Red Sea and Gulf of Aden define the geochemical signature attributed to the Afar plume (^{87}Sr/^{86}Sr 0.7034-0.7037, ^{143}Nd/^{144}Nd 0.5129-0.5130; La/Nb 0.6-0.9; Nb/U 40-50). These suites commonly record mixing with ambient upper mantle having less radiogenic isotopes but generally overlapping incompatible trace element abundances. Within the Ethiopian dome both lithospheric and sub-lithoshperic contributions can be documented clearly; lithospheric contributions are manifest in more radiogenic isotope values (^{87}Sr/^{86}Sr up to 0.7050) and distinctive trace element abundances (e.g., La/Nb <2.0, Nb/U > 10). The degree of lithospheric contribution is lowest within the active Main Ethiopian Rift and increases towards the southern margin of the dome. The estimated depth of melting (65-75 km) is consistent with geophysical observations of lithospheric thickness. In regions of prolonged volcanism the lithospheric contributions and estimated melting depths decrease through time, corresponding to a higher degree of rifting. In the Kenyan dome, including the western rift, the degree of extension is low and lithospheric melting is the dominant source for basaltic magmatism. Mafic lavas from these regions have generally lower MgO but higher contents of alkalis, P2O5 and many incompatible trace elements than are observed in the Ethiopian Rift. High values of ^{87}Sr/^{86}Sr, ^{207}Pb/^{204}Pb and Zr/Hf relative to other parts of the EARS indicate melting of metasomatized lithosphere. Melting in this area occurs at depths up to 100+ km, consistent with the thick crustal section observed seismically. Between the topographic domes, basalts from the Turkana region record melting at shallow levels ($\sim$35 km) consistent with seismic evidence for nearly complete rifting of the crustal section. The geochemistry of these lavas is dominated by asthenospheric source materials, with only minor lithospheric involvement. Temporal evolution of EARS geochemistry reflects progressive rifting of the thick craton. This change is manifest within lavas that are interpreted as plume-derived, as Tb/Yb values decrease from 30 Ma through the present. The modern thermal anomaly associated with Afar volcanism does not appear to extend below the shallow mantle, but may reflect a large blob of deep mantle material that became stuck to Africa 30 Ma and has contributed to regional volcanism ever since. Relative contributions from this deep mantle source, shallow asthenosphere and lithosphere are controlled by the extent of rifting and cannot be predicted solely on the basis of surface topography.

S52G-04 1435h

Magma Genesis during Continental Rifting: Isotopic Constraints from Quaternary lavas of the Main Ethiopian Rift

Julia G Bryce[1] (603-862-3139; julie.bryce@unh.edu)

Tanya Furman[2] (furman@geosc.psu.edu)

Barry B Hanan[3] (barry.hanan@sdsu.edu)

Dereje Ayalew[4]

Gezahegn Yirgu[4]

[1]Dept. Earth Sciences, University of New Hampshire, Durham, NH 03824, United States

[2]Dept. Geological Sciences, Pennsylvania State University, University Park, PA 16802, United States

[3]Dept. Geological Sciences, San Diego State University, San Diego, CA 92812, United States

[4]Dept. Geology and Geophysics, University of Addis Ababa, Addis Ababa Box1176, Ethiopia

The East African Rift System (EARS) provides an unparalleled opportunity to study the links between tectonic activity and magma genesis in a plume-driven continental rift setting. As an example, the geochemistry of primitive EARS lavas offers detailed information about the interplay between lithospheric and sub-lithospheric magma sources in the continental rifting process. In order to test for geographical control on this process in the active Main Ethiopian Rift, we have studied magnesian basalts from five Quaternary volcanic centers in the Main Ethiopian Rift (MER: Fantale, Kone, Boseti, Gedemsa, and Tulu Moye), which lie immediately south of the highly extended Afar region. Incompatible element ratios (e.g., Zr/Nb, La/Nb) and isotopic data (Sr,Nd) of these MER lavas trend towards primitive earth values, signaling incorporation of both enriched and depleted mantle components. There are, however, lithospheric or crustal overprints in the more evolved basaltic samples (those with MgO < 6 wt. %), as have been found in the southern portion of the study area (1). Both isotopic and incompatible trace elemental signatures of the more primitive samples support the notion of increased lithospheric involvement in the generation of basaltic magmas with increasing distance from the Afar region. This phenomenon of lithospheric erosion during the onset of continental rifting has been observed in other temporally controlled suites in the EARS (e.g., (2),(3)) as well as other sites of continental rifting (e.g., (4)). High precision Pb isotopic analyses currently underway on the Quaternary MER samples will provide a more detailed picture of the number of source contributions and the nature of the mixing and transport processes significant in the genesis of MER lavas. (1) Trua et al., Chem Geol, 155, 201-231, 1999. (2) Furman and Graham, Lithos, 48, 237-262, 1999. (3) Furman et al., J Pet, in press (4) DePaolo and Daley, Chem. Geol. 169, 157-185, 2000.

