation of Alkalic Lava in Abyssal Depths at the North Arch Volcanic Field, Hawaii

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Pyroclastic submarine eruptions are generally considered to become less likely with increasing depth due to the increasing hydrostatic pressure of the overlying water column. Volcaniclastic deposits from the North Arch Volcanic Field, north of Oahu, have textural characteristics of explosive fragmentation. The presence of glass spheres and bubble-wall, spindle- and ribbon-shapes, or Pele's hair-like fragments, indicate at least mildly explosive eruptions occurred in water depths greater than 4200 m. Given the tectonic setting and young age of these deposits, there is no doubt that sampling depths closely corresponds with eruption depth. The most abundant volcaniclastic samples from the North Arch are clast-supported breccia of highly vesicular, angular clasts that most likely are near vent, pyroclastic deposits formed from eruption columns of limited height. Interbedded with highly vesicular pillow lava, they form steep-sided cones of low height (50 to 200 m) around the vent sites. Less common stratified samples with graded bedding, include one sample with a layer of imbricated, bubble-wall fragments that probably formed from density currents associated with the collapse of an eruption column. Numerous glass spheres, delicate spindle, ribbon and Pele's hair-like fragments as well as curved bubble-wall glass fragments resembling limu o' Pele occur in the finer size fraction of some samples. Another sample consists of glass fragments dispersed in a marine clay matrix that apparently was reworked and deposited farther from the vents by bottom currents. Glass compositions include low ($\sim$0.4%) and medium ($\sim$0.7%) K_2O alkalic basalt, basanite, and nephelinite. Sulfur and chlorine are high reaching a maximum of 1800 and 1300 ppm, respectively. The ubiquitous presence of bubble-wall fragments regardless of glass composition suggests bursts of strombolian-like activity accompanied most eruptions. The coalescing vesicles observed in larger pyroclasts and some pillow lava suggest accumulation of gas, dominated by CO_2, was driving the eruptions. Initial explosive eruptions apparently were followed by effusive eruptions that formed thin, degassed sheet flows that traveled long distances over nearly flat terrain. If these volatile-rich magmas had erupted in shallow water depth or subaerially, tall fountains would likely have resulted. The great hydrostatic pressure (>400 Pa) limited fountain and eruption column heights.

V22C-0593 1330h POSTER

Eruptive style and geochemistry of North Arch lavas

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Following JAMSTEC's initial bathymetric survey of the North Arch volcanic field in 1999 (Clague et al., 2002), we revisited the area with R/V Yokosuka in 2002 and have now mapped 90% of the lava field using SeaBeam 2112. Two types of volcanic cones are recognized; 1) flat top cones representing lava lakes formed above vents, and 2) steep sided cones made of highly vesiculated pillow lava and hyaloclastite. These volcanic cones are distributed mainly on the southern slope from the hinge line of the arch, perhaps reflecting the steeper slope south of the flexural arch. In the area where the volcanic cones are clustered, there is a subtle swell, which might be explained by a series of shallow level intrusive sheets (sills) near the vents. Two submersible dives were conducted in 2002. The first dive was in the central vent area and observed and sampled a flat top cone and an adjacent steep sided cone to clarify the volcanic sequence. The steep sided cone consisted of highly vesiculated pillow lava and breccia (hyaloclastite) of basanite composition. The lavas in the flat top cone and the sheet flow are dense alkali-olivine basalt. The steep sided cone appears to have erupted after the flat-topped cone was emplaced as the flat top cone is covered by pyroclastic ejecta (including submarine limu o Pele and Pele's tears) that most likely came from the steep sided cone. The second dive, on a sheet flow at the western edge of North Arch, explored the vent region for a long narrow flow. Uplifted and disrupted sediment observed during the dive suggest that intrusions were important in the development of the flow field. Trace element compositions of recovered samples, determined by LA-ICPMS have patterns generally similar to other ocean island basalts, except for significantly higher Ba and lower K, Zr, and Hf. The basanite lavas have distinctly higher concentrations of LILE, HFSE and LREE than the alkali basalts but are similar in HREE. These geochemical variations imply that the lavas formed from different degrees of partial melting of similar source in the stability field of garnet as proposed by Frey et al., (2000). Our preliminary conclusions are; 1) the eruption style of North Arch lavas is largely determined by volatile contents (Dixon et al., 1997); and 2) at the first dive site, voluminous effusive alkali-olivine basalt lavas formed flat top cones and sheet flows that were followed by submarine strombolian-type eruptions of basanite that formed steep sided cones. A more detailed geologic history of the North Arch volcanic field should be developed, but will require more dives and radiometric dating of lava flows.

