[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 breakup 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 breakup 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

[4]Keiji Takemura, Kyoto University, Institute for Geothermal Sciences, Noguchihara, Beppu 874-0903, Japan

[5]Atsumasa Okada, Kyoto University, Graduate School of Science, Kitashirakawa-Oiwake-Cho, Sakyo-Ku, Kyoto 606-8502, Japan

We present structural models constrained by tectonic geomorphology, surface geologic mapping and high-resolution seismic reflection profiles to define the kinematic evolution and geometry of active fault-related folds along the Nobi-Ise active fault zone (NAFZ). The NAFZ is an active intraplate fault system in central Japan, and consists of a 110-km-long array of active, east-verging reverse faults. We focus on the northern half of the NAFZ, where we use the kinematic evolution of active fault-related folds to constrain rates of slip on underlying blind thrusts and the rate of contraction across the belt since early Quaternary time. Fluvial terraces folded across the east-dipping forelimb, and west-dipping backlimb of the frontal Kuwana anticline suggest that it grows above a stacked sequence of thin-skinned wedge thrusts. Numerous secondary, bedding-parallel thrusts also deform the terraces and are interpreted to form by flexural slip folding that acts to consume slip on the primary blind thrusts across synclinal axial surfaces. Late Holocene fold scarps formed in the floodplain of the Ibi River east of Kuwana anticline coincide with the projected surface trace of the east-vergent wedge thrust tip and indicate the structure has accommodated coseismic (?) kink-band migration of a fault-bend fold during a historic blind thrust earthquake in 1586. A topographic cross-section based on a detailed photogrammetric map suggests 111 m of uplift of ca. 50-80 ka fluvial terraces deposited across the forelimb. For a 35° thrust, this yields the minimum slip rate of 2.7-4.8 mm/yr on the deepest wedge thrust beneath Kuwana anticline. Kinematic analysis for the much larger thrust defined to the west (the Fumotomura fault) suggests that folding of fluvial terraces occurred by trishear fault-propagation folding above a more steeply-dipping (54°), basement-involved blind thrust that propagated upward from the base of the seismogenic crust (about 12 km). Pleistocene growth strata defined by tephra (ca. 1.6 Ma) suggest the Fumotomura fault slips at a rate of 0.7-0.9 mm/yr.

S11B-1141 0830h POSTER

Earthquake Recurrence in the Kachchh-Saurashtra Region, Northwest India: Insights from Historical Data

C.P. Rajendran[1] (303 492 6189; cp$_r$@vsnl.com)

Kusala Rajendran[1] (303 492 6189)

[1]C.P. Rajendran, Center for Earth Science Studies,, Trivandrum 695031, India

The occurrence of two M >7.5 earthquakes in 1819 and 2001, is unexpected in the mid-plate setting of the Kachchh basin, a Mesozoic rift system in northwestern India,. Three issues are recognized as central to the assessment of future seismic hazards in the region. First, the perceived inactivity of surface structures may result from long interseismic intervals. Second, potentially active structures, as exemplified by the Bhuj earthquake (whose rupture terminate below 9 km depth), may lie hidden beneath surface geology. Finally, seismic source zones may be characterized by varying recurrence rates and styles of deformation. The study of past seismicity in the Kachchh region is facilitated by an exceptionally rich >5000 year archaeological and historical database, with paleoseismological data providing additional constraints (Rajendran and Rajendran, 2001). We report here evidence for three earlier earthquakes in 893 AD, c. 30 AD and 2500-2200 BC .

Trench investigations indicate that an earthquake sharing similar deformational characteristics as that of the 1819 event occurred in 893 AD (Rajendran and Rajendran, 2002). Evidence for a still older event (30 AD) has been obtained from archaeological excavations near Dwarka, a coastal town 200 km SW of the 1819 and 2001 earthquake sources, suggesting a millennium-long interval between events.

In contrast, trenching excavations in the meizoseismal area of the 2001 earthquake, and the pattern of documented damage to historical and ancient monuments, suggest that the 2001 source region may be associated with a much longer recurrence interval. Ancient ruins at Dholavira, a major Harappan city (2600 to 1600 BC) about 60 km from Bhuj epicenter, is the oldest structure in the 2001 epicentral area. Archaeologists attribute repairs undertaken during Stage III of this settlement (2500- 2200 BC) to earthquake related damage (Joshi and Bisht, 1994). Paleoliquefaction features near Ahmedabad, a site located within the Cambay basin, provide additional evidence for the occurrence of an earthquake dated at 2948295 yr BP, its source remaining uncertain (Rajendran et al., 2002). Our study suggests the existence of multiple seismic sources within the Kachchh-Saurashtra rift system that can generate large earthquakes, and these may be characterized by varying recurrence patterns and styles of deformation. A fundamental issue is to understand the driving mechanism for the multiplicity of large earthquakes within a short period of about 5000 years, in an area traditionally classified as a stable continental region.

S11B-1142 0830h POSTER

Large Historic Earthquakes of the Northern Canadian Cordillera: The 1953-1957 MacKenzie Mountains Earthquake Sequence

John F. Cassidy[1] (250-363-6382; cassidy@pgc.nrcan.gc.ca)

Allison Bent[2] (bent@seismo.nrcan.gc.ca)

[1]John F. Cassidy, National Earthquake Hazards Program, Geological Survey of Canada, P.O. Box 6000, Sidney, BC V8L 4B2, Canada

[2]Allison Bent, National Earthquake Hazards Program, Geological Survey of Canada, 7 Observatory Cr., Ottawa, ON K1A 0Y3, Canada

The northern Canadian Cordillera is a region of intense, yet poorly understood seismicity. Between 1953 and 1957 a series of five moderate-to-large earthquakes (M=5.5-6.5) struck the northern MacKenzie Mountains. These are the largest earthquakes ever recorded in the immediate area, although earthquakes as large as 6.5-6.9 have occurred in a similar tectonic environment, both a few hundred km's to the northwest, and to the southeast. With renewed interest in seismic hazards in this region, we have examined this previously unstudied earthquake sequence to better define the epicentres, focal depths, and magnitudes, and to determine the focal mechanisms.

