$\sim$ 2.3 $\times$ 10^{20} Nm, has a rupture length of $\sim$65 km and assuming a rupture width of 15 km, has an average slip of $\sim$8 m with a stress drop of $\sim$90 bars. Most of the aftershocks cluster next to the dominant asperity, near the eastern bifurcation of the Kunlun fault. For such a large event, few moderate sized aftershocks were recorded and all of them have thrust or normal focal mechanisms rather than strike-slip. This suggests a high degree of complexity for the mainshock. Correlation of the rupture characteristics with other earthquakes, the amount of radiated seismic energy, and the mainshock to largest aftershock energy ratio support an interplate earthquake classification for this event.

S72E-06 1630h

Detection and location of slow seismic sources using surface waves

Göran Ekström[1] (ekstrom@seismology.harvard.edu)

Meredith Nettles[1] (nettles@eps.harvard.edu)

[1]Department of Earth and Planetary Sciences, Harvard University, 20 Oxford Street, Cambridge, MA 02138, United States

The vast majority of earthquakes follow a remarkably simple scaling relationship such that the source duration is proportional to the cube root of the seismic moment. Only a very small number of slow seismic events of significant size ($M_W \geq 5$) deviating from this relationship have been identified. The dearth of slow events may in part be a consequence of the traditional practice of detecting, locating, and assigning magnitudes to earthquakes using high-frequency seismograms. Systematic analysis of longer-period seismic waves may lead to the identification of previously undetected slow events. The recently discovered continuous excitation of the Earth's fundamental normal modes generates a noise threshold that prevents single-station detection of surface waves from smaller events at long periods. To extract a buried long-period signal in the seismograms, a stacking technique is required. We have developed a method of surface-wave cross correlation and stacking to search for seismic events using near-real-time data from the GSN. Given a test location, seismograms are corrected for propagation effects to each station in the network. The envelopes of the resulting waveforms are stacked and cross correlated with a model wavelet to determine whether an event has been detected. For a detection, maximizing the cross correlation as a function of latitude and longitude leads to the determination of an origin time and location. Regular shallow earthquakes of $M_W > 5$ are commonly located to within $\sim$ 50 km using the new surface-wave method. Off-line application of the technique to GSN data from July and August of 2000 leads to the detection of numerous slow earthquakes with $M_W = 4.5$–5.7 associated with the caldera collapse on Miyake Island, Japan; these events were not identified by traditional short-period techniques, and do not appear in global earthquake catalogs. A magmatic mechanism has been proposed for the source process of these events, but a tectonic explanation in terms of complex slip on a circular caldera fault is a viable alternative.

S72E-07 1645h

Teleseismic Analysis of the 2001 Kunlun Earthquake and the Comparison with Field Observations

Masayuki Kikuchi[1] (81-3-5841-5764; kikuchi@eri.u-tokyo.ac.jp)

Aiming Lin[2] (slin@ipc.shizuoka.ac.jp)

[1]Earthquake Research Institute, University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-0032, Japan

[2]Institute of Geoscience, Shizuoka University, 836 Oya, Shizuoka 422-8529, Japan

A largest class inland-earthquake occurred on Nov. 14, 2001 in the Central Kunlun mountain area. About 400 km long surface rupture with strike-slip was observed along the pre-existing Kunlun fault. To investigate the source rupture process, we retrieved body wave records at teleseismic distances from IRIS-DMC. The observed records are highly complex, indicating a multiple shock nature. Thus, we first carried out the iterative deconvolution to derive discrete subevents with variable mechanisms. The derived mechanisms were nearly pure strike-slips and remained almost unchanged during the source process. Thus, we next modeled the source process by faulting on a fixed fault plane to estimate the spatio-temporal distribution of the moment release. Then the initial break and the rupture front velocity were determined by a grid search manner.

The results indicate that a rupture propagated mainly to the east in a unilateral manner. The mechanism for the total source is a nearly pure strike-slip: (strike, dip, rake)=(96, 86, 1). The total length amounts to 360 km: 330 km to the east and 30 km to the west from the relocated epicenter: (36.01N, 91.10E). There are two distinct slip areas (asperities). The largest dislocation is 6.6 m at about 220 km east from the epicenter. The overall pattern of moment-release distribution is very well consistent with that observed in the field. The total seismic moment is 6.6e20 Nm (Mw 7.8). The averaged stress drop is 1.4 MPa, while the local stress drop on the asperity is about 7 MPa, indicating that relatively narrow regions possess a strong coupling which prevented aseismic slip there. The rupture front velocity is 3.4 km/s, as large as the S wave velocity. This may suggest that faulting on the asperity was triggered by S wave arrival from the initial break rather than a rupture propagation.

S11A MCC: Hall C Monday 0830h

Plumes, Hot Spots, and Calderas III Posters *(joint with G, GP, OS, T, V, DI)*

***Presiding:* G R Foulger,** University of Durham**; G Waite,** University of Utah

S11A-1098 0830h POSTER

Interaction of the lithosphere with mantle plume material

Norman H Sleep (650-723-0882; norm@geo.stanford.edu)

Stanford University, Department of Geophysics, Stanford, CA 94305, United States

Mantle plumes impinge on the base of the lithosphere and produce primary hotspots above the plume and secondary hotspots where buoyant plume material flows along the base of the lithosphere. Variations in lithospheric thickness associated with plate age form an upside-down drainage pattern. Secondary hotspots occur from pressure-release melting above flowing material between plumes and ridge-axes and above ponded material at ridge axes. However, when viewed in detail, this process is not straightforward. One might expect prominent secondary hotspots where plume material cascades over the lithospheric relief associated with fracture zones. Instead, volcanic edifices do not occur preferentially in these locations on old crust. This lack of correlation results because even weak stagnant-lid convection (5-10 mW m-2) causes the step in lithospheric thickness to prograde to the old side of the fracture zone over time. A second phenomenon is that hotspot tracks appear to jump from off-axis chains to on-axis hotspots. An example is the gap between the New England and Corner seamounts. These features result from the intraplate membrane stress on the ascent of dikes toward the surface. The thickness of off-axis ponded material, which tends to put the off-axis lithosphere into membrane tension, decreases when a hotspot approaches the axis. The thickness of plume material ponded at the axis increases, tending to put the off-axis region near the plume into membrane compression. The net effect is that intraplate compression shuts down the off-axis hotspot by inhibiting dikes at about the time that the on-axis hotspot becomes active.

S11A-1099 0830h POSTER

Plumes do not Exist: Plate Circulation is Confined to Upper Mantle

Warren B. Hamilton (3033842047; whamilto@mines.edu)

Dept. of Geophysics, Colorado School of Mines, Golden, CO 80401, United States

Plumes from deep mantle are widely conjectured to define an absolute reference frame, inaugurate rifting, drive plates, and profoundly modify oceans and continents. Mantle properties and composition are assumed to be whatever enables plumes. Nevertheless, purported critical evidence for plume speculation is false, and all data are better interpreted without plumes. Plume fantasies are made ever more complex and ad hoc to evade contradictory data, and have no predictive value because plumes do not exist. All plume conjecture derives from Hawaii and the guess that the Emperor-Hawaii inflection records a 60-degree change in Pacific plate direction at 45 Ma. Paleomagnetic latitudes and smooth Pacific spreading patterns disprove any such change. Rationales for other fixed plumes collapse when tested, and hypotheses of jumping, splitting, and gyrating plumes are specious. Thermal and physical properties of Hawaiian lithosphere falsify plume predictions. Purported tomographic support elsewhere represents artifacts and misleading presentations. Asthenosphere is everywhere near solidus temperature, so melt needs a tensional setting for egress but not local heat. Gradational and inconsistent contrasts between MORB and OIB are as required by depth-varying melt generation and behavior in contrasted settings and do not indicate systematically unlike sources. MORB melts rise, with minimal reaction, through hot asthenosphere, whereas OIB melts react with cool lithosphere, and lose mass, by crystallizing refractories and retaining and assimilating fusibles. The unfractionated lower mantle of plume conjecture is contrary to cosmologic and thermodynamic data, for mantle below 660 km is more refractory than that above.

Subduction, due to density inversion by top-down cooling that forms oceanic lithosphere, drives plate tectonics and upper-mantle circulation. It organizes plate motions and lithosphere stress, which controls plate boundaries and volcanic chains. Hinge rollback is the key to kinematics. Arcs advance and collide, fast-spreading Pacific shrinks, etc. A fore-arc basin atop an overriding plate shows that hinge and non-shortening plate front there track together: velocities of rollback and advance are equal. Convergence velocity commonly also equals rollback velocity but often is greater. Slabs sinking broadside push upper mantle back under incoming plates and force rapid Pacific spreading, whereas overriding plates flow forward with retreating hinges. Backarc basins open behind island arcs migrating with hinges. Slabs settle on uncrossable 660-km discontinuity. (Contrary tomographic claims reflect sampling and smearing artifacts, notably due to along-slab ray-paths.) Plates advance over sunken slabs and mantle displaced rearward by them, and ridges spread where advancing plates pull away. Ridges migrate over asthenosphere, producing geophysical and bathymetric asymmetry, and tap fresh asthenosphere into which slab material is recycled upward. Sluggish deep-mantle circulation is decoupled from rapid upper-mantle circulation, so plate motions can be referenced to semistable lower mantle. Global plate motions make kinematic sense if Antarctica, almost ringed by departing ridges and varying little in Cenozoic paleomagnetic position, is stationary: hinges roll back, ridges migrate, and directions and velocities of plate rotations accord with subduction, including sliding and crowding of oceanic lithosphere toward free edges, as the dominant drive. (The invalid hotspot and no-net-rotation frames minimize motions of hinges and ridges, and their plate motions lack kinematic sense.) Northern Eurasia also is almost stationary, Africa rotates very slowly counterclockwise toward Aegean and Zagros, Pacific plate races toward surface-exit subduction systems, etc.

S11A-1100 0830h POSTER

Shear-Wave Anisotropy at the Yellowstone Hotspot

Greg Waite[1] (gpwaite@mines.utah.edu)

Derek Schutt[2] (schutt@dtm.ciw.edu)

Robert B Smith[1] (rbsmith@mines.utah.edu)

[1]Department of Geology and Geophysics, University of Utah, 135 S. 1460 E., Salt Lake City, UT 84112, United States

[2]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, NW, Washington, DC 20015, United States

Several features of the 800-km long Yellowstone-Snake River Plain volcanic system can be explained by the steady motion of the North American lithosphere over a hotspot source, often thought to originate from a mantle plume. A 10 m geoid high centered on Yellowstone, a series of progressively older calderas that track the southwestern motion of the North America Plate, and a parabolic pattern of high topography, seismicity, and active faulting around the eastern Snake River Plain are consistent with a model in which buoyant plume material flattens against the moving lithosphere. We examine the upper mantle strain field in the Yellowstone region using shear-wave splitting measurements of teleseismic core phases (SKS, SKKS, and PKS). The teleseismic data were recorded at six permanent USNSN stations and a temporary array of 47 IRIS-PASSCAL seismographs deployed in a 300 km by 500 km area centered on Yellowstone.

The shear-wave splitting fast polarization directions are dominantly aligned parallel to the direction of North America Plate motion. While the fast polarization directions are not as coherent as those observed farther down the Snake River Plain to the southwest, there is no clear evidence for the divergent mantle flow commonly expected to be produced as a plume interacts with the lithosphere. It is possible that near the plume top, the overturn of material from the plume-plate interaction would not align olivine, and thus produce a region of no anisotropy. However, the largest split times of more than 2 sec are observed at the stations located within the present-day Yellowstone caldera, implying no cornerflow. The average delay time at stations outside the caldera is 0.9 sec. The splitting data are consistent with deformation from shearing by the North America Plate. In addition, upper mantle flow velocity may be parallel to the direction of plate motion as indicated by some global-scale models. There may also be significant lithospheric anisotropy related to several large-scale Precambrian tectonic features which trend northeast-southwest roughly parallel to the direction of plate motion and fast shear-wave polarization.

