Analysis of Earthquake Data from the Greater Los Angeles Basin and Adjacent Offshore Area, Southern California

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Element I & III

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ABSTRACT

We synthesize and interpret local earthquake data recorded by the Caltech/USGS Southern California Seismographic Network (SCSN/CISN) in southern California. The goal is to use the existing regional seismic network data to: (1) refine the regional tectonic framework; (2) investigate the nature and configuration of active surficial and concealed faults; (3) determine spatial and temporal characteristics of regional seismicity; (4) determine the 3-D seismic properties of the crust; and (5) delineate potential seismic source zones. Because of the large volume of data and tectonic and geologic complexity of the area, this project is a multi-year effort and has been divided into several tasks.

RESULTS

Comprehensive waveform cross-correlation of southern California seismograms: Part 1. Refined hypocenters obtained using the double-difference method and tectonic implications

We present preliminary results applying waveform cross-correlation to southern California seismograms for over 380,000 events between 1984 and 2002. Waveforms recorded by the SCSN are first extracted from the SCEDC data center in 50 s windows that include both P and S waves. The resulting online waveform archive uses about 0.5 TB on a RAID system. The traces are then re-sampled to a uniform 100 Hz sample rate and band-pass filtered to between 1 and 10 Hz. Next, we apply time domain waveform cross-correlation for P and S waves between each event and 100 neighboring events (identified from the catalog based on a 3-D velocity model of Hauksson (2000). We identify and save differential times from the peaks in the cross-correlation functions and use a spline interpolation method to achieve a nominal timing precision of 0.001 s. These differential times, together with existing P and S phase picks, are input to the double-difference program of Waldhauser and Ellsworth (2000). We define a grid across southern California and locate hypocenters near each grid node. Because some events may be located many times as hypocenters are calculated near successive grid-points, we assign a weight to each hypocenter and calculate a weighted average hypocenter for each earthquake.

The new HypoDD hypocenters show improved clustering both horizontally and vertically, creating a more focused picture of the previously identified, spatially complex distributions of seismicity. In many cases, the late Quaternary faults, such as the Elsinore and Hollywood-Santa Monica faults appear to bracket the seismicity distributions; in other cases, the faults trace the median within a symmetric distribution of hypocenters. The depth distribution of the seismicity shows sudden changes across some of the major strike-slip faults, while regions of dip-slip faulting are often bound by dipping surfaces that are clearly defined by the deepest hypocenters. The seismicity around the southern San Andreas fault shows clear alignment along the Carrizo Plain segment while both the Mojave and Coachella Valley segments are dominated by off-fault hypocenters. A prominent horizontal boundary striking a few degrees north of west with a prominent depth change in the seismicity cuts across Banning Pass towards San Bernardino. Earthquake swarms in the Salton Sea at the south end of the San Andreas fault suggest the presence of two north-northwest striking seismic zones at the south end of the San Andreas fault. The seismicity along the San Jacinto fault forms sharp alignments that in most cases are adjacent to, but not coincident with, the mapped surface traces that are either parallel to the traces or form high angles to them. In the Los Angeles basin, the major aftershock sequences appear as densely focused clusters within a cloud of scattered background seismicity (Figure 1). The seismicity along the Newport-Inglewood fault forms a sharp alignment to the north and a diffuse distribution to the south, where the 1933 Long Beach earthquake occurred. Similarly, several clusters as well as scattered background seismicity extending from east to west across the basin illuminate the blind thrusts beneath the north edge of the basin. The major aftershock sequences such as 1992 Landers, 1994 Northridge, and 1999 Hector Mine form clusters, with distinct internal structures, illuminating secondary faults and a heterogeneous main fault rupture surface. Some of these alignments suggest that high angle cross-faults were activated by the mainshock.

Three-dimensional Vp and Vp/Vs Velocity Models and Spatial Seismicity Patterns Along the Intra-Continental Plate Boundary in Central-Eastern California: Imaging H_2O Zones and a Magma Chamber Beneath Coso

We inverted P and S-P arrival times from 11,500 earthquakes that occurred in central eastern California, to determine the 3-D Vp and Vp/Vs velocity structures to depths of 25 km. The 3-D Vp model of this region is laterally uniform with only minor localized spatial variations. The Vp model shows prominent near surface, low-Vp features such as the Indian Wells Valley and Searles Valley. The eastern edge of the Sierran batholith that approximately follows the Ash Hill and Panamint Valley faults to the east is imaged as Vp of 6.0 km/s on the west and Vp of 5.8 km/s on the east side at a depth of 4 km.

