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Kilauea volcano is the type locale to study the dynamic interplay between slope failure and volcanic spreading; this was recognized very early by Jim Moore and colleagues. New geophysical data and seafloor mapping in the area now better resolve the dramatic history of Kilauea volcano. In this seismically active setting, the interface between the oceanic crust and volcanic edifice accommodates seaward sliding of the south flank of Kilauea, probably rooted along Kilauea's East Rift Zone. Present day displacement of the south flank is punctuated by intermittent movement of the Hilina slump, defined by a set of arcuate normal faults that break the flank just downslope of Kilauea's summit. Analysis of recent multichannel seismic (MCS) data and high-resolution bathymetry over the submarine slopes of Kilauea volcano reveals that the active slump has a relatively shallow detachment, 3-5 km deep, comprises largely slope sediments, and is restricted to the upper northwestern portion of the mobile south flank. Offset morphologic features along the marginal ridge known as Papa'u seamount, constrain measurable downslope displacement of the slump to 3 km, directed oblique to its western boundary. The MCS data also reveal the buried scar of a large-scale slope failure to the northeast of the submarine Hilina slump, which is the probable source of thick deposits of volcaniclastic breccias presently contained within the frontal midslope bench. The midslope bench developed as the mobile south flank of Kilauea plowed seaward into and offscraped the landslide debris, trapping a broad basin above the landslide scar. Uplift and backtilting of young basin fill indicate recent, and possibly ongoing, bench growth. The Hilina slump now impinges upon this frontal bench, a buttress that may tend to reduce the likelihood of future catastrophic detachment of the landslide.

V11G-06 1145h

Rapid Mass Wasting Following Nearshore Underwater Volcanism on Kilauea Volcano

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The rapid mass wasting of shallow submarine basalts was documented during SCUBA dives (with extensive underwater video and photography) along the flanks of Kilauea volcano, Hawaii during the Ki'i lava entry of the current eruption (19^{o}20.4'N, 155^{o}00.0'W). Lava entered the ocean at this site from mid-February to late March 1990, with several pauses. Dives on 19-20 March 1990 confirmed the widespread formation of lava pillows, as well as channelized lava flows, at this site over a water depth range of 20-40 m. Visual observations suggested that the resulting volcanic deposits were generally stable, despite the steep incline of the seafloor (~40 degrees). (The pre-eruptive seafloor slope was ~14 degrees.) However, dives on 2 April 1990 revealed that nearly all of these relatively large submarine volcanic features had been subject to mass wasting, as the offshore area had been transformed into a debris field composed of material ranging in size from fine sand to boulder fragments. This generally featureless seascape extended uniformly to beyond the visual range of divers (~60 m water depth). High resolution side-scan bathymetry and imaging indicate that steeply sloped talus fields extend down the flanks of Kilauea in this area to abyssal depths, implying a possible linkage between coastal submarine volcanism and deep-water deposits. This work, combined with other observations at Kilauea, also suggests that coastal submarine volcanism may not generally result in the accumulation of stable rock formations.

V11G-07 1200h

Megatsunami Generation From Giant Submarine Landslides on Oceanic Islands: New Insights Gained From the Hawaii Evidence and Modeling