S11A-1101 0830h POSTER

Tomography of Yellowstone

Jason A Crosswhite[1] (jason@newberry.uoregon.edu)

Gene Humphreys[1] (gene@newberry.uoregon.edu)

[1]University Of Oregon, 1272 University of Oregon, Eugene, OR 97403-1272, United States

Seventy-five seismometers were deployed for approximately one year over the Yellowstone region of the western United States. Sites were spaced approximately 75 km apart in a two dimensional array, creating roughly 700 km of aperature.

Delay times from teleseismic P-waves are late over Yellowstone and the Snake River Plane, and are early to the northwest and southeast. North of Yellowstone, in central Montana, arrivals average slightly delayed. A sharp boundary between the late arrivals over Yellowstone and the early arrivals around it imply a relatively shallow volume of low velocity upper mantle. Tomographic inversions show very low velocities extend to approximately 150 km. More careful analysis of these data continue.

URL: http://darkwing.uoregon.edu/~jacrossw

S11A-1102 0830h POSTER

Mantle transition zone thickness beneath the Yellowstone hotspot

Brian D Zurek[1] (307-766-3363; zurek@uwyo.edu)

Ken Dueker[1] (307-766-2657; dueker@uwyo.edu)

[1]University of Wyoming - Dept of Geology and Geophysics, PO Box 3006, Laramie, WY 82071-3006

The Yellowstone hotspot is one of the largest continental hotspots, however whether the hotspot actively derives from a lower mantle plume or an upper mantle convective instability is not constrained. The plume model is supported by the 2-3 cm/yr volcanic age progression approximately parallel to the absolute North American plate motion and an elevated He3/He4 signature. Correspondingly, evidence against a plume model derives from the lack of dynamic topographic uplift (Lowry et al., 1998), absence of a low velocity anomaly below 200 km depth (Dueker et al., 2001) and shear-wave splits that show no plume related flow anomalies (Waite et al., 2002).

To better constrain the origin of the hotspot, The Yellowstone Intermountain Seismic Array (YISA) with 47 PASSCAL broad-band seismometers was deployed for one year covering a region 250 km in radius from the center of the Yellowstone hotspot. Here we present images of the mantle transition zone from receiver function common conversion point imaging. Lateral velocity heterogeneity corrections are applied to the receiver functions using the teleseismic P-times calculated from the array.

The mantle transition zone is composed of the 410 and 660 km discontinuities, these discontinuities are generally regarded to derive from phase changes that have opposite Clapeyron slopes. Thus if the mantle is assumed to be compositional homogenous, >100 degree lateral thermal gradients are resolvable from transition zone thickness maps. Preliminary results show that the transition zone beneath the Yellowstone hotspot has a mean thickness of 245 km with 20 km of variation across the array. The mean values of the 410 and 660 km discontinuities are, 412 km and 660 km, with 16 and 14 km of topography, respectively. The processes that could produce this topography are the focus of our current research.

S11A-1103 0830h POSTER

Dynamics of Melting Applied to the Yellowstone Hotspot Track: Plume vs. no Plume

John W Hernlund[1] (hernlund@ess.ucla.edu)

Paul J Tackley[1] (ptackley@ess.ucla.edu)

[1]Department of Earth and Space Sciences, UCLA, 3806 Geology Building Box 951567, Los Angeles, CA 90095-1567, United States

Seismic investigations of the Salt River Plain show that the axis of the Yellowstone hotspot track is underlain by a low velocity zone that is flanked on either side by high velocity material. If the structure along a hotspot track were produced by a deep-seated plume, then thermal effects alone would produce a broad slow velocity region. An alternative mechanism for generating small-scale volcanism is runaway asthenospheric instabilities driven by melt and residuum buoyancy [Tackley and Stevenson, 1993] and investigated recently using three-dimensional numerical modeling. In this scenario, the slow region is produced by the presence of partial melt, while the high velocity regions are produced by the pushing aside of melt-depleted residuum. Under the influence of plate motion, such small-scale convective instabilities tend to form rolls and align themselves in the direction of plate motion, and so present an attractive alternative to the plume hypothesis for the origin of hot spots. Special conditions are required, however, for this mechanism to exhibit time-progression similar to that observed along the Yellowstone hotspot track, whereas this time progression is generated simply by a deep-seated plume. We have conducted three-dimensional fluid dynamical simulations of both scenarios including the effects of plate motion, lithospheric extension, melt and depletion buoyancy. The presence of melt and depleted residuum are mapped into seismic velocities and can then be compared with one another and also with the seismic results. Preliminary results indicate that the two mechanisms may be difficult to distinguish on the basis of seismic structure, although the effect produced by a deep-seated plume can be stronger and more focused than that produced by melt-driven instability alone because additional thermal buoyancy supplied by the plume aids in pushing aside depleted residuum.

S11A-1104 0830h POSTER

GPS-Derived Models of Intraplate Deformation of the Yellowstone Hotspot

Christine M Puskas[1] (801-581-7856; cmpuskas@mines.utah.edu)

Robert B Smith[1] (801-581-7129; rbsmith@mines.utah.edu)

Charles M Meertens[1] (303-497-8011; chuckm@unavco.ucar.edu)

[1]University of Utah, 706 WBB, Salt Lake City, UT 84112, United States

The 800-km long Yellowstone-Snake River Plain (YSRP) is interpreted to be the track of the Yellowstone hotspot. It has experienced over 150 giant silicic volcanic eruptions in the last 16 Ma from magmatic sources derived from interaction of the N. American Plate with a mantle heat source. GPS measurements at more than 170 temporary stations and 10 continuous sites were made between 1987 and the present to assess the kinematic deformation field. The GPS observations cover a 800 by 600 km area affected by the volcanic system and are used to constrain kinematic and dynamic models. The present center of YSRP volcanic activity, at the Yellowstone Plateau, exhibits extensive earthquake activity and anomalously high rates of crustal deformation of $\sim$4 mm/yr SW extension. In contrast, the hotspot track along the eastern Snake River Plain has much lower displacement rates of $\sim$2 mm/yr SW extension. GPS-derived principal strain rate fields for the entire YSRP reveal rotation of the extensional strain axes from N-S to E-W at Yellowstone. This change corresponds to similar directions for tensional stress axes derived from focal mechanisms, post-caldera vent alignments, and active faults. The YSRP deformation field is compared with other geodetic, geologic, and seismic observations of the strain field for western North America to examine how it fits into the plate boundary framework. Finite-element models of the resolved deformation incorporate GPS rates, fault slip rates, volcanic features, seismicity, etc. These models suggest compression of the Snake River Plain, which apparently deforms as a single block within the resolution of the GPS data. Higher displacement rates at the Yellowstone caldera are likely due to local volcanic activity combined with with regional extension, for regional extension rates alone do not account for the observed rates. Volcanic acitivity has reworked the topography, enhanced heat flow, and modified lithosphere composition through melting and magmatic intrusions, and must be accounted for in geodynamic models. Key questions that will be addressed in the modeling are: What are the mechanisms for the rotation of strain axes at Yellowstone? How do the YSRP deformation rates and consequently stress rates fit into the western North America intraplate motions? What do the observed displacement rates imply about the mechanical properties of the YSRP lithosphere? and Can we resolve plume-plate interaction stresses at the earth's surface?

S11A-1105 0830h POSTER

Sharp variations in upper mantle structure beneath the Gulf of California

Teh-Ru Alex Song[1] (alex@gps.caltech.edu)

Siado Ni[1] (stone@gps.caltech.edu)

Donald V. Helmberger[1] (helm@gps.caltech.edu)

[1]Seismological Laboratory, Division of Geological and Planetary Science, California Institute of Technology, Pasadena, CA 91125, United States

Broadband upper mantle triplication data recorded on TriNet from distant East-Pacific Rise events can be modeled very well with the 1-D TNA model containing a thin lid. However, the direct S triplication data from events along the Mexican coast sampling beneath the Gulf of California display very rapid variation. We use Love wave to constrain shallow structure which appear quite uniform and match absolute arrival time of S before modeling the triplication from 410. In general, a thinner lid is needed to model data recorded at stations near Owens Valley compared to other stations. Stations along the eastern edge of California show the CD branch (410) crossing the AB branch (upper mantle) near 18^o as in TNA. Coastal stations display this cross-over at 16.5^o. Considerable amplitude difference between AB and CD and timing differentials exist over this large dataset indicating a strong deep velocity anomaly. Following previous receiver function analysis in other regions, sharp variation in topography of 410 discontinuity is a possible scenario with variation of 40 km over distance of about 50-100 km. However, P-wave triplication data while supporting such rapid variations as observed in S indicates smaller depth changes. This feature suggests possible localized low velocity zones below 350 km which cause larger changes in S-velocity than in P-velocity. Some preliminary synthetics generated from 2-D cross-sections will be presented to test various possibilities and model the data.

S11A-1106 0830h POSTER

Long Valley caldera GIS Database

Meredith J Williams[1] (mjwilliams@stanford.edu)

Maurizio Battaglia[2] (battag@pangea.stanford.edu)

David Hill[3] (hill@andreas.wr.usgs.gov)

John Langbein[3] (langbein@shasta.wr.usgs.gov)

Paul Segall[2] (segall@pangea.stanford.edu)

[1]Stanford University, Branner Earth Sciences Library 397 Panama Mall, Stanford, CA 94305-2211, United States

[2]Department of Geophysics, Stanford University, Stanford, CA 94305-2215, United States

[3]US Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, United States

In May of 1980, a strong earthquake swarm that included four magnitude 6 earthquakes struck the southern margin of Long Valley Caldera associated with a 25-cm, dome-shaped uplift of the caldera floor. These events marked the onset of the latest period of caldera unrest that continues to this day. This ongoing unrest includes recurring earthquake swarms and continued dome-shaped uplift of the central section of the caldera (the resurgent dome) accompanied by changes in thermal springs and gas emissions. Analysis of combined gravity and geodetic data confirms the intrusion of silicic magma beneath Long Valley caldera.

In 1982, the U.S. Geological Survey under the Volcano Hazards Program began an intensive effort to monitor and study geologic unrest in Long Valley Caldera. This database provides an overview of the studies being conducted by the Long Valley Observatory in Eastern California from 1975 to 2000. The database includes geological, monitoring and topographic datasets related to the Long Valley Caldera, plus a number of USGS publications on Long Valley (e.g., fact-sheets, references). Datasets are available as text files or ArcView shapefiles.

Database CD-ROM Table of Contents:

- Geological data (digital geologic map)
- Monitoring data: Deformation (EDM, GPS, Leveling); Earthquakes; Gravity; Hydrologic; CO2
- Topographic data: DEM, DRG, Landsat 7, Rivers, Roads, Water Bodies
- ArcView Project File

URL: http://www.seismo.berkeley.edu/~battag/LVO_GIS/intro.html

S

S11A-1107 0830h POSTER

Constraints on the Upper Mantle Viscosity From 3-D Numerical Modeling of the Hawaiian Swell Topography

Jeroen van Hunen[1] (303-492-0985; hunen@colorado.edu)

Shijie Zhong[1] (303-735-5095; zhong@spice.colorado.edu)

[1]University of Colorado at Boulder, Department of Physics, Campus Box 390, Boulder, CO 80309, United States

The seafloor topography around the Hawaiian islands is related to the dynamics of a rising plume. An approximately 1000 km wide bathymetric swell around the Hawaiian chain is a direct indication of the buoyancy of sublithospheric plume material. The size of this swell is a result of the competing effects of the input of new plume material from below, and the advection of this material by the moving overlying oceanic lithosphere. Lubrication theory has been invoked to describe the dynamics of the spreading upwelling plume material below the moving lithosphere. This theory

assumes that the rheology of the swell material determines the spreading rate, and therefore the swell shape. In this study, we examine whether the behavior of the cooler, and therefore stronger, asthenopheric material around the swell also contributes significantly, and maybe predominantly to this spreading.

We use a 3-D numerical model to relate the plume dynamics to the surface topography. Analysis of a large set of model calculations enabled us to predict the numerically obtained plume buoyancy flux F as a function of the plume excess temperature ΔT, the plume tail radius R_p, and the rheological flow parameters E^* and η_0 in the following theoretically derived simple scaling law: $F \propto \eta_0^a R_p^b \Delta T^c \exp(d \Delta T E^*)$, where the scaling parameters a, b, c, and d fit best the values -1.2, 3.4, 2.2, and 1.2×10^{-5}, respectively. The scaling law predicts the buoyancy flux of a model calculation within 10% correct over an order of magnitude flux range, which enables us to perform a set of experiments for the expected plume buoyancy range of the Hawaiian plume.

