V32C-1045 1330h POSTER

The Enigma of the Ubiquity of ^{14}C in Organic Samples Older Than 100 ka

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An early expectation of the accelerator mass spectrometry (AMS) technique was that the dramatically improved AMS precision relative to beta counting methods would roughly double the range for ^{14}C dating from about 40 ka (7 times the half-life) to about 80 ka (14 times the half-life). Very soon it was discovered, however, that organic samples throughout the Phanerozoic record commonly display ^{14}C levels hundreds of times the AMS detection threshold. Thought to be contamination, AMS researchers mounted a major campaign to identify the source or sources of this ^{14}C. Although a few minor sources of contamination were identified and corrected, the majority of the ^{14}C in samples that should have been ^{14}C dead given their location in the geological record appeared to be intrinsic to the samples themselves. Studies on *insitu* production of ^{14}C from U and Th decay indicated this source to be too feeble to account for the elevated ^{14}C levels being detected. This situation motivated us to investigate this phenomenon in a more systematic fashion. We selected ten coal samples from the DOE Coal Sample Bank at Penn State University. These samples had been carefully collected and preserved in argon since collection. Our samples were selected for geographical diversity and to span a significant fraction of the geological record. They included three Eocene, three Cretaceous, and four Pennsylvanian coals. They were analyzed using AMS with multiple runs for high precision. After subtracting a standard background correction of 0.08 percent modern carbon (pMC), the results for these ten samples ranged from 0.10±0.03 pMC to 0.46±0.03 pMC with a mean of 0.25 and standard deviation of 0.11. In terms of radiocarbon ages, the range is between 44 ka and 57 ka with a mean of 50 ka. When averaged by geological interval, we obtained mean values of 0.26 pMC (49 ka) for Eocene, 0.021 pMC (51 ka) for Cretaceous, and 0.027 pMC (49 ka) for Pennsylvanian. These results match closely AMS determinations for coal reported in the radiocarbon literature by other investigators. This study indicates that ^{14}C levels in coal are indeed well above the background correction commonly used today and that there is little if any dependence of ^{14}C level on position in the geological column. We conclude the phenomenon of intrinsic ^{14}C in organic material throughout the Phanerozoic record is genuine and persists as an unresolved research question.

V32C-1046 1330h POSTER

Abundant Po Radiohalos in Phanerozoic Granites and Timescale Implications for Their Formation

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Radiohalos are significant as a physical, integral, historical record of the decay of radioisotopes in their tiny central mineral inclusions. In thin section the typical dark concentric rings in the host minerals are due to the α-emissions, with the ring radii related to the distinctive a energies of the different radioisotopes in the ^{238}U and ^{232}Th decay series. ^{238}U and ^{232}Th radiohalos typically form around zircon and monazite inclusions, respectively, commonly in biotite, within granitic rocks. Radiohalos are also observed without central mineral inclusions and consisting only of rings from the last three α-emitters in the ^{238}U series: ^{218}Po, ^{214}Po and ^{210}Po. Because rings for all the Po precursors are missing, one infers there may have been migration of a Po precursor, most likely ^{222}Ra, away from a ^{238}U source in the genesis of such halos. Early research to understand how Po radiohalos might have formed focused on Precambrian granitic rocks. Thus it was claimed that the Po radiohalos were largely confined to such rocks. Furthermore, their formation was described as "a tiny mystery", because the half-lives for ^{218}Po of 3.1 minutes, ^{214}Po of 164 μs, and ^{210}Po of 138 days place severe time constraints on the processes for separating the Po precursor from parent ^{238}U and concentrating it and/or Po prior to halo formation. We report new research which establishes that Po radiohalos are also common in Phanerozoic granites, for example, in the Lachlan Fold Belt of southeastern Australia and the Peninsular Ranges Batholith of southern California. Their abundance is approximately ten ^{210}Po radiohalos for every ^{214}Po radiohalo, while ^{218}Po radiohalos are rare. The frequency of ^{238}U halos in these rocks is typically comparable to that of the ^{210}Po halos. Po halos are usually found in the same biotite grains as ^{238}U halos. The zircon inclusions in the latter often contain >100 ppm U and therefore represent a potentially adequate source of precursor ^{222}Rn and Po for the Po halos. Hydrothermal fluids appear to play a critical role in the formation of these Po halos, both in nuclide transport and in chemical reactions to precipitate Po at localized sites. Because of α-track annealing, the halos can form only below 150° C. The time window for the required hydrothermal activity in the cooling granite hence would have been extremely short compared with the timescale of ^{238}U decay. As a consequence the amount of ^{222}Rn available during this brief cooling window falls far short of the amount required to generate the observed mature halos. We view this seeming paradox as a hint that nuclear decay processes may have been occurring more rapidly during the interval in which these granites were cooling.