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High-elevation marine gravels on the Hawaiian islands of Lanai and Molokai either mark uplifted shorelines or are deposits from massive tsunamis. The subsidence history of those islands has been too ambiguous to differentiate these causes, leading to controversy over the deposit's origins and to confusion over the impacts, or even the existence of megatsunamis generated from giant submarine landslides (GSL) mapped offshore. U-series ages of these deposits that correlate with sealevel high stands have added to the confusion. Landslide tsunami simulations have now advanced to the point where the tsunamigenic potential of GSLs can be affirmed. We show that megatsunamis are a sufficient explanation for the observed pattern of debris height of calcareous marine deposits on the southeast Hawaiian islands. Further, our tsunami simulations, using the Alika GSL as example, can be used to reduce the considerable uncertainty in subsidence history of the different Hawaiian islands. Modeled runups of 800 m occurred directly landward of the Alika 2 slide on west Hawaii and were up to 300 m on west Lanai, in agreement with previous deposit estimates there (Moore & Moore, 1984, 1988). Recently, we rediscovered calcareous marine deposits on Kohala volcano on Hawaii island, where continuous subsidence is well established from its stairway of submerged reefs. On Kohala, we found a marine fossiliferous basalt boulder conglomerate from 1.5 to 61 m above present sea level exposed at the coast and up to 1 km inland. U-series dates of corals from the deposit are approximately the same age, 100 to 120 ka, as the giant Alika 2 landslide from nearby Mauna Loa volcano, directly dated using sediment stratigraphy (McMurtry et al., 1999). The present depth of the 120-ka shoreline implies that the deposit was left by a tsunami whose runup at 6 km inland exceeded 490 m. For the late Pleistocene, large volcanic failures and exposed marine deposits both correlate foremost with sea level high stands, and in particular with the onset of interglacial conditions that are reflected in Hawaii by the apex ages of the lowstand fringing reefs. We show that such large volcanic failures inevitably generate megatsunamis, and we conclude that persistent climate effects during sea level high stands eventually unleash large volcanic failures and megatsunamis amongst the Hawaiian islands and perhaps all volcanically active oceanic islands, with invariable propagation toward the continental coasts.

V11H MCC: 2010 Monday 1020h

U-Series in Continental Environments: Soils, Rivers, and Groundwaters I *(joint with H)*

Presiding: **B Bourdon,** Institut de Physique du Globe de Paris**; F Chabaux,** Université de Strasbourg**; D Porcelli,** University of Oxford

V11H-01 1020h

High Precision Measurements of 235U/238U Isotopic Fractionations Resulting From Uranium Reduction Induced by Zero Valent Iron

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Uranium is a widespread natural and anthropogenic contaminant in surface and subsurface waters. Like several other inorganic contaminants, uranium is mobile under oxidizing conditions but may be immobilized by chemical reduction. U(VI) moves with groundwater as (UO2)2+ and as soluble complexes with carbonate, phosphate, and fluoride. In many groundwater systems, uranium undergoes chemical reduction to U(IV), which is insoluble and immobile. Therefore, understanding the extent of reduction is essential for predicting the mobility of uranium in groundwater. Mass dependent isotopic fractionations of redox sensitive contaminants frequently found in groundwater (including chromate, selenate, and nitrate) have proven exceptionally useful for estimating the rate and extent of reduction and immobilization. Until recently, however, analytical limitations have prevented these techniques from being applied to heavier redox sensitive elements, such as uranium. The advent of highly sensitive multi-collector inductively coupled plasma mass spectrometers (MC-ICP-MS) enables high precision measurements of previously undetected variations in many elements. Laboratory reduction experiments with zero valent iron (ZVI) were performed in a controlled environment to test the hypothesis that uranium isotopes, specifically 235U/238U, behave similarly to other redox sensitive contaminants and produce a mass dependent fractionation during the transformation between valence states. Because of the large abundance differences between 235U and 238U, initial experiments used U500, an enriched uranium standard with approximately equal parts 235U and 238U. Results suggest that the highly sensitive MC-ICP-MS distinguishes 235U/238Uvariations to approximately + 0.02per mil. Measured isotopic fractionations between the 235U/238U of the initial and final experimental solutions (70% reduced) are approximately 1.1 per mil, and increase with decreasing concentration. Measured variations in 235U/238U suggest that uranium isotopic ratios could also prove to be valuable indicators of contaminant immobilization and paleoenvironmental conditions.