S52G-05 1450h INVITED

Understanding the Transition From Continental to Oceanic Rifting in the Northern Ethiopian Rift the EAGLE Project

Graham Stuart[1] (graham@earth.leeds.ac.uk)

. Eagle Working Group

[1]School of Earth Sciences, University of Leeds, Leeds LS2 9JT, United Kingdom

A consortium of UK (Leeds, Leicester, Royal Holloway, Edinburgh,), US (Stanford, UTEP, Penn State,) and Ethiopian (Addis Ababa) universities are exploring the kinematics and dynamics of continental breakup through the Ethiopia Afar Geoscientific Lithospheric Experiment (EAGLE), which aims to probe the crust and upper mantle structure between the Main Ethiopian (continental) and Afar (ocean spreading) rifts. EAGLE is a multi-disciplinary study centered around a set of passive and controlled-source seismic experiments, and incorporates additional magnetotelluric, gravity, GPS and petrological studies. The initial Phase I seismic experiment consisted of a deployment of 30 broadband seismometers for a period of 16 months (Oct. 2001 to Jan. 2003) over a 250 km x 250 km area of the rift valley and its uplifted flanks. P- and S-wave tompography from teleseismic traveltime residuals, SKS splitting analyses and receiver functions provide images of crust and deep earth structure. The Phase II seismic experiment consisted of a further 50 broadband instruments for a period of 4 months over a 200 km x 100 km area encompassing 4 magmatic segments in the Main Ethiopian Rift. These recordings have furthered our understanding of the location of active seismicity, fault plane mechanisms and segmentation of rift crustal structure. Phase III consisted of the deployment of a further 1100 seismic instruments during a controlled source seismic project involving 20 shots being fired into one 450 km cross-rift profile (Profile 1), one 450 km axial profile (Profile 2), and a dense 2D array of instruments in a 150 km diameter circle around the profiles intersection (Profile 3), all centered on the magmatically active Nazret region. The crust and upper mantle velocity models derived provide estimates of total crustal thinning across the rift, assess the role of basement in the location of major faults and magmatic segments, and determine whether significant underplating takes place. An 18 sounding magnetotelluric profile along the cross rift profile I provides additional constraints on the nature and distribution of crustal heterogeneity, and images melt accumulation zones. New gravity and geodetic information have also been acquired.

S52G-06 1510h

Initiation and Along-Axis Segmentation of Seaward-Dipping Volcanic Sequences Captured in Afar

C Ebinger[1] (cindy@gl.rhul.ac.uk)

E Wolfenden[1] (ellenwolfenden@yahoo.co.uk)

Gezahegn Yirgu[2] (yirgu.g@geol.aau.edu.et)

D Keir[1] (d.keir@gl.rhul.ac.uk)

[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 N, Ethiopia

The Afar triple junction zone provides a unique opportunity to examine the early development of magmatic margins, as respective limbs of the triple junction capture different stages of the breakup process. Initial rifting in the southernmost Red Sea occurred concurrent with, or soon after flood basaltic magmatism at 31 Ma in the Ethiopia-Yemen plume province, whereas the northern part of the Main Ethiopian rift initiated after 12 Ma. Both rift systems initiated with the development of high-angle border fault systems bounding broad basins, but 8-10 My after rifting we see riftward migration of strain from the western border fault to narrow zones of increasingly more basaltic magmatism. These localised zones of faulting and volcanism (magmatic segments) show a segmentation independent of the border fault segmentation. The much older, more evolved magmatic segments in the southern Red Sea, where not onlapped by Pliocene-Recent sedimentary strata, dip steeply riftward and define a regional eastward flexure into transitional oceanic crust, as indicated by gravity models constrained by seismic refraction and receiver function data. The southern Red Sea magmatic segments have been abandoned in Pliocene-Recent triple junction reorganisations, whereas the process of seaward-dipping volcanic sequence emplacement is ongoing in the seismically and volcanically active Main Ethiopian rift. Field, remote sensing, gravity, and seismicity data from the Main Ethiopian and southern Red Sea rifts indicate that seaward-dipping volcanic sequences initiate in moderately stretched continental crust above a narrow zone of dike-intrusion. Our comparison of active and ancient magmatic segments show that they are the precursors to seaward-dipping volcanic sequences analogous to those seen on passive continental margins, and provides insights into the initiation of along-axis segmentation of seafloor-spreading centers.

