

S12A-0381 1330h POSTER

Geotechnical and Surface Wave Investigation of Liquefaction and Strong Motion Instrumentation sites of the Denali Fault, Mw 7.9, Earthquake

Robert Kayen¹ (rkayen@usgs.gov); Eric Thompson² (erict@email.unc.edu); Diane Minasian¹ (dminasian@usgs.gov); Brian Collins³ (bcollins@ce.berkeley.edu); Robb Moss⁴ (rmoss@Fugro.com); Nicholas Sitar³ (nsitar@ce.berkeley.edu); Gary Carver⁵ (woak@ptialaska.net)

¹USGS, 345 Middlefield Rd, Menlo Park, CA 94025, United States

²University of North Carolina, Mitchell, Chapel Hill, NC 27599-3315, United States

³University of California, Berkeley, Davis Hall, Berkeley, CA 94720, United States

⁴FUGRO Corp., WO, Ventura, CA 94100, United States

⁵Carver Geologic, PO Box 52, Kodiak, AK 99615, United States

Following the Mw 7.9 earthquake on the Denali and Totschunda faults on 3 November 2002, we conducted two investigations to map the regional extent and severity of liquefaction ground failures and assess the geotechnical properties of these sites, as well as profile the soil properties beneath three seismometers located at Alyeska Pump Stations 9, 10, and 11. The most noteworthy observations are that liquefaction damage was focused towards the eastern end of the rupture area. For example, liquefaction features in the river bars of the Taana River, north of the fault-break, are sparsely located from Fairbanks to Delta, but are pervasive throughout the eastern area of the break to Northway Junction, the eastern limit of our survey. Likewise, for the four glacier-proximal rivers draining toward the north, little or no liquefaction was observed on the western Delta and Johnson Rivers, whereas the eastern Robertson River and non-glacial Tok River, and especially the Nabesna River, had observable-to-abundant fissures and sand vents. Several rivers systems were studied in detail. The Nabesna River emerges from its glacier, and drains and fines northward as it crosses the fault zone resulting in an asymmetrical liquefaction pattern. South of the fault, falling liquefaction resistance of soil (fining from sandy gravel to gravely sand) and rising loads from ground motions (approaching the fault) abruptly intersect such that there is a well defined, narrow, soil transition from undisturbed-to-fully liquefied approximately 5 kilometers from the fault. North of the fault, both liquefaction resistance (continued fining) and ground motions fall in tandem, leaving a much broader zone of liquefaction. The Delta River liquefaction occurrence is more complex, where side-entering glacial rivers form non-liquefiable gravel fans and alter the composition and compactness of the main-stem deposits. Immediately upstream of the gravelly Canwell glacier tributary, and immediately at the fault crossing, liquefaction features are abundant. To characterize soil properties, we used a portable continuous sine wave-spectral analysis of surface waves (CSS-SASW) apparatus to profile the shear wave velocity of the ground, and an auger to profile the corresponding texture of the river deposits. We occupied 25 liquefaction evaluation test sites along with the three Alyeska seismometer sites. On the Nabesna, Delta and other rivers, we only find liquefaction features in soil deposits where normalized shear wave velocities fall below 225 m/s. Severity of fissures and lateral spreads dramatically increase in soils as the velocities fall, especially below 170 m/s. In some cases, the most pronounced ground failures are far from the fault zone (60-100 km) in extremely loose, low velocity fine sands. Geotechnical testing performed on field samples revealed that liquefied soils ranged from well graded sandy gravels in close proximity to the fault (< 5km) to silty sands and low plasticity silts at greater distances. At the Alyeska pump station seismometer sites, we are able to invert profiles of shear wave velocity to depths of 140-200 meters. The averaged NEHRP (30 meter) velocities for pump stations 9, 10, and 11 are 376 m/s, 316 m/s, and 362 m/s, respectively.

S12B MCC: Level 1 Monday 1330h

Total Recall: Paleoseismology Posters (joint with G, T, PA)

Presiding: P Bodin, Center for Earthquake Research and Information, University of Memphis; A E Blythe, University of Southern California

S12B-0382 1330h POSTER

Location and Shallow Structure of the Frijoles Strand of the San Gregorio Fault Zone, Pescadero, California

Catherine Fox-Lent^{1,2} (Catherine.Fox-Lent@brown.edu); Rufus D Catchings¹ (650-329-4749; catching@usgs.gov); Michael J Rymer¹ (650-329-5649; mrymer@usgs.gov); Mark R Goldman¹ (650-329-5496; goldman@usgs.gov); Clare E Steedman¹ (650-329-5652; csteedman@usgs.gov); Carol S Prentice¹ (650-329-5690; cprentice@usgs.gov)

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

²Brown University Department of Geological Sciences, 324 Brook St. Box1846, Providence, RI 02912, United States

The San Gregorio fault is one of the principal faults of the San Andreas fault system in the San Francisco Bay area. Located west of the active trace of the San Andreas fault and near the coast, the San Gregorio fault zone consists of at least two northwest-southeast-trending strands, the Coastways and Frijoles faults. Little is known about the slip history on the San Gregorio, and information for the Frijoles fault is especially scarce, as it lies mostly offshore. To better understand the contribution of the San Gregorio fault zone to slip along the San Andreas fault system, we conducted a high-resolution, seismic imaging investigation of the Frijoles fault to locate near-surface, on-shore, branches of the fault that may be suitable for paleoseismic trenching. Our seismic survey consisted of a 590-meter-long, east-west-trending, combined seismic reflection and refraction profile across Butano Creek Valley, in Pescadero, California. The profile included 107 shot points and 120 geophones spaced at 5-m increments. Seismic sources were generated by a Betsy Seisgun in 0.3-m-deep holes. Data were recorded on two Geometrics Strataview RX-60 seismographs at a sampling rate of 0.5 ms. Seismic p-wave velocities, determined by inverting first-arrival refractions using tomographic methods, ranged from 900 m/s in the shallow subsurface to 5000 m/s at 200 m depth, with higher velocities in the western half of the profile. Migrated seismic reflection images show clear, planar layering in the top 100-200 meters on the eastern and western ends of the seismic profile. However, to within the shallow subsurface, a 200-m-long zone near the center of the profile shows disturbed stratigraphic layers with several apparent fault strands approaching within a few meters of the surface. The near-surface locations of the imaged strands suggest that the Frijoles fault has been active in the recent past, although further paleoseismic study is needed to detail the slip history of the San Gregorio in this area.