V11H-02 1035h

Isotope Fractionation of Uranium in Low-Temperature Environments

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Uranium is the heaviest naturally occurring element. It has three isotopes, ^{238}U, ^{235}U and ^{234}U, and two redox states, U(IV) and U(VI). Large isotopic fractionations have been previously documented for ^{234}U/^{238}U that are attributed to lattice damage and subsequent preferential leaching and oxidation at the α-recoil site. However, fractionation between ^{235}U and ^{238}U is not expected due to the small ~1% difference between the masses of these two isotopes. It is therefore usual to assume ^{238}U/ ^{235}U is constant in the terrestrial environment and equal to 137.88. Stable isotope fractionation is normally restricted to the light and intermediate mass elements due to relatively large mass differences of several percent. Recently, however, thallium, a heavy element with stable isotopes at masses 203 and 205, has been shown to display large, permil-level ^{205}Tl/^{203}Tl variability (Rehkamper et al., 2002, Earth Planet. Sci. Lett. 197, 65). Given their similar redox chemistries, it is not unreasonable to propose that ^{235}U/^{238}U may show similar variability in certain terrestrial environments. We have developed experimental protocols for the precise measurement of ^{235}U/^{238}U by multiple-collector ICPMS (MC-ICPMS) and have analyzed a suite of samples formed in a range of low- and high-temperature environments. Using a Nu Instruments NuPlasma MC-ICPMS, we are able to resolve variations in ^{235}U/^{238}U at the 0.5 ϵ level (2σ; 1 ϵ = 1 part in 10,000) on sample sizes comprising 30 ng of uranium. Data can be acquired on smaller 4 ng samples with 1-2 epsilon 2σ uncertainties. High quality U measurements are possible because we have used a high-purity ^{233}U-^{236}U double spike to internally monitor the large (percent-level) but essentially constant instrumental mass bias effects that are inherent to plasma source mass spectrometry. The natural variability in ^{235}U/^{238}U shown by the analyzed samples is 13 ϵ units and exceeds the analytical reproducibility by more than an order of magnitude. Reproducible compositions both heavier and lighter than our terrestrial standard are observed. Importantly, the largest excursions are observed in old samples that can not have been disturbed by anthropogenic contamination. The observed variability in ^{235}U/^{238}U indicates that uranium isotopes may offer the potential to monitor redox processes during the transition between U(IV) and U(VI) oxidation states. Our observations will also impact on U-series and U-Th-Pb applications in geochemistry, paleoclimatology and cosmochemistry, which currently assume invariant ^{235}U/^{238}U in all terrestrial and extraterrestrial environments.

V

V11H-03 1050h INVITED

230Th/U Dating of Pedogenic Carbonate

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Quantitative determination of the timing of pedogenesis of calcic soils is of fundamental interest for many aspects of soil science and Quaternary geology. For example, if the onset of soil development is rapid, pedogenic materials can provide useful constraints on the ages of Quaternary deposits themselves, thereby facilitating studies of geomorphic change, neotectonics and paleoclimate. Furthermore, accurate dating can provide a quantitative time-axis for paleoenvironmental information commonly preserved in the oxygen and carbon isotopic compositions of pedogenic carbonates. Newly formed pedogenic carbonate generally contains ppm-levels of U and is depleted in Th relative to secular equilibrium because U is immensely more soluble than Th in oxygenated, infiltrating soil waters. Moreover, the initial concentration of 234U in pedogenic carbonate generally exceeds secular equilibrium because it is enriched in soil waters by recoil and enhanced solubility relative to 238U. Therefore, middle Pleistocene and younger pedogenic carbonate is potentially suitable for dating via the 230Th-234U-238U system. Potential pitfalls for U-series dating of pedogenic carbonate include correction for initial U-Th isotopes introduced by detrital contamination and failure of the U-Th system to remain closed. Moreover, if age-estimates for clastic deposits are sought, the interval between surface stabilization and formation of datable carbonate must be estimated. Several studies now show that reliable and precise ages for dense pedogenic carbonate coatings on the undersides of alluvial gravel-clasts (termed rinds) can be obtained using carefully selected, milligram-size samples drilled from polished slabs and analyzed by TIMS. Rinds from well-sorted alluvium, such as river terraces, sampled using this approach commonly have high 230Th/232Th activity ratios (generally >10, and commonly >100); thus, corrections for initial U and Th isotopes are minor and are made using a model-silicate detrital composition with 232Th serving as an index isotope. This "single sample, single date" approach precludes meaningless 230Th/U ages that can sometimes result from chemical fractionation of Th from U by leach-residue techniques. Furthermore, small samples allow the long (up to >100 kyr), and sometimes visibly discontinuous, depositional histories of individual rinds to be resolved. Using large data sets, reliability of rind-ages may be assessed from the ages themselves; that is, valid ages should be reproducible along microstratigraphic horizons and preserve microstratigraphic order within individual rinds. Datable carbonate can form within a few thousand years of surface stabilization, as shown by comparison with independent ages, allowing ages of Quaternary deposits and surfaces to be closely estimated. For example, a glacio-fluvial terrace of the Wind River basin, Wyoming (USA) that formed penecontemporaneously with the last Rocky Mountain glacial maximum yields rind-ages that overlap with cosmogenic surface exposure ages for last-glacial pavements, moraines and terraces. Moreover, rind dating provides the best available age constraints for terraces formed during the penultimate Rocky Mountain glacial cycle. These ages show that, contrary to previous suggestions, final maximum advances of the penultimate Rocky Mountain glaciation were broadly synchronous with the global ice-volume maximum of marine isotope stage 6.