S52G-07 1525h

Faults, Fissures and Flexures: Upward Propagating Normal Faults in the Koka Magmatic Segment, Main Ethiopian Rift System.

Julie V Rowland (64 09 373 7599; j.rowland@auckland.ac.nz)

Department of Geology The University of Auckland, Private Bag 92019, Auckland 1701, New Zealand

Where do normal faults nucleate? The intra-rift structural fabric of the Main Ethiopian Rift System (MER) provides constraints on normal fault growth models, with a recent interpretation arguing for nucleation in the near-surface consequent on the downward propagation of surface fissures. Examples of genetically related fissures and normal faults occur within the Koka Magmatic Segment near its southern termination against the Asela Border Fault. Considerable along-strike variations in displacement are evident, resulting in flexure of the rift floor. Ramps, breached ramps, hanging wall anticlines and footwall synclines indicate that normal faults have grown by segment linkage. Fault spacing, throw, and back tilting decrease toward the intra-rift axial zone, which comprises subparallel grabens separated by narrow, occasionally synclinal, horsts. Fissures on the order of 1 to several meters wide occur within these grabens and have similar length scales to primary segment lengths revealed by linkage structures along the normal faults. Commonly, fissures are located at the top of narrow monoclinal flexures trending parallel to the axial graben. Where a throw (< 1-2m) occurs across the fissure, the associated flexure is more subdued. Monoclinal flexures continue for some distance (generally < a few 10s of meters) beyond the lateral tips of the associated fissure, though their curvature reduces significantly. Partially filled fissures of similar width occur at the foot of steep normal fault scarps with throws of > 20m. Thus, there appears to be an evolution from small-offset fissure to large-offset fault. The top-down fault nucleation model invokes fault drag as a consequence of higher friction at the fissure-fault transformation depth to explain the observed surface flexure. However, examples of monoclines without fissures or with small poorly connected fissures occur both along the graben floor and within hanging walls of large normal fault splays, suggesting that in some cases flexure development precedes fissure development. This may arise as a consequence of upward propagation of a blind normal fault nucleated at depth, which induces warping and associated fissuring in cover materials; or alternatively, as a consequence of localised sub-surface mass transport into or out of the axial zone.

S52H MCC: 3011 Friday 1340h

Collateral Damage: Earthquake Source Characteristics I *(joint with T)*

Presiding: **S Baher,** U.S. Geological Survey**; J Ampuero,** Princeton University

S52H-01 1340h

Systematic Determination of Earthquake Rupture Directivity and Fault Planes From Analysis of Long-Period P-Wave Spectra

Linda M. Warren[1] (warren@igpp.ucsd.edu)

Peter M. Shearer[1] (pshearer@ucsd.edu)

[1]IGPP, SIO, UCSD, 9500 Gilman Drive, La Jolla, CA 92093-0225, United States

If an earthquake has a primarily unilateral rupture, the pulse width observed on seismograms will vary depending on the angle between the rupture direction and the takeoff vector to the station. We have developed a method to estimate the amount of pulse broadening from the spectrum and apply it to a long-period

database of large, globally-distributed earthquakes that occurred between 1988 and 2000. We select vertical-component P waves at epicentral distances of 20°–98°. We compute the spectrum from a 64-s-long window around each P wave arrival. Each spectrum is the product of source, receiver, and propagation response functions as well as local source- and receiver-side effects. Since there are multiple receivers for each source and multiple sources for each receiver, we can estimate and remove the source- and receiver-side terms by stacking the appropriate P log spectra. For earthquakes deeper than $\sim$200 km, directivity effects dominate the residual spectra. We use our pulse-width estimates to determine the best rupture direction and to identify which nodal plane of the Harvard CMT solution is most consistent with this rupture direction for 66 events. In about 40% of the cases, one of the two nodal planes produces a much better fit to the data and can be identified as the true fault plane. Our results show good agreement with the known rupture directions and slip planes of recent earthquakes.