The 1953 and 1955 earthquakes, which occurred in a sparsely populated region, were felt (up to intensity V) to distances of 230-280 km. The magnitudes (Ms) of these events have been determined at 6.3 and 6.5, respectively. Epicentres have been re-determined using teleseismic path corrections obtained from well-recorded modern earthquakes (M=4.5-5) in this region, and by waveform comparison techniques. The relocated epicentres are distributed in a ESE-WNW direction over a distance of about 45 km. The first earthquakes in the sequence are located to the ESE and later events appear to migrate to the WNW. The 1955 mainshock and largest aftershock are separated by about 20 km, with the aftershock being located to the NNE of the mainshock. The 1957 (M=5.3) earthquake is located a similar distance and direction from the 1956 (M=5.6) earthquake, suggesting that it may be an aftershock of that event. Focal mechanisms and depths were determined using body wave modelling. All depths ranged between 9 and 15 km, and focal mechanisms show thrust faulting along either a plane dipping at 30-40 degrees to the NNE, or a plane dipping at 50-60 degrees to the SSW. The orientation of the WNW-ESE striking nodal planes is consistent with the distribution of epicentres and the regional geology. The NNE-SSW striking, shallow-dipping P-axes are consistent with the regional stress field. It is likely that these earthquakes are caused by stresses transmitted from the plate boundary more than 700 km to the west, activating favourably oriented thrust faults in the northeastern Canadian Cordillera.

S11B-1143 0830h POSTER

Paleoseismic Evidence for Prehistoric Earthquakes on the Northern Maacama Fault, Willits, California

Clark H Fenton[1] (510-874-1775; clark_fenton@urscorp.com); Carol S Prentice[2] (650-329-5690; cprentice@usgs.gov); Jennifer L Benton[1]; Christopher J Crosby[2]; Robert R Sickler[2]; Tom A Stephens[3]

[1]URS Corporation, 500 12th Street, Suite 200, Oakland, CA 94607, United States

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

[3]SHN Consulting Engineers Geologists, Inc., 812 West Wabash, Eureka, CA 95501, United States

The right-lateral strike-slip Maacama fault zone (MFZ) has been interpreted as the northern continuation of the Hayward-Rodgers Creek fault system, and is considered to be an active structure because of its youthful tectonic geomorphology, association with an elevated rate of small magnitude seismicity, and contemporary creep. However, it has not generated any known large historical earthquakes. The MFZ is known to creep at a rate of about 6.5 mm/yr (measured over a 10 year period) through the town of Willits (Galehouse, 2002). Modeling of geodetic data across northern California suggests approximately 14 mm/yr of strike-slip motion across the MFZ (Freymueller et al., 1999). Therefore, we expect the MFZ, like the Hayward fault, to both creep and produce large earthquakes in order to reconcile the difference between the creep rate and the total slip rate across the fault. Previous paleoseismic investigations near Ukiah, 30 km south of Willits, suggest that the most recent large earthquake on the MFZ occurred between 1500 AD and 1630 AD (Sickler et al., 1999). We excavated six trenches across the MFZ in Willits. Four trenches crossed a southwest-facing, two- to five-m-high fault scarp on the southwest side of a pressure ridge, and two trenches were excavated across the projection of the fault to the south in an area of younger alluvium with no surface expression of the fault. The trenches across the scarp exposed a steeply northeast-dipping fault plane, juxtaposing Pleistocene lacustrine clays (dated at 18,810 80 radiocarbon years BP) overlain by a cap of Holocene alluvium to the northeast, against a sequence of Holocene fluvial and colluvial deposits to the southwest. Structural and stratigraphic relations suggest at least four and probably five faulting events during the (late?) Holocene. Slickensides plunging 10-12° to the northwest show a horizontal to vertical slip ratio of about 5:1. The trenches excavated across the area of younger alluvium show evidence for only one faulting event. We interpret the uppermost deformation in these trenches, a series of upward fanning fractures with little displacement, to be the result of fault creep.

S11B-1144 0830h POSTER

Historical analysis of the 1884 Bear Lake earthquake, northern Utah and southern Idaho: Slip on Basin and Range faults

James P. Evans[1] (435-797-1267; jpevans@cc.usu.edu)

Dawn Martindale[1] (435-797-1273; dcmartindale@yahoo.com)

Richard D. Kendrick (435-797-1273; rdkendri@cc.usu.edu)

[1]Utah State University, Dept. of Geology 4505 Old Main Hill, Logan, UT 84322-4505

We use the results of a detailed historigraphical analysis of accounts of the M 6.3 1884 earthquake in northern Utah to determine its location, nature of ground shaking, and the geologic setting of the hypocenter. Previous reports were based on newspaper reports, and placed the event at 0130 local time, 10 November 1884, at 42° N 111° W. We found 75 new felt reports from 19 sites to constrain the event. Detailed reports were found by examining journal reports of settlers, year-end reports of local churches, and letters to newspapers. Reports of the time are rich in detail and reflect a relatively uniform lifestyle that allows us to define Mercalli felt zones. Our work reveals that the epicenter of the Mercalli VIII event was approximately 42.3° N, 111.4° W, approximately 30 km NW of the events original location. Detailed reports of damage to structures and the consequences of ground shaking to define a felt area of approximately 70,000 km^2, and estimate the peak ground accelerations as 100 300 cm/sec^2. The felt zone was a northwest-southeast trending ellipse in the basin, which may reflect settlement patterns at the time. The hypocentral depth was 5.9 ± 3.2 km. Analysis of the geologic structure of the area indicates that the epicentral area is a graben bounded on the east by the listric Bear Lake fault and on the west by the West Bear Lake fault. The east Bear Lake fault has 4-5 km of slip, and controls the structure of the basin. However, the earthquake epicenter was on the west side of the basin, and we interpret the event to have been the result of slip on the West Bear lake fault, or on a smaller displacement fault in the hanging wall of the Bear Lake fault. Quaternary activity on the West Bear Lake fault is documented by trenching studies (McCalpin, 1993), and by offset Quaternary surfaces. These data suggest that moderate magnitude earthquakes on antithetic or small displacement faults do pose a significant seismic hazard in the northeastern Basin and Range province. We also demonstrate the utility of combining geological and historigraphic analyses to examine pre-instrument earthquakes of the western United States.

S11B-1145 0830h POSTER

Depth Analysis of Historic Seismicity Using Intensity Data With Special Reference to Arizona Events

David S. Brumbaugh (1-928-523-7191; david.brumbaugh@nau.edu)

Northern Arizona University, Department of Geology Box 4099, Flagstaff, AZ 86011, United States

Intensity derived focal depths can be a useful parameter for historic tremors because of the lack of constraint from instrumental data. The well known Bath equation: $I_o=3\log[(r^2+h^2)/h^2]+2$ tends to give foci that are too deep. A newer modified equation: $I_o=2.8\log[(2.79A_v/pi+h^2)/h^2]+2-6/1.2h+(6-I_o)/6$, was empirically developed from a data base of 24 earthquakes that had well constrained instrumental depths and intensity maps. The average difference between instrumental depths and modified equation depths was 3 kilometers. Half of the events differed from the instrumental depth by 2 kilometers or less.