V22C-0594 1330h POSTER

Rheology of Pahoehoe Lava Surfaces Across Their Glass Transition: Preliminary Results on Thermal Histories and Melt Viscosities, Pu'u 'O'o-Kupaianaha Eruption, Hawaii

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Glassy pahoehoe lava flow surfaces from the ongoing Pu'u 'O'o-Kupaianaha eruption on Hawaii are being analyzed using relaxation geospeedometry to determine their thermal histories upon vitrification. This technique is based on a calorimetric quantification of the relaxation process of enthalpy that allows modeling of the thermal path involved in cooling a liquid across its glass transition to form a glass. We are investigating various pahoehoe flow morphologies including spongy (S-type), pipe- vesicle bearing (P-type) and "blue-glassy" sub-types, collected over the last ten years of the eruption. Initial results on S-type pahoehoe surface glass transition temperatures (Tg) show minor variations around 670 deg C. Tg is taken as the temperature of the peak of the heat capacity trace determined during reheating the vitrophyres at constant pressure. Cooling rates modeled across the glass transition interval for S-type samples vary between 10 and 40 K/min. These rates are linear approximations of the thermal history of the flow surfaces during their cooling across their glass transition intervals. The intervals cover a temperature range of approximately 100 K to temperatures as low as 630 deg C, where the melt structure finally "freezes in" to form the glass. Ultimately, these limiting temperatures mark the transition from ductile to brittle behavior of the flow surface. A recently developed model based on the equivalence of the activation energies for enthalpy relaxation and viscous flow allows us to predict melt viscosities for these samples. The model gives melt viscosities for S-type pahoehoe flow surfaces of $\log_{10}$ 10.2 $\pm$ 0.3 Pa s at their glass transition. The cooling rates determined are in excellent agreement with thermal data obtained directly at active flows during the eruption via remote sensing techniques. This agreement provides validation of our technique and a case for a comprehensive study on the cooling processes involved in generating pahoehoe flow fields on Hawaii. We hope to be able to correlate individual thermal histories with specific flow morphologies in order to constrain rheological processes such as in-situ surface vesiculation and lava lobe inflation. Ultimately, our results will provide valuable input parameters for computational flow propagation models employed for hazard assessment and risk mitigation on Hawaii and elsewhere.

V22C-0595 1330h POSTER

Eruption Rate Control On Morphology And Structure Of Submarine Monogenetic Volcanoes - Insights From Sumersible Dives Off Maui And Hawaii Islands