S52H-02 1355h

EGF Search for Compound Source Time Functions in Microearthquakes

Jean Paul Ampuero[1] (609-258-2598; jampuero@princeton.edu)

Allan M Rubin[1] (609-258-1506; arubin@princeton.edu)

[1]Department of Geosciences, Princeton University, Princeton, NJ 08544, United States

Numerical simulations of stopping ruptures on bimaterial interfaces seem to indicate a pronounced asymmetry in the time it takes to reach the peak Coulomb stress shortly beyond the rupture ends. For the rupture front moving in the direction of slip of the stiffer medium, the timescale is controlled by the arrival of stopping phases from the opposite side of the crack, but for the opposite rupture front this timescale is controlled by the much shorter-duration tensile stress pulse that moves in front of the crack tip as it slows down. This behavior may have implications for rupture complexity on bimaterial interfaces. In addition to observing an asymmetry in aftershock occurrence on the San Andreas fault, Rubin and Gillard (2000) noted that for all 5 of the compound earthquakes they observed in a cluster of 72 events, the second subevent occurred to the NW of the first (that is, near the rupture front moving in the direction of slip of the stiffer medium). They suggested that these 5"second events" were simply examples of "early aftershocks" which also occur preferentially to the NW; however, the fact that these 5 earthquakes could not be recognized as compound at stations located to the SE indicates that the second event actually occurred on the timescale of the passage of the dynamic stress waves. Thus, observations of asymmetry in rupture complexity may form an independent dataset, complimentary to observations of aftershock asymmetry, for constraining models of rupture on bimaterial interfaces. Microseismicity recorded on dense seismological networks has proved interesting for earthquake physics because the high number of events allows one to gain statistical insight into the observed source properties. However, microearthquakes are usually so small that the range of methods that can be applied to their analysis is limited and of low resolution. To address the questions raised above we would like to characterize the source time functions (STF) of a large number of microearthquakes, in particular the statistics of compound events and the possible asymmetry of their spatial distribution. We will show results of the systematic application of empirical Green's function deconvolution methods to a large dataset from the Parkfield HRSN. On the methodological side the performance and robustness of various deconvolution schemes is tested. These range from trivially stabilized spectral division to projected Landweber and blind deconvolution. Use is also made of the redundance available in highly clustered seismicity with many similar seismograms. The observations will be interpreted in the light of recent numerical simulations of dynamic rupture on bimaterial interfaces (see abstract of Rubin and Ampuero).

S52H-03 1410h

Self-consistent Derivation of Earthquake Source Properties: Method and Examples from Seismic Networks at ANZA, CA, and the Karadere-Duzce faults, Turkey

Zhigang Peng[1] (213-740-7174; zpeng@terra.usc.edu)

Frank L Vernon[2] (858-534-5537; vernon@epicenter.ucsd.edu)

Yehuda Ben-Zion[1] (213-740-6734; benzion@terra.usc.edu)

Deborah L Kilb[2] (858-822-4607; dkilb@epicenter.ucsd.edu)

Glenn Biasi[3] (glenn@seismo.unr.edu)

[1]Department of Earth Sciences, University of Southern California, 3651 Trousdale Pkwy, Los Angeles, CA 90089-0740, United States

[2]Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0225, United States

[3]University of Nevada Reno, Seismological Laboratory MS-174, Reno, NV 89557, United States

The functional forms and parameters of the static scaling relation (seismic moment vs. corner frequency) and dynamic scaling relation (seismic moment vs. radiated seismic energy) of earthquakes have been debated for decades. A significant difficulty in determining robust solutions for these source properties is that parameter uncertainties are large for the small earthquakes (M < 3) due to the limited recording bandwidth and severe attenuations of high frequency energy in the near surface layer. These issues can be partially resolved by analyzing a large number of events with a wide range of magnitudes in a self-consistent manner. Large data sets collected by seismic networks near active fault zones provide opportunities for studying earthquake source properties and scaling relations in detail. We are in the process of developing a method that will fit the observed body wave spectra recorded at multiple seismic stations using a Brune (JGR, 1970) omega-square model, and simultaneously apply corrections for the radiation pattern, path and site effects. The method is applied to seismograms collected by the ANZA seismic network in southern California (http://www.eqinfo.ucsd.edu/) and a temporary network around the Karadere-Duzce branch of the North Anatolian fault, which was in operation for 6 months following the 1999 Izmit, Turkey, earthquake. The full methodology and results from those data sets will be presented in the meeting.