The Vp/Vs model shows several spatial features. Anomalously low Vp/Vs values are found in the Indian Wells Valley and Coso basins reflecting the poor compaction of the sediments derived in part from the volcanics in the Coso Range to the north. At depth, the Vp/Vs ratio shows spatial variations of alternating high and low Vp/Vs of 10 to 20 km length. These Vp/Vs anomalies form alternating northwest trending patterns suggesting possible crystal anisotropy possibly related to northwest striking dike swarms in the region. In contrast, the region south of the Garlock fault is characterized by fairly uniformly low Vp/Vs.

The abundant seismicity is scattered across the region with spatial clusters along the crest of the Sierra Nevada and in the Indian Wells Valley and Coso region. The seismicity appears to be related to broad regional crustal extension superimposed on right lateral shear as well as localized movement of crustal fluids in the Coso area.

Layered zones of both high and low Vp, Vs, and Vp/Vs are present beneath the Coso area (Figure 2). These zones consists of the geothermal area at 0 to 2 km depth, a zone of 4-6% geothermal fluids of H_2O extending from 6 to 11 km depth, and a possible magma chamber in the depth range of 11 to 16 km (Figure 3). The abundant seismicity in the 2 to 8 km depth range may be induced by fluid flow between the deeper geothermal reservoir and the surface geothermal area. The presence of a capped geothermal H_2O zone and a deeper magma chamber feeding small successively shallower chambers, suggests two different sources providing heat to the surface geothermal area.

PUBLICATIONS and REPORTS

Fuis, G.S, R.W. Clayton, P.M. Davis, T. Ryberg, W.J. Lutter, D.A. Okaya, E. Hauksson, C. Prodehl, J.M. Murphy, M.L. Benthien, S.A. Baher, M.D. Kohler, K. Thygesen, G. Simila, and G.R. Keller, Fault systems of the 1971 San Fernando and 1994 Northridge earthquakes, southern California: Relocated aftershocks and seismic images from LARSE II, *Geology, 31, no.2,* 171-174, 2003.

Hauksson, E., L. M. Jones, K. Hutton, The 1999 Mw7.1 Hector Mine, California earthquake sequence: complex conjugate strike-slip faulting, *Bull. Seismol. Soc. Am., 92,* 4, 1154-1170, 2002.

Hauksson, E., L. M. Jones, S. Perry, K. Hutton, Emerging from the Stress shadow of the 1992 Mw7.3 Landers southern California earthquake? A preliminary assessment, *Seism. Res. Lett*., 73, 33-38, 2002.

Liu, J., K. Sieh, and E. Hauksson, A structural interpretation of the aftershock “cloud” of the 1992 Mw7.3 Landers Earthquake, *Bull. Seismol. Soc. Am., 93*, no. 3, 1333-1344, 2003.

Nazareth, J. J., and E. Hauksson The Seismogenic Thickness of the Southern California Crust, *Bull. Seismol. Soc. Am. In review*, 2003.

Woessner, J., E. Hauksson, S. Wiemer, and S. Neukomm, The 1997 Kagoshima (Japan) Earthquake Doublet: A quantitative analysis of aftershock rate changes, *Geophys. Res. Lett.,* submitted, 2003.

Rymer, M., V. E. Langenheim, and E. Hauksson, The Hector Mine, California, Earthquake of 16 October 1999: Introduction to the Special Issue, *BSSA Special Issue on the Hector Mine Earthquake in California*, *92,* 4, 1147-1153, 2002.

Unruh, J. R., E. Hauksson, F. C. Monastero, R. J. Twiss, Seismotectonics of the Coso Range-Indian Wells Valley region, California: Transtensional deformation along the southeastern margin of the Sierra Nevada, *GSA Memoir 195, 277-294,* 2002.

Wiemer, S., M. Gerstenberger, and E. Hauksson, Properties of the aftershock sequence of the 1999, Mw7.1 Hector Mine earthquake: Implications for aftershock hazard, *Bull. Seismol. Soc., Am*., *92,* 4, 1227-1240, 2002.