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This paper presents the results of submersible dives off Hawaii Islands during four research cruises (R/V Kairei-ROV Kaiko 1998 and 2001, R/V Yokosuka-DSV Shinkai 1999 and 2002) by the Japan Marine Science and Technology Center. Morphologies and structures of submarine volcanic edifices were observed during dives on the Hana Ridge, submarine extension of Haleakala rift zone of East Maui and the south rift zone of Loihi Seamount. Three types of volcanic edifices are recognized: 1) Conical seamount with a small summit and steep slopes [Clague et al., 2000]; 2) Flat-topped cone [Clague et al., 2000] or terrace [Smith et al., 2002] with a wide, flat summit compared to the relative height; 3) Lobate terrace with a hemi-circular lobate outline with a smaller areal ratio of the summit to the base than flat-topped cones. These volcanic edifices are morphologically classified into two groups: Group A (flat-topped cones and lobate terraces) shows a positive correlation of an areal ratio of summit/base with slope. Group B (conical seamounts) has a low areal ratio of summit/base and a positive correlation between a volume and slope. ROV Kaiko and DSV Shinkai dives were carried out on 6 conical seamounts, 5 flat-topped cones and 3 lobate terraces. Conical seamounts with moderate slopes have aprons of elongate pillows and a summit crater filled by lobate sheet flows, which gradually change into elongate pahoehoe flows downslope. Steep cones are surrounded by talus slopes of pillow rubble with elongate pillows sporadically exposed between pillow clasts. Embedded pillow lobes are all elongate downslope, indicating that fragmentation took place while pillows were flowing. Under a very low extrusion rate, flowing lava congealed on the steep slope in a short distance from the source and collapsed into rubble that formed the lower part of the cone. Flat-topped cones have elongate pillows on moderate slopes, and pahoehoe and lobate sheet flows interbedded with pillows on gentle slopes. Flat summits are overlain by lobate sheets but do not have any collapse pits. Successive change in flow morphology from lobate sheets on the summit through pahoehoe sheets into elongate pillows downslope indicates that lava quietly spilt over the crater rim flowed as elongate pillows on steep slopes. Because lobate sheets are present interbedded with pillows in the lower slope, several eruptive episodes with higher extrusion rates of lava were repeated to form the flat-topped cones. Lobate terraces have similar constituents as flat-topped cones but collapse pits on the summit. Lava channels are present both on the bottom of the pits and on the aprons of the terraces, through which lava was rapidly expelled. Lobate terraces are more like a single large inflated sheet flow grown on a gentle ridge that broke out channeled lava at the final stage of growth.

V22C-0596 1330h POSTER

Hawaiian Shield Stage Submarine Volcaniclastics: Insights From HSDP Core

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Ocean island volcanoes are traditionally associated with the non-explosive eruption of fluid lavas, but volcaniclastic rocks comprise a significant portion of many submarine shield volcanoes. Deep drilling (3,098 m) by the Hawaiian Scientific Drilling Project (HSDP) into the flank of Mauna Kea volcano has exposed the volcaniclastics within the pedestals of a Hawaiian volcano that were previously poorly known. The HSDP continuously cored 2,019 m of submarine Mauna Kea deposits with $\sim$95% recovery and revealed that volcaniclastics comprise $\sim$55% of this section. The shallow submarine section consists of $\sim$80% volcaniclastics interbedded with thin ($\sim$3 m) massive lava flows and the deep section is $\sim$35% volcaniclastics interbedded with packages of pillow lavas up to 180 m thick. Throughout the submarine section, the volcaniclastics can occur in thick

packages up to ∼100 m. The emplacement of submarine volcaniclastics is not well understood. Possible origins include primary fragmentation of lava via magmatic explosivity and magma-water interactions, and secondary fragmentation via erosion. Secondary transport of material down the steep submarine flanks by gravity flows is expected to be common, as is reworking by currents. Emplacement processes are predicted to evolve as the volcano shoals. In this study major element analyses of glassy clasts in the volcaniclastics are used to distinguish monomict and polymict assemblages, which can indicate primary versus secondary fragmentation. Clast shapes reflect fragmentation mechanisms and secondary processes and this study attempts to improve on this approach with quantitative analysis of clast shapes for the HSDP volcaniclastics and for samples of known origin. The first documentation of the textures of the Mauna Kea volcaniclastics, integrated with geochemistry, petrography, and quantitative clast shape analysis and inferences about their origins and modes of transport and deposition will be presented to better understand the shoaling of Hawaiian volcanoes.