V11H-04 1105h

Environmental control of U concentration and $^{234}U/^{238}U$ in speleothems at subannual resolution

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Trace element and isotope variability in speleothems encodes a range of information about the past environment, although its interpretation is often problematic. U concentration and isotopes have frequently been analysed in speleothems in order to provide chronology, but their use as environmental proxies in their own right has not been comprehensively investigated. In this study, we have investigated the environmental controls of U in a stalagmite from the Central Yangtze Valley in China. This stalagmite grew rapidly throughout the Holocone and contains visible annual layers about 300microns thick. Analysis of a portion of the stalagmite corresponding to the 1970s by electron probe, LA-ICP-MS, and by physical subsampling indicate clear annual cycles in Sr/Ca, Mg/Ca, and Ba/Ca. The reasonably open cave structure and the correlation of Sr/Ca with Mg/Ca suggest that temperature exerts considerable control over these trace element variations. U/Ca also varies seasonally by up to 42 % and shows a clear anti-correlation with Mg/Ca (correlation coefficient −0.64). Based on the inverse relationship between U/Ca and temperature exhibited in other carbonates (e.g. corals) the speleothem U/Ca is suggested to be controlled primarily by temperature and may provide a paleo cave thermometer with less rainfall influence than Mg/Ca. Ongoing monitoring of the cave temperature and humidity will assess the robustness of this conclusion and the sensitivity of speleothem U/Ca to temperature. ($^{234}U/^{238}U$) in this stalagmite range from 1.733 to 1.872 during the Holocene. The U concentration is high enough (typically 0.48 ppm) and growth rate fast enough, that ($^{234}U/^{238}U$) can also be measured at a subannual resolution. The expected alpha-recoil control of excess ^{234}U supply suggests that these measurements may provide a measure of the transit time of recharge waters to the stalagmite during the seasonal cycle. Such a proxy would enable deconvolution of temperature and recharge-rate control in trace element records from speleothems.

V11H-05 1120h INVITED

Modelling of Groundwater Weathering Rates From U- and Th- Series Nuclides

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The transport of U, Th, Ra and Rn nuclides of the ^{238}U- and ^{232}Th decay series in continental groundwaters can be used to constrain important physicochemical parameters that occur within the aquifer, principally long-term weathering rates, α-recoil effects, and adsorption-desorption characteristics and irreversible precipitation. These naturally occurring radionuclides are ideal for modelling the mobility of pollutant nuclides. In terms of understanding the aquifer system, and to decouple the effects of the vadose zone from the water chemistry evolution within the aquifer, it is important to look at large aquifer systems and waters with older groundwater ages. The simple measurement of U activity ratios gives an estimate of the importance of α-recoil effects compared to the bulk dissolution rates within the aquifer system, rather than any age information. This usually leads to observed increases in $\delta^{234}U$ away from the vadose zone, where bulk dissolution rates are highest. Given a constant recoil fraction, that predominately reflects grain size of accessory minerals, $\delta^{234}U$ will be a direct measure of the localised weathering rate. Rn gas concentrations also reflect the α-recoil inputs; activities are generally too high to reflect direct recoil from within mineral grains and are mainly derived from a Th enriched surface coating within the aquifer system. This Th enriched layer slowly develops over millions of years within an aquifer system, and can contain over 10 % of the immobile (insoluble) elements within the aquifer. It will also have a ^{230}Th activity that has reached a steady state value. The surface layer contributes significantly to the Ra activity from the parent Th isotopes incorporated in this layer. If the entire decay series is modelled for an aquifer system it is possible to derive the amount of Th within the surface layer and thus the long-term recoil fraction and weathering rate. In turn, differences between observed and modelled activities (rather than ratios) can be used to deduce localised adsorption coefficients for U and Ra. Unfortunately, the model estimates the relative adsorption rather than the effective distribution co-efficient needed to evaluate retardation factors and more effectively model the mobility of pollutant nuclides within the natural environment.