The modified equation was applied to tremors of M5.0 or greater in Arizona that occurred between 1906 and 1959. These tremors had no depth estimates or ones that were inaccurate. A calibration test of the modified equation was performed on a 1976 Arizona event that had instrumental depth estimates of 10-15 kilometers. The intensity depth from the modified equation was 11-12 kilometers. The modified equation was then used to calculate depths for the following earthquakes in northern Arizona: 1-25-1906, M6.2, depth=30 $\pm 3 kilometers; 8-18-1912, M6.2, depth = 20 \pm 3 kilometers; 7-25-1959, M5.75, depth = 11 \pm 3 kilometers$.

The 1959 tremor had a published depth of 0.5 kilometers from instrumental data. The intensity derived depth of 11 kilometers appears more reasonable. The 1906 and 1912 tremors did not have instrumentally determined depths due to lack of data. The mid to lower crustal depths of these two events suggests a thick seismogenic layer, unusual in continental areas. A cold, thick Colorado Plateau crust and upper mantle is documented by other tremors of more than 40 kilometers depth and relatively low heat-flow values.

S11B-1146 0830h POSTER

Aftershock Relocation, Rupture Area, Mantle Magnitude and Energy Estimates of the 1946 Aleutian Tsunami Earthquake and Neighboring Events

Alberto M Lopez[1] (847-491-5379; alberto@earth.northwestern.edu)

Emile A Okal[1] (847-491-3194; emile@earth.northwestern.edu)

[1]Northwestern University , Dept. of Geological Sciences Locy Hall 1850 Campus Drive, Evanston, IL 60208, United States

Using the iterative interactive method of Wysession et al. (1991),we have relocated 48 aftershocks of the April 1, 1946 Aleutian earthquake from original ISS bulletin listing of P and S arrival times, to obtain better constraints on the rupture zone associated with this tsunami earthquake. For each event, we obtained an uncertainty ellipse using a Monte Carlo statistical simulation. The new distribution of aftershocks and their respective error ellipses were then used to formally determine a minimum rupture area for the event. With a length of 180 km and width of 115 km, the rupture zone is larger than previously suggested by the analysis of fewer but larger aftershocks that occurred a maximum of weeks after the main shock. The position of the mainshock epicenter close to the center of the rupture zone along the subduction zone indicates bilateral rupture. This rupture would suggest an overlap of the proposed Unalaska seismic gap to the West but not of the Shumagin gap to the East. We will refine this conclusion by similarly studying the 1938 and 1948 series occurring to the East of the 1946 earthquake. We confirm a seismic moment for the 1946 event of 5 to 8 times 10^{28} dyne-cm, based on mantle magnitude measurements, notably on a recovered Benioff 1-90 record at Pasadena. By contrast, the energy of the event is strongly deficient, with a THETA parameter (log of energy-to-moment ratio) estimated at only -6.74, the lowest value of computed so far for any subduction zone, close to 2 full units less than predicted by standard scaling laws.

S11B-1147 0830h POSTER

Asperity Map Along the Subduction Zone in the Northeastern Japan Inferred From Historical Seismograms

Yoshiko YAMANAKA[1] (sanchu@eri.u-tokyo.ac.jp)

Masayuki KIKUCHI[1] (kikuchi@eri.u-tokyo.ac.jp)

[1]ERI, Univ. of TOKYO, 1-1-1 Yayoi Bunkyo-ku, Tokyo 113-0032, Japan

In the off-Tohoku region, northern Japan, M7 class earthquakes have repeatedly occurred in an interval of about 30years. The seismic observation by low-gain seismometers has been carried out by Japan Meteorological Agency and universities in Japan since the beginning of 1900's. Collecting these historical seismograms, we examined the fault asperity (large slip area) for individual large earthquakes greater than M7.0. They include the earthquakes of 1931(Mw7.3), 1936(7.4), 1937(7.1), 1960(7.2), 1968(8.3), 1968(7.0), 1978(7.5), 1980(7.1), 1989(7.0), 1994(7.7). We obtained that the events of 1931, 1968, and 1994 shared a common asperity and the events of 1960, 1968, and 1989 also shared another common asperity. Some characteristic features of the asperities are as follows:

(1) The individual asperity has its own location and extent.

(2) The asperity locates away from the hypocenter.

(3) The asperity is surrounded by aftershocks.

The patterns of asperity distribution in northern Japan subduction zone are divided into three different categories. In northern part (40N-41.3N) the seismic coupling in asperity is almost 100% and the size of asperity is large. In central part (39N-40N) little seismic moment is released by large earthquakes and asperity size is small. In southern part (37.8N-39N) the seismic coupling coefficient is about 50%. The variation in seismic coupling along the Japan Trench seems to correlate with bathymetry of the subducting plate such that the graven-rich structure at the ocean bottom corresponds to the aseismic moment release. It is also interesting to note that a large back-slip motion in the northern part, which is derived from GPS data, may be consistent with the existence of two large asperities.

S11B-1148 0830h POSTER

Source characteristics of the 1936 Kawachi-Yamato, near Osaka, earthquake (M=6.4)

Haruo Horikawa[1] (+81-298-61-3989; h.horikawa@aist.go.jp)

Kenji Satake[1] (kenji.satake@aist.go.jp)

Yuzo Ishikawa[2] (catfish@wa2.so-net.ne.jp)

Yasuhiro Umeda[3] (umeda@rcep.dpri.kyoto-u.ac.jp)

[1]Active Fault Research Center, GSJ/AIST, Tsukuba Central 7, 1-1-1 Higashi,, Tsukuba, Iba 305-8567, Japan

[2]Meteorological Research Institute, JMA, 1-1 Nagamune, Tsukuba, Iba 305-0052, Japan

[3]Disaster Prevention Research Institute, Kyoto University, Gokasho, Uji, Kyo 611-0011, Japan

Analysis of strong ground motion records from the 1936 Kawachi-Yamato earthquake (M_{JMA}=6.4) shows that slip of 90 cm occurred below a depth of 10 km and rupture propagated almost unilaterally to NNE over a 8 km-long fault.

The 1936 Kawachi-Yamato earthquake occurred about 20 km southeast of Osaka. Detailed reports on this earthquake sequence and associated damage as well as strong ground motion records are available for our analysis.