S52H-04 1425h

Spectral Element Moment Tensor Inversions for Earthquakes in Southern California

Qinya Liu[1] (626-395-3825; lqy@gps.caltech.edu)

Dimitri Komatitsch[1] (komatitsch@yahoo.com)

Jeroen Tromp[1] (jtromp@gps.caltech.edu)

[1]Seismological Laboratory California Institute of Technology, 1200 E. California Blvd., Pasadena, CA 91125, United States

We have developed and implemented a Centroid Moment-Tensor (CMT) inversion procedure to determine source parameters for southern California earthquakes. The method is based upon spectral-element simulations of regional seismic wave propagation in a recently developed three-dimensional southern California model. Sensitivity to source parameters is determined by numerically calculating the Fréchet derivatives required for the CMT inversion. We use a combination of waveform and waveform-envelope misfit criteria, and facilitate pure double-couple or zero-trace moment-tensor inversions. The technique is applied to six recent southern California earthquakes: the September 9, 2001, $M_W = 4.2$ Hollywood event, the October 31, 2001, $M_W = 4.9$ Anza event, the September 3, 2002, $M_W = 4.2$ Yorba Linda event, the February 22, 2003, $M_W = 5.2$ Big Bear event and $M_W = 4.5$ Big Bear aftershock, and the July 15, 2003, $M_W = 3.8$ Lucerne Valley event. Using more than half of the available three-component data at periods of 6 seconds and longer, the focal mechanisms, locations, and magnitudes we obtain are in good agreement with estimates based upon classical body-wave, surface-wave, and first-motion inversions.

S52H-05 1440h

Earthquake Processes of the 1995 Waitangi Day Sequence, offshore, North Island, New Zealand

Leandro Trevino[1] (915-747-5501; trevino@geo.utep.edu)

Diane Doser[1] (915-747-5501; doser@geo.utep.edu)

[1]University of Texas at El Paso, 500W. University Ave., El Paso, Tx 79902

The 1995 (February 5) Waitangi Day sequence, offshore North Island, New Zealand, began with a magnitude 7.0 mainshock and was followed by 21 smaller events within the first 24 hours of the main rupture. Over the next three weeks a prolific aftershock sequence (> 800 events) continued in the outer rise and trench of the Hikurangi margin. The New Zealand Digital Seismic Network recorded over 1200 events of this sequence were relocated using HypoDD. Results indicate the sequence progressed from north to south. Focal mechanisms from the Harvard CMT catalog suggest normal faulting at shallow depths within the subducting slab. Future work will concentrate determining the stress regime in the area of study and use of empirical Green's functions to determine the directivity of the mainshock. Broadband data is also available and will be used to determine focal mechanisms for the aftershock sequence.

S52H-06 1455h

Regional Wave Propagation in Southeastern United States

Alemayehu Lakew Jemberie[1] (1-901-678-1728; ajemberi@memphis.edu)

Charles A Langston[1] (1-901-678-4869; clangstn@memphis.edu)

[1]CERI, The University of Memphis, 3876 Central Avenue, Memphis, TN 38152, United States

Broad band seismograms from the April 29, 2003, M4.6 Fort Payne, Alabama earthquake are analyzed to infer mechanisms of crustal wave propagation, crust and upper mantle velocity structure in southeastern United States, and source parameters of the event. In particular, we are interested in producing deterministic models of the distance attenuation of earthquake ground motions through computation of synthetic seismograms. The method first requires constraining the source parameters of an earthquake and then modeling the amplitude and times of broadband arrivals within the waveforms to infer appropriate layered earth models. A first look at seismograms recorded by stations outside the Mississippi Embayment (ME) show clear body phases such P, sP, Pnl, Sn and Lg. The ME signals are qualitatively different from others because they have longer durations and large surface waves. A straightforward interpretation of P wave arrival times shows a typical upper mantle velocity of 8.18 km/s. However, there is evidence of significantly higher P phase velocities at epicentral distances between 400 and 600km, that may be caused by a high velocity upper mantle anomaly; triplication of P-waves is seen in these seismograms. The arrival time differences between regional P and the depth phase sP at different stations are used to constrain the depth of the earthquake. The source depth lies between 9.5 km and 13km which is somewhat more shallow than the network location that was constrained to 15km depth. The Fort Payne earthquake is the largest earthquake to have occurred within the Eastern Tennessee Seismic Zone.

S52H-07 1510h

Estimating Earthquake Hazards in the San Pedro Shelf Region, Southern California

Shirley Baher[1] (650 329 4878; sbaher@usgs.gov)

Gary Fuis[1] (fuis@usgs.gov)

William R. Normark[1] (wnormark@usgs.gov)

Ray Sliter[1] (rsliter@usgs.gov)

[1]U. S. Geological Survey, 345 Middlefield Rd MS 977, Menlo Park, CA 94025, United States

