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

S52H-08 1525h

The Intersection Model and the Charleston, South Carolina Seismicity

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

S52I MCC: 3007 Friday 1600h

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

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

S52I-01 1600h

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

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

S52I-02 1615h

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

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

S52I-03 1630h

Seismotectonics of the San Fernando Basin

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

S52I-04 1645h

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

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

related to EVT3, and makes it difficult to identify the earthquake's contribution to the observed deformation. Because of this, the geodetic mechanism for EVT3 is less well constrained than the mechanism for EVT15. However, both the seismic and GPS data prefer a non-double-couple mechanism for EVT3. The mechanism of this earthquake is clearly anomalous, and might be related to the interaction between an inflational source and a faulting source.

S52I-05 1700h

New Inferences on the Campi Flegrei Caldera Structure from microearthquakes P- and S- delay time tomography

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The recently upgraded dataset collected during the 1982-1984 bradyseismic crisis of the Campi Flegrei caldera has been used to image its shallow structure by a three-dimensional delay-time tomography. Data selection provided 2500 P- and 2027 S- weighted pick times from 403 well located earthquakes. Data have been modeled by using a tomographic method based on an accurate finite-difference travel-time computation which, simultaneously inverts P- and S- first-arrival times for both velocity and hypocenter locations. We explored the dependence of results on the grid parameterization as well as on the initial velocity model, through a statistical study of the final solution inferred from 400 randomly sough initial 1-D models. The interpretation of the retrieved P- and S- wave velocity models and of the deduced Vp/Vs and Vp*Vs images has been supported by rock physics modeling of a laboratory dataset available in this area. This allowed us for mapping zones with different fluid saturation and fracture accruement down to 6 km depth. Between the surface and 3 km depth, the slighter increase of Vs as a function of depth compared with Vp seems to account for the high Vp/Vs and low Vp*Vs anomalies. Anomalies are also spatially correlated to the seismicity occurring at this depth. These seismic signatures suggest that the shallow caldera structure is formed by fractured and brine bearing formations. A nearly circular shaped Vp*Vs anomaly characterizes the deeper structure between 3 km and 5 km. Its inner part shows low values in which seismicity also occurs and a low Vp/Vs superimposes. Both low Vp and Vs anomalies are responsible for the aforementioned low Vp*Vs and Vp/Vs features: we are more inclined to interpret the deeper part as a fractured medium having partial or predominant steam saturation. The low Vs values characterizing the inner part of the caldera between 1 km and 4 km suggest that fluids might stand overpressured.

S52I-06 1715h

Along-Arc Variation in the Magma Distribution Beneath NE Japan Inferred From Travel Time Tomography

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Volcanoes in active plate margins are generally considered as being regularly spaced along the strike of the arc [e.g., Marsh, 1979, JGR], and this has been used to derive constraints on the characteristics of the deep source of magma and on the mechanisms of magma ascent. However, Bremond d'Ars et al. [1995, JGR] investigated the distribution of volcanoes in 16 active plate margins and concluded that volcanoes are randomly distributed. Recently, Tamura et al. [2002, EPSL] investigated spatial distribution of Quaternary volcanoes in the NE Japan arc and pointed out that Quaternary volcanoes in the NE Japan arc are grouped into 10 volcanic clusters striking transverse to the arc. They have an average width of 50 km, and are separated by 30-75 km wide gaps. Tamura et al [2002] proposed that these observations are surface manifestations of locally developed hot regions having the form of inclined, about 50 km wide fingers extending from >150 km depth below the back-arc region to approximately 40 km depth below the volcanic front within the mantle wedge. To confirm this interpretation by Tamura et al. [2002], we conducted a specialized tomographic inversion of S-wave velocity structure of the mantle wedge beneath NE Japan. Only S-wave velocities of the mantle wedge portion were estimated by using the same data set of our previous study [Nakajima et al., 2001, JGR] but with those of the other portions being fixed. Obtained images have higher spatial resolutions of 10 km in both the horizontal and vertical directions. As predicted by Tamura et al. [2002], velocity decrease in the inclined low-velocity zone has an along-arc variation and is locally large below the areas where Quaternary volcanoes are clustered. In other words, the hot mantle fingers have extremely low S-wave velocities. Moreover, deep, low-frequency microearthquakes are also clustered above such locally low velocity areas. Prominent S-wave low-velocity zones in the mantle wedge, distribution of Quaternary volcanoes at the surface, and deep, low-frequency microearthquakes are closely correlated in space, suggesting that the spacing of Quaternary volcanoes at the surface is determined by along-arc variation of melt contents in the low-velocity zones in the mantle wedge.