We first relocated the hypocenters of the mainshock and 17 aftershocks. The hypocenter of the mainshock was relocated near the northern edge of Kongo fault system. Depth of the hypocenter of the mainshock is about 17 km near the bottom of the aftershock distribution.

Focal mechanism of the mainshock was determined from P-wave first motions. One of the nodal planes strikes NNE–SSW and steeply dips to WSW with right-lateral and reverse slip components. This nodal plane seems to agree with the trend of aftershock distribution, but the correspondence is not clear because linear alignment of the aftershock distribution was not distinct.

Strong motion seismograms recorded at the Abuyama observatory, about 40 km away from the hypocenter, were modeled by a trial and error approach. We assumed a constant slip and rupture velocity over a single fault. The fault location was inferred from the aftershock distribution, and the fault size was adjusted to the synthetic waveforms to best fit the observed waveforms.

The fault length was estimated to be 8 km, and the depth extent of the fault was confined to be between 11 and 17 km. The slip amount and the seismic moment were estimated to be 90 cm and 2×10^{19} Nm, respectively. Waveforms from rupture velocity of 2.5 km/s explained the observed waveforms best among the values between 2.0 and 3.0 km/s. The rupture mainly propagated to NNE.

S11B-1149 0830h POSTER

The 1930 Irpinia earthquake: collection and analysis of historical waveforms

Graziano Ferrari[1] (ferrari@sga-storiageo.it); Antonella Megna[2] (megna@ingv.it); Anna Nardi[2] (nardi@ingv.it); Barbara Palombo[2] (palombo@ingv.it); Bruna Perniola[3] (perniola@axub02.fis.uniurb.it); Nicola Alessandro Pino[2] (pino@ingv.it)

[1]SGA Storia Geofisica Ambiente, Via Bellombra, 24/2, Bologna 40136, Italy

[2]Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata, 605, Roma 00143, Italy

[3]Universit degli Studi di Urbino, Via S. Chiara, 27, Urbino, PU 61029, Italy

The 1930 Irpinia earthquake is one of the most destructive events recorded by instruments in Italy. Several large events occurred in the same area before (1456, 1694, 1702, 1732, 1910) and after (1962, 1980, 1983) 1930. It has been hypothesized that significant differences characterized the source geometry.

Early work carried out by several authors on macroseismic studies and a single-station waveform analysis, suggests a quasi-strike slip mechanism on an approximately EW-oriented fault plain. Conversely, all the major events in the area display normal fault mechanisms on Apennine-oriented (NW-SE) fault planes.

In the present work we have collected about 45 waveforms for the 1930 earthquake, recorded in various European observatories, aiming to find precious hints on source geometry and kinematics.

The seismograms have been rasterized, digitized and processed within the framework of the SISMOS project.

The study of this earthquake is part of a wider ongoing research program on the 20th century Irpinia earthquakes (1910, 1030, 1962 and 1980) within the collaboration between the TROMOS and SISMOS projects of the National Institute of Geophysics and Volcanology. The search and recovery of the historical recordings is a unique opportunity to shed light upon scientific aspects related to this kind of investigation.

Preliminary results about the 1930 earthquake waveform analysis are presented here.

S11B-1150 0830h POSTER

The 1978 Miyagi-oki earthquake

Yuichiro Tanioka (+81-298-52-9206; ytanioka@mri-jma.go.jp)

Meteorological Research Institute, 1-1 Nagamine, Tsukuba 305-0052, Japan

On June 12, 1978, a large earthquake (M=7.4) occurred off the Pacific coast of Miyagi prefecture, northeastern Japan. The earthquake killed 28 persons and caused extensive damage in Miyagi prefecture. The previous large earthquake occurred in this region on November 3, 1936. Therefore, a next large earthquake is expected in this region in near future. It is important to estimate the slip distribution of both the 1978 and 1936 events in order to discuss a possible rupture area of the next event. In this paper, we estimate the slip distribution of the 1978 Miyagi-oki event using the tsunami waveforms observed at 12 tide gauge stations along the Pacific coast of northeastern Japan.

Previously, the rupture process of the 1978 Miyagi-oki earthquake was estimated using the seismological data (eq. Seno (1980)). Seno (1980) show that the focal mechanism of the earthquake is a thrust type and the seismic moment is 3.1x10**20Nm. The event was separated into two subevents, one ruptured the eastern (trench-ward) part and the other ruptured the western (landward) part of the aftershock area.

We numerically compute the tsunami waveforms using the finite-difference computation for the linear long-wave equations. The grid size is basically 20 sec of arc (about 600m), but finer grids (4 sec of arc) are nested near the tide gauge stations. Tsunami waveforms at 12 stations are computed for two subfaults (the western and eastern parts) with a unit amount of slip, and use as the Green's function for the inversion. The subfault size is 30km X 30km. The result of the inversion shows that the slip amounts of the western and eastern parts are about 1.3 m and 1.0 m, respectively. The total seismic moment is calculated as 1.4 X 10**20Nm (Mw=7.4) assuming that the rigidity is 5 X 10**10 N/m**2. This estimate is smaller than the seismic moment estimated from seismological data. The slip amount in the western subfault is larger than that in the eastern subfault. This slip pattern is consistent with the previous result. It will be interesting to estimate the slip pattern of the 1936 event and compare it with the slip pattern of the 1978 event in this study.

S

S11B-1151 0830h POSTER

Crustal Structure Near Coalinga, California Revisited: Implications for the Hypocentral Region of the 1983 M_L 6.7 Earthquake

Drew A Popovich[1] (915-747-5501; dpopovich@kmg.com)

Kate C Miller[1] (915-747-5424; miller@geo.utep.edu)

[1]University of Texas at El Paso , Department of Geological Sciences, El Paso, TX 79968-0555, United States

On May 2, 1983, a M_L 6.7 earthquake occurred about 12 km northeast of the town of Coalinga, California on a previously unknown fault zone that underlies the boundary between the Coast Ranges and the Great Valley. Aftershock and focal mechanism studies have shown that the earthquake probably occurred on a southwest-dipping thrust fault at ca. 10 km depth. A number of geophysical studies including acquisition and interpretation of seismic reflection and refraction data were conducted by the U. S. Geological Survey shortly after the earthquake in order to illuminate the hypocentral zone. These studies showed that the earthquake likely occurred within a wedge of Franciscan material that lies beneath folded sedimentary rocks of the Great Valley.