V32C-1047 1330h POSTER

Recently Measured Helium Diffusion Rate for Zircon Suggests Inconsistency With U-Pb Age for Fenton Hill Granodiorite

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Gentry *et al.* (*GRL*, 9, 1129-1130, 1982) reported high levels of helium retention in zircons extracted from granodiorite core obtained from the 4300 m deep borehole GT-2 at Fenton Hill, NM, drilled as part of a Los Alamos geothermal research project. These investigators measured, for example, 27% retention at a depth of 2170 m and temperature of 151° C and 17% retention at a depth of 2900 m and temperature of 197° C. The U-Pb concordia age determination for this rock was 1500±20 Ma at a depth of 2900 m. They inferred the total helium production from the radiogenic lead in the zircons. These surprisingly high levels of radiogenic helium retention motivated us to determine the helium diffusion rate in zircon extracted from this same granodiorite. We contracted with a high precision laboratory for these determinations. We used the same zircon size as Gentry *et al.* (50-75 μm) and obtained diffusion rate measurements over the temperature range 50-500° C. At 200° C, for example, the measured diffusion coefficient was 1.42 x 10^{-17} cm^2/s. We also confirmed the high helium retention, finding 1320 nmol/cc (42% retention) in zircons from a depth of 1490 m and a temperature of 125° C. By contrast, the surrounding biotite had only 7 nmol/cc. Our determinations gave a U-Pb concordia age of 1440±2 Ma. Astonishingly, for the current borehole temperatures and measured diffusion coefficients, we find the zircons could have retained the observed levels of helium only if the time span were less than about 10 ka. Today, most of the rock column is well above the calculated zircon helium closure temperature of 128° C. According to published Los Alamos thermal models, temperatures in the region sampled by the borehole would have been much higher for the past 2 Ma, cooling down to today's levels only during the last 0.1 Ma. Even with present temperatures, our diffusion rates (which agree with published rates for other zircons) require retentions to be orders of magnitude lower than the observed levels to be consistent with the U-Pb age for these rocks.

V32D MCC: Level 2 Wednesday 1330h

Isotopic Constraints on Rates of Building Active Volcanoes II Posters

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

V32D-1048 1330h POSTER

History and Eruptive Style of Mount Veniaminof, a Huge Alaskan Basalt-to-Dacite Volcano With Pleistocene and Holocene Caldera-Forming Eruptions