S12B-0383 1330h POSTER

Integrated Seismic Imaging of the Carlsberg Fault in the Copenhagen City Center

Lars Nielsen¹ (+45 35322454; ln@geo.geol.ku.dk)

Hans Thybo¹ (+45 35322452; thybo@geo.geol.ku.dk)

Mette I. Jorgensen¹ (gf97mj@geo.geol.ku.dk)

¹Geological Institute, Univ. Copenhagen, Oester Voldgade 10, Copenhagen K 1350, Denmark

Images of the Carlsberg Fault in the area of the Copenhagen city center, Denmark, are obtained from normal incidence and refraction seismic data collected along a 3 km long E-W trending profile, which is oriented approximately perpendicular to the strike of the fault. The integrated seismic data set provides the most detailed images to 500 m depth so far obtained of this fault. The fault zone appears as a flower structure in the normal incidence section, and an abrupt change in the P-wave velocity structure across the fault zone further indicates that significant lateral movements have taken place along the fault. Vertical movements of up to 90 m are evident in the fault zone. Even the shallowest layers that can be imaged by the seismic data (approximately 30 m depth) are clearly vertically offset by the fault. In order to constrain the

strike of the fault zone through the Copenhagen area we use shots detonated inside the fault zone, which are recorded by geophones distributed along arcs of circles situated up to 7 km away from the shots. Ground penetrating radar measurements are conducted to image the fault structures in the topmost 10 m. Geodetic measurements conducted in the Copenhagen area during the last 165 years indicate that the fault may still be active with horizontal displacements of about 5 cm over a 73-year period. Small cracks in walls and displacements of buildings may further indicate that the fault is still playing an active role in forming the Copenhagen area. However, no earthquakes are detected along the fault, and the seismicity of the study area is very weak. The formation of the Carlsberg Fault may be related to extensional stresses in a strike-slip system associated with the Sorgenfrei-Tornquist zone, which is situated only 40 km east of the study area. The Sorgenfrei-Tornquist zone is a major tectonic element in southern Scandinavia where it is situated close to the boarder between the Danish Basin to the southwest and the Baltic Shield to the northeast.

S12B-0384 1330h POSTER

Refined Slip History of the North Anatolian Fault at Gerede on the 1944 rupture

Koji Okumura¹ (81-824-246657;

kojiok@hiroshima-u.ac.jp); Thomas K Rockwell² (trockwell@geology.sdsu.edu); Tamer Duman³ (tduman@mta.gov.tr); Fatma Tokay³ (ftokay@mta.gov.tr); Hisao Kondo¹ (kondoh@hiroshima-u.ac.jp); Cengiz Yoldirim³ (cengizyildirim@mta.gov.tr); Vİkan Ozaksoy³ (volkan@mta.gov.tr)

¹Hiroshima University, Kagamiyama 1-2-3, Higashi-Hiroshima 739-08522, Japan

²Department of Geological Sciences, San Diego State University, San Diego, CA 92182, United States

³MTA Geological Research Department, Eskisehir Yolu, Ankara 06520, Turkey

We excavated four new fault crossing trenches and a complex of fault parallel trenches at Ardiçli, 15 km east of Gerede on the 1944 Bolu-Gerede segment of the North Anatolian fault to resolve timing and slip in past earthquakes. A unique large gravel-filled channel (unit 10) was determined to be offset 17 to 20 m. Preliminary age control on the gravel shows it dates to the 6th or 7th century AD. Fault crossing trenches show evidence for 5 events after deposition of unit 10. Preliminary 14C dates place the earlier 3 of 5 events at AD 643-918 (EV5), AD 943-1298 (EV4), and AD 1171-1668 (EV3). These 3 events are recorded in 3 clayey units (8, 6, and 4). EV3 is the best represented with disruption into the base of unit 4 and on the main and subsidiary faults. The two most recent events are the 1944 (E1) and presumably the great 1668 earthquake (E2). Based on the offset of small channels cutting into the unit 4 surface at the site, slip in 1944 and 1668 was 5 +/- 1 m in each event. This suggests that the prior 3 events collectively produced 7 to 10 m slip, slightly less than that which occurred in the most recent events. EV4 may be correlated with 1050 earthquake, but no catalog has mentioned about EV5 and EV3, indicating that historic records of the large North Anatolian fault earthquakes are incomplete for this period. The finding of EV3 is important for the analysis of earthquake cycles. According to the catalogs, the interval of 618 years between 1050 and 1668 was much longer than the 1668-1944 interval and that around the Marmara Sea. With EV3, the recurrence may be much more periodic. Our detailed studies on the repeated slips along the 1944 segment indicate the slips during past 5 earthquakes are similar. The 1944 segment, especially in its central portion around Gerede is quite unique and straight. The refined slip history here will help to define regularity and irregularity of earthquake recurrence.