We have revisited the U.S. Geological Survey data set along with COCORP reflection data and refraction data from the 1994 Southern Sierra Continental Dynamics experiment. First arrivals from the refraction

data were used to develop a 3D velocity model for the region. This velocity model was then used to depth-convert the seismic reflection data . The results of this analysis suggest that Great Valley group sedimentary rocks occur to depths of 10 km in the vicinity of the Coalinga earthquake hypocenter. Previous analysis has put the base of Great Valley sedimentary rocks at 5 to 6 km depth. Our result implies that the Coalinga earthquake occurred at the interface between Great Valley and Franciscan rocks, rather than within a wedge of Franciscan material. This interface may represent a natural rheological boundary which focused slip during the earthquake.

S11B-1152 0830h POSTER

Recurrence of Large Earthquakes on the 1999 Izmit Surface Rupture, North Anatolian Fault, Turkey

Hiroyuki Tsutsumi[1] (tsutsumh@kugi.kyoto-u.ac.jp); Shinji Toda[2] (s-toda@aist.go.jp); Omer Emre[3] (emre@mta.gov.tr); Mitsuru Okuno[4] (okuno@fukuoka-u.ac.jp); Selim Ozalp[3] (ozalps@mta.gov.tr); Cengiz Yildirim[3] (cengizyildirim@mta.gov.tr); Keita Takada[5] (keita@fukken.co.jp); Toshio Nakamura[6] (nakamura@nendai.nagoya-u.ac.jp)

[1]Department of Geophysics, Kyoto University, Kitashirakawa, Sakyoku, Kyoto 606-8502, Japan

[2]Active Fault Research Center, GSJ/AIST, Higashi 1-1, Tsukuba 305-8567, Japan

[3]Geological Research Department, Mineral Research and Exploration, MTA, Ankara, Ankara 06520, Turkey

[4]Department of Earth System Science, Fukuoka University, Jonanku, Fukuoka 814-0180, Japan

[5]Fukken Co. Ltd, Iwamoto-cho 3-8-15, Chiyoda-ku, Tokyo 101-0032, Japan

[6]Tandetron AMS 14C Dating Laboratory Center for Chronological Research, Nagoya University, Nagoya, Nagoya 464-8602, Japan

To reveal the evidence for paleoearthquakes and their recurrence intervals on the NAF, especially the Izmit segment that ruptured at the 1999 Izmit, we have performed a trench excavation survey at Tiktik, east of Izmit. We found evidence for three or possibly four surface-rupturing events including the Izmit earthquake, since the 17th century. Thus the average recurrence interval in the past 400 years can be estimated to be 100-200 years. Such an interval is significantly shorter than ones previously estimated, such as 450 years. However, our result is consistent with calculations from historical coseismic offsets of 2-3 m at the trench site, divided by the observed geodetic slip rate(22+-3 mm/yr) as inferred from GPS networks.

Our excavation site is located on a Holocene alluvial flood plain underlain by Tertiary bedrock. At the site, 2.5-3.0 m of right-lateral displacement of a couple of footpaths in a cone field was measured immediately after the Izmit earthquake. The vertical separation associated with the earthquake was roughly estimated at 0.3-0.4 m. The trenches exposed a sequence of fine-grained flood deposits intercalated with paleosol units. These flood deposits are depression-filling sediments overlying deformed paleosol layers with onlap or offlap unconformities. Considering the divided flooding events into four stratigraphic units. At the bottom of the upthrown southern block, extensively-weathered bedrock with vertical separation more than 2 m across the fault zone shows accumulated slip due to multiple faulting events. On the basis of three sets of angular unconformities atop a paleosol and postdated depression-filling units, four surface-rupturing events, including the Izmit shock, are inferred to have occurred at the trench site. As well as the event horizons, a remarkable finding in this trench is a buried offset channel trending nearly perpendicular to the fault zone. We used the channel edges as piercing lines. Our best estimate of the right-lateral offset is 4.8+-0.3 m, which also involves the penultimate event. Thus, the offset by the penultimate event might be the same as or a little smaller than the one by the Izmit earthquake. Although we are currently intensively performing radiocarbon dating to constrain the timing for each event, recovery of 400 yr old wood fragments from the oldest paleosol suggest these three or four surface-rupturing events might have occurred since the 17th century.

S11B-1153 0830h POSTER

New perspectives on the fault geometry and segmentation of the Coalinga - Kettleman Hills blind-thrust system

Chris A. Guzofski[1] (guzofski@fas.harvard.edu)

John H. Shaw[1] (shaw@eps.harvard.edu)

[1]Harvard University, Dept. of EPS 20 Oxford St., Cambridge, MA 02138

We map the three-dimensional (3-D) geometry of the seismogenic Coalinga - Kettleman Hills fold and thrust system in the San Joaquin basin of central California using regional seismic reflection profiles and seismicity to provide new insights into how structural geometry controls blind-thrust earthquake segmentation. In order to characterize the structural geometry of this system, we integrate two-dimensional seismic reflection ($\sim$ 10,000 line km), well-bore, and surface geologic data into a 3-D subsurface structural model. Additionally, we include over 1200 hypocenter and 200 focal mechanisms from the blind-thrust system into our structural model in order to identify the presence of seismically active faults. In this region, the 1982 New Idria (Mw = 5.4), 1983 Coalinga (Mw = 6.5), and the 1985 Kettleman Hills (Mw = 6.1) earthquakes and corresponding aftershock sequences defined a southward progression of deformation on the blind-thrust fault system. Structural analysis of the Coalinga anticline demonstrates that it is a fault-related fold underlain by two large thrust ramps, rather than a single fault. The 1983 mainshock occurred on the deeper of these ramps, which uplifts, but generally does not fold, the Coalinga anticline. In contrast, the upper ramp is responsible for the growth of the Coalinga fold. Both ramps merge with a series of imbricated and actively deforming backthrusts forming structural wedges.

The temporal clustering of events along the system provides evidence that the Coalinga and Kettleman Hills blind thrusts are linked. However, the en echelon pattern of the folds and the spatially distinct aftershock sequences suggest that the ruptures were arrested by a geometric segment boundary. The hypothesis that rupture propagation was controlled by a discrete tear fault is supported by strike lines that image a steeply dipping (strike slip?) fault between the the Coalinga and Kettleman Hills anticlines (Polvadero Gap) which accommodates differential motion between the Coalinga and Kettleman Hills fault-related folds.