The San Pedro Shelf (SPS) region of the inner California Borderland offshore southern California poses a significant seismic hazard to the contiguous Los Angeles Area, as a consequence of late Cenozoic compressional reactivation of mid-Cenozoic extensional faults. The extent of the hazard, however, is poorly understood because of the complexity of fault geometries and uncertainties in earthquake locations. The major faults in the region include the Palos Verdes, THUMS Huntington Beach and the Newport-Inglewood fault zones. We report here the analysis and interpretation of wide-angle seismic-reflection and refraction data recorded as part of the Los Angeles Region Seismic Experiment line 1 (LARSE 1), multichannel seismic (MCS) reflection data obtained by the USGS (1998-2000) and industry borehole stratigraphy. The onshore-offshore velocity model, which is based on forward modeling of the refracted P-wave arrival times, is used to depth migrate the LARSE 1 section. Borehole stratigraphy allows correlation of the onshore and offshore velocity models because state regulations prevent collection of deep-penetration acoustic data nearshore (within 3 mi.). Our refraction study is an extension of ten Brink et al., 2000 tomographic inversion of LARSE I data. They found high velocities (> 6 km/sec) at about 3.5 km depth from the Catalina Fault (CF) to the SPS. We find these velocities, shallower (around 2 km depth) beneath the Catalina Ridge (CR) and SPS, but at a depth 2.5-3.0 km elsewhere in the study region. This change in velocity structure can provide additional constraints for the tectonic processes of this region. The structural horizons observed in the LARSE 1 reflection data are tied to adjacent MCS lines. We find localized folding and faulting at depth (2 km) southwest of the CR and on the SPS slope. Quasi-laminar beds, possible of pelagic origin follow the contours of earlier folded (wavelength 1 km) and faulted Cenozoic sedimentary and volcanic rocks. Depth to basement, where observed, is approx. 1.7 km. beneath the base

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then shallows to approx. 1 km at the top of the SPS. This corresponds to the results obtained by Fisher et al. (in press) and Wright (1991). The pattern of faulting changes from southwest to the northeast. West of CF, faulting is confined to the pelagic and older units. Closely spaced faulting (0.75 km) is prominent between CF and Avalon Knoll (AV), while generally more widely spaced faults (5 km) with localized fracture zones is observed from AV to the SPS. The SPS is dominated by major faults such as the Cabrillo, Palos Verdes, THUMS Huntington Beach and Newport-Inglewood fault zones. The Cabrillo and Palos Verdes fault are major stratigraphic discontinuity with laminar beds (30 cm) adjacent to gently folded sediments (wavelength 1.5 km). There is evidence of recent displacement on the Cabrillo fault.

S52H-08 1525h

The Intersection Model and the Charleston, South Carolina Seismicity

Pradeep Talwani[1] (803-7776449; talwani@geol.sc.edu)

Abhijit Gangopadhyay[1] (803-7774528; abhijit@seis.sc.edu)

Inmaculada Dura-Gomez[1] (803-7774523; idura@geol.sc.edu)

[1]Department of Geological Sciences University of South Carolina, 701 Sumter Street EWSC Building, Columbia, SC 29208, United States

According to the intersection model for intraplate earthquakes, seismicity occurs in the vicinity of suitably oriented (with respect to S_{Hmax}) intersecting faults located in weak zones in the crust (such as failed rifts) in response to plate tectonic forces. The intersections are locations where small pockets of stress accumulation occurs, associated with increased strain rates. Support for this model was provided by multidisciplinary data and simple 2-D modeling of the inferred faults associated with the Charleston earthquakes. Seismicity in the Middleton Place Summerville Seismic Zone (MPSSZ) is located at the southern end of the >200 km long, NNE trending Woodstock fault where it is cut and offset approximately 5 km by the NW trending Ashley River fault. These faults lie within the South Georgia rift basin. Simple 2-D modeling of blocks bounded by these faults, showed that the largest strain rates are located near the jogs, which are also the locations of intense low-level seismicity. A series of GPS surveys in the 1990s in the MPSSZ and surrounding areas showed the presence of strain zonation. The approximately 600 km^2 MPSSZ was associated with strain rates of about 10^{-7}/year. In the surrounding region with an area of 5000 km^2, the strain rate was about 10^{-8}/year and that outside it is 10^{-9}/year compatible with observed values for the North American plate. The results of modeling and GPS surveys - large strain rates in the vicinity of intersecting faults, and the observed seismicity are in accordance with, and provide confirmation of, the intersection model.