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The eruptive history of Mount Veniaminof, one of the largest and most active volcanoes in the Aleutian arc, is being established through geologic mapping, geochemistry, and $^{40}Ar/^{39}Ar$ and K-Ar geochronology. The Veniaminof edifice has a basal diameter of ~40 km, a volume of ~350 km^3, and an 8-km-diameter ice-filled caldera whose wall reaches an elevation of 2500 m. Glassy lava flow carapaces with polygonal and columnar joints are common and indicate widespread ice/lava interaction, which resulted in ice-marginal flows and tuyas. Exposures from deep glacial valleys to the caldera rim reveal a long history of dominantly basaltic and basaltic andesitic activity from at least 250 ka to 100 ka that produced lavas with compositions as primitive as 9.4% MgO and 130 ppm Ni at 50% SiO_2. Silicic magmas vented beginning ~100 ka are represented by virtually aphyric dacitic lavas (to 68% SiO_2) on the south and west flanks. Similarly, voluminous nearly-aphyric andesite and dacite were produced as recently as 36.4±6.5 ka (andesite) from a northwest-trending set of flank vents. Abundant dikes follow this arc-normal trend. Other abundant dikes have arc-parallel orientations and were emplaced prior to 100 ka pre-caldera lavas. Most lava compositions fall in the tholeiitic field on an SiO_2 versus FeO/MgO diagram. With the exception of a small volume hornblende dacite lava flow (79.0±1.4 ka), no hydrous phenocrysts are known in any Veniaminof juvenile eruptive products. Basalts and basaltic andesites carry olivine and plagioclase (to 1 cm) phenocrysts, joined by augite in some crystal-rich lavas. Andesites and dacites typically have few, small phenocrysts of plagioclase, augite, and low-Ca pyroxene ± Fe-Ti oxide. Caldera collapse may have initiated in the Pleistocene with eruption of dacitic magma locally preserved as pumiceous pyroclastic-flow and -fall deposits on the west side of Veniaminof (Miller et al. 2002) and capped by basaltic andesitic lava dated at 27.9±4.4 ka. Although the caldera may have collapsed further during two large Holocene andesitic explosive eruptions, eroded lava displaying ice-contact jointing drapes the caldera wall and indicates that a caldera was present in the late Pleistocene. The youngest dated Veniaminof lavas on the south, ice-blanketed side of the caldera are ~50 ka; a few south flank cinder cones may be latest Pleistocene/early Holocene. Despite the absence of an exposed southern caldera wall, no debris-avalanche-deposit evidence has been found for an alternative, sector-collapse origin of the caldera structure. Two voluminous andesitic Holocene pyroclastic eruptions (3700 yr BP and >4700 yr BP; Miller et al., 2002) emplaced pyroclastic-flow deposits on Veniaminof's flanks and in surrounding valleys. The younger deposited lithic breccia at higher elevations, including plutonic clasts with textures ranging from coarse-grained cumulate gabbro to medium-to-fine-grained miarolytic hornblende tonalite compositionally like Veniaminof dacite. A still younger (subplinian?), widespread dacitic (63.5% SiO_2) fall deposit up to ~30 cm thick suggests that this long-lived magmatic system may produce explosive silicic eruptions in addition to the historically-known basaltic andesitic strombolian and effusive eruptions from the intracaldera cone.

Miller, T.P., Waythomas, C.F., and Gardner, J.E., 2002, Possible multiple late Quaternary caldera-forming eruptions at Mount Veniaminof volcano, Alaska: Eos Trans. AGU 83(47), V11A-1376.

V32D-1049 1330h POSTER

Silicic Eruptions of the Past 50 kyr at the Three Sisters Volcanic Cluster

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The Three Sisters volcanic cluster in the central Oregon Cascades consists of mafic to intermediate stratovolcanoes surrounded by mafic and silicic flows and domes. The bulk of South and Middle Sister are late Pleistocene while North Sister is middle Pleistocene (Schmidt and Grunder, 2003 GSA abs.). Thick rhyolite and dacite lava flows and domes are rich in potassium, and young glaciation exposes holocrystalline groundmass textures ideal for argon geochronology. Several of these silicic flows bracket stratovolcano growth, and precise geochronology illuminates a rich basalt to rhyolite history in the cluster over the past 50 kyr. Careful step-heating $^{40}Ar/^{39}Ar$ experiments yield excellent plateau ages with radiogenic yields often above 5% on rocks as young as 20 ka. Most samples have well-determined isochrons with atmospheric (40/36 = 295.5) intercepts, although several have intercepts as low as 286. South Sister is a composite cone with an andesite/dacite base (Hodge Crest) and a young andesite summit sequence. The basal flow of the 300m-thick, youngest conformable stack of andesite lavas at the summit is 27±3 ka. Unconformably underlying portions date back to at least 50 ka based on ages of overlapping silicic flows. The base of Middle Sister is andesite overlain by ~300m of olivine basalt. Some Middle Sister andesites and all basalts overlie a distinctive dacite agglutinate (20±2 ka) in the South/Middle Sister saddle. All Middle Sister lavas underlie a thick dacite flow (14±3 ka) that vented at 8500 ft (2600m) on its S flank. Dacite lava flows erupted from the Middle/North Sister saddle at 27±2 and 18±2 ka. Additionally, several >100m-thick rhyolite and dacite lavas vented low on the flanks of the cluster. Obsidian Cliff rhyolite (37.8±1.8 ka) and Lane Plateau dacite (21.4±1.9 ka) erupted W of Middle Sister, the Dew Lake dacite (32.3±1.8 ka) located near the locus of the INSAR anomaly W of South Sister flowed around a 148±4 ka (knob 6482) basalt and near the 149±5 ka (The Husband), 159±10 ka (Upper Mesa Creek) and 279±6 ka (The Sphinx) basalts. The south flank of South Sister is dominated by the late Holocene rhyolites of Rock Mesa and the Devil's Hill chain and about ten 24-50 ka rhyolite and dacite domes and flows. A 100m-thick 35±2 ka rhyolite lava also extends NE from South Sister into Squaw Creek. In sum, South and Middle Sisters are mafic to intermediate and their youngest activity is coeval. Silicic flows on and around the volcanic cluster are voluminous, abundant and young.