Our model calculations suggest that, for given plume flux, the swell height H and width W near the plume are largely controlled by the E*, with smaller observed ratios H/W for larger E*. The spreading rate of the swell is predominantly a function of the asthenospheric viscosity η_{asth}, with more rapid swell widening for lower η_{asth}. Comparison of the swell shape from the model calculations to the Hawaiian swell observations enables us to limit the viable range of asthenospheric viscosity.

S11A-1108 0830h POSTER

Aftershock Decay and Productivity in Hawaii: Indicators of Temperature and Stress from Magma Sources?

Fred W Klein[1] (klein@usgs.gov)

Tom L Wright[2] (twright@usgs.gov)

Jennifer Nakata[3] (jnakata@usgs.gov)

[1]U.S. Geological Survey, 345 Middlefield Rd, Menlo Park, CA 94025, United States

[2]U.S. Geological Survey, Volcano Res. Center, Univ. of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-0032, Japan

[3]U.S. Geological Survey, Hawaii Volcano Obs., box 51, Hawaii Nat. Park, HI 96718, United States

We examined two parameters from dozens of aftershock sequences from Hawaii Island: the aftershock rate decay parameter p, and the aftershock productivity relative to a standard Hawaii sequence. Aftershock rates are assumed to follow the Gutenberg-Richter and modified Omori laws: $R(t,M) = 10^{a+b(Mm-M)} (t + c)^{-p}$. The decay parameter p ranges from 0.5 to 2.7. p-values larger than 1.2 are generally found only near active volcanic centers. We associate this high aftershock decay with higher temperatures near shallow magma reservoirs and faster stress relaxation following mainshocks. High p-values are also associated with higher temperatures in Southern California (Kisslinger and Jones, 1991) and regions of high slip (and higher heating) in some mainshocks (Weimer and Katsumata, 1999). We found a mixture of high and normal p-values near Kilauea's vertical magma conduit near 30 km depth, suggesting a range of temperatures, and that no major magma storage occurs at this depth. We also compute aftershock productivity (Ap), which we define as the ratio of the observed number of aftershocks to the number expected after a shock of the same magnitude, using the a, b, c and p values from a reference sequence, namely the 11/29/75 M=7.2 Kalapana earthquake on Kilauea's south flank. Aftershock sequences with Omori decay often are triggered by rift zone intrusions, or terminate intrusive swarms. Ap is higher than 4.0 for these flank earthquakes known to be triggered by intrusions, but is normal (0.25 to 4.0) for other mainshocks in the same areas. We infer that continuing stress from the intrusion after it ends adds to the mainshock's stress step and causes higher aftershock productivity. High Ap in two other zones suggests the mainshocks were triggered by less obvious intrusions. Rapid aftershock decay and high aftershock productivity may be two signs of high temperature and stress from dikes associated with volcanic centers.

S11A-1109 0830h POSTER

High Precision Relocations of Hawaiian Earthquakes

Cecily J. Wolfe[1] (808-956-6347; cecily@soest.hawaii.edu)

Paul G. Okubo[2] (pokubo@usgs.gov)

Peter M. Shearer[3] (pshearer@ucsd.edu)

[1]Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, 1680 East West Road, Honolulu, HI 96822, United States

[2]Hawaiian Volcano Observatory, US Geological Survey, PO Box 51, Hawaii National Park, HI 96718, United States

[3]Scripps Institution of Oceanography, University of California San Diego, IGPP 0225, La Jolla, CA 92093, United States

The abundant earthquakes in Hawaii provide key information on the nature of magmatic and tectonic processes at this oceanic hotspot. Here, we present the results of an ongoing project to study earthquakes recorded on the United States Geological Survey Hawaiian Volcano Observatory seismic network. We have applied waveform cross correlation analysis and high precision relocation to 14,605 deep (>13 km) earthquakes recorded from 1988–1998. We find about half of the analyzed earthquakes are strongly correlated multiplets that delineate fault zones in the lower crust and mantle. Relocations and focal mechanism analyses demonstrate that mantle seismicity beneath Kilauea is focused on a primary fault zone at 30-km depth, with seaward slip on a low-angle plane, and other distinct fault zones. These results refute previous suggestions that hypocenters at Kilauea outline a magma conduit through the lithosphere. Rather, we suggest deep seismicity at Kilauea reflects rupture in the brittle lithosphere away from the zone of magma movement, although the earthquakes are apparently induced by background stresses of magmatic origin. In addition to the study of deep earthquakes, we will also present the results of applying cross correlation analyses and relocations to ∼7,000 earthquakes located west of -155.5 degrees and recorded from 1988–1998. This component of our study is aimed at understanding the characteristics of faulting on the west flank of Mauna Loa.

S11A-1110 0830h POSTER

A Detailed Receiver Fuction Study of the Hawaiian Plume Conduit

Ingo Woelbern[1] (++49-331-2881265; woelbern@gfz-potsdam.de); Brian A.W. Jacob[2]; Tom A. Blake[2] (tb@cp.dias.ie); Rainer Kind[1] (kind@gfz-potsdam.de); Xueqing Li[1]; Stephan V. Sobolev[1]; Fred Duennebier[3]; Keith Priestley[4]; Michael Weber[1]

[1]GeoForschungsZentrum, Potsdam, Telegrafenberg, Haus E, Postdamm D-14473, Germany

[2]Dublin Institute for Advanced Studies, 5 Merrion Square, Dublin 2 IRL, Ireland

[3]SOEST, UNiversity of Hawaii at Manoa, Geology and Geophysics, Honolulu, HAW US, United States

[4]University of Cambridge, Department of Earth Sciences, Cambridge UK-, United Kingdom

From June 1999 to May 2001 the Dublin Institute for Advanced Studies (DIAS) and the GeoForschungsZentrum (GFZ), Potsdam, operated eleven mobile seismic broadband stations on the Hawaiian islands. In addition, a semipermanent broadband station was set up on Maui which is still operational. Our data base has been extended by using data from IRIS- and USGS stations.

We used the Receiver Function technique to investigate and to map effects and influences of the Hawaii Plume on the upper mantle discontinuities and the crust-mantle-boundary and to verify the zone of reduced velocity at 140 km depth beneath the Big Island found by Li et al. (2000).

Arrival times of Moho conversions have been used to calculate depths of the crust-matle-boundary. Moho depth decreases from about 14 km in the Northwest beneath Kauai to less than 4 km beneath the Southeast of Big Island. The low velocity zone in 140 km (Li et al., 2000) is confirmed beneath the Southwest of the Big Island. It has a 35 km radius Delay times of the mantle conversions at 410 km and 660 km have been mapped. Late arrivals are found in the entire area northwest of the Big Island. A significant thinning of the mantle transition zone has only been found southwest of the Big Island, which might indicate that the plume is penetrating the transition zone at this location.

S11A-1111 0830h POSTER

PLUME: the French Polynesian Upper Mantle Under Study

Guilhem Barruol[1,2] (guilhem.barruol@upf.pf)

Eric Debayle[3] (Eric.Debayle@eost.u-strasbg.fr)

Fabrice Fontaine[2] (Fabrice.Fontaine@dstu.univ-montp2.fr)

Dominique Reymond[4] (reymond.d@labogeo.pf)

Andrea Tommasi[2] (Andrea.Tommasi@dstu.univ-montp2.fr)

[1]Jeune Equipe Terre Ocean, CNRS, Universite de la Polynesie Francaise, BP6570, Faaa 98702, French Polynesia

[2]Laboratoire de Tectonophysique, CNRS, Universite Montpellier II, Montpellier 34095, France

[3]Ecole et Observatoire des Sciences de la Terre, CNRS, Universite Louis Pasteur, Strasbourg 67084, France

[4]Laboratoire de Geophysique, CEA, Pamatai, Faaa 98702, French Polynesia

By combining seismological observations, petrophysical and geochemical investigations of mantle xenoliths brought to the surface by the hotspot volcanism, analyses of bathymetric and gravimetric data and multi-scale numerical models, PLUME (Polynesian Lithosphere and Upper Mantle Experiment) aims to study the upper mantle structure beneath the french Polynesia. Our objectives are to image hotspots in the upper mantle and their connection with the South Pacific "superplume", to probe the large-scale mantle flow and how this flow is affected by the plumes and the lithospheric structure (e.g., fracture zones) and to investigate the plume-lithosphere interaction. Monitoring of local seismicity and T waves should be also improved, especially for the Pacific-Antarctic ridge far from the permanent seismic networks.

The LDG/CEA permanent stations in the region have been supplemented by the deployment of 9 broadband stations, started in november 2001 for a period of two years. PLUME stations cover the various archipelagos and sample three oceanic domains with lithospheric ages varying from 30 to 100 ma, separated by two oceanic transforms (the Marquesas and Australs transforms). The covered area could contains five hotspots. The first few months of records allow us to estimate the data quality and show that despite the rather high ocean-related noise, good quality data are recorded, especially at periods larger than 10 s. The abundant seismicity surrounding the Pacific plate should allow to improve significantly the resolution of tomographic images (especially for surface waves) and the seismic anisotropy database (SKS splitting and surface waves anisotropy) available in the Pacific mantle.

S11A-1112 0830h POSTER

Pitcairn Hotspot Produces Bountiful Earthquake Swarm

Valerie I. Peyton[1] (505-462-3209; valerie@asl.cr.usgs.gov)

Jonathan M. Lees[2] (919-962-0695; lees@smtp.unc.edu)

Harold Bolton[1] (505-462-3211; bolton@asl.cr.usgs.gov)

[1]USGS Albuquerque Seismological Laboratory, 801 University SE, Suite 300, Albuquerque, NM 87106-4345, United States

[2]University of North Carolina, Department of Geological Sciences CB 3315, Mitchell Hall University of North Carolina, Chapel Hill, NC 27599-3315, United States

The Pitcairn hotspot (Stoffers, et al. Marine Geology, 1990) experienced its first significant earthquake swarm in recorded history during the fall of 2001. During peak swarm activity in November 2001, the residents of Pitcairn Island felt tremors daily. Using 20Hz data from the GSN station PTCN, we have determined that the primary swarm activity began on October 4, 2001 and continued through the first week of January, 2002. Rudimentary particle motion analysis seems to indicate there are two primary sources for the swarm events: one to the southeast of Pitcairn Island and the other to the northeast. Some arrivals appear to come from due east. Pn - Sn times recorded on the island are approximately 5 seconds, giving an approximate epicentral distance of 20km. These observations agree well with the locations published by the NEIC for the two largest events of the swarm (magnitudes 4.4 and 4.6, occurring on Nov. 15 and Nov.23 of 2001), as well as a third event of magnitude 4.7, which occurred on July 24, 2002 well after the main swarm abated. The swarm itself has an unusual quiescent period that lasts at least 5 days in early December. After this period, swarm activity gradually rises to nearly the level it achieved just before the quiet period. Although the swarm had mostly abated by the beginning of January 2002, two large events were observed later in the year: a magnitude 4.7 on July 24, 2002 (PDE from the NEIC); and a magnitude 3.5 on August 9, 2002. Preliminary counting estimates indicate over 10,000 events were recorded at 20Hz by the seismometer at PTCN during the peak months of the swarm. The small events of the swarm can be grouped by their similar characteristics, indicating that there are multiple distinct sources for the small events. There also are intermittent, apparently volcanic sequences interspersed among the earthquakes. These sequences tend to last 30 minutes to 2 hours, are not large enough to be felt on the island, and occur less than once a month. Since all the swarm-related events have sources closer to the island than expected from previous studies of the Pitcairn hotspot, we propose the activity may be related to a new expression of this hotspot.

S11A-1113 0830h POSTER

Deep Mantle Origin for the DUPAL Anomaly?