S11B-1154 0830h POSTER

Re-evaluation of Fault Geometry and Slip Distribution of the 1944 Bolu-Gerede Earthquake Rupture, North Anatolian Fault System, Turkey

Hisao Kondo[1] (81-824-24-6656; kondoh@hiroshima-u.ac.jp); Yasuo Awata[2] (81-298-61-3823; awata-y@aist.go.jp); Omer Emre[3] (90-312-287-3430; emre@mta.gov.tr); Ahmet Dogan[3] (90-312-287-3430; dogan@mta.gov.tr); Selim Ozalp[3] (90-312-287-3430; ozalps@mta.gov.tr); Fatma Tokay[3] (90-312-287-3430; tokay@mta.gov.tr); Cengiz Yildirim[3] (90-312-287-3430; cengizyildirim@mta.gov.tr)

[1]Faculty of Letters, Hiroshima University, 1-2-3 Kagamiyama, Higashi-Hiroshima 739-8522, Japan

[2]Active Fault Research Center, Geol. Surv. Japan / AIST, Tsukuba Central 7, Higashi 1-1-1, Tsukuba 305-8567, Japan

[3]Department of Geology Researches, Mineral Research and Exploration of Turkey, 06520, Ankara 06520, Turkey

The successive earthquakes along the North Anatolian Fault System in 20th century provides us fundamental data on fault segmentation, characteristics faulting behavior, and dimensions and scaling laws of faulting. In this point of view, we re-evaluate geometry and slip-distribution of the Ms7.3 Bolu-Gerede earthquake rupture of 1944, which has not been studied since 1970.

The 1944 rupture is traceable for about 185-km, from 30-km west of Bolu (40.6N, 31.4E) to 20-km west of Ilgaz (41.0N, 33.4E) almost continuously and straightly, trending N75E. Amount of slip along the rupture varies between 2 and 6 m right-laterally. In the middle-east section of the rupture, east of Gerede, the slip is as large as 4.5 to 6 m. Along the other sections, the amount of slip decreases to about 2-4 m. The rupture can be subdivided into 5 to 7 geometrical segments of 10 to 45-km-long, which are separated by small separation, bend, step, push-up and pull-apart structures. At 6-km east of Iametpasa (40.9N, 32.7E), a series of foundation of a stone-bridge, which is built approximately AD 680+190-90 (Ikeda, 1994), has been offset for about 20 m. The 3.5 to 4.0 m slip-per-event during the 1944 earthquakes suggests that the 20 m displacement has been accumulated by 5 to 6 faulting events with an average recurrence interval of about 200 to 350 years.

Re-evaluated average slip of the 1944 rupture is about 3.5 m that is almost twice of the previously well-known amount. The straightness and continuance of the fault strands foresee that the 1944 earthquake had more simple rupture process and shorter source time than those of 1999 Izmit earthquake of Ms 7.4.

S11B-1155 0830h POSTER

Rupture History of the 1944 Bolu-Gerede Segment of the North Anatolian Fault: Gerede-Ardicli Trench Re-excavated

Koji Okumura[1] (81-824-24-6657; kojiok@hiroshima-u.ac.jp); Yasuo Awata[2] (81-298-61-3696; awata-y@aist.go.jp); Tamer Y Duman[3] (90-312-287-3430; tduman@mta.gov.tr); Fatma Tokay[3] (90-312-287-3430; ftokay@mta.gov.tr); Ismail Kuscu[3] (90-312-287-3430; environ@mta.gov.tr); Hisao Kondo[1] (kondoh@hiroshima-u.ac.jp)

[1]Hiroshima University, Kagamiyama 1-2-3, Higashi-Hiroshima 739-8522, Japan

[2]AIST-GSJ Active Fault Research Center, Higashi 1-1-1 Chuo-7, Tsukuba 305-8647, Japan

[3]MTA Geological Research Department, 06520, Ankara 06520, Turkey

Though the intensive research on the North Anatolian fault after the 1999 Kocaeli earthquake brought a lot of information on the present and past activity of the fault, our knowledge about the rupture history and the past slips along the entire length of the North Anatolian fault is still very limited. More precise data on the timing and amount of past slips along the fault is indispensable to understand the fault behavior in the past and in the future. The Aridicli trench site, 15 km east of Gerede, is one of the most promising sites for this investigation, for abundant datable material and for ideal sedimentation history to record recent earthquakes. Okumura et al. (1990, 1993) opened a trench here in 1990 and concluded 8 earthquake events in 2000 years. However, the conclusion depended mostly on indirect evidence of coseismic deformation along the fault because few master fault strands repeatedly ruptured in pure strike-slip condition and dating was not enough. The Gerede 2002 trench was opened about 18 m east of the 1990 trench, cutting into a 10 m by 10 m light-toned area on an aerial photography. The light-toned area turned out to be a small pressure ridge or dome associated with an a-few-meter-wide restraining jog of the fault. The north side of the fault in the 3-metere-deep trench consists of an anticline of ca. 1000 B.P. to 2000 B.P. lacustrine deposits underlain by 1000 B.P. and younger flood and marsh deposits. Two distinct levels of overlap indicate the timing of events that accompanied the growth of the anticline. The south side of the faults consists of 0 to ca. 1000 B.P. flood and marsh deposits. A basement of a brick kiln is cutting into the deposits and tilted conformably with the dip of the sedimentary units. Steeply north dipping oblique-reverse faults bifurcates from vertical master fault zone. There are three discrete levels of upper terminations of these subsidiary faults, beside the flower structure at the top of the master fault. These four events occurred during these 1000 years. Based on the radiocarbon dates and events from the 1990 trench, and historic earthquakes, these events are likely to be correlated with 1944, 1668 (Ambraseys and Finkel 1988), 14th century (Okumura et al., 1994), and 1050 (Ambraseys, 1970) events. This time series, yet to be confirmed by the dating under way, shows quasi-periodical recurrence of every 250 to 300 years. The offset streams around the trench may also indicate 4 to 5 meters slips have been regularly repeated during these events.