V32D-1050 1330h POSTER

Volcanism during the past 84 ka at Atitlan caldera, Guatemala

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During the ~84 ka Los Chocoyos eruption, Atitlan caldera erupted 250 to 300 km^3 of magma (DRE). The plinian-fall deposit covered 6 x 10^6 km^2, including significant parts of three ocean basins. Pyroclastic flow deposits extend more than 100 km to the NE and NW filling valleys to depths of 200m. The Los Chocoyos ignimbrite deposit also extends S to the Pacific Ocean. Since 84 ka, Atitlan caldera has produced at least 4 explosive, rhyolitic sequences, numerous andesitic tephras, and constructed 3 stratovolcanoes. Shortly after the Los Chocoyos eruption, an explosive andesitic eruption produced a 1-12m-thick fall deposit with 10-100cm blocks at the W end of the caldera, perhaps representing the first product of San Pedro volcano. Two rhyolitic eruptions of Atitlan caldera occurred between 84 ka and about 60 ka, and two more eruptions, closely spaced in time, occurred about 40 ka. The first tephra, the San Pablo ash, comprises a plinian-fall deposit with accretionary lapilli-bearing fine ash deposits above and below. The second deposit, the voluminous Las Canoas ash, contains a sequence of phreatomagmatic, plinian, and pyroclastic-flow deposits, and thickens toward its likely source at the E end of Lake Atitlan. The San Pablo and Las Canoas deposits are bracketed between 84±5 ka and 68±7 ka, and plagioclase from Las Canoas yields a provisional 86±16 ka $^{40}Ar/^{39}Ar$ age. The youngest two rhyolitic tephra sequences, separated by a thin soil, have plinian fall deposits that are coarsest on the slopes of San Pedro volcano on the S caldera margin. The lower unit yields $^{40}Ar/^{39}Ar$ plagioclase ages of 38±9 ka and 43±9 ka. Both tephras overlie even the youngest San Pedro lavas (43±16 ka), but predate exposed Toliman and Atitlan lavas. Since the major caldera-forming event of 84 ka, three stratovolcanoes, Atitlan, Toliman and San Pedro, have formed within the caldera. Toliman and San Pedro have produced thick lava flows or domes and some tephra layers, whereas Atitlan has erupted more frequently and explosively to form pyroclastic flows and widespread tephras in addition to lavas. Although eruptions at the 3 volcanoes likely overlapped, San Pedro grew to about its present size prior to 40 ka. Toliman probably remains active and began growing after about 40 ka and Atitlan grew almost entirely in the last 10 ka.

V32D-1051 1330h POSTER

31±17 ka $^{40}Ar/^{39}Ar$ Plateau Age on the Very Low-Potassium Hat Creek Basalt Fits Stratigraphic and Geochronologic Constraints of Contiguous Units