Stephanie Ingle[1] (32-2-650-22-40; single@ulb.ac.be)

Dominique Weis[1,2] (dweis@eos.ubc.ca)

[1]D.S.T.E. Université Libre de Bruxelles, Ave. F. D. Roosevelt, 50 CP 160/02, Brussels B-1050, Belgium

[2]E.O.S. University of British Columbia, 6339 Stores Road, Vancouver, BC V6T 1Z4, Canada

Twenty years after the discovery of the Dupal Anomaly, its origin remains a geochemical and geophysical enigma. This anomaly is associated with the Southern Hemisphere oceanic mantle and is recognized by basalts with geochemical characteristics such as low ^{206}Pb/^{204}Pb and high ^{87}Sr/^{86}Sr. Both mid-ocean ridge basalts (MORB) and ocean island basalts (OIB) are affected, despite originating from melting at different depths and of different mantle sources. We compile geochemical data for both MORB and OIB from the three major oceans to help constrain the physical distribution and chemical composition of the Dupal Anomaly. There is a clear decrease in ^{206}Pb/^{204}Pb and an increase in ^{87}Sr/^{86}Sr with more southerly latitude for Indian MORB and OIB; these correlations are less obvious in the Atlantic and non-existent in the Pacific. The average* ^{143}Nd/^{144}Nd for Pacific and Atlantic OIB is 0.5129, but is lower for Indian OIB (0.5128). Interestingly, Pacific, Atlantic and Indian OIB all have ^{176}Hf/^{177}Hf averages of 0.2830. Indian MORB also record this phenomenon of low Nd with normal Hf isotopic compositions (Chauvel and Blichert-Toft, EPSL, 2001). Hf isotopes appear, therefore, to be a valid isotopic proxy for measuring the presence and magnitude of the Dupal Anomaly at specific locations. Wen (EPSL, 2001) reported a low-velocity layer at the D boundary beneath the Indian Ocean from which the Dupal Anomaly may originate. This hypothesis may be consistent with our compilations demonstrating that the long-lived Dupal Anomaly does not appear to be either mixing efficiently into the upper mantle or spreading to other ocean basins through time. We suggest that the Dupal source could be continually tapped by upwelling Indian Ocean mantle plumes. Plumes would then emplace pockets of Dupal material into the upper mantle and other ascending plumes might further disperse this material into the shallow asthenosphere. This could explain both the presence of the Dupal signature in MORB and OIB and the geochemical similarities between some Indian Ocean mantle plumes, such as Kerguelen, and the Dupal signature.

* To avoid sampling biases, data for each ocean island (or group) are averaged and these values are used to calculate the average for each ocean.

S11A-1114 0830h POSTER

Long-lived Seamount Volcanism in the Western Pacific, and Early Cretaceous Motion of the Pacific Plate

Naoto Hirano (+81-3-5734-2338; nhirano@geo.titech.ac.jp)

Earth and Planetary Scdience, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo 152-8551, Japan

Most seamounts, islands, and atolls on the present western Pacific Plate were formed by submarine intraplate volcanism, mainly during the Cretaceous. Some seamount chains in the West Pacific Seamount Province, including the Magellan group, define hotspot trails and plate motions. Samples of peralkaline rhyolite pillow lava and radiolarian-bearing pelagic sedimentary rocks were collected by the Japanese submersible *Shinkai6500* from Quesada Seamount (western Magellan Seamount group), on the oceanward slope of the Mariana Trench. The Ar-Ar age of the peralkaline rhyolite is 129.3±2.6 Ma, about 10 m.y. younger than the radiolarian age of the oldest intercalated tuffaceous claystone (early Berriasian: approximately 140 Ma). The claystone contains fragments of alkali-basalt glass of the shield-building volcanic stage. Because peralkaline rhyolite commonly erupts during the last stage of shield activity, volcanic activity appears to have lasted for approximately 10 m.y. at Quesada Seamount. Slow Early Cretaceous motion of the Pacific Plate permitted the Quesada edifice to remain above the source hotspot for a long time. At Hemler Seamount on the northeastern tip of Quesada Seamount, a Late Cretaceous Ar-Ar age has previously been reported for nephelinite phenocrysts in strongly alkaline basalt, which also records the rejuvenated stage of a long-lived Early Cretaceous seamount volcano. Such seamount trails can be used to calculate the absolute Early Cretaceous motion of the Pacific Plate; in addition to the Quesada to Hemler SW to NE trail, others have been previously reported from Shatsky Rise and western Mid-Pacific Mountain.

S11A-1115 0830h POSTER

The Cobb Hotspot: A Fixed Mantle Plume With MORB Geochemical Characteristics

John Chadwick[1] (chadjohn@isu.edu); Michael Perfit[2] (perfit@geology.ufl.edu); Paul Mueller[2] (mueller@geology.ufl.edu); Ian Ridley[3] (iridley@helios.cr.usgs.gov); Petrus le Roux[4] (leroux@dtm.ciw.edu); David Graham[5] (dgraham@coas.oregonstate.edu)

[1]Idaho State University, Dept. of Geological Sciences, Pocatello, ID 83209

[2]University of Florida, Dept. of Geological Sciences, Gainesville, FL 32611

[3]U.S. Geological Survey, Mineral Resources Team, Denver, CO 80225

[4]Carnegie Institute of Washington, Dept. of Terrestrial Magnetism, Washington, DC 20016

[5]Oregon State University, College of Oceanic and Atmospheric Sciences, Corvallis, OR 97331

The Cobb-Eickelberg (C-E) seamount chain, created by the Cobb hotspot, extends from the currently-active Axial Seamount astride the Juan de Fuca Ridge (JdFR) to the 33 Ma Patton Seamount near the Aleutian Trench. The C-E chain has the temporal and spatial characteristics of other hotspots, but basalts from the C-E chain do not have OIB isotopic or incompatible trace element characteristics. C-E basalts have Sr (.70237-.702614) and Nd (.513109-.513240) isotopic ratios that are within JdFR MORB ranges, and Pb (18.377-18.809, 15.404-15.521, 37.895-38.233) isotopic ratios that are only slightly elevated relative to the JdFR. C-E basalts are modestly enriched in some incompatible trace elements, particularly LREE, Sr, Nb, and K2O/TiO2, distinguishing them from JdFR MORB (south of the Endeavor Segment), but they fall within global MORB ranges. He isotopes and volatiles from Axial Seamount basalts are also MORB-like (3/4He 7.9 to 8.4 Ra,<0.25 wt.% H2O). Axial Seamount basalts are modeled to be thoroughly mixed with the JdFR MORB source (>60%), however, and may not reflect the true composition of the Cobb plume.

The radiogenic isotopic ratios of the Cobb hotspot indicate that the source of the plume must have had MORB-like depletions in incompatible elements over most of its history, and the decoupling of trace elements and radiogenic isotopes is likely due to a recent metasomatic event. Young model ages calculated for the C-E chain (<85 Ma) ostensibly show the time elapsed since the separation of the Cobb plume and MORB sources, and suggest that the plume source does not reflect a contribution from oceanic crust that has undergone a cycle of subduction, heating at the core mantle-boundary, and diapiric rise through the entire mantle. Instead, the Cobb hotspot source appears to reflect a fixed location of melting of shallow asthenospheric material.

S11A-1116 0830h POSTER

Shear-wave splitting measurements across the Eifel hotspot: A plume interpretation of the mantle strain field

Kristoffer T. Walker[1] (ktwalker@pangea.stanford.edu)

Goetz H.R. Bokelmann[1] (goetz@pangea.stanford.edu)

Simon L. Klemperer[1] (sklemp@pangea.stanford.edu)

Guenter Bock[2] (bock@gfz-potsdam.de)

[1]Dept. of Geophysics, Stanford Univ., Mitchell Building, Stanford, CA 94305-2215, United States

[2]GeoForschungsZentrum, GeoForschungsZentrum, Telegrafenberg, Potsdam 14473, Germany

Direct seismological evidence for the existence of plumes is difficult to obtain because of the dense wide-aperture array needed to image the narrow cylindrical conduit in the mantle. However, measurements of seismic anisotropy using teleseismic shear-wave splitting have the potential to illuminate the geometry of the mantle strain field around hotspots if conditions are conducive, and thus provide direct seismological evidence for the existence of plumes since mantle strain from plume/lithosphere interaction can be predicted.

We have made apparent splitting measurements across the Eifel hotspot in Western Europe, a hotspot for which a recent tomographic image showing a cylindrical low-velocity anomaly in the underlying mantle is suggestive of a plume conduit. The 7-month data set is unusual in that there is a very high station density in the greater Eifel region, which allows us to study mantle strain beneath the hotspot with high spatial resolution and reasonable confidence. In addition, we also made apparent splitting measurements for the permanent stations (operational for up to 15 years) in and around the greater Eifel region. These permanent stations serve as reference stations because they have recorded many more split shear-wave phases than stations in the Eifel array. Our measurements at these stations are consistent with those made during earlier studies by Vinnik and coworkers.

We report the finalized shear-wave splitting data set, the results of anisotropy modeling at each station, and the tectonic interpretation for the dense seismic array across the Eifel hotspot and several permanent stations in the surrounding Eifel region. In particular, we find that a parabolic asthenospheric model explains the apparent fast polarization azimuths better than any uniform azimuth expected from either (1) plate drag of a passive asthenosphere, (2) lithospheric extension associated with the Rhine graben, or (3) along-strike flow associated with one of the European orogenies. In addition, such a model allows us to estimate the absolute motion direction of the European plate with respect to the interpreted Eifel plume.

URL: http://sycamore.stanford.edu/ktwalker/Eifel

S11A-1117 0830h POSTER

Mantle Flow Around the Iceland Plume: Preliminary Results From Geodynamic and Seismic Anisotropy Models

Jennifer Georgen[1] (401-874-6684; jgeorgen@gsosun1.gso.uri.edu)

Yang Shen[1] (401-874-6848; yang@gso.uri.edu)

[1]Graduate School of Oceanography, University of Rhode Island, South Ferry Road, Narragansett, RI 02882, United States

The nature of mantle flow around an oceanic hotspot is a long-standing question in ridge-hotspot interaction studies. Plume flow channeled along the ridge axis in the shallow mantle is one end-member possibility; the other is broad, radial dispersion away from the plume conduit at greater mantle depths, without any preferential direction imparted by the strike of the mid-ocean ridge. Insight into plume dispersion patterns can come from observations of mantle anisotropy, which reveal patterns in mantle fabric and the history of mantle deformation. Measurements of shear-wave splitting [Bjarnason et al., 2002; Li and Detrick, 2002] show that fast polarization directions are generally NNW-SSE in eastern Iceland, and N-S in western Iceland. The fast directions of azimuthal anisotropy of Rayleigh waves sensitive to the shallowest upper mantle and crust are parallel to the spreading center [Li and Detrick, 2002]. While the contribution to shear-wave splitting and azimuthal anisotropy of non-plume factors (i.e., plate motion and N-S asthenospheric flow) vs plume-related factors (i.e., radial and along-axis flow) have been speculated on, geodynamic models have yet to incorporate these new observational constraints.

This study uses a combination of geodynamical and seismic modeling to predict the contribution of non-plume factors to the observed mantle anisotropy beneath Iceland. We compute a series of simple, finite element flow models, using plate motions or inferred asthenospheric flow as boundary conditions. As a first approximation, we use finite strain to estimate the spatial distribution of lattice preferred orientation (LPO) of olivine and resultant shear-wave splitting. A comparison of predictions to observations quantifies the relative importance of the contribution of various factors and isolates the classes of geodynamic models that satisfy the observed seismic anisotropy beneath Iceland.

References

Bjarnason, I. Th., P. G. Silver, G. Rumpker, S. Solomon, J. Geophys. Res., in press.

Li, A., R. S. Detrick, submitted to Science.