S52I MCC: 3007 Friday 1600h

Red Heat: Volcano Seismology and Small-Scale Tomography II *(joint with V)*

Presiding: **B R Julian,** U.S. Geological Survey**; J Pujol,** Center for Earthquake Research and Information, University of Memphis

S52I-01 1600h

Four-dimensional tomography reveals changes in structure 1996 - 2002 at the Coso geothermal area, California

Bruce R. Julian[1] (650 329 4797; julian@usgs.gov)

G. R. Foulger[2] (g.r.foulger@durham.ac.uk)

Francis C. Monastero[3] (francis.monastero@navy.mil)

Keith Richards-Dinger[3] (keith.richards-dinge@navy.mil)

[1]U.S. Geological Survey, 345 Middlefield Rd., MS 977, Menlo Park, CA 94025, United States

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

[3]Geothermal Program Office, NAWS, Code 837000D, 1 Administration Circle, China Lake, CA 93555, United States

The Coso geothermal area, at the southern end of Owens Valley in eastern California, has been commercially exploited for electricity generation for more than a decade. Seismic activity in the area is monitored by a network of three-component digital borehole seismometers operated by the US Navy, and several thousand locatable earthquakes occur each year. This situation is ideal for Local Earthquake Tomography. Inversions for three-dimensional Vp and Vp/Vs structure with resolution of 2 km horizontally and 1 km vertically show that between 1996 and 2002 the Vp/Vs ratio decreased at depths shallower than 2 km below the surface, primarily because of an increase in Vs. This change might be caused by either drying of the rock matrix or decrease in the pore pressure. Time-varying tomography of this kind, previously applied to Long Valley caldera and The Geysers geothermal field, provides a method of monitoring physical changes such as fluid depletion in volcanoes and exploited geothermal reservoirs.

S52I-02 1615h

Variations in the Residual of P Wave Travel-time before and after the 1999 Chi-Chi, Taiwan Earthquake

Chien-Ping Lee[1] (cplee@geps.gep.ncu.edu.tw)

Yi-Ben Tsai[1] (ybtsai@geps.gep.ncu.edu.tw)

[1]Institute of Geophysics, National Central University, 300 Chung-Ta Road, Chung-Li 320, Taiwan

P wave velocity decrease before large earthquakes was suggested as one of the physical clues for earthquake prediction. It may be caused by dilatancy of rocks in the source zone due to development of cracks. In order to verify this hypothesis, we used a simple method for comparing P wave travel-time residuals in order to analyze the variations of velocity changes before and after Chi-Chi earthquake. The residuals were obtained from routine earthquake location using one dimensional velocity model by the Central Weather Bureau of Taiwan. The seismic data from the Central Weather Bureau Seismic Network (CWBSN) were used from 1991 to 2002 with magnitudes greater than ML 3 and focal depths less than 40 kilometers. Since the velocity model was one-dimensional, the travel-time residuals will clearly show lateral inhomogeneity of the crustal velocity structures of Taiwan. However, the travel-time residuals will change with time if the velocity structure changes. In this study, we intended to find the mean residual at each station and the possible changes of the mean residual with time at each of the stations near the Chelungpu fault. The results showed that positive mean travel-time residuals of P wave were high in the Kaohsiung area, southwestern Taiwan and northwestern Taiwan, reflecting thick alluvial sediments in these areas. The mean travel-time residuals of P wave east of the source zone changed very little before and after the Chi-Chi earthquake. However, the mean travel-time residuals of P wave at stations just west of the Chelungpu fault clearly changed before and after the Chi-Chi earthquake. The changes of the velocity structure after the Chi-Chi earthquake could be caused by deformation and movement of the Chelungpu fault associated with the Chi-Chi earthquake. On the other hand, before the Chi-Chi earthquake, there was a long term precursor of velocity decrease because of dilatancy and development of cracks. We can use this method to monitor possible P wave travel-time residual variations as precursors to large earthquakes if variations of the residuals exceed a threshold.

S52I-03 1630h

Seismotectonics of the San Fernando Basin

Jose Pujol[1] (901-678-4827; pujol@ceri.memphis.edu)

Karl Mueller[2] (303-492-7336; Karl.Mueller@colorado.edu)

Peng Shen[3] (pshen@rice.edu)

Vani Chitupolu[4] (vanivamsipriya@hotmail.com)

[1]Center for Earthquake Research and Information, The University of Memphis, Memphis, TN 38152, United States

[2]Department of Geological Sciences, University of Colorado, Boulder, CO 80309, United States

[3]Department of Geology and Geophysics, Rice University, Houston, TX 77005, United States

[4]Department of Mathematical Sciences, The University of Memphis, Memphis, TN 38152, United States