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The Hat Creek Basalt is a late Pleistocene low-K olivine tholeiite that floors much of the Hat Creek Valley, north of the Lassen volcanic highland in NE California. The flow erupted from a fissure trending N 10° W located 0.5 to 4.0 km SSE of Old Station and flowed north nearly 30 km, mainly through lava tubes. Paleomagnetic data indicate that the Hat Creek Basalt is a single eruptive unit with an inclination of 64.3° and a declination of 1.0°. The Hat Creek Basalt is overlain by gravel related to the last major glaciation, which ended about 15 to 17 ky ago. The Hat Creek Basalt overlies numerous andesite and basaltic andesite lava flows that are closely related geographically, stratigraphically, petrographically and geochemically and probably represent the same eruptive episode (although not necessarily the same year or century). Three of these flows have been dated by the $^{40}Ar/^{39}Ar$ method and yield concordant plateau, integrated (total fusion), and isochron ages: Little Potato Butte (1.42% K_2O; 67±4 ka), Sugarloaf (1.85% K_2O; 55±7 ka), and Big Potato Butte (1.62% K_2O; 73±14 ka). The Hat Creek Basalt also overlies the basaltic andesite of Cinder Butte (1.65% K_2O) with a $^{40}Ar/^{39}Ar$ plateau age of 38±7 ka. Given that the age of the Hat Creek Basalt is thus firmly bracketed between ~15 ka and 38±7 ka, we attempted to date this low-potassium tholeiitic basalt directly. One sample produced $^{40}Ar/^{39}Ar$ data that cannot be interpreted, but a second sample (0.17% K_2O) yielded concordant plateau, integrated (total fusion), and isochron ages of 31±17 ka, 30±20 ka, and 24±6 ka; within the time bracket determined by stratigraphic relations. These data indicate that samples of latest Pleistocene tholeiitic basalt with very low K_2O can give useful $^{40}Ar/^{39}Ar$ ages. As with all isotopically determined ages, the confidence of the results are significantly enhanced when additional constraints imposed by other isotopic ages within a stratigraphic context are taken into account.

V32D-1052 1330h POSTER

Evolution of the Krafla Central Volcano, North Volcanic Zone, Iceland

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The Krafla central volcano forms a low, broad shield c. 25 km in diameter astride the on land extension of the Mid-Atlantic Ridge in northern Iceland, with an 8 by 10 km caldera in its center. Recent volcanic activity (including the 1724-1729 Myvatn and 1975-1984 Krafla fires, respectively) and an extensive high temperature geothermal area under the summit region (340 deg C at 2 km depth) attest to the active nature of the volcanic system. The purpose of this study was to use high precision Ar/Ar techniques to document the temporal evolution of this important natural resource in Iceland (including a geothermal-powered 60 MW of generated electricity). Sixteen samples were chosen for initial analysis. Eight (4 of 10 basalts, 4 of 5 rhyolites) yielded useful age information, i.e., better than 1% precision on rhyolite and 3-10 k.y. precision basalt, and span the entire stratigraphic succession at Krafla. The ages show for the first time that (1) an Icelandic central volcano evolves in less than c. 250 k.y., (2) the caldera collapse and welded ash-fall tuff formed at c. 110 ka, and (3) the complicated glacial-interglacial volcanic stratigraphy of the system is consistent with known climatic records. However, the ages of several tall (600-800 m), subglacially erupted rhyolite domes suggest that the ice thickness around Krafla at c. 90 ka was significantly greater than previously thought. Also, the central caldera collapse feature has undergone 1-2 km of extension since formation, suggesting that 50-100

V32D-1053 1330h POSTER

Multiple Lava Types Erupted Over Short Spatial and Temporal Scales at the Southern East Pacific Rise: 17°23'-17°35'S

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Major, trace element and U-series disequilibria data reveal both short- and long-term compositional heterogeneity in lavas from the southern EPR 17°23'-17°35'S. Major-element compositional variation in the ~18km-long Aldo-Kihi flow (MgO 7.7-8.4 wt %) is consistent with shallow-level fractional crystallization. $(^{230}Th)/(^{238}U)$ disequilibria for samples from the Aldo-Kihi flow cover a narrow range of 1.85±0.15. However, the range of Th/U ratios (2.61-2.84) and $(^{226}Ra)/(^{230}Th)$ disequilibria (2.26-2.65) are very broad for a single eruptive unit and cannot be a result of shallow-level fractional crystallization of a single magma composition. MgO contents, Th/U ratios, and $(^{226}Ra)/(^{230}Th)$ disequilibria for Aldo-Kihi samples all peak at ~17°30.6'S and generally are greater for samples south of 17°30'S implying that more than one magmatic component has contributed to this lava flow. This along-axis compositional diversity is hard to reconcile with propagation of a dike originating from a small area, and suggests vertical eruption from a magma chamber that is compositionally zoned along-axis. Along this ~22km-long section of the southern EPR, major, trace element and U-series disequilibria data indicate that at least six compositionally distinct lava types are present within 1km of the axis. $(^{210}Pb)/(^{226}Ra)$ deficits of ~5 % for the Aldo-Kihi lava and two other compositionally distinct units suggest they are substantially younger than ~100 yrs. Although geologic relationships demonstrate that Aldo-Kihi is the youngest of these, the range of $(^{210}Pb)/(^{230}Ra)$ disequilibria for the individual units overlap making relative age determinations impossible using that criteria alone. Regional trends in major-element data show that twenty-three other samples older than Aldo-Kihi contain >8.0 wt % MgO; all but two occur south of 17°28.4'S suggesting that the location of hottest sub-axial magma is a long-lived feature of this region. The distribution of rock types in this area requires a complex history of mantle melting, recharge, cooling, and eruption that varies considerably over along-axis distances of ~22 kilometers and between successive eruptions.