S

S11A-1118 0830h POSTER

Finite-Frequency Seismic Traveltime Tomography of the Iceland Mantle Plume

Shu-Huei Hung[1] (886-2-23649352; shung@ccms.ntu.edu.tw)

Yang Shen[2] (401-8746848; yang@island.gso.uri.edu)

Ling-Yun Chiao[3] (chiao@ccms.ntu.edu.tw)

[1]National Taiwan University, Department of Geosciences, Taipei 106, Taiwan

[2]University of Rhode Island, Graduate School of Oceanography, South Ferry Road, Narranganset, RI 02882, United States

[3]National Taiwan University, Institute of Oceanography, Taipei 106, Taiwan

Iceland is widely known for a ridge-centered hotspot and has been extensively studied to understand the source and dynamics of upwelling plume materials from deep mantle. Two broadband seismic experiments, ICEMELT and HOTSPOT, were undertaken to image mantle velocity structures beneath Iceland. The results include revealed a cylindrically-shaped region of low P and S wave speeds that extends from shallow upper mantle to at least 400 km and a thinner-than-normal mantle transition zone beneath central Iceland (Wolfe et al., 1997; Allen et al., 1999; Shen et al., 2000). Whether this low-velocity zone extends into deeper mantle and how deep is the melt generation zone remain unclear. One of the keys to unravel these questions is to improve the resolution of tomographic images in the deeper mantle and to determine the ratio of $\delta V_p/\delta V_s$ accurately. In ray-based regional traveltime tomography, the resolution of deep mantle velocity structures is limited because of the lack of crossing rays. However, seismic traveltimes are intrinsically finite-frequent and sensitive to 3D structures off the geometrical raypaths. Relative traveltime shifts between two nearby but non-crossing rays could "feel" overlapping heterogeneous volumes from their broadening sensitivity in deep mantle. To properly take into account such wave diffraction effects on seismic traveltimes, we measure frequency-dependent traveltime residuals by cross correlation of P (PKP) and S (SKS) waveforms filtered in three frequency bands. The unique 3D sensitivity kernels for individual arrivals are constructed for tomographic inversions of P and S-wave velocity variations beneath Iceland. Given similar data variance reductions, our preliminary results show that the magnitudes of both P and S-wave velocity perturbations derived from kernel tomography are approximately twice larger than those from ray inversion. The slow anomaly exists insistently throughout the transition zone. Resolution tests demonstrate that finite-frequency traveltimes together with 3D finite-volume kernels greatly improve resolution of deep structures in both the magnitude and geometry of a synthetic cylindrical mantle plume.

S11A-1119 0830h POSTER

A Dynamic Model of the Iceland Plume Based on Tomography

Gabriele Marquart[1] (0031 30 253 5142; marquart@geo.uu.nl)

Harro Schmeling[2] (0049 69 798 23335; schmeling@geophysik.uni-frankfurt.de)

Wim Spakman[1] (w.spakman@geo.uu.nl)

[1]Faculty of Earth Sciences, Budapestlaan 4, Utrecht 3584 CD, Netherlands

[2]Institute of Meteorology and Geophysics, Feldbergstrasse 47, Frankfurt D-60323, Germany

Iceland is the surface expression of a large thermal anomaly in the North Atlantic. Following the tomography model of Bijwaard and Spakman (1999) one finds clear indications for a deep reaching structure of low seismic velocity, stretching down to the CMB. Based on this tomography data and using a 3D Cartesian convection code we modelled the gravity field and dynamic topography in the North Atlantic. We determined the density anomaly by using a constant conversion factor and estimated the temperature anomaly by accounting for a pressure and temperature dependent thermal expansivity. We found a maximum excess temperature of about 250 C in the proposed plume, not decreasing significantly from the lower to the upper mantle. The fitting of the observed geoid anomalies in the North Atlantic by the dynamic model demands a viscosity increase from the upper to the lower mantle of not more than 1 order of magnitude. Temperature dependent viscosity improves the fit, but does not change the general finding. The best fit is obtained in the area North of Iceland, which is characterized by shallow ocean depth and high temperature anomalies at the lithosphere base. The origin of this anomaly is explained in conjunction with a thermal anomaly below the eastern part of the Greenland Shield, which may represent the ancient plume head.

S11A-1120 0830h INVITED POSTER

The Melt Anomaly at the Iceland Volcanic Province can be Explained by Mantle Fertility in the Caledonian Suture

G. R. Foulger[1] (650 329 4797; g.r.foulger@durham.ac.uk)

Don L. Anderson[2] (626 395 6901; dla@gps.caltech.edu)

James H. Natland[3] (jnatland@msn.com)

[1]University of Durham, Science Laboratories, South Rd., Durham DH1 3LE, United Kingdom

[2]California Institute of Technology, Seismological Laboratory MC 252-21, Pasadena, CA 91125, United States

[3]Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149, United States

The Iceland volcanic province may be explained by a mantle fertility anomaly associated with oceanic crust in the Caledonian suture and shallow mantle, in the midst of the broad, warm mantle region that occupies the entire north Atlantic. Contrasting styles of spreading to the north and south of the Caledonian suture, over which Iceland presently lies, have furthermore given rise to complex, unstable, leaky-microplate tectonics which encourage magmatism by providing pathways along which melt may rise. The moderate, broad, regional temperature high of the north Atlantic may be a result of earlier continental insulation. The melting of a source containing a few tens of percent of old oceanic crust in the Caledonian suture, mixed with normal mantle, can explain both the quantity of melt at Iceland and the geochemistry, including REE patterns, major elements and isotope ratios. The Caledonian suture is orientated easterly at this latitude, parallel to the direction of plate motion, and this is consistent with the constant, high rate of magmatism at this part of the MAR for the last 54 Myr. The chronic local tectonic disequilibrium in this region has featured the persistent, southward-migration of a pair of parallel, spreading axes, local variations in spreading direction and extension across easterly orientated shear zones. Such complex, transient tectonics may both encourage, and be a consequence of, high magmatism, thus comprising a positive feedback system. This hypothesis requires fewer forced explanations and contradictions than a plume model, which cannot explain many first-order observations from the Iceland region without special pleading. These include the absence of evidence for high, plume-like temperatures, the presence of a prominent volcanic zone oriented parallel to the spreading direction in Iceland, the fixity of the melt extraction anomaly over the mid-Atlantic ridge, the absence of the predicted hotspot track, the pattern of crustal thickness and the confinement of seismic velocity anomalies to the upper mantle.

S11A-1121 0830h POSTER

Mantle Source Heterogeneity in the North Atlantic Igneous Province and the Iapetus Connection

C E Lesher (530-752-9779; lesher@geology.ucdavis.edu)

Department of Geology, University of California, Davis, CA 95616, United States

The prevailing paradigm for the early Paleogene North Atlantic igneous province holds that the large volumes of basalt erupted during continental breakup were generated by decompression of the ancestral Iceland plume arriving at the base of Pangea ~60 mys ago. Based on a comparative study of the geochemistry of early Paleogene basalts from the Greenland margins, an alternative model is explored. In this model, mantle sources tapped by partial melting reflect ambient upper mantle conditions at that time, specifically lateral differences in sublithospheric mantle composition coupled with modest temperature anomalies (<100 K). Basalts from central east Greenland are dominated by tholeiites enriched in iron and titanium, strongly fractionated rare earth element ratios, low Zr/Nb ratios, and radiogenic isotope compositions corresponding to immature HIMU values. These characteristics are not shared by early Paleogene basalts erupted in southeast and west Greenland, which are instead low in titanium, depleted in incompatible trace elements and possess radiogenic isotope compositions similar to depleted OIB and MORB. Isotopic relations for basalts from central east Greenland indicate a mantle source with a mean age of ~600 Ma, while southeast and west Greenland basalts are derived from significantly older mantle (>2 Ga). Such regional differences are not readily explained by current plume models, but correspond well to the basement geology of the region. It is deemed significant that the southwestern boundary of the Caledonian front and zone of closure of the Iapetus ocean correspond closely to the southwestern limit of the geochemical anomaly associated with the central east Greenland volcanic province. The distinctive basalt geochemistry and high melt productivity accompanying rifting within the Caledonian suture zone are attributed to the presence of subducted Iapetus crust in the upper mantle along this portion of the rifted margin. Given the depleted nature of basalts from southeast and west Greenland, similar recycled material apparently was not available south and west of the Caledonian suture. Likewise, comparisons between central east Greenland and modern Iceland basalts suggest that source heterogeneities north of the Caledonian front have changed through time. The connection between subduction processes involved in supercontinent assembly and mantle heterogeneities sampled during breakup reduces the necessity to introduce recycled material via a lower mantle plume early in the development of the North Atlantic ocean basin.

S11A-1122 0830h POSTER

Melting and Dynamics of a Ridge-Centered Plume and the Effect on Geophysical Observables with Application to Iceland

Thomas Ruedas[1] (+49-69-798-24949; ruedas@geophysik.uni-frankfurt.de)

Anja Kreutzmann[1] (akreutz@geophysik.uni-frankfurt.de)

Harro Schmeling[1] (schmeling@geophysik.uni-frankfurt.de)

Andreas Junge[1] (junge@geophysik.uni-frankfurt.de)

Gabriele Marquart[2] (marquart@geo.uu.nl)

[1]Institut fr Meteorologie und Geophysik, University of Frankfurt am Main, Feldbergstr.47, Frankfurt am Main D-60323, Germany

[2]Faculty of Earth Sciences, Utrecht University, Budapestlaan 4, Utrecht 3584 CD, Netherlands

A series of combined numerical mantle convection and melt segregation experiments was conducted together with the application of theoretical relations between v_S, T and porosity and magnetotelluric modelling to investigate the influence of different excess temperatures and amounts of retained melt on observables like crustal thickness, seismic velocities and electrical conductivities for the case of a ridge-centered plume in the upper mantle. The results are compared to the present situation of Iceland, where a considerable amount of data has been collected over the years by several groups.

The point of reference is a model with a plume with a radius of 125 km and a temperature anomaly of 250 K at the model bottom; a maximum of 1 % melt is retained in the mantle, i.e., all melt in excess of this is extracted instantaneously from the model and brought to the surface, where it forms the crust and moves along with the drifting plate. Starting from this reference plume, we explore the parameter space in two directions: one series considers the effect of anomalies weaker resp. stronger by 100 K, the other probes the effect of a change of the melt extraction threshold from 1 to 0.1, 3, and 100 %, respectively.

The models result in a wide range of maximum crustal thicknesses for the plume, from 33 km ($\Delta T = 250$ K, $\varphi_{\mathrm{ex}} = 0.03$) to 146 km ($\Delta T = 350$ K, $\varphi_{\mathrm{ex}} = 0.01$). Judging from the crustal thickness, the most reasonable models are those closely resembling the reference plume ($h_{\mathrm{max}} = 58$ km); additional models indicate that the Iceland plume might as well be a bit cooler than our reference, allowing for a lower extraction threshold.

A conversion of T and melt content to seismic velocities was performed to compare these models with field data, e.g. from seismic tomography (ICEMELT, HOTSPOT); the depth range considered was limited to ca. 350 km, and anomalies were taken with respect to a lithosphere and mantle of 20 Ma age. While the temperature effect alone as expressed in the deeper parts of the plume stem causes only a v_S reduction by 1–3 %, the combined effect of temperature and melt in the melting region is quite strong, e.g. reaching -10 % in the shallowest part of the reference plume; the contribution of the plume is about a quarter. Another remarkable feature of the v_S anomalies of the models with hotter plumes and low extraction thresholds is the presence of a second velocity minimum just above the solidus depth.

The temperature and melt distributions were also converted into electrical conductivities which are the input for the 3-D magnetotelluric (MT) modelling. The conductivities depend on both excess temperature and melt threshold, whereby the influence of the melt is stronger. Based on the computed magnetic and electric fields the MT transfer functions (apparent resistivities and phases) were calculated. Depending on the input parameters, melt and temperature, these transfer functions are affected by the plume. The larger the amount of melt and the larger the melt region, the more distinctive are these influences.