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

S12B-0385 1330h POSTER

Geophysical Investigation of a Slow Active Thrust Fault: the Trevasse Fault, France

Frederic Hoa Nguyen¹ (32 43662032;

fnuyen@ulg.ac.be); Stephane Garambois² (33 476828046; stephane.garambois@ujf-grenoble.fr); Dominique Chardon³ (33 442971544; chardon@cerege.fr); Denis Jongmans² (33 476828117; Denis.Jongmans@ujf-grenoble.fr); Olivier Bellier³ (33 442971660; bellier@cerege.fr); Daniel Hermitte³ (33 442971556; hermitte@cerege.fr)

¹GEOMAC, University of Liege, Geomac Chemin des Chevreuils 1 Bat B52, Liege 4000, Belgium

²LIRIGM, Joseph Fourier University, LIRIGM Maison des Geosciences 1381 rue de la piscine BP 53 cedex 9, Grenoble 38041, France

³CEREGE-CNRS Aix-Marseille University, CEREGE-CNRS Europole Mediterranee de l'Arbois BP80 13545 Aix en Provence cedex 04, Aix en Provence 13545, France

As many regions of Western Europe, the Provence area is characterized by slow deformation rates, substantial erosion rates, dense vegetation coverage and human activity. These combined factors affect the detection of geomorphological evidence of slow active faults and consequently the selection of trench sites for paleoseismological studies. However, in terms of seismic hazard, these regions have to be studied carefully. For example, the most important instrumental seismic event in France history, the Lambesc earthquake (M=6), occurred in Provence in 1909. A review of recent combined studies (Chardon et al., Bull. Soc. Géol. France, t. 174, no. 5, 2003) allows constraining the tectonic and geomorphic evolution of the Trévaresse ridge anticline and associated thrust ramp that obviously ruptured during the 1909 event. In this context, the use of combined geophysical methods can be interesting to determine i) their ability to detect directly, from physico-mechanical contrasts, the location of an active fault (and its characterization) in such a compressional regime where deformation rates are slow, ii) their efficiency in imaging at depth the area around the fault (and consequently, in further constraining geological interpretations), and iii) to observe possible recent displacements in Quaternary deposits. A wide geophysical survey was conducted on four sites along the Trévaresse thrust with multiple methods (radar, electromagnetic, seismic, electrical tomography). Although the fault could not be directly detected from the data, the geophysical survey allowed to unveil the complex structure of the fault zone and, together with geological evidences, provided indications for a southward propagation of the fault system (Nguyen et al., GRA, Vol. 5, 10878, 2003; Chardon et al., GRA, Vol. 5, 08882, 2003). Further geophysical measurements have been made on the site of Ganay, where Quaternary deposits crop out, to investigate this southern branch. Electrical tomographies and the use of forward modelling provide further constraints on the fault system geometry and on the inter-relations between the different geological units. Parallel GPR profiles also show anomalies which could result from the signature of the fault trace, and thus should at least help in locating trenches for paleoseismological studies. This study is developed with the E.U. S.A.F.E. and the ACI PCN programs.

URL: <http://safeproject.free.fr/safe.swf>

S12B-0386 1330h POSTER

The last two faulting events on the southern strand of the North Anatolian Fault Zone, NW Turkey

Selim Ozalp¹ (ozalps@mta.gov.tr)

Ahmet Dogan¹ (dogan@mta.gov.tr)

Omer Emre¹ (emre@mta.gov.tr)

¹MTA, General Directorate of Mineral Research and Exploration, Ankara 06520, Turkey

The North Anatolian Fault Zone (NAFZ) in the Eastern Marmara Region consists of two main strands, the northern and the southern. GPS data indicate 25 mm/yr slip rate along the NAFZ. The slip rate of the southern strand is approximately half of that observed on the northern strand. Relatively few historical earthquakes are associated with the southern strand. The southern strand consists of four main segments: Geyve-Iznik, Gemlik, Zeytinbagi and Bandirma that follow each other in a right stepping pattern between Dokurcan valley and Bandirma Bay. The Gemlik segment is 40 km-long, between the Gemlik and Iznik pull-apart basins. The eastern and western parts of the segment cut Holocene alluvial fans while the central part cuts basement rocks. We excavated six trenches at three different sites along the segment at Asil Celik, Terme and Tuzlaburnu, from east to west. Faulting structure was observed at the Terme site near Gemlik, but not at the other sites, despite clear active fault morphology. The Terme trench is 10m long, 2m wide and only 2.5m deep due to high ground water level. The stratigraphy of the trench consists of four units from bottom to top: 1) coarse gravel and gravel, 2) fine sand and silty clay, 3) silty mud with fine gravel and 4) soil. We identified two faulting events. Event 1 was observed between units 3 and 4. This event is younger than 180 ± 40 years BP. Event 2 was observed between units 2 and 3. Event 2 occurred between 820 to 180 years BP. There is no detailed paleoseismological data for more than one event on the southern strand of the NAFZ. This study found two faulting events along the Gemlik segment in the last six century. Event 2 is larger than the last event based on the faulting structures. This event can be correlated with the 1419 historical earthquake in the region. Our findings confirm that it was a large earthquake probably rupturing several segments of the southern strand including the Gemlik segment. Event 1 can be correlated with the 1857 historical earthquake west of Lake Iznik which may have been triggered by the 1855 Bursa earthquake.

S12B-0387 1330h POSTER

Activity of the Offshore Newport-Inglewood Rose Canyon Fault Zone, Coastal Southern California, From Relocated Microseismicity

Lisa B. Grant¹ (949-824-5491; lgrant@uci.edu)

Peter M. Shearer² (pshearer@ucsd.edu)

¹Dept. Environmental Analysis and Design, University of California, Irvine, CA 92697-7070, United States

²IGPP, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093-0225, United States

An offshore zone of faulting approximately 10 km from the southern California coast connects the seismically active strike-slip Newport-Inglewood fault zone in the Los Angeles metropolitan region with the Holocene Rose Canyon fault zone in the San Diego area. Relatively little seismicity has been recorded along the offshore Newport-Inglewood Rose Canyon fault zone although it has long been suspected of being seismogenic. Active low-angle thrust faults and Quaternary folds have been imaged by seismic reflection profiling along the offshore fault zone, raising the question of whether a through-going, active strike-slip fault zone exists. We applied a waveform cross-correlation algorithm to identify clusters of microseismicity consisting of similar events. Analysis of two clusters along the offshore fault zone shows that they are associated with nearly vertical, NNW-striking faults, consistent with an offshore extension of the Newport-Inglewood and Rose Canyon strike-slip fault zones. P-wave polarities from a 1981 event cluster are consistent with a right-lateral strike-slip focal mechanism solution.