V32D-1054 1330h POSTER

A new Geochronological and Geochemical Study of the Mt. Amiata Volcano (Tuscany Province, Italy)

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Mt. Amiata (1738 m a.s.l.) is the least known of the major volcanoes of Central Italy. It is the youngest (Late Pleistocene) and the southernmost volcanic complex of the Tuscan Magmatic Province (TMP). Built between 300ka and 180ka over a horst bounded to the west by the Siena-Radicofani graben, Mt. Amiata consists essentially of felsic effusive products erupted from a set of ENE-WSW fractures and covering an area of 85km2. Mt. Amiata products are grouped in 3 main units: the Basal Trachydacitic Complex (BTC), the Domes and Lava Flows Complex (DLC), and the final Olivine Latitic Lava flows (OLL). The origin of BTC

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is controversial: either a lava flow-unit or a pyroclastic flow (rheoignimbrite or ignimbrite) has been suggested. The chaotic aspect of the flow, highly fragmented crystals and flow-like texture of the glassy groundmass, suggest an ignimbrite flow; however, the massive and homogeneous aspect of this unit, and the lack of welded blocks, rather suggests a lava flow. Whatever the origin, observed flow banding structures indicates that the BTC emplaced at high temperature. We performed a geochronological (K-Ar; "Cassignol-Gillot" technique) and geochemical study to trace the magmatic evolution of Mt. Amiata, and discuss it in the context of the TMP. Preliminary K-Ar ages show that the BTC emplaced quickly, in less than 10,000 yrs, between 294ka±4ka and 283ka±5ka, covering more than 90km2 and reaching a volume of 18km2. After 15,000 yrs of apparent quiescence, DLC emplaced between 268±5ka and 200±11ka, differing from previous results that restrained this episode at 200±10ka. The final latitic unit erupted at 209 ka±4ka. The erupted products of Mt. Amiata define a shoshonitic sub-alkaline serie, the rocks of the BTC and DLC being trachydacites, while the final lava flows are trachyandesites (latites). They all display Nb-Ta negative anomalies reflecting metasomatic events affecting their sources and/or involvement of a crustal component. Their high Th/Ta (25-27) and La/Nb ratios (> 3) indicate an IAB-type orogenic affinity. Nb/Ta ratios (9-10) are similar to crustal values. Y/Nb ratios >1.2 reflect a source chemically similar to island arc or continental margin basalts. For all these ratios, the final latites display higher values. When plotted in Rb-Yb-Ta-Y-Nb geotectonic discriminating binary diagrams, Mt. Amiata products fall in the field of syn-collision setting, with the nearby Pliocene (5.4 to 2.3 Ma) rhyolites of Roccastrada and San Vincenzo

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V32E MCC: 3008 Wednesday 1340h

Frontiers in High-Pressure Research: Earth's Deep Interior I *(joint with GP, MR, DI)*

Presiding: **P C Burnley,** Georgia State University**; S V Sinogeikin,** University of Illinois at Urbana