V22C-0597 1330h POSTER

Transient Deformation Following the January 30, 1997 Dike Intrusion at Kilauea Volcano, Hawaii

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On 30 January 1997 a new fissure opened within the East Rift Zone (ERZ) of Kilauea Volcano at Napau Crater, 3km uprift from the ongoing eruptions at Pu'u O'o. The fissure eruption lasted for two days and opened a nearly vertical dike 1.96m wide by 5.15km long that extended from the surface to a depth of 2.4km (Owen et al., GRL, 1997). During the fissure eruption, the lava pond at Pu'u O'o drained pausing the eruptions there for nearly a month until it eventually refilled in late February; eruptions there resumed on 28 March 1997. The Kilauea Volcano permanent GPS network recorded the eruption and a significant transient following the dike intrusion in the ERZ. In the 120 days following the event the closest station to the fissure, KTPM, moved an additional 7 cm to the south. We invert continuous and campaign GPS data using an extended Network Inversion Filter (McGuire and Segall, in press, Geophys. J. Int.) for the time dependent volume change of a Mogi source under Kilauea's summit, opening of a nearly vertical dike in the ERZ and slip on a decollement under the south flank. The extended filter allows simultaneous estimation of slip rate with temporal smoothing, spatial smoothing, positivity, random walk and data error scale parameters resulting in improved spatial and temporal resolution over previous filters (Segall et al., EOS Mtg. Abs., 1998). This study models post eruptive deformation as the crust accommodates the opening of the dike to gain understanding about the relaxation time of the Hawaiian crust and the potential for catastrophic failure of the south flank of Kilauea Volcano. Preliminary results show that most dike opening is accommodated in the top 2-3 km of with maximum velocity around 15 cm/day. Every model shows Mogi source under Kilauea rapidly inflating after months of gradual pre-fissure eruption deflation. The decollement slips gradually seaward during the first month after the eruption.

V22C-0598 1330h POSTER

Structural and palaeomagnetic Analysis of the Koolau Dyke Swarm Exposed in the Kapa'a Quarry, Oahu: Implications for the Structural Evolution of Kilauea - Type Volcanic Rift Zones.

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The Koolau dyke swarms, exposed within the Kailua embayment on the northeastern side of Oahu, have been interpreted as feeders to rift zones in the Koolau volcano, analagous to the rift zones of Kilauea volcano (Walker, 1987), that developed prior to the giant Nuuanu lateral collapse at about 2.0 Ma. Systematic determination of cross-cutting relationships between Koolau dykes has proved difficult because of dense vegetation and rapid weathering in the humid tropical climate of windward Oahu. For this study we have concentrated on exposures of the dykes in the large (450 m wide and 200m deep) Kapa'a quarry, about 3 km NE of the near vertical Nuuanu Pali escarpment. Kapa'a quarry was chosen for this study because it has large, freshly exposed sections nearly perpendicular to the dyke swarm trend in hydrothermally altered but largely unweathered rocks. The hydrothermal alteration indicates that the dykes exposed in the quarry were emplaced well below a high water table resulting from trapping of water between dykes: this high water table may have played a part in the eventual collapse. The excellent exposure at Kapa'a allows systematic, accurate determination of structural data and cross-cutting relationships for every dyke in the measured sections. These data were collected for 171 dykes, of which 10 dykes have so far been sampled for palaeomagnetic analysis (i.e remanence and petrofabrics). Most dykes at Kapa'a dip steeply, from around 70 degrees SW (away from the unstable flank of the volcano) through vertical to 50 degrees NE (towards the unstable flank). NE dipping dykes are more abundant overall. Groups of SW - dipping dykes alternate with groups of subvertical to NE - dipping dykes, suggesting a quasi-periodic alternation of the stress regime within the Koolau volcano. Dyke dilations were typically subhorizontal. A final group of dykes, cross-cutting all the others, dip from 50 degrees NE to as little as 35 degrees NE, and dilated in a steeply SW - plunging orientation implying uplift to the NE side of the dykes and a major change in the stress field within which the dykes were emplaced. All 10 dykes for which palaeomagnetic data are so far available, including 2 of the low-angle group of dykes, show reversed polarity indicating dyke emplacement between 2.6 Ma and (at the latest) 1.77 Ma.