S12B-0388 1330h POSTER

A 100-Year Average Recurrence Interval for the San Andreas Fault, Southern San Francisco Bay Area, California

Thomas E. Fumal¹ (650-329-5630; tfumal@usgs.gov); G F Heingartner²; T E Dawson¹; R Flowers¹; J C Hamilton¹; J Kessler¹; L M Reidy³; L Samrad¹; G G Seitz⁴; J Southon⁴

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

²San Jose State University, Department of Geology, San Jose, CA 95192, United States

³University of California Berkeley, Department of Earth and Planetary Science, Berkeley, CA 94720-4767, United States

⁴Lawrence Livermore National Laboratory, 7000 East Avenue, L-397, Livermore, CA 94551, United States

Paleoseismic excavations at Mill Canyon and Arano Flat, two sites 0.6 km apart on the San Andreas fault near Watsonville, California, provide the first high-resolution chronology of large earthquakes on the Santa Cruz Mountains segment of the fault. At Mill Canyon, a 2-m-wide zone of faulting has deformed latest Holocene deposits consisting of well-sorted sand and gravel interbedded with poorly sorted, commonly organic-rich debris flows ponded behind a small shutter ridge. We found evidence for the 1906 San Francisco earthquake and three additional ground-rupturing earthquakes since about 1500 A.D.. Radiocarbon ages and pollen analyses indicate that the penultimate earthquake at this site occurred about 1700-1790 A.D.. This indicates that the 1838 San Francisco peninsula earthquake did not rupture this portion of the fault. At Arano Flat, faulting is expressed as a 1 to 2-m-wide zone that deforms alluvial fan deposits overlying well-bedded overbank deposits. We found evidence at this location for at least nine earthquakes since about 1000 A.D. We constrain earthquake ages using a chronological model incorporating AMS radiocarbon ages of 113 samples of detrital charcoal from 19 layers and stratigraphic ordering. The mean recurrence interval is about 105 years, while individual intervals range from about 10-310 years. Two offset features at Arano Flat provide slip-per-event and slip rate data. A partially buried channel containing bottles from 1887-1890 is offset 3.5 m. Given that we found no evidence at either site for the 1890 M 6.3 earthquake, which produced surface rupture on the San Andreas fault southeast of Parajo Gap, this entire slip may have occurred during the 1906 earthquake. This value is unexpectedly high compared to the geodetic estimate of 2.3-3.1 m for the slip at depth (Thatcher et al., 1997) or the geologic estimate of 1.7-1.8 m of surface slip at Wright's tunnel (Prentice and Ponti, 1997), about 33 km north-west of Arano Flat. A fold that formed during two earthquakes, most recently about 1400-1470 A.D., is offset about 10.5 m during the past five earthquakes. This yields a slip rate of 22.5 ± 2 mm/yr, significantly higher than values previously used for this segment. Average slip for the four earthquakes prior to 1906 is

1.2-1.8m indicating M?7. Thus the mean recurrence interval is half the value used by the Working Group on California Earthquake Probabilities (WG 03) for earthquakes of this magnitude on the Santa Cruz Mountains segment.

S12B-0389 1330h POSTER

Three-dimensional Geometry of Buried Fold Scarps Associated With Ancient Earthquakes on the Puente Hills Blind Thrust Fault

Lorraine A Leon¹ (213-740-6890; lorrainl@usc.edu)

James F Dolan¹ (213-740-8599; dolan@usc.edu)

Jeff S. Hoefft¹ (213-740-6890; hoefft@usc.edu)

John H Shaw² (617-495-8008; shaw@eps.harvard.edu)

Ross D Hartleb¹ (213-740-6890; hartleb@usc.edu)

¹Dept. of Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740, United States

²Dept. of Earth & Planetary Sciences, Harvard University, Cambridge, MA 02138, United States

The Puente Hills thrust fault (PHT) is a large blind thrust fault that extends east-west beneath the heart of the metropolitan Los Angeles region (Shaw and Shearer, 1999; Shaw et al., 2003). Christofferson (2002; in prep.) and Dolan et al. (2003) identified four buried fold scarps associated with large (Mw greater than or equal to 7), ancient earthquakes on the PHT beneath the City of Bellflower, in northern Orange County. One of the major outstanding questions regarding this research concerns the subsurface, three-dimensional geometry of these buried scarps. Specifically, we want to determine the extent to which the subsurface geometry of these scarps is controlled by tectonic versus fluvial processes. In order to begin addressing these questions, we drilled a north-south transect of hollow-stem, continuously cored boreholes across the buried fold scarps. This new borehole transect, which comprises six, 20-m-deep boreholes, was drilled parallel to, and ~ 100 m west of, the original Carfax Avenue transect of Christofferson (2002) and Dolan et al. (2003). The overall pattern of progressive southward thickening of sedimentary units observed in the Carfax borehole transect extends westward to the new transect. Moreover, several key sedimentary contacts that are traceable laterally between the two transects occur at approximately the same depths at all locations along both transects. This three-dimensional data set thus defines several buried fold scarps that extend east-west beneath the study site. These observations confirm that the buried scarps are primarily tectonic, rather than fluvial features.