V11H-06 1135h

Decay-Series Disequilibria in a Chalk Aquifer : Characterisation of Water-Rock Interaction

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We have studied uranium-series disequilibria in a chalk aquifer and the unsaturated zone above it in order to characterise the time scales of radionuclide migration from the water recharge zone of the aquifer to the nearby river. Our field area is located in Champagne (France). The aquifer is characterized by a double porosity : matrix and fracture, providing both a fast and a slow pathways for water flow. We have collected both carbonate rocks and groundwater samples from boreholes and spring and river water from the same area. Rock/water interaction inside the aquifer induces dissolution and reprecipitation of carbonates, together with a mobilization of uranium, and (-recoil effect results in preferential mobilization of daughter nuclides. We have measured uranium and thorium isotopes for carbonates samples from the aquifer by TIMS and multi-collection ICP-MS. The fractionation of uranium and thorium isotopes is distinctive in the various parts of the aquifer. Rock samples from the saturated zone show a depletion in 234U with a (234U/238U) ratio ranging from 0.945 to 0.993 (± 0.005). This indicates that uranium 234U has been released by rock/water interaction over the last million year. Nevertheless, rock samples from the water table oscillation zone display a (234U/238U) activity ratio greater than 1 and range from 1.002 to 1.052 (± 0.005), suggesting uranium reprecipitation possibly by a redox front. (230Th/238U) ratios range from 1.25 to 1.59 (± 0.03) in both the saturated and vadose zone, whilst (230Th/232Th) ratios vary from 1.89 to 5.68 (± 0.05) with the highest values for the water table oscillation zone. The 238U-230Th system suggests the existence of a iron oxihydroxide and/or silicate phases which influence the redeposition and/or adsorption of elements inside the zone of water oscillation. Modelling is in progress in order to determine leaching rate of the radionuclides in the substratum together with the adsorption/desorption rate constants on surface coating. We are also curently analysing radium isotopes which will provide us further insights on the migration timescale of uranium-series nuclides in groundwater.

V11H-07 1150h

Measuring the timescales of sediment production, transport, and deposition - U-234 sediment comminution ages

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Isotopic and paleontological methods exist to estimate the ages of clastic sediment provenance, the age of sediment deposition, and the timescales of diagenesis. An additional interesting timescale is that encompassing the transformation of bedrock to sediment, including the time required to break down rock into transportable fragments, and the residence time of these particles in soils, streambeds, floodplains, dunes, and moraines prior to deposition on the seafloor or in lakes. The 234U/238U ratio of sediment particulates can provide such information. The "clock" is provided by the loss of the 238U decay product, 234Th, by recoil associated with alpha emission and the concomitant lowering of the 234U/238U ratio in small sediment grains. The timescale is set by the mean life of 234U (240,000 years) which is appropriate to the expected timescales of sediment production and transport. The recoil distance is a about 0.1 micron in silicates. Sand-size grains lose negligible 234Th by recoil, but the recoil effects become significant and measurable when the grain diameter is about 50 microns or smaller. Measurements of sediment 234U/238U ratios suggest that the fraction of 234Th atoms lost by recoil is typically greater than that predicted by the spherical grain model (fractional loss = 3L/2d, where L is the recoil distance and d is the grain diameter). In deep sea sediments, grains with dimensions of 1 to 10 microns exhibit fractional depletions of 20 to 30 percent, which can now be measured with an accuracy of 0.05 percent. When a small grain is produced by erosion, it begins to leak 234Th to its surroundings and its 234U/238U ratio starts to decrease. To reach the steady state 234U/238U ratio appropriate to its size and fractional loss rate requires about 1 million years. In the meantime the 234U/238U is measuring the time since the small grain was produced, which we refer to as the "comminution age." Since the 234U/238U ratio continues to decrease after sedimentation and burial, the method can also potentially be used to measure sedimentation rates and the age of clastic sediments in the range 10,000 to 1 million years. Measurements of sediment size fraction 234U/238U ratios as a function of depth below the seafloor or age allows retrieval of the effective fractional loss rate, and the comminution age at the time of deposition. The