We summarize the results of a tomographic inversion of aftershocks of the Northridge earthquake (recorded during 1994) and San Fernando earthquake carried out using a high resolution inversion package (Benz, et al., JGR, 1966). The study area covers an 80 by 80 km region and the velocity model is parameterized by 2 km wide cubic blocks. The dependence of the inversion model on the initial velocity model (including the SCEC 3-D model) is relatively minor. Moreover, the inversion of realistic synthetic arrival times suggest that our results are reliable. A narrow and well-defined 10 km wide zone of Northridge aftershocks is located in basement rocks between about 10 and 20 km and defines the fault that slipped during the mainshock. The fault plane inferred from seismicity is in good qualitative agreement with the geodetic fault plane determined by Hudnut et al. (BSSA, 1996). Horizontal velocity slices show that the Northridge earthquake occurred within a narrow basement wedge, which may have controlled the size of the earthquake. A dense cluster of aftershocks located immediately above the fault plane is coincident with the deepest portion of the San Fernando Basin where the mainshock rupture offsets sedimentary rocks. Most of the aftershocks of the Northridge earthquake occurred within the basin with a large concentration of events located to the east of the eastern boundary of the mainshock fault plane. The latter events also dip to the southwest, most of them are shallower than 12-13 km and form a band of seismicity 3 to 4 km wide within and near the edge of the basin that we interpret as a major transfer fault that limited the extent of the Northridge rupture. These results are confirmed by the inversion of a larger data set of arrival times from events in an area that is to the east of, and partially overlaps, the Northridge aftershock zone. These events do not lie on the mainshock fault plane, which we interpret as suggesting the San Fernando and Northridge mainshocks are formed as a pair of en-echelon conjugate faults, and that the San Fernando fault does not truncate the Northridge fault, as stated by previous workers. Alternatively, an 8 km wide, almost N-S cross section of the Northridge aftershocks east of the mainshock and aftershocks of the San Fernando earthquake shows that seismicity occurs in a zone that trends across a high velocity basement high (e.g. an extensional horst block). We interpret this as suggesting that older Miocene fault block architecture in this region was subsequently truncated by the Northridge blind thrust, which is a new structure forming in response to shortening across the Transverse Ranges.

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Seismically and Geodetically Constrained Source Mechanisms of Volcanic Induced Seismicity - Miyakejima, Japan, 2000

Sarah E. Minson[1] ((626) 396-1736; minson@seismo.berkeley.edu)

Douglas S. Dreger[2] ((510) 643-1719; dreger@seismo.berkeley.edu)

Roland Burgmann[3] ((510) 643-9545; burgmann@seismo.berkeley.edu)

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

[2]University of California, Berkeley, 281 McCone Hall, Berkeley, CA 94720, United States

[3]University of California, Berkeley, 389 McCone Hall, Berkeley, CA 94720, United States

During a period of volcanic unrest on Miyakejima, Japan in 2000, the largest recorded earthquake swarm in Japan occurred (Japan Meteorological Agency (JMA), 2000). More than 100,000 earthquakes were recorded in the next two months (Ito and Yoshioka, 2002). But the most notable feature of this seismicity is that it migrated northwest with an offshore dike intrusion. In this study, seismic and GPS data are used to independently determine source mechanisms for the two largest earthquakes in this sequence. Broadband seismic data from stations operated by the F-net Broadband Seismograph Network were used in linear moment tensor inversions (Dreger et al, 2000; Dreger and Woods, 2002) to determine deviatoric and full moment tensor mechanisms. Nonlinear inversions of GPS data (Bürgmann et al., 1997) recorded at stations operated by the Geographical Survey Institute of Japan (GSI) were used to find the geometry and slip distribution for each event. Seismic data alone was used to invert for the mechanisms of an additional sixteen earthquakes. Of the eighteen events studied, three have particularly significant mechanisms: EVT3, EVT7, and EVT15. EVT7 occurred on July 8, the same day as the first summit eruption and the formation of a caldera on Miyakejima. The source mechanism for EVT7 has a large volumetric component and appears to be directly related to these processes. For EVT15, the source mechanism from the moment tensor inversions is that of a north-south orientated strike-slip earthquake, making it one of the few double-couple earthquakes in this sequence. The GPS data for EVT15 independently predict a mechanism that is very similar to the mechanism determined by the moment tensor inversions. Furthermore, synthetic seismograms generated using the mechanism determined by the GPS inversions fit the observed seismograms extremely well. This is particularly noteworthy because it shows that the GPS data can predict a completely independent data set. When EVT3 (a large earthquake near the northwest edge of the inferred dike) occurred, the GPS data indicate that there was a significant amount of deflation on Miyakejima. This deflation is clearly not directly