S12B-0390 1330h POSTER

Paleoseismologic Evidence for Long-Distance and Long-Term Elastic Interactions in Southern California

James F. Dolan¹ ((213) 740-8599; dolan@earth.usc.edu)

David D. Bowman² ((714) 278-5436; dbowman@fullerton.edu)

Charles G. Sammis¹ ((213) 740-5836; sammis@earth.usc.edu)

¹Dept. of Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740, United States

²Dept. of Geological Sciences, California State University, Fullerton, Fullerton, CA 92834-6850, United States

Paleoseismologic data reveal four temporal clusters of large earthquakes in the Los Angeles region during the past 12,000 years. The 200-year-long historic period in Los Angeles is part of the most recent, and ongoing, lull between earthquake clusters. The Los Angeles-region clusters are temporally anti-correlated with similar seismic clusters along the Eastern California Shear Zone and the Garlock fault in the Mojave Desert. These three fault systems serve collectively to accommodate N-S compression across the Big Bend region of the SAF. Simple elastic models demonstrate that motion on the Los Angeles-region fault network moves the Garlock and ECSZ faults away from failure, and vice versa. This slight unloading of the faults, combined with a non-linear response, will cause the system to evolve towards the observed out-of-phase behavior, even if the two parts of the system are initially in phase. These results suggest that long-distance elastic strain interactions exert a first-order control on earthquake occurrence on the scale of the entire plate boundary. Moreover, these data indicate that seismic slip on regional fault systems is not a temporally and spatially random process, thus calling into question Poissonian models of seismic hazard assessment.

S12B-0391 1330h POSTER

Behavioral Segment <ETH>Based Active Fault Database of Japan, Application to the Evaluation of Active Fault and Seismotectonic Study

Yasuo Awata¹ (+81-29-861-3823; awata-y@aist.go.jp)

Toshikazu Yoshioka¹ (+81-29-861-2465; yoshioka-t@aist.go.jp)

¹Active Fault Research center, GSJ/AIST, AIST Center-7, Higashi 1-1-1, Tsukuba 305-8567, Japan

The Active Fault Research Center, GSJ / AIST has been constructing an active fault database to make a probabilistic evaluation of the future faulting event and earthquake occurrence on major active faults in Japan. The database consists of three sub-databases, (1) sub-database on individual site, which including long-term slip data and paleoseismicity data with error range and reliability, (2) sub-database on details of paleoseismicity, which includes the excavated geological units and faulting event horizons with age-<ETH>control, and (3) sub-database on characteristics of behavioral segments, which includes the fault length, long-term slip-rate, recurrence interval, most-recent event, slip-per-event and vest estimated segment for cascade earthquake. Major seismogenic faults, those are approximately the best-estimated segments of cascade earthquake, each has a length of 20 km and longer and slip-rate of 0.1 m/ky and larger, is composed of about two behavioral segments segment in average, are including in the database. The result of national project on active fault research, which has been carrying out since the Kobe earthquake of 1995 are put together. The input of data will be complete by early 2004, and a tentative database will be opened to the public on the AFRC web-site. The easily expandable and renewable database will promote not only the evaluation of future earthquake on active faults, but also the study on seismotectonic settings of Japan. We introduce tentative application to the evaluation of Kinki District and the Median Tectonic Line (MTL) active fault system in Central-Western Japan, and the Late Quaternary seismotectonics in the northeast Honshu, the main island of Japan.

S12B-0392 1330h POSTER

Paleoseismic Investigation on the Pinto Mountain fault at the Oasis of Mara, Mojave Desert, California

Ana Marisa Cadena¹ (619-279-0095; ana@geology.cwu.edu); Charles Rubin¹ (509-963-2827; charlier@geology.cwu.edu); Christian Walls² (chriswalls@cox.net); Faten Khatib⁴ (fie00@hotmail.com); Tom Rockwell⁴ (tom.rockwell@geology.sdsu.edu); Scott Lindvall³, Christopher Madden²

¹Central Washington University, Dept of Geological Sciences Mail Stop 7418 400 East University Way, Ellensburg, WA 98926, United States

²Earth Consultants International, 150 El Camino Real, Suite 212, Tustin, CA 92780, United States

³William Lettiss and Associates, Inc, 25050 Avenue Kearny #108, Valencia, CA 91355, United States

⁴San Diego State University, Dept of Geological Sciences 5500 Campanile Dr, San Diego, CA 92182, United States

Preliminary results from the first paleoseismic investigation across the Pinto Mountain fault reveal evidence for three Holocene events. The left-lateral Pinto Mountain fault bounds the Eastern Transverse Ranges and the Mojave Desert block of the eastern California shear zone. We excavated just west of the Oasis of Mara, along trend with a subdued Holocene scarp. A fault-perpendicular trench exposes chiefly alluvial and lacustrine deposits, as well as highly liquefied silt, sand and pebble gravel that define the main fault zone. North of the main fault zone, massive to moderately bedded Holocene alluvium unconformably overlies the oldest exposed units that consist of locally tilted, highly sheared, massive to weakly-bedded, indurated silty clay, sand and pebble gravel. Analysis of stratigraphic relations in Holocene alluvium indicates two events in the northern fault zone. The penultimate event horizon is faulted and folded to the south in the main fault zone. South of the primary bounding fault the lowermost unit consists of silt to pebble gravel characterized by dominantly vertical, liquefaction-induced fabric. The liquefied units are juxtaposed with the indurated silty clay, sand and pebble gravel exposed to the north. Lacustrine sediment and alluvium overlying the liquefied material underwent folding and faulting during the most recent event. We acquired seven radiocarbon dates on detrital charcoal and peat that provide initial stratigraphic age constraints. The oldest dated unit exposed south of the main fault zone is 13,350 to 14,050 years B.P. The base of the lacustrine sediment

is 9,270 to 9,500 years B.P. corresponding to the early Holocene wet period (pluvial). Events that pre-date the pluvial deposit may be constrained by further analysis of cross-cutting relations of liquefied units. The penultimate, penultimate, and most recent event horizons lie stratigraphically above the lacustrine sediment. Luminescence dating methods are required to constrain the timing of these events.