latter can be considered to be the "sediment production time." Our measurements of Late Pleistocene sediment retrieved from ODP Site 984 in the North Atlantic (mean grain size 10 - 20 micron, fractional loss rate 0.20) suggest that the timescale for sediment production there is about 20 kyr. Measurements of Bering Sea and North Pacific sediments from the literature (Yamada and Tsunogai, Marine Geol., v.54, 1983) suggest sediment production times of 60 and 250 Kyr respectively. Broader application of the technique will require further work to establish reliable approaches to removing diagenetic components.

V11H-08 1205h

On the 234,238U isotope systematics in two tropical estuaries: the Amazon and Fly Rivers.

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Natural concentrations of 238U and d234U were determined in estuarine surface waters of the Amazon and Fly (Papua New Guinea) Rivers to investigate U transport phenomena across river-dominated land-sea margins. On the Amazon shelf, salinity-property plots of dissolved organic carbon (DOC), pH and total suspended matter (TSM) revealed two vastly contrasting water masses that were energetically mixed. In this mixing zone, the distribution of uranium isotopes was highly non-conservative and exhibited extensive removal from the water column. Uranium removal was most pronounced within a salinity range of 0 to 16.6, and is likely the result of scavenging and flocculation reactions with inorganic (i.e., Fe/Mn oxides) and organic colloids/particles. Removal of uranium may also be closely coupled to exchange and resuspension processes at the sediment/water interface. In the Fly River estuary, 238U appears to exhibit a reasonably conservative distribution as a function of salinity. The absence of observed U removal does not necessarily imply non-reactivity, but instead may record an integration of concurrent U removal and release processes. There is not a linear correlation between d234U versus 1/238U that would imply simple two component mixing. It is likely that resuspension of bottom sediments, prolonged residence times in the lower reaches of the Fly River, and energetic particle-colloid interactions contribute to the observed estuarine U distribution. The supply of uranium discharged from humid, tropical river systems to the sea appears to be foremost influenced by particle/water interactions that are ultimately governed by the particular physiographic and hydrologic characteristics of an estuary.

V11I MCC: 2000 Monday 1020h

Isotopic Constraints on Rates of Building Active Volcanoes I

Presiding: **A Calvert,** U.S. Geological Survey, Menlo Park**; B Singer,** University of Wisconsin-Madison