V22C-0599 1330h POSTER

3D Onshore-Offshore Seismic Investigation of Kilauea Volcano, HI

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Kilauea volcano is one of the most active oceanic volcanoes. The interplay of intrusion, eruption, volcanic spreading and slope failure defines a dynamic system which is largely hidden from view. Earthquake data, recorded by the onland seismic stations, have illuminated the internal structure of Kilauea's subaerial edifice. Marine reflection profiles have provided insight into its submarine south flank. However, there are few constraints to link the onshore-offshore regions, nor to resolve the deep structure of the submarine edifice. Our study attempts to image the shallow and deep crustal structure of Kilauea volcano and adjacent regions to better understand this dynamic volcanic system. In 1998, a marine seismic survey conducted on the R/V *Maurice Ewing* generated 2,000 km of shots, which were recorded by the HVO-USGS Seismic Network on the Island of Hawaii. This arrangement of receivers and active seismic sources yields a unique set of ray paths that cover the onshore and offshore region of Kilauea's south flank. The data recorded at about 30 onland stations have high enough quality to permit arrivals to be picked to more than 100 km offset. As an initial test of data quality, we compared observed traveltimes to those predicted through 3D forward modeling of several simple velocity models developed for Kilauea and surrounding volcanoes, yielding very good fits. Using these initial velocity volumes as starting models, we conducted 3D tomographic inversions of observed first arrivals. Our preliminary results reproduce high velocity anomalies correlated with intrusive complexes that have been previously recognized on-land beneath Mauna Loa and Kilauea summits and rift zones, and extend these observations into the offshore regions. Low velocity zones are detected beneath the upper submarine flanks of Mauna Loa and Kilauea, suggestive of thick packages of volcaniclastic sediment or landslide debris. Further analysis is expected to better resolve the detailed internal structure of Kilauea volcano and surrounding areas.

V22C-0600 1330h POSTER

Composition and Structure of Mauna Loa's Submarine West Flank, Hawaii

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James Moore's pioneering work on submarine landslides in the Hawaiian Islands contributed significantly to early models for the structure and evolution of Mauna Loa's submarine western flank. The west flank experienced catastrophic failure in the past, generating massive blocks and debris fields offshore. Moore recognized that the midslope bench near the base of the submarine flank must have postdated the debris avalanche, but little data existed to determine if it formed in response to further landsliding or to deeper volcanic processes. As the processes that shaped Mauna Loa are thought to be analogous to those currently active at Kilauea, an improved understanding of Mauna Loa's history can provide valuable insight into the future of the younger Hawaiian volcanoes. Several recent marine surveys in the area, including submersible surveys conducted by MBARI and JAMSTEC, and a multichannel seismic (MCS) survey carried out by the University of Hawaii, provide important new data about the composition and structure of Mauna Loa's submarine west flank. We carried out detailed geochemical, petrographic and structural analyses of rock samples and dive videos collected from the exposed northern wall of the midslope bench, documenting a repeated sequences of volcaniclastic sandstones and breccias. This stratigraphy contrasts with the predominantly subaerially erupted basalts composing the upper flank. Several thick ponded flows or sill-like diabase units are also interspersed in the section. The volcaniclastic units are highly cemented, and many contain hydrothermal alteration products, including chlorite, zeolites, and actinolite. The most altered rocks occur near the base of the bench and the degree of alteration decreases upward in the section. Samples collected from the outer scarp of the bench show evidence for intense shearing and cataclasis at all scales. The new MCS line crosses Mauna Loa's southern submarine flank and central bench. More than 500 m of finely layered slope strata overlie the upper flank to the south, and are truncated above the Ka Lae avalanche scar. The central bench to the north, sampled by the MBARI dives, shows only thin sediment cover above a poorly reflective interior. Strong deep reflections in both locations begin to resolve the underlying oceanic crust, as well as probable fault planes that may be responsible for flank deformation in this area. The abundance of volcaniclastic rocks with Mauna Loa affinities within the bench supports the idea that giant landslides from Mauna Loa were the source of much of the offshore debris. The stratal repetition, deformation fabrics, and cementation of the volcaniclastics also suggest that the rocks composing the bench were once deeply buried and have been subsequently exhumed by thrusting, most likely driven by deep volcanic spreading.