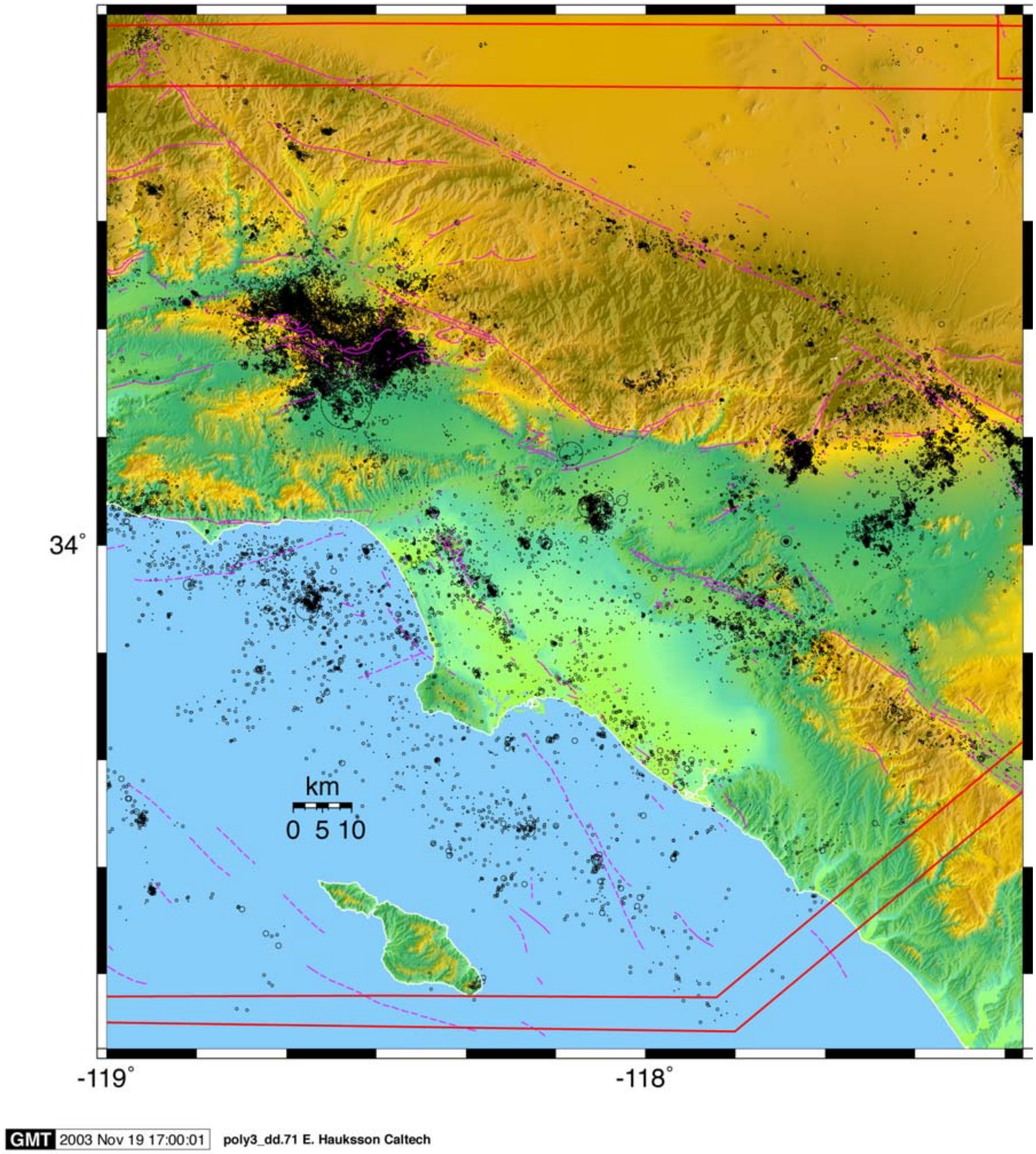

Figure 1. Seismicity in the greater Los Angeles basin, relocated using hyopDD and cross-correlation travel-times.