V11I-01 1020h INVITED

Application of K-Ar Dating to the Chronology of Young Volcanic Centers

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K-Ar dating and a derivative technique, $^{40}Ar/^{39}Ar$ dating, are methods of high-precision chronology applicable to young volcanic centers. Cascade volcanoes studied in detail by several USGS volcanologists, Duane Champion paleomagetist, and me include Mt. Baker, WA; Mt. Rainier, WA; Mt. Adams, WA; Mt. Hood, OR; Crater Lake, OR; and Medicine Lake, CA. For Mt. Adams using detailed geologic mapping by Hildreth and Fierstein and 74 K-Ar ages for 63 mapped units, Hildreth and Lanphere established a detailed chronology for the stratovolcano. Good agreement has been achieved for K-Ar ages and $^{40}Ar/^{39}Ar$ ages of rocks from Mt. Adams as young as 36 ka. A similar detailed chronology has been established for other Cascade volcanoes using andesites, in particular. These chronologies often take 10 years or more to develop. Major advantages of the $^{40}Ar/^{39}Ar$ technique are the ability to work with small sample sizes and the possibility to push the technique to very young ages. The Campanian Ignimbrite erupted from the Campi Flegrei crater near Naples, Italy is an example of the use of small samples. Nine incremental-heating ages were determined on samples of sanidine ranging in size from 47 mg to 67 mg. These samples yielded ages for the Campanian Ignimbrite ranging from 37.1 ± 0.75 ka to 39.5 ± 0.62 ka and averaging 38.1 ± 0.8 ka. Other workers have proposed $^{40}Ar/^{39}Ar$ ages for the Campanian Ignimbrite of 37.1 ± 0.4 ka and 39.3 ± 0.1 ka. An example of the use of $^{40}Ar/^{39}Ar$ dating of very young samples is the Christian Era (CE) age of the Vesuvius eruption of year 79. Eight packets of sanidine weighing 213-296 mg from two localities, Casti Amanti in Pompeii and Villa Poppea in nearby Oplontis, yielded a weighted-mean incremental-heating age of 1924 ± 66 years. The known age for the CE 79 eruption of Vesuvius is 1924 years. Earlier studies of Vesuvius by other workers yielded an $^{40}Ar/^{39}Ar$ age for the Villa Poppea locality of 1922 ± 72 years.

V11I-02 1035h

New Insights Into Volcanic Hazards in Western Mexico: Multiple Cone-Building Episodes at Arc Stratovolcanoes Revealed by 40Ar/39Ar Geochronology

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The detailed eruptive histories of two andesitic stratocones, Volcáns Ceboruco and Tequila, in the western Mexican arc have been documented using $^{40}Ar/^{39}Ar$ geochronology. The volumes of these volcanoes were obtained with mapping, airphotos, and digital elevation models. The age and volume data constrain the rate and duration of major cone-building events, which bears on the longevity of the underlying upper-crustal magma chambers that fed the eruptions. The results indicate that at each stratovolcano there were two discrete cone-building events, separated by a hiatus. At V. Tequila, six samples from the edifice yielded dates (196 ± 8, 196 ± 19, 178 ± 8, 191 ± 13, 216 ± 11, and 198 ± 11 ka; errors are 1 sigma) with a mean eruption age of 196 ± 12 ka. Thus the bulk of the main edifice (∼31 km^3) erupted within 24 kyrs (at the 2 sigma level), leading to a cone-building rate of > 1.3 km^3/kyr. After a hiatus of ∼110 kyrs, ∼14 km^3 of andesite erupted along the NW and SE flanks of V. Tequila at 90 ± 19 ka. The last activity at V. Tequila produced a ∼2 km^3 parasitic cone at ∼60 ka. Since an eruption has not occurred in the last 60 kyrs, V. Tequila is often considered an extinct volcano. This may be the view held by the > 75,000 inhabitants of the town of Tequila located on the northern flanks. A similar history of two discrete cone-building events is found at V. Ceboruco, ∼75 km to the NW. Seven samples taken from various parts of the edifice, including the inner caldera wall, indicate an initial cone-building event at ∼45 ka in which ∼37 km^3 of andesite erupted. After a hiatus of nearly 44 kyrs, a second eruptive period began ∼1000 years ago. The first eruption to occur after the hiatus was Plinian and released 3-4 km^3 of dacite. In the last 1 kyr, 9.5 km^3 of andesite and dacite erupted effusively, culminating in the historic 1870 flow. The sobering conclusion, in terms of volcanic hazards assessment, is that the only Plinian eruption to occur happened after a 44 kyr hiatus. Thus prior to the Plinian eruption, it would have been reasonable to conclude that the volcano was dormant and possibly extinct. Both V. Ceboruco and V. Tequila straddle prominent NW-SE faults, along which peripheral domes and cinder cones are also aligned. The location of these two large stratocones suggests that they each overlie a major passageway for magmas ascending from the lower/middle crust into the upper crust. Voluminous batches of magma appear to have collected episodically for relatively short periods in the upper crust, forming chambers. The short duration and recurring nature of voluminous cone-building eruptions have been documented at other stratovolcanoes, such as at Mt. Adams in the Cascade arc. Hildreth and Lanphere (1994) documented three discrete and relatively short-lived, cone-building events at ∼500, ∼450, and ∼30 ka. The emerging concern is that in a region of active subduction and faulting, the concept of an extinct volcano is tenuous. A hiatus of tens or even hundreds of kyrs, during which time no upper crustal magma chamber exists, cannot be used as evidence that the overlying volcano is unlikely to produce future eruptions. A new upper crustal magma chamber may form again along the same fracture system.