URL: http://home.hiroshima-u.ac.jp/kojiok

S11B-1156 0830h POSTER

Stable creeping and distant triggered slips by the 1999 Izmit Earthquake along the Ismetpasa section, North Anatolian Fault Zone, Turkey

Ahmet Dogan[1] (90 312 2879176; dogan@mta.gov.tr); Hisao Kondo[2] (kondoh@hiroshima-u.ac.jp); mer Emre[1] (emre@mta.gov.tr); Yasuo Awata[3] (awata-y@aist.go.jp); Selim zalp[1] (ozalps@mta.gov.tr); Fatma Tokay[1] (ftokay@mta.gov.tr); Cengiz Yldrm[1] (cengizyildirim@mta.gov.tr)

[1]General Directorate of Mineral Research and Exploration, Dept. of Geological Researches, Balgat, Ankara 06520, Turkey

[2]Department of Geography, Hiroshima University, Higashi-Hiroshima, Hiroshima 739-8522, Japan

[3]Active Fault Research Center, Geological Survey of Japan, AIST, Higashi 1-1-1-7, Tsukuba 305-8567, Japan

The Ismetpasa section of the central North Anatolian Fault Zone, which has ruptured during the 1944 Bolu-Gerede earthquake (Ms 7.3) and the 1951 Kursunlu earthquake (Ms 6.9) is known as creeping. We present new findings on the rate of stable creeping and triggered slip associated with the distant 1999 Izmit Earthquake. Across the eastern wall of a highway station at Ismetpasa (N 405215, E 323730), we measured

41cm of displacement using total station on 31st August 2002. In 1969, Ambrasys (1970) reported 24 cm displacement of the wall and Aytun(1995) measured 18cm. Between 1969 and 1972, Aytun(1995) also measured 0.6cm/yr average creeping rate using geodetic methods at the same site. Altay et al. (1991) observed 0.77cm/yr creeping rate using creep-meter between 1982 and 1990. These data provides us that cumulative displacement is 23cm and average creeping rate is approximately 0.7cm/yr between 1969 and 2002. In the early summer of 2002, we found the triggered surface slips of 3-6cm of right lateral probably associated with the 1999 Izmit earthquake of Ms7.4, at three sites along 3km-long strand of the Ismetpasa. The epicenter of the earthquake is located 225km, and the eastern tip of the surface rupture is 155km west of Ismetpasa. Those sites are 1) 2km west of the highway station, we observed 3cm displacement on the concrete garden wall of s gas station. The owner of the gas station explained that significant damage of the wall was realized right after the Izmit earthquake. 2) 200m west of the station we measured 6cm displacement on the railway road. 3) At Hamamli village, 1km east of the station, a few cm offset was founded on the brick-wall of house for livestock and on the paved road near the house a few days after the Izmit earthquake. We measured 6cm horizontal and 2cm vertical offset there. There is no information on a stable creeping at sites 1) and 2) since the 1999 earthquake.

It is not clear whether creeping on the section has been constant or consisted of episodic small slips like the 1999 event since 1990. In addition such a high creeping rate cant be neglected when we consider the recurrence of large earthquake events on NAFZ. From these points of view, we started the periodic geodetic measurements of the fault creep at Ismetpasa.

S11B-1157 0830h POSTER

Jog Structures at Both Ends of the Tepetarla Segment Ruptured as the First Subevent of the 1999 Izmit Earthquakes, Turkey, Revealed by Acoustic Surveys in the Izmit Bay and the Sapanca Lake

Yasuo Awata[1] (81-298-61-3823; awata-y@aist.go.jp); Makoto Okamura[2] (81-88-844-8324; mako-ok@cc.kochi-u.ac.jp); Hiromi Matsuoka[2] (81-88-844-8331; hmatsuoka@cc.kochi-u.ac.jp); Selim Ozalp[3] (90-312-287-3430; ozalps@mta.gov.tr); Soma Kinjo[3]; Fatma Tokay[3] (90-312-287-3430; tokay@mta.gov.tr); Ahmet Dogan[3] (90-312-287-3430; dogan@mta.gov.tr); Omer Emre[3] (90-312-287-3430; emre@mta.gov.tr); Ismail Kuscu[3] (90-312-287-3430; environ@mta.gov.tr)

[1]Active Fault Research Center, Geol. Surv. Japan / AIST, Thukuba Central 7, Higashi 1-1-1, Tsukuba 305-8567, Japan

[2]Faculty of Science, Kochi University, Akebono-machi 2-5-1, Kochi 780-8520, Japan

[3]Department of Geology Researches, Mineral Research and Exploration of Turkey, 06520, Ankara 06520, Turkey

Size and geometry of jogs among fault segments play important roles in rupture propagation during large earthquakes. We carried out a very detail acoustic survey around the both ends of the Tepetarla (Sapanca) segment, which ruptured as the first sub-event of the 1999 Izmit earthquakes of Mw7.4, in the Izmit Bay and the Sapanca Lake, using a very high-resolution, acoustic profiling system ?Sono-prob?(SP-3W; 3-8kH) and a sidescan sonar (DF1000). Survey lines were designed at 250 m interval to capture the details of fault geometry.

The Tepetarla segment on land is traceable for 19km almost straightly and continuously trending east to west with an average displacement of 2.8+-0.2 (one sigma) m. East of the segment continues in to the Sapanca Lake for about10km and makes a releasing double bends as the jog structure between Tepetarla and Arifiye segments. The double bends is 8 km-long and 2 km-wide consists of en-echelon faults with normal component of slip. East on the lake, the jog appeared on land for 2 km-long, as a 500 m-wide graben. Although South on the Arifiye segment there are several secondary faults making a hose tail structure, we couldn?t find any recent fault south of the tepetarla segment in the Sapanca Lake. West of the tepetarla segment continues into the Izmit Bay for 6 km making a releasing pull-apart structure between Golcuk and Tepetarla segments. The basin is 8 km-long , 3 km-wide and about 15 square km, surrounded by faults that have normal component. Subsidence of the large area of south coast of the Izmit Bay during the earthquake suggests that this pull-apart structure stretches at least several km deep. Those differentiations of geometry and size of jogs might strongly influence the rupture process of the 1999 Izmit earthquake.

S11C MCC: Hall C Monday 0830h

Volcano Seismology Posters *(joint with V)*

Presiding: **B R Julian,** U.S. Geological Survey**; L House,** Los Alamos Seismic Research Center

S11C-1158 0830h POSTER

Using Accurate Hypocenter Locations to Understand Volcanic Earthquake Mechanisms

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

G. R. Foulger[2] (+44 197 374 2514; G.R.Foulger@durham.ac.uk)

David P. Hill[1] (650/329-4795)

[1]U.S. Geological Survey MS977, 345 Middlefield Rd., Menlo Park, CA 94025, United States

[2]Dept. of Geological Sciences University of Durham, Science Labs, South Road, Durham DH1 3LE, United Kingdom

Many well-determined moment-tensor focal mechanisms for earthquakes in volcanic and geothermal areas have significant non-double-couple components and involve volume changes. This observation rules out pure shear faulting, even on multiple faults, as the cause of such earthquakes, but is not in itself sufficient to uniquely resolve the source process. Radiated seismic waves depend only on the equivalent force system, which is not uniquely related to the source process. The geometry of seismic failure zones, as delineated by precise locations of earthquake hypocenters within clusters, offers a promising additional constraint.