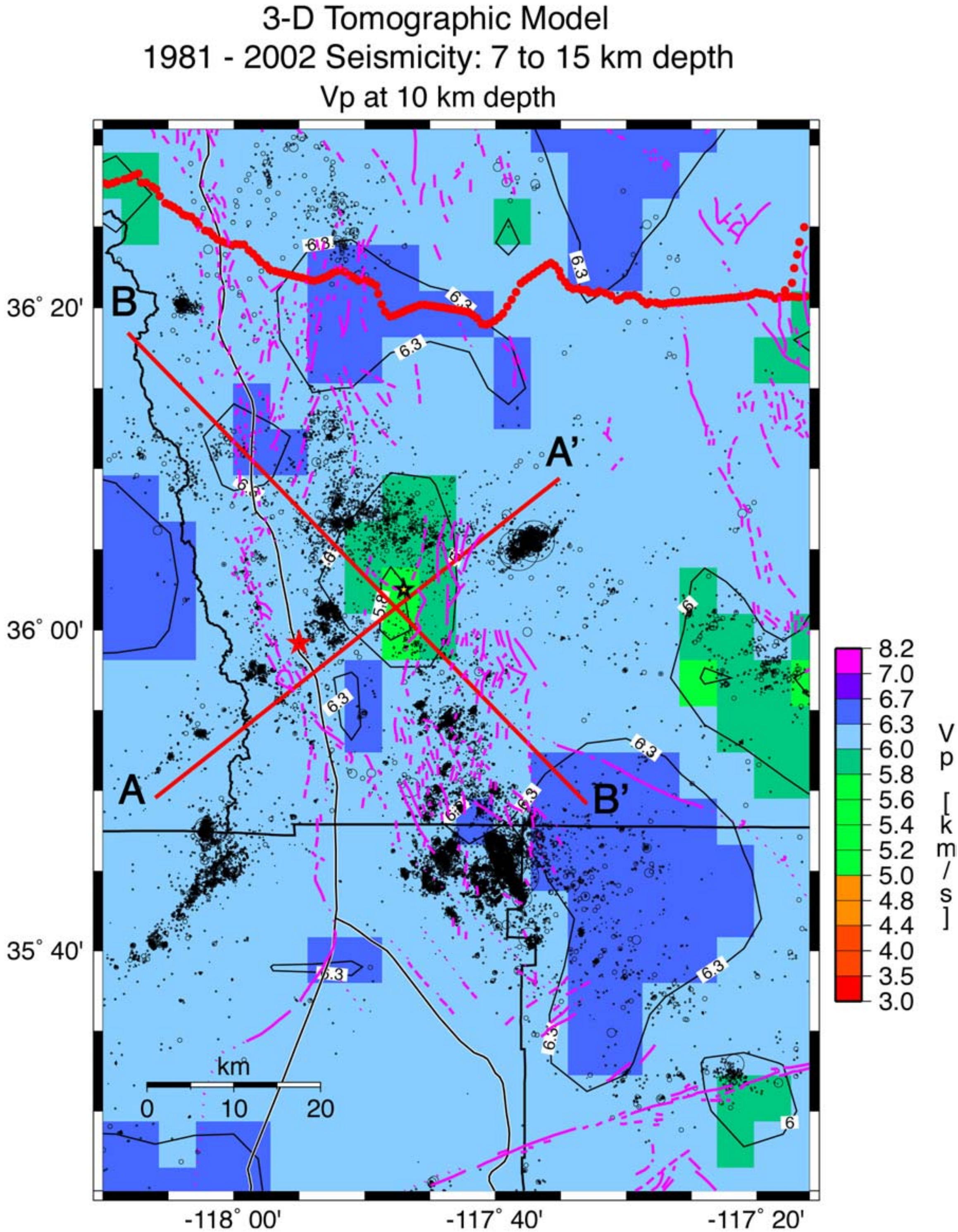

Figure 2. Map of Vp model in the Coso area at 10 km depth. The two red lines indicate the locations of the two cross sections shown in Figures (8 to 11). The red irregular curve to the north is the location of the refraction line shot by Ruppert et al (1998). The 1981-2002 seismicity in the depth range of 7 to 15 km is shown as black circles, whose size is proportional to magnitude. The location of the Coso geothermal area is indicated by the black star while the location of Red Hill volcano is indicated by a red star.