V11I-03 1050h

Short Magma Residence Times at Mt. Rainier and the Probable Absence of a Large, Integrated, and Long-lived Magma Reservoir System

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Intensive, high-precision K-Ar and $^{40}Ar/^{39}Ar$ geochronology have proven essential for producing modern geologic maps of volcanoes and from these determining the volcanoes' time-volume histories. If sufficiently abundant, these data can also reveal aspects of the magma supply system. For Cascade volcanoes a general result has been the demonstration that edifice growth is highly episodic. Mount Rainier grew in the last 500,000 years atop the remains of an ancestral edifice that was active in the same location 1 - 2 Myr ago. The 500,000 year history of the modern edifice falls into four stages of alternating high and low magmatic output of subequal duration, but major and trace element compositions of eruptives show no correlation with volcano growth stages. Instead, the same spectrum of magmas (andesite to low-Si dacite) erupted throughout the history of the volcano with compositions in the same relative abundances. Superimposed on this seemingly null result are at least 6 brief but pronounced excursions in magma trace-element compositions. Concentrations of Zr, Ba, or Sr can double and then return to background values passing into and out of a single flow or flow-group. Some excursions are tightly bracketed by mapping and by measured ages and have durations no more than the geochronologic measurement precision of about 10,000 years. True excursion durations are potentially much shorter. The brevity and abrupt onsets and cessations of these compositional excursions are evidence against the presence of a sizeable, long-lived magma reservoir anywhere beneath the volcano, including a MASH zone in the lower crust, that would have attenuated, dampened, and homogenized compositional excursions introduced into the magmatic system. Instead, we take 10,000 years as a probable upper limit to the average residence time of magma batches transiting the crustal portion of Mount Rainier's plumbing system. A consistent scenario is that parental magmas enter the crust, differentiate, assimilate, and either erupt or solidify in less than 10,000 years. Geochronologic evidence from much larger magmatic systems (Reid and coworkers, Long Valley, Yellowstone) suggests that more productive systems can have much longer average residence times than modestly active arc stratovolcanoes like Mt. Rainier.

V11I-04 1105h

Pleistocene-Recent Growth and Collapse of an Island arc Volcano: Precise $^{40}Ar/^{39}Ar$ Dating of Seguam Island, Central Aleutian arc, Alaska

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Quantifying the long term growth of arc volcanoes can be done through geologic mapping supported by K-Ar or $^{40}Ar/^{39}Ar$ age determinations, and is essential to connect rates of geochemical and petrologic processes to a volcano's eruptive history. Yet, few island arcs have benefitted from K-Ar or $^{40}Ar/^{39}Ar$ dating. No $^{40}Ar/^{39}Ar$ data is published from the 24 active volcanoes in the Aleutian Island arc. Seguam Island, located in the central Aleutian Island arc, is a ∼ 80 km^3, low-K, tholeiitic complex with multiple eruptive centers. Previous K-Ar dating of 11 whole rock samples from Seguam indicated a 1.07 myr eruptive history. Using $^{40}Ar/^{39}Ar$ furnace incremental heating techniques on replicate samples of 200-400 mg groundmass separates, we have obtained precise ages from Seguam lavas and pyroclastics. Twenty one of the 23 new $^{40}Ar/^{39}Ar$ age determinations constrain the duration of most of the Pleistocene-recent volcanism to 142 ± 2 ka. Experiments from two different 0.5 km^3 eroded dike swarms yielded older, less precise ages of 155 ± 78 ka and 230 ± 70 ka. We suspect that the ∼ 1 Ma K-Ar ages obtained from a basalt and basaltic andesite reflect low

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