S12B-0393 1330h POSTER

Hyperspectral Analysis of Paleoseismic Trench Stratigraphy: Toward Improving the Recognition and Documentation of Past Earthquakes

Daniel E Ragona¹ (6198886957; dragona@ucsd.edu)

Bernard Minster¹ ((858)534-5650; jbminster@ucsd.edu)

Yuri Fialko¹ (858-822-5028; yfialko@ucsd.edu)

Tom Rockwell² (619-667-0512; trockwel@cox.net)

¹IGPP, Scripps Institution of Oceanography, 8765 Biological Grade, La Jolla, CA 92093, United States

²San Diego State University, 5500 Campanile Dr., San Diego, CA 92182

We are conducting a pilot project to use hyperspectral imagery to assist in the recognition and documentation of paleoseismic events in trench exposures. Recent advances in hyperspectral imagery suggest that stratigraphy can be analyzed in much the same way as Aviris imagery of Earth's surface. In principle, hyperspectral images may be able to elucidate and record otherwise-poor stratigraphy in some exposures, thereby improving the information that can be gleaned from a paleoseismic site. This technique may also eliminate some problems in interpretation of the earthquake history of a site by illuminating details of the stratigraphy and structure that are not apparent to the human eye, such as unique unit correlations across complicated fault ruptures. The trench site chosen for this study is located at Hog Lake in the Anza seismic gap along the San Jacinto Fault in southern California. The site was selected because of its detailed, well defined stratigraphy. The method adopted was to obtain a 50 cm side square matrix of samples that could be used to generate a low-resolution image of the sampled area, in the sense that each sample represents a single pixel. The samples were collected 2.5 cm apart in a square matrix of 20x20 samples. Each of the 400 samples collected are stored into PVC or metallic cylinders of 3/4" or 1/2" diameter. All samples were spectrally analyzed at JPL using a FieldSpec Pro instrument that measure radiation in the 350-2,500 nm wavelength window. Five measurements of each sample were performed, along with measurements of the radiation reflected by a reference surface (Spectralon), under natural light and clear sky conditions. The data obtained was then processed to obtain reflectance spectra for all samples. Principal Component Analysis was used to create a pixilated image from the three dominant components. That image shows promising similarity with the standard digital picture of the sampled trench wall. However, large random measurement errors created problems in some samples when we tried to separate classes of different materials. We are currently working on the identification of the source of noise to either correct the data or to improve the experimental procedure. Our current preliminary results show that the hyperspectral data can discriminate between different lithologies for those samples that provide consistent spectrums with high signal to noise ratio. Whole spectrum comparisons yielded better results than single absorption features identification.

S12B-0394 1330h POSTER

Earthquake History of the Northern Imperial Fault, Imperial Valley, California, since the last Lake Cahuilla Highstand, circa A.D. 1680

Aron J Meltzner¹ (1-626-676-4848; meltzner@geology.sdsu.edu)

Thomas K Rockwell¹ (1-619-667-0512; trockwell@geology.sdsu.edu)

Danielle M Verdugo¹

¹Department of Geological Sciences, San Diego State University, 5500 Campanile Drive, San Diego, CA 92182, United States

The Imperial fault (IF) is the only fault in southern California to have ruptured in two major earthquakes in the 20th century. In 1940, it ruptured end-to-end (both north and south of the international border) in an M 6.9 earthquake, and in 1979, the northern segment of the fault (north of the border) ruptured again in an M 6.4 event. Slip in 1940 was highest (5-6 m) along the central portion of the fault and lowest (<1 m) along the northern portion, with a high slip gradient between these two segments just north of the

border. The 1979 earthquake involved surface rupture along only the northern 30 km of the fault, with dextral offsets being <1 m and being nearly identical to 1940 offsets along the northern 20 km of the rupture. The similarities and differences of the two events led Sieh (1996) to propose a "slip-patch model" for the Imperial fault, whereby the fault ruptures with frequent moderate earthquakes along its northern end, like in 1979, and with less frequent larger events like 1940 along its entire length. According to the model, the central patch, which experienced high slip in 1940 and did not rupture in 1979, would rupture with relatively infrequent events (roughly every 260 years) with typically 5-6 m of slip per event; meanwhile, the northern patch, which corresponds to the 1979 rupture, would rupture more frequently (roughly every 40 years) with up to 1 m of slip per event. This model is consistent with the slip distribution observed in 1940 and in 1979. Paleoseismic investigations along the central patch also support this model, as the penultimate event there occurred shortly after the last Lake Cahuilla (LC) highstand at around A.D. 1680 (Thomas and Rockwell, 1996). Prior to the present investigation, however, there were no data on events prior to 1940 on the northern patch, which could serve to either support or refute the slip-patch model. We have opened a trench across the IF south of Harris Road, adjacent to Mesquite Basin, where the fault has both dextral and normal slip components. On the down-dropped side of the fault, a laminated clay unit (inferred to be the most recent LC clay, at ca. A.D. 1680; dating results are pending) is exposed in the trench and is overlain by nearly 2 m of younger deposits; the overlying material consists of bedded fine sands and silts (inferred to be overbank deposits from a nearby channel), which interfinger with massive silts and clays (inferred mostly to be colluvium). Unfortunately, the normal component of slip for all earthquakes in the trench was almost exclusively restricted to a single east-dipping plane or set of closely spaced planes, so that the amount of dip slip per event cannot be resolved; nonetheless, a series of fissures and flower structures adjacent to the main fault in the hanging-wall block permit the distinction of individual events. There is good evidence for 4, and possibly 5 events since the last LC highstand, based on filled-in fissures and abrupt upward terminations of multiple fault strands and liquefaction cracks. The youngest of these events are inferred to be 1979 and 1940; the oldest, which produced liquefaction and ruptured to the top of the most recent lake deposits, probably occurred at or very soon after the highstand, based on the arguments that no lake deposits post-date the event, and that the ground was still saturated at the time of the earthquake. This event may have been the penultimate (ca. A.D. 1680) event seen on the central patch of the IF.