S11A-1123 0830h POSTER

Upper Mantle $Sv-$Wavespeed Heterogeneity Beneath the North Atlantic

S. Pilidou[1] (pilidou@esc.cam.ac.uk)

O. Gudmundsson[2] (og@dlc.ku.dk)

E. Debayle[3] (eric@tomo.u-strasbg.fr)

K. Priestely[1] (44-1223-337195; keith@esc.cam.ac.uk)

[1]Bullard Laboratories University of Cambridg, Madingley Rise Madingely Road, Cambridge CB30EZ, United Kingdom

[2]Danish Lithosphere Centre, Oester Voldgade 10 L, Copenhagen 1350, Denmark

[3]Ecole et Observatoire des Sciences de la Terre, 5, rue Rene Descartes, Strasbourg F67084, France

The Iceland plume has played a major role in the opening of the North Atlantic and is a dominant influence on the present-day structure, bathymetry and melt generation of the NE Atlantic. While several studies have examined upper mantle structure directly beneath Iceland, little is known about the upper mantle structure beneath the surrounding NE Atlantic. We have built a $Sv-$wavespeed tomographic model for the upper mantle beneath the NE Atlantic derived from the analysis of ~3000 fundamental and higher mode regional Rayleigh waveforms. These data come from broadband seismographs we deployed in the western British Isles, the Faroe Islands, western Norway, Iceland and eastern Greenland, plus data from FDSN and other seismographs in Canada and Scandinavia. We construct the 3D upper mantle model by first determining 1D path-average upper mantle velocity models compatible with the observed waveforms, and then combining the 1D velocity models in a continuous tomographic inversion to obtain the local $Sv-$wavespeed at each depth. The dense coverage provided by the data set allows the resolution of $S-$wave heterogeneity at wavelengths of several hundred kilometers. Analysis of the fundamental mode in the period range 50-120 s, and up to the fourth higher mode in the period 50-90 s provides good vertical resolution over most of the upper mantle. Our results show two major negative velocity anomalies in the NE Atlantic – one centered beneath Iceland and a second covering a more extended region beneath the Azores. With respect to PREM, velocities in the shallow upper mantle (75-150 km) are 5-7% lower beneath both regions. The lowest velocities extend to approximately 200 km depth for both anomalies.

S11A-1124 0830h POSTER

The Compensation of the Azores Plateau: Results From a 2D Admittance Study.

J. F. Luis[1] (351-289-800900; jluis@ualg.pt)

M. C. Neves[1] (351-289-800900; mcneves@ualg.pt)

[1]Universidade do Algarve, FCMA, Campus de Gambelas, Faro 8000, Portugal

The ratio of geoid and gravity to bathymetry in the long-wavelength range is investigated for the region of the Azores swell by means of a 2D admittance technique in the frequency domain. The geoid, free-air gravity and predicted bathymetry data are from the global satellite grids of Smith and Sandwell. The longest-wavelength components of the geoid associated with large-scale mantle dynamics are removed by subtraction of a low degree and order spherical harmonic geoid representation of the EGM96 model. Grids rather than profiles are used to compute the admittance function. The advantage of computing the admittance between two grids over the traditional analysis based on profile data is obvious, for it allow us to use all the data inside the region of interest. Theoretical models of surface loading of an elastic lithosphere, and subsurface loading by thermal buoyancy forces or dynamic uplift from a rising plume, are compared to the spectral ratio of the geoid and gravity to bathymetry. The results show that the Azores Plateau is compensated by thick crust alone with an effective elastic thickness of about 6 km. Therefore, gravity and geoid data do not support the hypothesis of an hotspot related swell for the Azores Plateau.

S11A-1125 0830h POSTER

Evidence for a Thinned Mantle Transition Zone beneath the Azores Hotspot

Derek L Schutt[1] ((202) 478-8841; schutt@dtm.ciw.edu)

Sean C. Solomon[1] (scs@dtm.ciw.edu)

Peter G Burkett[1] (burkett@dtm.ciw.edu)

[1]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, N.W., Washington, DC 20015

As part of the Coordinated Seismic Experiment in the Azores (COSEA) - a cooperative project being carried out by the Centro de Geofisica da Universidade de Lisboa; the Universidade dos Acores; the Instituto de Meteorologia, Portugal; the Eidgenossische Technische Hochschule (ETH), Zurich; the Institut de Physique du Globe de Paris (IPGP); and the Department of Terrestrial Magnetism (DTM) of the Carnegie Institution of Washington - DTM has operated broadband portable seismic stations on five of the islands in the Azores archipelago for the past two years. One of the goals of COSEA is to understand the mantle structure beneath the Azores hotspot. Several other oceanic hotspots that have been the focus of seismic imaging experiments (Iceland, Hawaii, Galapagos, Society) have mantle transition zones resolvably thinner than the global average. Because the top and bottom of the transition zones are defined by discontinuities associated with phase transformations having positive and negative Clapeyron slopes, respectively, this thinning has been attributed to anomalously high temperatures, consistent with penetration of a plume of hot upwelling material from the lower mantle. We present a preliminary assessment of transition zone structure beneath the Azores Islands and Platform from the differential times of the converted phases P410s and P660s, determined from radial receiver functions. Using data from the DTM stations, as well as from the GSN station CMLA, we stack low-pass filtered receiver functions corrected for moveout. Stacking is an essential step, because wave-induced noise is substantial in this locale and affects the number of events that can be used. The converted phases can be identified in the stacked receiver functions, and the differential P660s - P410s time is 2-3 s less than predicted by the iasp91 global Earth model. The transition zone is therefore thinner than that in the average radial Earth by more than 20 km, a degree of thinning comparable to that seen beneath the Iceland, Hawaii, Galapagos, and Society hotspots. We infer that the transition zone beneath the Azores is anomalously hot, a result consistent with the hypothesis that the Azores hotspot is underlain by a mantle plume.

S11A-1126 0830h POSTER

Seismic Detection of Plume Head Residue Beneath the Pitcairn Hot-Spot Chain

Sebastian Rost[1] (+1-(831)-459-1437; srost@es.ucsc.edu)

Quentin Williams[1] (+1-(831)-459-3132; qwilliams@es.ucsc.edu)

[1]University of California, Department of Earth Sciences, 1156 High St, Santa Cruz, CA 95064, United States

We study array seismograms of French nuclear explosions from two Islands in French-Polynesia and use these to constrain the structure in the upper mantle beneath the islands. Seismograms of nuclear explosions on the hot-spot related Fangataufa atoll show discrete, large-amplitude P-coda phases which are not observed in recordings of explosions from Mururoa ~40 km to the north. We are able to locate the source for these P-coda phases beneath the Fangataufa atoll, indicating structural heterogeneities in this oceanic region on very small scale-lengths most likely produced by the Pitcairn hot-spot. Synthetic seismograms for models of the upper mantle beneath Fangataufa require a layer with P-wave velocity elevated by ~10% between depths of 51 km and 85 km with a sharp northern boundary to match these P-coda phases.

Few mineralogic scenarios exist that can explain this structure and the properties of this layer imply that extensive enrichment in garnet occurs in this depth range. The garnet-enriched layer is likely of similar origin to the well-known xenolithic "garnet megacryst" suite found in kimberlitic regions.

We propose a model for the formation of the Fangataufa and Mururoa atolls involving garnet-enriched zones being generated at depth through magmatic processes involving extensive fractional crystallization, beneath the Pitcairn plume-head. Thus, the initiation of hot-spots could produce complex geochemical and structural heterogeneities at depth in the suboceanic mantle on lengthscales of a few tens of km's.

S11A-1127 0830h POSTER

Seismic Anisotropy of the French Polynesian Upper Mantle: PLUME Preliminary Results

Fabrice Fontaine[1] (Fabrice.Fontaine@dstu.univ-montp2.fr)

Guilhem Barruol[2] (guilhem.barruol@upf.pf)

Dominique Reymond[3] (reymond.d@labogeo.pf)

Eric Debayle[4] (Eric.Debayle@eost.u-strasbg.fr)

Andrea Tommasi[1] (Andrea.Tommasi@dstu.univ-montp2.fr)

[1]Laboratoire de Tectonophysique, CNRS, Universite Montpellier II, Montpellier 34095, France

[2]Jeune Equipe Terre Ocean, CNRS, Universite de la Polynesie Francaise, BP6570, Faaa 98702, French Polynesia

[3]Laboratoire de Geophysique, CEA, Pamatai, Faaa 98702, French Polynesia

[4]Ecole et Observatoire des Sciences de la Terre, CNRS, Universite Louis Pasteur, Strasbourg 67084, France

In order to investigate upper mantle structure and flow beneath french Polynesia, we deploy a broad-band seismic network in november 2001 for a two years period. After completion, this project called PLUME (Polynesian Lithosphere and Upper Mantle Experiment) should improve the body and surface wave tomographic imaging of the upper mantle beneath the french Polynesia. We present preliminary results of SKS and SKKS shear wave splitting obtained at PLUME temporary stations, at the permanent LDG/CEA stations in the Tuamotu (TPT), Gambier (RKT) and Austral (TBI) archipelagos and at the CEA/Geoscope station PPT in Tahiti.

In such oceanic environment, the generally low signal-to-noise ratios render the shear wave splitting measurements difficult. Despite the presence of few good events, the first few months of recording at the temporary PLUME stations do not show clear individual splitting. We observe instead several unsplit SKS phases of good quality arriving from backazimuth of N70°W. We find clear splitting at RKT with fast split shear waves oriented roughly N60°W, i.e., parallel to the Absolute Plate Motion (APM) of the Pacific plate, and delay times between fast and slow waves around 1.5 s. We do not observe clear individual splitting at TPT and TBI stations, but interestingly, the stacking methods of Wolfe and Silver (1998) indicates at these stations an anisotropy trending parallel to the plate motion (respectively N70°W and N80°W) and rather small delay times (respectively of 0.7 and 1.0 s). We find no detectable anisotropy at PPT. This upper mantle apparent isotropy may be explained by short-scale heterogeneities, vertically oriented mantle flow, or simply by the fact that the mantle plume may have thermally erased the preexisting upper mantle fabric.

S11A-1128 0830h POSTER

Anisotropic Signature of the Afar plume in the Upper Mantle.

Deborah Sicilia[1] (33 1 4427 2469; sicilia@ipgp.jussieu.fr); Jean-Paul Montagner[1] (33 1 4427 4895; jpm@ipgp.jussieu.fr); Eric Debayle[2] (Eric.Debayle@eost.u-strasbg.fr); Jean-Jacques Leveque[2] (leveque@sismo.u-strasbg.fr); Michel Cara[2] (mcara@eost.u-strasbg.fr); Jean-Claude Lepine[1] (lepine@ipgp.jussieu.fr)

[1]Dept. Seismology, Institut de Physique du Globe, Case 89, 4 Place Jussieu, Paris 75252, France

[2]EOST, 5 rue Descartes, Strasbourg 67084, France

Plumes remain enigmatic geological objects and it is still unclear how they are formed and whether they act independently from plate tectonics. The role of plumes in mantle dynamics can be investigated by studying their interaction with lithosphere and crust and their perturbations on flow pattern in the mantle. The flow pattern can be derived from seismic anisotropy. An anisotropic surface wave tomography in the Horn of Africa was performed. The choice of the experiment in the Horn of Africa is motivated by the the presence of the Afar hotspot, one of the biggest continental hotspot. In the framework of the mantle degree 2 pattern, the Afar hotspot is the antipode of the Pacific superswell, but its origin at depth and its geodynamic importance are still debated. Data were collected from the permanent IRIS and GEOSCOPE networks and from the PASSCAL experiment in Tanzania and Saudi Arabia. We completed our data base with a French deployment of portable broadband stations surrounding the Afar Hotspot. Path average phase velocities are obtained by using a method based on a least-squares minimization (Beucler et al.,2002). A correction of the data is applied according to the a priori 3SMAC model (Nataf & Ricard, 1996). 3D-models of velocity, radial and azimuthal anisotropies are inverted for. Down to 250km, low velocities are found beneath the Red Sea, the Gulf of Aden, the South East of the Tanzania Craton, the Afar hotspot. High velocities are present in the eastern Arabia and the Tanzania Craton. These results are in agreement with the isotropic model of Debayle et al. (2002). The anisotropy model beneath Afar displays a complex pattern. The azimuthal anisotropy shows that the Afar plume might be interpreted as feeding other hotspots in central Africa. Deeper in the asthenosphere, a wide stem of positive radial anisotropy ($V_{SH} > V_{SV}$) comes up, where we might expect the reverse sign. The same observation was made below Iceland (Gaherty, 2001) and Hawaii (Montagner, 2002). Different interpretations of this observation can be proposed, in terms of perturbation of the flow pattern around Afar or of the predominant influence of water-rich plume material where other mechanisms of alignment prevail (Jung and Karato, 2001).

S

S11A-1129 0830h POSTER

The Afar Depression: Was There a Triple Junction Above the Mantle Plume?