V32E-01 1340h INVITED

Seismic tomography and mineral physics

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Information from mineral physics is essential in interpretation of results of seismic tomography in order to interpret them in terms of dynamic processes rather than a snapshot of the state of the mantle. On occasion, seismic tomography can provide independent, *in situ*, measurement of certain quantities; this was the case with the early tomographic estimates of $d \ln v_S / d \ln v_P$ to be about 2.0, while the mineral-physics estimate was 1.3. In general, however, interpretation of velocity perturbations in terms of changes in temperature, density or composition requires input from mineral physics. Over the last 20 years there has been significant progress in seismic tomography. Examples are the discovery of the anisotropy of the inner core, the anti-correlation of the bulk-sound and shear velocities in the lower mantle, and the unique anisotropy of the Pacific plate. At this time, some of the most spectacular tomographic results remain an enigma. For example, are the Pacific and African low-velocity mega-plumes an expression of higher temperature, and therefore lighter material, or of different composition, thus perhaps being heavier. Of course, linear combinations of these two end-member interpretations are also possible. In addition to the symbiotic relationship between mineral physics and seismology, there is also an important role for geodynamics, which must show that a model can reproduce the observed results, as well as for geochemistry, which has to verify that all available information is consistent with the geochemical data.

V32E-02 1355h INVITED

Joint Modelling of Seismic, Geodynamic and Mineral Physics Data: Implications for the Origin of 3-D Density and Seismic Velocity Anomalies in the Mantle.

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Models of instantaneous (present-day) mantle dynamics provide strong constraints on the distribution and amplitude of 3-D density anomalies. In recent work [Forte, Mitrovica & Espesset, Phil. Trans., 2002], we developed models of 3-D mantle flow based on high-resolution tomographic models of global seismic shear velocity heterogeneity [e.g., Grand, Phil. Trans., 2002] which reconcile a wide variety of surface manifestations of mantle convection which include global gravity anomalies, plate tectonic motions, dynamic surface topography and the dynamic ellipticity of the core-mantle boundary. These diverse geodynamic observables provide direct constraints on the mantle density anomalies which are the driving force of the convective flow field. These density anomalies may be inferred by carrying out joint inversions of the geodynamic data sets, in which we assume a correlation between mantle density anomalies and the seismic velocity anomalies in a given tomography model. Neither the sign of the correlation (which may be positive or negative), nor the amplitude of the density anomalies is constrained to a-priori values in these inversions but are instead allowed to vary in order to provide optimal fits to the surface geodynamic data sets. The relationship between the geodynamically inferred density anomalies and seismic anomalies, when taken in conjunction with the separate mineral physical constraints on thermal and compositional derivatives [e.g., Karato, 1993; Wang & Weidner, 1996; Stacey, 1998], provide direct insights on the relative importance of thermal and chemical contributions to mantle heterogeneity [e.g., Forte & Mitrovica, Nature, 2001]. We will present the results of new density inversions employing mantle flow models based on the most recent mantle viscosity profiles derived by jointly inverting an updated and enlarged set of glacial isostatic adjustment data and mantle convection data sets [Mitrovica & Forte, 2003]. We have also devised a new and independent test of the origin of mantle heterogeneity by carrying out joint global inversions of seismic and geodynamic data [Grand & Forte, this meeting] assuming different scalings between density and seismic velocity which may be derived from mineral physics data. These hypothesis tests, as well as the direct inversions for mantle density, show a simple positive correlation between seismic shear velocity and density which is in accord with a dominant thermal origin for this heterogeneity.