We determined high-resolution earthquake hypocenters from Long Valley caldera, California, by applying the "HYPODD" algorithm (Waldhauser and Ellsworth, 2000) to data from 64 3-component digital seismometers deployed in the summer of 1997. This network also provides a rich set of P- and SH-wave polarities and amplitude ratios that are well distributed over the focal spheres of earthquakes in the south moat of the caldera, and which tightly constrain their focal mechanisms.

The hypocenters clearly resolve numerous planar failure zones with sizes ranging from a few hundred meters to 2 km. In many cases these planes pass through the middle of the dilatational P-wave polarity field, a situation compatible with the planes representing tensile faults, but not shear faults. The hypocenter locations thus support the conclusion drawn from moment tensors derived from amplitude ratios. The simplest interpretation of the focal mechanisms plus the hypocentral distributions is that the seismic source processes involve simultaneous tensile and shear failure, with the volume change reduced by some compensating process, probably related to rapid fluid flow.

S11C-1159 0830h POSTER

Waveform inversion of oscillatory signatures in long-period events beneath volcanoes

Hiroyuki Kumagai[1] (+81-298-51-3015; kumagai@bosai.go.jp)

Bernard A. Chouet[2]

Masaru Nakano[3]

[1]National Research Institute for Earth Science and Disaster Prevention, 3-1 Tennodai, Tsukuba, Iba 305-0006, Japan

[2]U.S. Geological Survey, 345 Middlefield Road, MS 910, Menlo Park, CA 94025, United States

[3]Graduate School of Environmental Studies, Nagoya University, Chikusa, Nagoya, Aic 464-8601, Japan

The source mechanism of long-period (LP) events is examined using synthetic waveforms generated by the acoustic resonance of a fluid-filled crack. We perform a series of numerical tests in which the oscillatory signatures of synthetic LP waveforms are used to determine the source-time functions of the six moment tensor components from waveform inversions assuming a point source. The results indicate that the moment tensor representation is valid for the odd modes of crack resonance with wavelengths 2L/n,2W/n, n=3,5,7,..., where L and W are the crack length and width, respectively. For the even modes with wavelengths 2L/n, 2W/n, n=2,4,6,..., a generalized source representation using higher order tensors is required. In light of the small excitation efficiency of seismic waves in the even modes, the moment tensor inversion may be generally applicable to LP events. Our numerical tests also suggest that more than four, and ideally ten to fifteen, three-component stations surrounding an LP source are required for an accurate description of the moment tensor. We apply the moment tensor inversion to the oscillatory signatures of an LP event observed at Kusatsu-Shirane Volcano, central Japan. Our results point to the resonance of a sub-horizontal crack located a few hundred meters beneath the summit crater lakes. This finding may be regarded as the first direct and solid evidence supporting the idea that LP events originate in the resonance of a crack. The present approach may be useful to quantify the source location, geometry, and force system of LP events, and opens the way for moment tensor inversions of tremor.

S11C-1160 0830h POSTER

Seismicity at Great Sitkin Volcano, Andreanof Islands, Alaska

Seth C. Moran[1] (1-907-786-7462; smoran@usgs.gov); Scott D. Stihler[2] (scott@giseis.alaska.edu); John A. Power[1] (jpower@usgs.gov); Andy B. Lockhart[3] (ablock@usgs.gov); Tim A. Plucinski[1] (tplucin@usgs.gov); John F. Paskievitch[1] (jpaskie@usgs.gov); James P. Dixon[4] (jpdixon@usgs.gov)

[1]USGS-AVO, 4200 University Dr., Anchorage, AK 99508

[2]Geophysical Institute, University of Alaska Fairbanks 903 Koykuk Rd., Fairbanks, AK 99775

[3]USGS-CVO, 1300 SE Cardinal Ct., Vancouver, WA 98683

[4]USGS-AVO, University of Alaska Fairbanks 903 Koyukuk Rd., Fairbanks, AK 99775

In 1999, the Alaska Volcano Observatory (AVO) installed 6 telemetered, short-period seismic stations around Great Sitkin (GS) volcano as part of a 14-station volcano-monitoring network in the Andreanof Islands of Alaska. Since that time, AVO has located over 890 earthquakes within 10 km of GS, the third-highest seismicity rate of the 23 volcanoes monitored by AVO over the period 1999-present. GS has arguably the most diverse background seismicity of all 23 volcanoes. Recorded seismicity includes several minutes-to-hour long tremor episodes, shallow and deep ($>$ 10 km) long-period events, swarms of distal volcano-tectonic earthquakes, and two of the largest earthquakes (M_L 4.3) ever recorded by AVO near a monitored volcano. The rate and character of seismicity suggests that magma may be moving in the GS system.

Of particular interest are two earthquake swarms that occurred in March-April and May-July of 2002. The first began March 17, consisted of more than 320 events located 15-20 km west of GS at depths of 10-25 km, and lasted for over 5 weeks. The mainshock (M_L 4.3) occurred $\sim$20 hours after the swarm's onset. The second swarm began May 28, consisted of over 460 events located 5-8 km southeast of GS at depths of 5-15 km, and lasted for over two months. The mainshock (also M_L 4.3) occurred $\sim$9 hours after the swarm's onset. This second swarm was preceded by two tremor episodes on May 27, one lasting for 20 minutes, the second lasting for an hour. Although the spatial relationship between the tremor episodes and the second swarm is unclear, the close temporal relationship suggests a common seismogenic process that could be magmatic in origin. We use cross-correlation and relative relocation techniques to more precisely determine the location and depth extent of the swarms, and calculate Coulomb stress changes to investigate whether static stress adjustments associated with magma intrusion beneath GS could have caused the two swarms.

S

S11C-1161 0830h POSTER

Relocation of Seismicity at Mauna Loa, Hawaii and Hengill, Iceland: Improved Delineation of Seismogenic Structures.

Shirley A. Baher[1] (608 262-1921; sbaher@geology.wisc.edu)

Clifford Thurber[1] (608 262-1921; clifft@geology.wisc.edu)

Kyle Roberts[1] (608 262-1921; kyle@geology.wisc.edu)

Charlotte Rowe[2] (505 665-6404; char@lanl.gov)

[1]University of Wisconsin - Madison, 1215 W. Dayton St, Madison, WI 53706, United States

[2]Los Alamos National Laboratory, EES-11 M.S. D408 Los Alamos National Laboratory, Los Alamos, NM 87545, United States

Waveform cross-correlation based refinement of P arrival times and subsequent relocation of earthquakes was determined for events that occurred near the summit of Mauna Loa, Hawaii prior to the March, 1984 eruption and at the Hengill volcano, Iceland during a