S52I-07 1730h

Seismic Detection of Sediment Interface Beneath the Moat Regions of the Valles Caldera, New Mexico

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We examine seismic refraction data from the Jemez Tomography Experiment centered over the Valles Caldera, New Mexico. The Valles Caldera formed 1.2 Ma with a plinian eruption of the Bandelier Tuff and was preceded 1.6 Ma by the formation of the Toledo Caldera. After the initial collapse of the caldera, a resurgent dome formed in the central region bordered by subsided caldera moats, or valleys, along the periphery of the ring fracture zone. Six active seismic sources were used to analyze the shallow (<6 km) subsurface beneath the caldera. P-wave and P-S converted phase arrival times are identified and the difference between these traveltimes is used to compute the thickness of the caldera fill material. The most prominent secondary arrivals are centered on two moats within the region: the Valle Grande and the Valle San Antonio. These regions are free from the rhyolitic extrusions that occupy most of the caldera area and are believed to contain the most fill material. We interpret these secondary features as P-S conversions from a subsurface interface between 1 and 2.5 km depth. Previous work in the area has revealed a cyclic history of lake formation within the Toledo/Valles caldera complex throughout its 1.6 million year history. The strong secondary arrivals located beneath the moat regions denote lacustrine sediment interfaces, the boundary between lacustrine sediments and volcanic breccias, or the boundary between lacustrine sediments and the roof of the subsided caldera block.

S52I-08 1745h

High Resolution Waveform Tomography at a Groundwater Contamination Site: Surface Reflection and VSP Datasets

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We have applied a form of waveform tomography (Pratt et al., 1998) to datasets from a vertical seismic profile (VSP), coincident 2D reflection, and a 3D surface dataset from Hill Air Force Base (HAFB), Utah. The transmitted waves recorded at depths in the VSP data constrain deep structures better than the surface data. However, surface data with large offsets that are not contaminated by ground roll provide good depth-constraint on seismic phases such as the refraction and reflection wavefields. We have applied the waveform tomography to 45 36.0-meter-long 2D surface profiles that were extracted from the 3D dataset. The profiles are almost perpendicular to the surface spread of the VSP experiment. Travel time tomography applied to the profiles using first arrival picks provides initial velocity models for the waveform tomography. Source signatures for individual shots are inverted at each iteration of the waveform tomography. Seismic velocity increases from $\sim 300.0m/s$ at the surface to $\sim 1600.0m/s$ at 16.0m depth. The 11 profiles which intersect the VSP profile correlate reasonably well with the VSP velocity model. The cross-sectional geometry of a paleo-channel, the structural trap containing most of the DNAPLs, can be identified in each of the final velocity models. The combination of the cross-sectional images of the paleo-channel from waveform tomography provides a 3D perspective on velocity structure and the channel with relatively high vertical and lateral resolution (∼1.5m).

S52J MCC: 3009 Friday 1600h

African Superswell Province: From Core to Crust IV *(joint with T, V)*

Presiding: **N O Mariita,** University of Texas at El Paso**; M J Fouch,** Arizona State University

S52J-01 1600h

Mantle plumes as cause of long-lasting cratonic uplift implications for southern Africa

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Active mantle plumes are the prime suspects for midplate uplifts, like the Hawaiian swell. The question arises as to whether the effects of more ancient plumes can cause long-lasting uplifts like the swell in Southern Africa. Starting plume heads are unlikely to do this. First, the plume material flows laterally and ponds beneath regions of thin lithosphere. Only tens of kilometers of plume material remain beneath the cratonal keels. Second the ponded plume material suppresses secondary convection by having a stable boundary at its base. Heat continues to flow out of the top of the lithosphere. The net imbalance of heat flow in a column of material leads to subsidence. Even after the plume material has all cooled to the mantle adiabat, secondary convection supplies less heat flow to the lithosphere than is lost upward by conduction. The craton returns to its original thermal structure on a time scale of less than 200 m.y. In contrast, plume tails can linger for a long time beneath cratons and eventually raise the conductive geotherm into equilibrium with plume material. A lingering plume tail at ca. 80-90 Ma is a viable mechanism for the Southern African swell.

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S52J-02 1615h

A Preliminary Analysis of Crustal Structure Variations Along the Ethiopian Rift

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The EAGLE (Ethiopia Afar Geoscientific Lithospheric Experiment) is an ambitious effort that involved a 3-phase seismic experiment that was conducted in January of 2003 and was followed by a magnetotelluric project and a variety of supporting efforts