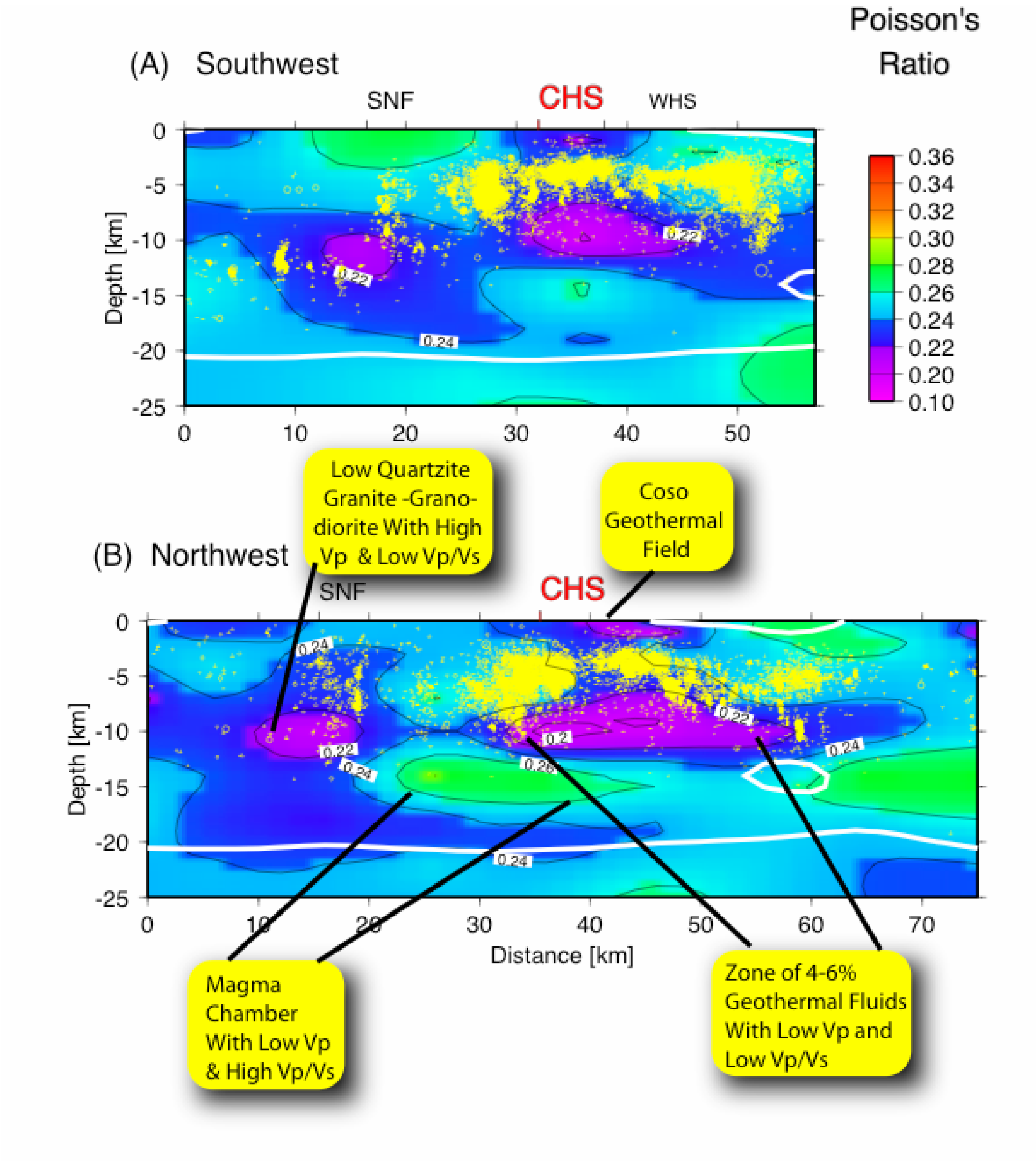

Figure 3. The Poisson's Ratio cross sections through Coso. Their location is shown in Figure 7. The magma chamber is interpreted to be at10 to 15 km depth, a zone of 4-6% geothermal fluids at from 6 to 10 km depth and more elongated in shape, and the Coso geothermal area extending from depths of 2-3 km below sea level up to the surface.

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NON-TECHNICAL SUMMARY