S12B-0395 1330h POSTER

SCEC CFM - A WWW Accessible Community Fault model for Southern California

Andreas Plesch¹ (617-495-2356; andreas.plesch@harvard.edu)

John H Shaw¹ (shaw@eps.harvard.edu)

¹ SCEC CFM Working Group²

¹Harvard University, 20 Oxford St., Cambridge, MA 02145, United States

²Southern Californian Earthquake Center, University of Southern California, 3651 Trousdale Parkway, Suite 169, Los Angeles, CA 90089-0742, United States

We present a community-based, coarse resolution fault model (CFM) of southern California. The model has undergone specification, design and implementation stages all of which had a large degree of input from the community provided with the Southern Californian Earthquake Center and in particular the CFM working group. Here, we deliver the first complete CFM to the user community and describe how to access the model database. The model consists of ca. 120 faults some of which have alternative representations based on contrasting geologic interpretations. The geometry of each fault surface is modelled by a triangulated mesh with the node location and connectivity stored in a simple ASCII formatted digital file. Access to these files is provided by WWW. The URL of this resource is <http://structure.harvard.edu/cfm>. A graphical map interface and search capabilities let users select individual faults or groups of faults. A icon style perspective view and list of attributes such as fault sense and slip rate of each selected faults is shown and users can download individual faults or the selection in a single collection. The web resource is driven by a relational database (postgresql) and WWW mapping software (mapserver).

URL: <http://structure.harvard.edu/cfm>

S12B-0396 1330h POSTER

Low Temperature Thermochronology From the SAFOD Pilot Hole: Constraining the Thermal History With Apatite Fission-Track and (U-Th)/He Analyses

Ann E Blythe¹ (213-821-1094; blythe@earth.usc.edu)Matthew A D'Alessio²
(dalessio@seismo.berkeley.edu)Roland Bürgmann²
(burgmann@seismo.berkeley.edu)Kenneth A Farley³ (farley@gps.caltech.edu)¹University of Southern California, Department of Geological Sciences, Los Angeles, CA 90089, United States²University of California, Department of Earth and Planetary Sciences, Berkeley, CA 94720, United States³California Institute of Technology, Division of Geological and Planetary Sciences, Pasadena, CA 91125, United States

The San Andreas Fault Observatory at Depth (SAFOD) pilot drillhole traverses the upper ~2 km of a site 1.8 km west of the San Andreas fault near Parkfield, California. We use apatite fission-track and (U-Th)/He analyses of drillhole cuttings samples to document the thermal signature of downhole samples currently at a temperature range of ~20 to 95 °C. Knowing the long-term thermal history of the site will be important for interpreting geochemical, structural, and geophysical observations in the SAFOD project. With these data we evaluate the geothermal gradient and exhumational history of the drillhole site. Preliminary (U-Th)/He analyses from drillhole samples decrease in age with depth, with He ages of ~20 Ma for samples at 800 m (where the Pilot Hole first encounters Salinian granitic rocks; current temperature ~50 °C) to a He age of 1 Ma in the deepest sample from the base of the hole (at 2.2 km depth; current temperature 95 °C). The pattern of ages is consistent with that expected for the observed geothermal gradient of ~35 °C km⁻¹ and shows little or no evidence of recent exhumation. Preliminary modeling of fission track length distributions also show that the block has been exhumed less than 1 km in the last 5 m.yr., despite its proximity to the active strand of the San Andreas fault and other related faults.

S12C MCC: 3011 Monday 1340h

Novel Ways of Analyzing the Seismic Coda II

Presiding: R Snieder, Center for Wave Phenomena/Colorado School of Mines;
M Fehler, Los Alamos National Laboratory

S12C-01 1340h INVITED

Extracting and Using Time Domain Green's Functions From Ocean Acoustic Noise

William A Kuperman¹ (858 534 7990;
wkuperman@ucsd.edu)Philippe Roux¹ (858 822 3155;
philippe@mpl.ucsd.edu)¹Scripps Institution of Oceanography, Marine Physical Laboratory, La Jolla, CA 92037-0238, United States

The long-time temporal correlation of random wave fields received at two receivers basically extracts the time domain Green's function (TDGF) between the receivers. This process applies to either scattered fields or noise, the former often referred to as signal-generated noise. We have shown with theory and data that the long-term temporal correlation of ocean noise between two points yields the effective TDGF between those two points. The deterministic nature of the random-noise extracted TDGF is further demonstrated by utilizing these TDGF's for time reversal (TR) focusing through the background ocean medium. The combination of extracting TDGF's from random fields and deterministic based TR processing suggests a potential for passive tomography and imaging.

S12C-02 1410h INVITED

Interferometric Imaging

George Papanicolaou (650 7232081;
papanico@math.stanford.edu)Department of Mathematics, Stanford University,
Stanford, CA 94305, United States

Seismic codas contain information about the environment in which the waves travel. How can this information be extracted and what can it be? I will present some recent work (jointly with L. Borcea and C. Tsogka) that models that behavior of cross correlations of seismic codas, which may also be called coda interferometry. I will use recent results about the time reversal of signals in randomly inhomogeneous media which help delimit the information content of the cross correlations. I will also present the results of numerical simulations that illustrate the way in which interferometry can be used for imaging.

URL: <http://georgep.stanford.edu>

S12C-03 1440h INVITED

Ultrasonic Waves in Strongly Scattering Media: a Symphony of Ultrasound That is Almost all Coda.