V22C-0601 1330h POSTER

Internal Structure of the West Submarine Flanks of Mauna Loa and Hualalai, Hawaii Island: investigation of ROV KAIKO and Manned Submersible SHINKAI

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Submersible-based exploration of basaltic rocks west flank of the Hawaii Island, mostly at 2000 to 5000 m depths, was a focus of Japan USA joint research during two cruises by the JAMSTEC in 2001-02. The observations from submersibles and samples recovered are summarized, based on the twelve recent submersible dives and numerous newly obtained samples from deep submarine flanks of Hualalai and Mauna Loa Topographic nature of the studied area are categorized using high-resolution bathymetric data obtained during the cruses and are very effective for deciphering the sequence of landslides. Because the west of Hawaii Island is lee side having a little rain, topographic characteristics of landslide deposits are preserved without buried by material of the later subaerial erosion process. Submarine geological map of the west flank of Hawaii Island has been revised on the basis of these investigations. Major difference between maps proposed previously and this work is twofold. The first is the submarine flank of this area consists mainly of pillow lavas. This is contrastive to the Nuuanu landslide

and Hilina slump regions in which hyaloclastite and fragmental debris are dominated. The debris avalanche deposits are prevailing only in the lower submarine slope. The second is the sequence of landslide events. Base on the topographic and geologic investigations major landslide events can be redefined in the sequence from early to late: South Kona Slide 1(South Kona slump and Ka Lae west debris-avalanche), South Kona Slide 2 (South Kona slide), North Kona Slump (North Kona slide + Alika 1 debris-avalanche), Ka Lae slump (newly defined), Ka Lae debris-avalanche (Ka Lae East debris-avalanche), Alika debris-avalanche (Alika 2 debris-avalanche). It is concluded that these slope failures were probably result in the rift propagation rather than instability of the slope itself which made of unstable fragmental lavas. Therefore, the pillow lava model is more suitable for present case. However, the fragmental lava model is also correct in other case, such as Nuuanu landslide and Hilina slump. Each cross section can not represent as a general model, because the growth conditions differ in the directions.

V22C-0602 1330h INVITED POSTER

Dynamic Submarine Flanks of Hualalai Volcano, Hawaii

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Four remote and manned submersible dives examined the Hualalai midslope bench scarps, NW rift zone, and an elongate ridge cresting at 3900 mbsl during 2001 and 2002 JAMSTEC cruises. Here we report the results of stratigraphic, petrographic, and geochemical studies of the latter feature (dive S692). The ridge is 2x8 km, 300-700 m above datum, oriented parallel to the midslope bench, and 1 km east of the Mauna Loa Alika 2 landslide chute and levee deposit. Although the vast majority of the ridge is sediment covered, dive videos and sampling of the steep seaward side of the ridge revealed the following in-place lithologies, from base to crest: (1) bedded, landward dipping glass sandstones consisting of arcuate, angular to subangular glasses, moderately vesicular, tholeiitic and fairly uniform in composition, dominantly low in S, and intensely chemically altered toward the base, (2) olivine basalt breccia with fresh tholeiite glassy matrix, including S-rich grains, (3) dense olivine basalt lava blocks, (4) coarsely crystalline, vesicular, and oxidized lava, and (5) a capping unit of layered, volcaniclastic siltstone beds rich in radiolarians. Finally, an apron of talus and a superficial coating of muddy clastic materials drape the base of the ridge. Samples of this material are compositionally distinct from the in-place samples: they include transitional basalt and S-rich hawaiite. Key inferences about the ridge deposits are: (1) glass sands were produced as shield stage Hualalai lava erupted subaerially or in shallow water, (2) sands were cemented and overlain by breccia and lava blocks following minimal transport as grain flows to a depth that allowed incorporation of high-S grains; the entire sequence was transported to its current deep water location as a coherent package, (3) the zone of intense hydrothermal alteration and mineralization at the base is consistent with fluid flow in a region of distributed strain, possibly associated with gravitational spreading of Hualalai volcano, (4) the alkalic and transitional materials may represent pre-shield Hualalai volcanism. Alternatively, they could represent pre-shield Mauna Loa lavas excavated and transported to their present location by the Alika 2 landslide, which truncated the package, exposed the observed outcrop, and capped the sequence with fossiliferous glassy silt.