V32E-03 1410h

Seismic mantle discontinuities and mineral physics

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Seismologists have been successful in measuring Clapeyron slopes for the transition zone discontinuities at 410 and 660 km depths; these are in approximate agreement with phase transitions in olivine. Clapeyron slopes are key to explaining the seismic discontinuities as either manifestations of phase transitions or of other mineral physical processes. Such observations place constraints on the thermal, compositional and physical state of the Earth's mantle and provide critical information able to distinguish between competing hypotheses concerning the upper mantle and transition zone reflectors. Here we extend the measurement of Clapeyron slopes to upper mantle discontinuities, in particular the Lehmann discontinuity at approximately 220 km depth, and seek to interpret the results in terms of mineral physics. We find that the Lehmann discontinuity is characterized by a regionally varying negative seismological Clapeyron slope. Reflections from greater depths (250-350 km) are required to possess a large negative seismological Clapeyron slope. In seeking mineralogical explanations of the Lehmann and X-discontinuities, we can reject hypotheses in disagreement with these observations. Of hypotheses proposed in the literature to account for the Lehmann discontinuity, only a transition in deformation mechanism from dislocation to diffusion creep has the required behavior. In the case of the X-discontinuity we are not aware of mechanisms having the observed characteristics. In addition, we show detailed seismic observations of the weak transition zone discontinuity at 520 km depth. In many regions we have confirmed the existence of a discontinuity at 520 km depth, but there are a number of regions in which we found two discontinuities at about 500 and 560 km depth, an effect which can be interpreted as 'splitting' of the discontinuity. These observations cannot be explained as the single effect of the olivine transition from the β-phase to the γ-phase, and the non-olivine transition from garnet to Ca-rich perovskite needs to be considered as well. Local variations in minor phases containing Fe, Ca and H_20 will probably also be needed to explain the regional variability in the seismic observations. This shows that mantle transition zone is less homogeneous than is generally assumed.

V32E-04 1425h

Generation of pressures exceeding 50 GPa in multianvil apparatus and some applications to lower mantle mineralogy

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We have been working to extend the pressure range available in Kawai-type multianvil apparatus using sintered diamond composites for the second stage anvils. Pressure was evaluated by unit-cell volume changes in some reference materials, based on in situ X-ray diffraction measurements using synchrotron radiation at SPring-8. Pressures to 55 GPa at room temperature has so far been produced in a cell assembly for anvils with TEL=1.5 mm, using the newly installed multi-anvil apparatus (SPEED-MkII) at BL04B1. Pressures greater than this may be available within the capacity of this apparatus by further modifications of the high-pressure cell. Phase transitions and P-V-T relations of some minerals relevant to the mantle and subducted crust lithologies, such as CaSiO3 perovakite, MgAl2O4 calcium ferrite, KAlSi3O8 hollandite, etc., have been successfully studied at pressures to 40 GPa, and temperatures to 2000K, equivalent to depths of 1200 km in the lower mantle, using the in situ X-ray diffraction measurements.

V32E-05 1440h

What do we Really Know About the Elastic Properties of Garnets at Upper Mantle Pressures?

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Garnets are a major constituent of the Earth's upper mantle. Detailed understanding of their elastic properties is essential for interpretation of seismic velocity profiles of the mantle. Garnets exhibit a wide compositional range and the elasticity of garnets have been studied far more extensively than any other mineral group. At ambient pressure, there is good agreement in both individual and aggregate elastic properties among various studies using different experimental techniques. At high pressures, however, there are drastic disagreements (up to 50% or more) in reported pressure derivatives of the bulk and shear modulus for a given composition. The magnitude of this effect completely precludes any assessment of high-pressure compositional effects using the current data set, and introduces considerable uncertainty in interpretation of features such as the transition zone seismic velocity gradient. To address these problems, we have carried out detailed single-crystal elasticity measurements on andradite ($Ca_3Fe_2Si_3O_{12}$), grossular ($Ca_3Al_2Si_3O_{12}$), and almandine-pyrope ($(Fe,Mg)_3Al_2Si_3O_{12}$) garnets to pressures in excess of 11 GPa by Brillouin spectroscopy. In these studies we have paid careful attention to sources of systematic error (e.g., vignetting), compositional heterogeneity, and have maintained strictly hydrostatic conditions in the diamond anvil cell. For the andradite-rich garnet (An98Gr2) we obtain K = 155 GPa, K' = 4.7, G = 90 GPa, and G' = 1.3. For the grossular-rich garnet (Gr87An9Py2Alm2), we obtain K = 165 GPa, K' = 3.8, G = 104 GPa, G' = 1.1. For the almandine-pyrope garnet (Alm72Py20Sp3Gr3An2), we obtain K = 175 GPa, K' = 4.7, G = 96 GPa, G' = 1.4. Compression curves derived from our results are generally consistent with static data under hydrostatic conditions, and the effects of non-hydrostaticity on previous static compression data can be identified. Our results allow us to assess the effects at high pressure of Fe-Al substitution on the octahedral site in andradite-grossular and in combination with earlier Brillouin scattering data for pyrope (Sinogeiken and Bass, 2000), the effect of