John H Page (204 474 9852;
jhpape@cc.umanitoba.ca)

University of Manitoba, Department of Physics and Astronomy, University of Manitoba, Winnipeg, MB R3T 2N2, Canada

Waves traveling through strongly scattering materials can behave in unusual ways, and in this presentation, I will review recent progress in probing their behavior using ultrasonic techniques. In random systems, ultrasonic experiments on simple model materials (spherical beads suspended in a liquid, porous materials made from sintered glass beads) have shown how the coherent ballistic component can be separated from the dominant multiply scattered waves (the coda), allowing a rather complete picture of wave propagation in such systems to be established. These experiments have also helped to elucidate how multiply scattered waves diffuse, giving a unified physical picture of the relationship between the velocities of energy transport by diffusive and ballistic waves. These fundamental studies of wave transport by multiply scattered waves have facilitated the development of three new techniques in ultrasonic correlation spectroscopy (or coda wave interferometry) for measuring the dynamics of strongly scattering materials: Diffusing Acoustic Wave Spectroscopy (DAWS), Diffusing Reverberant Acoustic Wave Spectroscopy (DRAWAS) and Dynamic Sound Scattering (DSS). Very different wave behavior can be observed by arranging the beads in an ordered crystalline array (a phononic crystal), giving rise to a complete bandgap through which the ultrasonic waves travel by tunneling. The presentation will end with a brief description of elastic wave diffusion in porous materials, where the multiply scattered ultrasonic energy is partitioned between P and S waves and remarkably strong scattering can be observed. Work performed with H.P. Schriemer, M.L. Cowan, Suxia Yang, J. Bobowski, R. Holmes, J. Beck, J. de Rosny, D.A. Weitz, Ping Sheng and Zhengyou Liu.

URL: <http://www.physics.umanitoba.ca/~jhpape>

S12C-04 1510h INVITED

Partitioning between P and S energies in the long-period seismic coda

Nikolai Shapiro¹ (303 735 1850;
nshapiro@fignon.colorado.edu)Michel Campillo²
(michel.campillo@obs.ujf-grenoble.fr)¹Department of Physics, University of Colorado, Campus Box 390, Boulder, CO 80309-0390, United States²Laboratoire de Géophysique Interne et Tectonophysique, BP53, Grenoble, Cedex 9 38041, France

Long-period seismic signals excited by large ($M > 8$) earthquakes remain above the noise level for tens of hours. This long-period seismic coda is composed of surface and body waves that circle or cross the Earth many times and, therefore, can be used to study its average anelastic and scattering properties. Because both direct and scattered waves remain trapped in the Earth, the scattering does not change the average energy balance of the long-period coda. As a consequence, traditional methods based on average time decay cannot be applied to the long-period coda to extract information about the Earth's scattering. Therefore, we propose here another approach that is based on recent theoretical developments of the radiative transfer theory and uses a partitioning between P and S energies as a marker for presence of multiple scattering. Without scattering, the P-to-S energy ratio and, as a consequence, the vertical-to-horizontal energy ratio (VHR) would grow infinitely with time because the quality factor inside the Earth is much higher for P waves than for S waves. This behavior is well predicted by synthetic seismograms computed in an average spherically symmetrical model (PREM). However, VHR calculated using the observed seismograms tend to stabilize after certain time (typically 40000 s at 100 s period) at a

value that is independent of earthquake and station locations. We interpret the observed stabilization as an indication of the presence of the multiple scattering and the diffuse waves. This motivates further investigations of a possibility to use the long-period seismic coda, and specifically the cross-correlations between records at two stations, to extract a coherent information about the elastic response of the Earth.

S12D MCC: 2002-2004 Monday 1340h

Theories of Earth's Interior III (joint with T, V)

Presiding: P J Tackley, University of California, Los Angeles; **J D Bass**, University of Illinois

S12D-01 1340h INVITED

20 years of seismic tomography

Adam M. Dziewonski¹ (dziewons@eps.harvard.edu)Guy Masters² (gmasters@ucsd.edu)¹Department of Earth and Planetary Sciences, Harvard University, 20 Oxford Street, Cambridge, MA 02138²Institute of Geophysics and Planetary Physics, University of California-San Diego, La Jolla, CA 92093-0225

With the papers by Masters *et al.* (1982), Nakanishi and Anderson (1982), Woodhouse and Dziewonski (1984) and Dziewonski (1984), global seismic tomography was well on its way to becoming one of the most important geophysical tools in the investigation of the Earth's interior. These early studies demonstrated the power of the method to discover new, unexpected features, such as the degree-two signal in the transition zone, the ring of fast velocities above the core-mantle boundary, and the Pacific and African megaplumes. Since then, tomography has moved towards higher resolution and the mapping of additional structural details, such as the topography of the internal boundaries and azimuthal and radial anisotropy. Anisotropy, in particular, is turning out to be a property that is likely to map the dynamic history of the Earth's interior. Tomographic studies extend to the very center of the Earth, where the inner core has been found to be anisotropic and, recently, to have an inner-most structure with a 300-km radius, which was discovered by identifying its distinct anisotropic properties. Higher resolution has its limits, and reports of slabs penetrating directly into the lower mantle and the detection of mantle plumes extending from the CMB to the surface remain controversial. An irreplaceable resource that has made this progress possible is the Global Seismographic Network, now transmitting most of the data in nearly real time, as envisioned 20 years ago by a small group of forward-looking seismologists.

S12D-02 1405h INVITED

Mantle Mineralogy and Mineral Physics: Paradigms and Paradoxes

Thomas S Duffy¹ (609 258-6769;
duffy@princeton.edu)Sang-Heon Shim² (617 324 0249; sangshim@mit.edu)¹Princeton University, Department of Geosciences, Princeton, NJ 08544, United States²MIT, Department of Earth, Atmospheric, and Planetary Sciences 77 Massachusetts Avenue, Cambridge, MA 02139, United States

Don Anderson has made important contributions to our understanding of the mineralogy and mineral physics of the earth's mantle and core for more than 4 decades. For example, Don's elucidation of elasticity systematics and his perceptive application of such knowledge to understanding the Earth's mantle has been one of the prime motivations for more than a generation of experimental studies. In this talk, we summarize the current status of laboratory experimentation on the mineralogy of the deep mantle, focusing on the areas of elasticity and phase changes. The connection of mineral physics to seismology, a particular area of interest to Don Anderson, will be emphasized. Recently, the study of elastic properties of mantle and core materials has mushroomed as a result of new experimental capabilities. These include the development of several synchrotron-based tools including, for example, x-ray inelastic scattering and lattice strain anisotropy measurements. These have greatly

S