V22C-0603 1330h POSTER

Obscure Subaerial Evidence for Landslides From West Maui Volcano and Haleakala, Island of Maui, Hawai‘i

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We propose two moderate-sized landslides from the Island of Maui. The submarine evidence for one is buried and for the other may be difficult to interpret in the narrow deep trough that contains it. On West Maui volcano, the herein-named Waikapū landslide chopped off the volcano's east flank. Subaerial evidence is an 18-km-long, linear eastern mountain front defined by an eastward limit of lava-flow exposures owing to alluvial onlap. Microgravity profiles show no abrupt change across the sediment-lava flow contact; instead, the Bouguer-anomaly trend defines monotonically diminishing gravity values eastward away from the volcano's core. Therefore the alluvial onlap is interpreted as a depositional contact over east-dipping lava flows, not a headwall scarp at currently exposed altitudes. The Waikapū landslide, comparable to or slightly larger than the Pololū slump on the Island of Hawai‘i, must have occurred during the shield-building stage prior to 1.4 Ma; its headwall subsequently was draped by tholeiitic lava late in the shield stage. Submarine evidence lies buried within the edifice of nearby Haleakalā volcano, which became emergent through the surf zone soon after the landslide. On East Maui volcano, or Haleakalā, the evidence for the herein-named Pāhihi landslide is found on the south flank, where the slopes are substantially steeper, 31-38%, than elsewhere on the volcano. The area of steepest slope coincides with the extent of a normal fault exposed in the south wall of the erosional summit valley, Haleakalā Crater. At the 2300-m altitude, this south-side-down fault juxtaposes reversed-polarity 0.9-Ma transitional basalt (north) against postshield basanite (south) younger than 0.78 Ma. Postshield lava flows have subsequently draped the south flank, masking any truncation of older flows. Bouguer gravity contours along this flank of the volcano are similar in form to free-air data, owing to the overwhelming correlation of topography and mass. The Pāhihi landslide may have matched the Waikapū in volume, depending on the extent of volcano sector involved, but direct comparison is difficult because their remnant subaerial geomorphic forms differ. Pāhihi debris presumably mantles the steep submarine south flank of Haleakalā or lies in the 2-km-deep trough beneath the ‘Alenuihāhā Channel.

V22C-0604 1330h POSTER

Volcanic Features in the Northwestern Hawaiian Islands Revealed by SWATH Mapping

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The Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve (NWHICRER) has only recently been established, and has already caused an infusion of interest and funds for studies to assess what is there to preserve and how best to do it. The Northwestern chain stretches over 2200 km to the northwest of the 775 km-long Main Hawaiian Islands (MHI). The MHI have only in recent years been systematically mapped with modern multibeam swath sonar systems and the work is not yet complete. With these southeastern islands being the population center, it is easy to imagine the lack of coverage along the Northwestern chain where no one lives except those stationed at remote outposts for scientific study. Manned and robotic submersible studies and limited multibeam mapping have been carried out by the Hawaii Undersea Research Lab every year in the NWHICRER for the past several years though focused on relatively shallow water biological sites. In late 2002, the first dedicated exploratory multibeam mapping expedition took place aboard the new University of Hawaii SWATH ship R/V *Kilo Moana*. While the primary mission was shallow mapping on carbonate platforms in support of the NWHICRER boundaries, a large amount of data were collected over the deeper volcanic foundations of the atolls. These surveys revealed dramatic rift zones on the same scale as those in the MHI, sea level terraces, submarine canyons cutting through the platforms with debris chutes continuing down to base of the islands, additional submarine landslide scars and debris fields in more detail than the USGS GLORIA sidescan program of the previous decade, and previously unmapped seamounts with some likely resulting from Hawaiian hot spot activity while others formed during creation of the Pacific Plate. A diving program is planned on many of these features in late 2003 and preliminary results will be presented.