C Ebinger[1] (cindy@gl.rhul.ac.uk); E Wolfenden[1] (wolfenden@gl.rhul.ac.uk); G Yirgu[2] (dggaau@telecom.net.et); D Ayalew[2] (dggaau@telecom.net.et); G Eagles[3] (geagles@AWIbremerhaven.DE); R Gloaguen[1] (r.gloaguen@gl.rhul.ac.uk); C Tiberi[1] (c.tiberi@gl.rhul.ac.uk); J R Rowland[4] (j.rowland@auckland.ac.nz); A Deino[5] (al@bgc.org); A Tesfaye[2]; S Tesfaye[6] (samson$_t esfaye@hotmail.com$)

[1]Royal Holloway, U of London, Department of Geology, Egham TW20 0EX, United Kingdom

[2]Addis Ababa University, Department of Geology and Geophysics, Addis Ababa A1, Ethiopia

[3]AWI Polar and Marine Research, Postfach 120161, Bremerhaven D-27515, Germany

[4]University of Auckland, Department of Geology, Auckland A1, New Zealand

[5]Berkeley Geochronology Center, 2255 Ridge Road, Berkeley, CA 94709, United States

[6]Lincoln University, Department of Geology, Jefferson City, MO 63017, United States

The Red Sea Gulf of Aden- Main Ethiopian rift systems (Afar Depression) have served as the textbook example of a R-R-R triple junction zone which formed above a mantle plume (Ethiopia-Yemen flood basalt province, 31-28 Ma). Recent work has documented the onset and propagation of seafloor along the length of the Gulf of Aden and Red Sea arms, but the timing of continental rifting had been poorly constrained. Our aims were to constrain the timing of rift initiation in each arm of the rift near the proposed Oligocene triple junction and to re-assess models for break-up above a mantle plume. Although much of the early history of rifting is deeply buried by Pliocene-Recent lavas, erosional dissection of the rift margins provides windows into the early rift history. Along the southernmost Red Sea, faults commonly marked by eruptive centers initiated at about 26 Ma, coincident with rifting along the easternmost Gulf of Aden. New data from the rift immediately south of the southernmost Red Sea basin (ca.10N) constrain the earliest rift sequences in the northern Main Ethiopian rift (MER). Field and Ar-Ar data from sequences overlying the pre-rift flood basalts show that extension in the northern MER commenced at 12-10 Ma when the two rift systems were finally linked. The active zone of extension and magmatism in the southern Red Sea and eastern Gulf of Aden, however, had migrated east and north, respectively. Summarising, rifting in southern Ethiopia had commenced by 16-18 Ma, and had propagated northward to cut across Oligo-Miocene rift structures of the Red Sea and Gulf of Aden by 10 Ma, consistent with plate kinematic data. A triple junction could have developed only during the past 10 My, long after flood basaltic magmatism. Inverse models of gravity data predict a significant step (2-4 km) in the Moho where the youthful, less extended MER breaks into the Afar Depression. Project EAGLE (UK-US-Ethiopia) is now acquiring seismic data across and along this zone to evaluate mechanisms for rift segmentation and propagation prior to breakup.

S11A-1130 0830h POSTER

The Tibesti Volcanoes of Chad: an ASTER-based Remote Sensing Analysis

Jason L Permenter[1] (44-0-1223-339-819; jlp36@cam.ac.uk)

Clive Oppenheimer[1] (44-0-1223-719-712; co200@cam.ac.uk)

[1]Department of Geography, University of Cambridge, Downing Place, Cambridge CB2 3EN, United Kingdom

Situated in the central Sahara desert, the Tibesti volcanic province of northern Chad, Africa, is a superb example of large-scale continental hot spot volcanism. The massif is comprised of seven major volcanoes and an assembly of related volcanic and tectonic structures, with a total surface area of over 350 km^2. Its highest peak (Emi Koussi) rises above the surrounding desert to ∼3415 m above sea level. Due, in part, to its remoteness, the Tibesti has never been described in volcanological detail. This study aims to provide the first modern synthesis of the volcanology of this significant hot spot province. It is based primarily on a detailed analysis and interpretation of a comprehensive set of multi-band imagery from NASAs Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). ASTER has 14 spectral bands, divided between 3 optical subsystems; 3 in the very-near infrared (VNIR), 6 in the short-wave infrared, and 5 in the thermal infrared regions. In addition, the VNIR subsystem has aft-viewing optics for stereoscopic observation in the along-track direction, which permits generation of digital elevation models.

The preliminary results presented here focus on the discrimination of lava composition, identification of pyroclastic deposits, and characterisation of the dimension of flows, craters, and other structural elements of the massif, using spectral and textural information gathered from the ASTER imagery. Furthermore, stratigraphic detail is obtained from the superposition of flow units and craters. The application of ASTER data to the Tibesti volcanic complex permits an initial first order description of the relative proportions and timing of different erupted materials, providing a framework for further interpretation of the volcanology and magmatic evolution of the Tibesti, based on modern geologic and tectonic concepts. It also allows intercomparisons to be made with other continental hot spot provinces.

URL: http://www-volcano.geog.cam.ac.uk/people/permenter

S11A-1131 0830h POSTER

Geochemistry and Volcanic Evolution of Mauritius

Debajyoti Paul[1] (dp555@cornell.edu)

William M. White[1] (607 255 7466; white@geology.cornell.edu)

[1]Dept. Earth and Atmos. Sci., Cornell University, Ithaca, NY 14853, United States

Three distinct phases of volcanism on the island of Mauritius occurred over a time span of nearly 8 million years. The Older Series, erupted between 7.8 and 5.4 Ma, consists of transitional basalts and their differentiation products that become more common near the end of this phase. The Older Series seems clearly analogous to the shield-building phase of Hawaii. Both the timing of their eruption and their Sr, Nd, and Pb isotopic compositions suggest Older Series lavas were produced by melting of the Reunion mantle plume. The Intermediate Series, erupted between 3.5 and 1.9 Ma, consists of small volumes of highly undersaturated magmas that experienced little or no differentiation before eruption. Their Sr and Nd isotopic signatures are more depleted than those of the Older Series. In all these respects, the Intermediate Series seems analogous to the post-erosional phase of volcanism on Hawaii. The Younger Series, which has no clear analog in Hawaiian volcanic evolution, was erupted between 0.7 and 0.17 Ma and consists of more voluminous K-poor alkali basalts that experienced moderate fractional crystallization. Their Sr and Nd isotopic compositions are intermediate between the Older and Intermediate Series, but their Pb isotopic compositions are distinctly less radiogenic.

The 3 series define 3 distinct fields in isotope space, implying they were produced by melting of 3 compositionally distinct sources. The Older Series have isotopic compositions intermediate between Reunion and older lavas of the Mascarene plateau, and document a progressive change in the composition of the Reunion mantle plume with time. The sources of Younger and Intermediate Series cannot be modeled as mixtures of the Older Series source (i.e., Reunion mantle plume) and the source of Indian Ocean MORB. This observation would seem to make a lithospheric source for either of these series improbable. A more likely source is the sheath of deeper mantle material viscously entrained by the Reunion mantle plume.

What caused the latter phases of volcanism? Construction of the two volcanic edifices of Reunion, located 170 km to the southwest, might have altered the stress and pressure field in the mantle beneath Mauritius and thus might have contributed to the cause of late-stage volcanism on Mauritius. However, we note that post-erosional volcanism seems restricted to volcanoes located in tropical climates (e.g., Hawaii, Societies, Samoa, Mauritius); it does not occur on non-tropical islands (e.g., Azores, Galapagos). This suggests that the rapid erosion that characterizes tropical island volcanoes might be, at least in part, responsible for eruption of the small degree melts of the post-erosional volcanic phase. Erosion would result in release of compressive stress in the lithosphere, allowing melts to migrate to the surface. Erosion might also cause decompression melting as the underlying hot asthenosphere rebounds in response to removal of the volcanic load.

S11A-1132 0830h POSTER

First Seismic Evidences for Anomalies Related to the Trindade Plume in SE and Central Brazil

Christian Escalante[1] (401-863-1360; escalan@emma.geo.brown.edu)

Martin Schimmel[2] (schimmel@ija.csic.es)

Marcelo Assumpcao[3] (marcelo@iag.usp.br)

[1]Brown University, Dept. of Geological Sciences, Box 1846, Providence, RI 02912, United States

[2]Institute of Earth Sciences "Jaume Almera", c/ Lluis Sole i Sabaris, s/n, Barcelona 08028, Spain

[3]IAG - University of Sao Paulo, Rua do Matao 1226, Sao Paulo, SP 05508-900, Brazil

Some of the most voluminous mafic potassic provinces of the world are located in SE and Central Brazil emplaced into proterozoic mobile belts and whose magmas date ∼85 Ma. Their origins are controversial, some interpreted these magmatisms as an end-stage of Paraná volcanism. On the other hand, reconstructions of plate motion suggest that, at ∼ 85 Ma ago, the location of the northeastern Paraná Basin alkaline magmatism coincided with the postulated position of the present-day Trindade Plume. Our tomographic inversions, using more than 7000 relative P-wave arrival times mainly recorded at portable broadband stations deployed at 55 sites along SE and Central Brazil during 1992-2001, reveal the presence of a strong low-velocity anomaly beneath Goiás at upper mantle depths suggesting a fossil remnant of the Trindade Plume which began 85 Ma ago with an impact zone of 500 km radius centered in Iporá, Goiás. The presence of this anomaly has direct implications in tectonic and thermal regimes of SE and Central Brazil, because it could explain the origin of the Late Cretaceous magmatism in this region. At the same time, its persistence underneath Goiás would imply that the upper mantle and the overlying South American plate have been in a coupled motion at least since the aperture of South Atlantic, confirming what was inferred in previous studies carried out in this region. (This work was supported by FAPESP grants, Brazil)

S11A-1133 0830h POSTER

Upper-Mantle Shear-Velocity Structure Beneath Antarctica and Surrounding Regions From Waveform Inversion of Rayleigh Waves

Anne Sieminski[1] (33390240090; anne@eost.u-strasbg.fr)

Eric Debayle[1] (eric@tomo.u-strasbg.fr)

Jean-Jacques Lévêque[1] (leveque@sismo.u-strasbg.fr)

[1]EOST, CNRS and Université Louis Pasteur, 5 rue René Descartes, Strasbourg 67084, France

We present a regional SV-wave velocity model for the upper mantle beneath the Antarctic region. The data are long period (50-160s) fundamental and higher mode Rayleigh waves from the permanent IRIS, GEOSCOPE and GTSN stations. About 3300 seismograms have been analysed using a two-step procedure. The first step consists of building a large number of 1D path-average velocity models compatible with multimode seismograms corresponding to paths crisscrossing the region under study. Then, the path-average models are combined in a tomographic inversion to retrieve the local structure. Both the shear velocity and the azimuthal anisotropy of surface waves can be inverted for, provided that the azimuthal distribution of paths is sufficient.

Our preliminary 3D SV-wave velocity model presents strong lateral variations in the uppermost 200 km of the mantle. At these depths, our model agrees well with previous surface wave studies of the region. Compared to these studies restricted to the analysis of the fundamental mode only, the use of overtones allows us to improve the resolution at depths between 200 and 400 km.

A geodynamical issue in the region is the origin of the West Antarctic Rift. The existence of a plume has been proposed on the basis of the large amount of volcanic rocks found in the rift together with their geochemical characteristics. Although strong lateral slow anomalies are observed beneath the West Antarctic Rift, they do not persist below 200 km. This result does not agree with what would be expected in presence of active upwelling. Indeed, it has been shown beneath the Horn of Africa where the same tomographic technique was applied, that when a dense coverage is available, even a narrow low-velocity anomaly should affect the path average measurements and should map in the tomographic model. We discuss whether the same conclusion can be drawn for the West Antarctic Rift.