V22C-0605 1330h POSTER

Revised Calculated Volumes Of Individual Shield Volcanoes At The Young End Of The Hawaiian Ridge

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Recent, high-resolution multibeam bathymetry and a digital elevation model of the Hawaiian Islands allow us to recalculate Bargar and Jackson's [1974] volumes of coalesced volcanic edifices (Hawaii, Maui-Nui, Oahu, Kauai, and Niihau) and individual shield volcanoes at the young end of the Hawaiian Ridge, taking into account subsidence of the Pacific plate under the load of the volcanoes as modeled by Watts and ten Brink [1989]. Our volume for the Island of Hawaii (2.48 x10^5 km^3) is twice the previous estimate (1.13 x10^5 km^3), due primarily to crustal subsidence, which had not been accounted for in the earlier work. The volcanoes that make up the Hawaii edifice (Mahukona, Kohala, Mauna Kea, Hualalai, Mauna Loa, Kilauea, and Loihi) are generally considered to have formed within the past million years and our revised volume for Hawaii indicates that either magma-supply rates are greater than previously estimated (0.25 km^3/yr as opposed to 0.1 km^3/yr) or that Hawaii's volcanoes have erupted over a longer period of time (>1 million years). Our results also indicate that magma supply rates have increased dramatically to build the Hawaiian edifices: the average rate of the past 5 million years (0.096 km^3/yr) is substantially greater than the overall average of the Hawaiian Ridge (0.018km^3/yr) or Emperor Seamounts (0.012 km^3/yr) as calculated by Bargar and Jackson, and that rates within the past million years are greater still (0.25 km^3/yr). References: Bargar, K. E., and Jackson, E. D., 1974, Calculated volumes of individual shield volcanoes along the Hawaiian-Emperor Chain, Jour. Research U.S. Geol. Survey, Vol. 2, No. 5, p. 545-550. Watts, A. B., and ten Brink, U. S., 1989, Crustal structure, flexure, and subsidence history of the Hawaiian Islands, Jour. Geophys. Res., Vol. 94, No. B8, p. 10,473-10,500.

V22D MCC: Level 1 Tuesday 1330h

Modeling Metamorphism I Posters

(joint with T)

Presiding: **J Liou,** Stanford University; **N Petford,** Kingston University

V22D-0606 1330h POSTER

Melt Redistribution During The Bending Of A Porous, Partially Melted Layer

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A numerical, poro-viscoelastic finite element flow model has been developed to simulate the redistribution of partial melt during the folding of a horizontal layer. Important mechanical properties governing the overall rheology of the buckling layer including porosity, matrix viscosity, melt pressure and changes in deviatoric stress are tracked simultaneously with deformation. Melt migrates down gradients in melt pressure to the outer hinges of the folds, away from sites of compression to regions of local extension. For a matrix with dynamic power law rheology, deformation results in the formation of low viscosity, strain weakening zones that coincide with zones of enhanced deviatoric stress that are potential sites for plastic deformation. During fast deformation of layers with large width to height ratios, the more rapidly bending material splits into domains of higher viscosity separated by lower viscosity zones. Porosity (melt fraction) distribution patterns do not appear to be controlled by the matrix rheology. The numerical results and predictions of melt distribution and geometry during deformation corresponds well with data from some physical (analogue) laboratory experiments and field observations. The quantitative nature of our results should help refine more qualitative models for the rates and mechanisms of melt extraction and transport in folded crustal migmatite terranes.