S11A-1134 0830h POSTER

3-D Velocity Structure Beneath Hakone Volcano Using Explosions and Micro Earthquakes Hybrid Inversion

Yoshiya ODA[1] (oda-yoshiya@c.metro-u.ac.jp)

Shintaro ABE[2] (shintaro@abiko.denken.or.jp)

Yasuhira AOYAGI[2] (y-aoyagi@criepi.denken.or.jp)

Takahiro IWATATE[1] (rock-tak@ecomp.metro-u.ac.jp)

[1]Tokyo Metropolitan University, 1-1 Minamiosawa, Hachioji 192-0397, Japan

[2]CRIEPI, 1646 Abiko, Abiko 270-1194, Japan

Hakone volcano is located in the northern part of Izu peninsula. It is well known as inactive volcano and hot springs resort. But sometimes there are swarm earthquakes activities. There was big swarm earthquakes activity in April 2001. Total number of earthquakes was 15,816 during April to October. The cause of this activity is not yet solved.

Explosion observation was carried out and 3-D velocity structure was estimated using explosions and micro earthquakes hybrid inversion method to know where magma exists or not. Not only micro earthquakes but also explosions were used, so the high resolution subsurface image and velocity value can be obtained with good accuracy.

As results, we can find some faults as lines of hypocenter beneath Hakone volcano, and there is no results that suggests existence of magma. So it is considered that the cause of swarm earthquakes activity that occurred on 2001, was not activity of magma.

S11A-1135 0830h POSTER

Synthetic Seismic Signature of Thermal Mantle plumes

Saskia Goes[1] (saskia@tomo.ig.erdw.ethz.ch)

Ulrich Hansen[2] (hansen@earth.uni-muenster.de)

[1]Institute of Geophysics, ETH Hoenggerberg (HPP), Zurich CH-8093, Switzerland

[2]Institute of Geophysics, Muenster University, Muenster D-48149, Germany

With increasing resolution in global tomographic models and targeted regional experiments the first seismic images of mantle plumes have emerged. The low velocity anomalies interpreted as plumes are generally significantly more complex than the simple head-tail model of a mantle upwelling. Although some models show low velocities crossing the 660 km discontinuity, the significance of the lower mantle anomalies is still heavily debated. In order to obtain a better idea of the expected seismic signature of a mantle plume we perform a set of three-dimensional numerical experiments with parameters relevant to the Earth's mantle. The thermal plumes thus obtained are converted into P and S velocity structure taking into account the effect of temperature, pressure, an average mantle composition including phase transitions and anelasticity on the seismic velocities. Excess plume temperatures were constrained to be about 300^{o}C below the lithosphere to be consistent with surface observations. Such plumes are 400-800 km wide. An abrupt lowering of the viscosity above 660 km causes additional narrowing in the upper mantle. V_P (V_S) anomalies range from 2.2 (-4) % above the transition zone to 0.5 (-1) % in the lower mantle. Due to the varying sensitivity of seismic velocities to temperature with depth and mineralogy, variations in amplitude and width of the seismic plume do not coincide with the variations in the thermal structure of the plume. Reduced sensitivity in the transition zone may hamper imaging continuous whole mantle plumes. Seismic anelasticity structure follows the thermal structure more closely and yields plume anomalies of up to 200% in dln($1/Q_S$).

S11A-1136 0830h POSTER

To Plume or Not To Plume: SC Mesozoic Diabase Dike Orientations, Stress Fields During the Break-up of Pangea, and the Feasibility of a Causal Plume.

Erin K Beutel[1] ((843) 953 5591; beutele@cofc.edu)

Mike Alexander[1] (malexander@edisto.cofc.edu)

Arpan Kotecha[1] (akotech@edisto.cofc.edu)

David Edwards[1] (dedwards@edisto.cofc.edu)

[1]College of Charleston, Dept. of Geology and Environmental Geosciences, Charleston, SC 29464

New compilations of Mesozoic diabase dikes in South Carolina suggest that previously unrecognized N-S and NE-SW dike orientations exist throughout the western Charlotte belt, into the Carolina belt and possible into the Laurens Thrust Stack. Previous studies indicated that the majority of dikes in South Carolina were solely NW trending. While we found that the majority of dikes did trend NW-SE, the number and size of the NE-SW and N-S trending dikes indicate that these are not mere fingers off the main NW trending dikes and are likely true swarms.

Previous studies of Mesozoic diabase dikes further north along the Atlantic coast have found evidence that suggests that NW-SE trending dikes are the oldest set, the N-S trending set followed, and the NE-SW trending dikes were injected last. Based on this relationship, and the stress field that most likely existed in the crust during the injection of each dike set, we have constructed a series of evolutionary models for the break-up of Pangea. Our models are based on the assumption that the multiple overlapping swarms negate the possibility of a plume being solely responsible for the break-up or for the dikes. These models suggest a complicated history of relative motion between Africa, North America, and South America. Finite element models were run to test the feasibility of these models.

Preliminary model results suggest that the extensional stresses necessary for the major dike patterns seen in northwestern Africa, northern South America, and the southeastern United States may have occurred when the relative motion of Africa was northeast of North America. Initial model runs suggest that multiple dike orientations are best accounted for by a strongly nonlinear rift trend, a temporary aulacogen in Georgia, and/or rift propagation. The affect of events in the Gulf of Mexico is strongly dependent on the location and trend of the rifts and micro-continents modeled.

S11A-1137 0830h POSTER

Large Igneous Province Emplacement Rates Since 150 Ma

Millard F. Coffin[1,2,3] (+81-3-5351-6430; mcoffin@ori.u-tokyo.ac.jp)

Olav Eldholm[4] (+47-2285-6676; olav.eldholm@geologi.uio.no)

[1]Ocean Research Institute, University of Tokyo, 1-15-1 Minamidai, Nakano-ku, Tokyo 164-8639, Japan

[2]Institute for Frontier Research on Earth Evolution, Japan Marine Science and Technology Center, 2-15 Natsushima-cho, Yokosuka 237-0061, Japan

[3]Institute for Geophysics, Jackson School of Geosciences, The University of Texas at Austin, 4412 Spicewood Springs Road, Building 600, Austin, TX 78759-8500, United States

[4]Department of Geology, University of Oslo, PO Box 1047, Blindern, Oslo N-0316, Norway

Large Igneous Provinces (LIPs) constitute broad areas, $>10^5$ km^2, of predominantly mafic rocks erupted over $\sim 10^6$ yr. LIPs originate in the mantle, via mass and energy transfer which acts both independently of, and in conjunction with, the wide-ranging upwellling systems producing new oceanic crust by sea floor spreading along the mid-oceanic ridge system. We evaluate all categories of LIPs - continental flood basalts, volcanic divergent margins, oceanic plateaus, submarine ridges, and ocean basin flood basalts - emplaced since 150 Ma, estimate their subaerial and submarine volcanic components, and combine volume and age information to produce subaerial and submarine volcanic output curves for Cretaceous and Cenozoic time. We carefully examine the two giant oceanic plateaus, Kerguelen/Broken Ridge (Indian Ocean) and Ontong Java (Pacific Ocean), recently sampled by Ocean Drilling Program Legs 183 and 192, respectively. The post-150 Ma LIP record reveals both many events and voluminous volcanism from 135-85 Ma, and a distinct decline since 50 Ma. These trends may reflect variations in mantle circulation and have links to global environmental change.

S11A-1138 0830h POSTER

A Comparison of Historic Caldera-Forming Events

John Stix (514-398-5391; stix@eps.mcgill.ca)

John Stix, Department of Earth and Planetary Sciences, McGill University, 3450 University Street, Montreal, QC H3A 2A7, Canada

Recent field, experimental, and theoretical studies of calderas have advanced our understanding of how calderas form. With this in mind, I compare and contrast the styles and mechanisms of caldera development for five historic events: Katmai 1912, Kilauea 1924, Fernandina 1968, Pinatubo 1991, and Miyakejima 2000. As well as affording an opportunity to compare felsic and mafic systems, these examples allow us to identify systematic similarities and differences during the process of caldera formation. Critical questions include the following. (1) What are durations of caldera formation, as well as precursory signals and triggering mechanisms? (2) Why is there frequently a mismatch between caldera volumes at the surface and magma volume changes in the subsurface? (3) What are the relative proportions of erupted magma vs. magma which is drained and/or transported laterally in the subsurface? (4) How much magma is displaced, either by eruption or by drainage, before a caldera starts forming at the surface? (5) Does caldera subsidence occur en masse, incrementally, or somewhere between these two extremes of behavior? (6) Does subsidence of the caldera block help magma to be evacuated from the chamber, or is the subsidence process a passive response to magma withdrawal by other means? In addition to addressing the above questions, I will discuss how caldera formation influences the development of "open" and "closed" magmatic systems. Finally, I will discuss the problems of scaling, as the historic examples discussed here are 1-3 orders of magnitude smaller than large-scale caldera-forming ignimbrite eruptions.

S11B MCC: Hall C Monday 0830h

Historic Earthquakes I Posters *(joint with HG)*

Presiding: **S Hough,** U.S. Geological Survey**; J F Cassidy,** Geological Survey of Canada

S11B-1139 0830h POSTER

A Subduction Source for the Great Lisbon Earthquake and Tsunami of 1755 ?

Maria Ana Baptista[1,2] (351218317000; mabaptista@sa.isel.ipl.pt)

Jorge Miguel Miranda[1] (351217500809; jmiranda@fc.ul.pt)

Marc Andre Gutscher[3] (33298498727; gutscher@univ-brest.fr)

[1]CGUL, FCUL, Campo Grande, Ed C8, Lisboa 1749-016, Portugal

[2]ISEL, Rua Cons Emidio Navarro,1, Lisboa 1900, Portugal

[3]IUEM, UBO, PLouzane, France, UMR 6538 Domaines Oceaniques, Place Nicolas Copernic, F-29280, Plouzan, France., Plouzan F-29280, France

The great Lisbon earthquake of 1 November 1755 (felt as far away as Hamburg, the Azores and Cape Verde Islands) has the largest documented felt area of any shallow earthquake and an estimated magnitude of 8.5 - 9.0. The associated tsunami ravaged the coast of SW Portugal and the Gulf of Cadiz, with run-up heights reported to have reached 5 - 15 m. The tsunami was recorded as far as the Lesser Antilles and SW England. While several source regions offshore SW Portugal have been proposed (e.g. - Horseshoe Abyssal plain, Gorringe Bank, Marqus de Pombal), no single source has been able to account for the great seismic moment and the tsunami amplitude and travel-time observations.

A recent marine seismic survey together with tomographic data provide compelling evidence for an active east dipping subduction zone beneath the Gibraltar Arc. We have performed tsunami wave form modeling to test the hypothesis of a subduction related "interplate" event as the source of the 1755 earthquake. A shallow east dipping fault plane with dimensions of 180 km (N-S) x 210 km (E-W) is tested with a co-seismic slip of 20 m. For convergence rates of 1 - 2 cm/yr an event of this magnitude could recur every 1000 - 2000 years. This corresponds well to the chronology of turbidites emplaced in the adjacent Horseshoe Abyssal plain. Hydrodynamic tsunami modeling using a single shallow dipping subduction source provides a good fit to historically reported amplitudes and arrival times from stations in the Gulf of Cadiz, Madeira and Porto Santo. However, amplitudes are low and arrival times too long for stations on the west coast of Portugal.

A subduction source for this earthquake implies a second simultaneous source area closer to the margin compatible with the tsunami observations along the western Iberian coast.

S11B-1140 0830h POSTER

Geomorphology and Kinematics of the Nobi-Ise Active Fault Zone, Central Japan: Implications for the kinematic growth of tectonic landforms within an active thrust belt

Tatsuya Ishiyama[1] (t-ishiyama@aist.go.jp)

Karl J Mueller[2] (Karl.Mueller@colorado.edu)

Masami Togo[3] (mtogo@mt.tama.hosei.ac.jp)

Keiji Takemura[4] (takemura@bep.vgs.kyoto-u.ac.jp)

Atsumasa Okada[5] (okada@kugi.kyoto-u.ac.jp)

[1]Tatsuya Ishiyama, Active Fault Research Center, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, Site 7, 1-1-1 Higashi, Tsukuba 305-8567, Japan

[2]Karl J Mueller, University of Colorado, Department of Geological Sciences, 2200 Colorado Blvd., Boulder, Co 80309, United States

[3]Masami Togo, Hosei University, Department of Geoscience, Aihara-Cho, 4342, Machida 194-0298, Japan