1998 SCEC Progress Report

Project Title: SCEC Borehole Instrumentation Initiative

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The SCEC borehole instrumentation program is now at the end of year two of a planned 4-year project. The initial plan was to instrument 3 sites per year. By the end of the second fiscal year we will have 5 sites fully operational. Four of the sites provide data in real-time to the Caltech/USGS Southern California Seismic Network (SCSN) and 1 site provides data in near real-time dial-up mode to the California Division of Mines and Geology's (CDMG) California strong motion instrumentation program (CSMIP). As the year-2 funding allocation for the program was cut by one site, we are right on schedule for the first two years. Data from the first site, the Griffith Park Observatory, became available on-line in September of 1998, and the remaining four sites are awaiting telemetry and some surface data acquisition systems. These remaining sites are scheduled to come on-line in late January and early February. Below is a background summary of the borehole instrumentation initiative and its scientific objectives, followed by highlights of the past years accomplishments.

<u>Project Description:</u>

One of the major goals of the Center is to compute theoretical seismograms for scenario earthquakes in the Los Angeles and Southern California region. The existing strong-motion data are used to calibrate and improve our computational techniques. Ground motions recorded at strong motion stations throughout Southern California are a combination of the complex earthquake source process, the propagation path from the source zone to the station, and the local near-surface site conditions at the station. The separation of source, path, and site effects is limited by the current availability of data, the detailed knowledge of the crustal structure, and our understanding of the earthquake source process. The widespread and varied ground motions and damage patterns over short distances produce a large degree of uncertainty in our ability to predict ground motion from future earthquakes. Much of the variability is thought to be caused by the local near-surface site conditions.

In order to reduce the uncertainty in our ability to compute theoretical seismograms predicting the ground motion from future earthquakes, we will remove the near-surface site effect at a few select stations by installing borehole instrumentation below the surface. The SCEC borehole instrumentation project will produce data that has not been distorted by the effect of the surface materials. This will allow for direct estimation of site effects, provide a test for the calibration and improvement of physical models of soil response, and give us a much clearer picture of the incident ground motion which can be used to study the earthquake source process and the regional crustal structure in more detail. In addition the borehole data can be used as empirical Green's functions (the input motion) for predicting ground motion at surface sites in the region surrounding the borehole station.

<u>Science Addressed</u>

Direct Estimation of Site Effects, Physical Modeling, and Understanding of Non-linear Effects

The new 1997 Uniform Building Code (UBC) to be used in the design of structures by the engineering community has placed a great deal of emphasis on the near surface soil conditions in the upper 30 meters. In fact, the site classification that will be used in this version of the UBC is determined by the shear-wave velocity or standard penetration tests in the upper 30 meters. Borehole geophysical data and seismic instrumentation for direct estimation of site effects at selected "typical" Southern California geologic site classes will help in calibrating and improving our physical models of soil response to different levels of ground motion. The degree of non-linear behavior in Southern California soils at large input ground motions is a critical issue for determining the maximum plausible ground motions from large earthquakes.

Borehole Data as Green's Functions for Predicting Ground Motion at the Surface

Results from a borehole study along the San Jacinto fault zone suggest that the input wavefield below the near-surface sediments is more coherent than at the surface, at soil or rock sites, even over distances as great as 5-20 km (*Steidl et al.*, 1996). The implication of this result is that a small array of borehole recordings can define the input motion for physical modeling of site effects within a large region surrounding the borehole stations. Is borehole ground motion consistent over these same scales across the Los Angeles basin, where the instrumentation will in some cases, due to the great depth of the basin, be installed in stiff soil instead of granitic rock? The coherency of borehole ground motion is most likely a function of the shallow regional crustal structure. This borehole initiative will address this issue by placing borehole stations in the rock at the edges of the Los Angeles basin, and at different stations spacing away from the rock locations.

Details of the earthquake source

Results from borehole data in the Parkfield area show evidence for repeating characteristic micro-earthquakes (*Nadeau and McEvilly*, 1997; *Nadeau et al*., 1995) that provide a detailed look at what is happening on the fault zone in both a spatial and temporal sense, on scales of meters and months respectively. With the increased signal to noise ratio that the borehole data provide and an ultra low-noise sensor, small earthquake clusters which have events with identical waveforms are recorded. The individual earthquakes within each cluster occur at periodic and quasi-periodic time intervals on the order of weeks to months. This unique data we will attempt to collect will let us examine the earthquake source zones in the Los Angeles region in detail, with on-scale recordings in the borehole from micro-g to 2.0 g accelerations.

<u>Project Progress: Year 2 Highlights</u>

Collaboration is once again the key word in describing the SCEC borehole instrumentation initiative. At the time of the SCEC annual report last year the project was still in the permitting phase without a single site having broken ground. At present, one year later, five sites have been drilled and characterized using various sampling and geophysical techniques, and cased with PVC for instrument installation. One of these sites is already providing real-time data that is available from the SCEC data center, and the other four sites will be online in Jan-Feb. 1999. This accomplishment would not have been possible without the collaboration with the ROSRINE program, the TRINET program and the SCSN, and the CDMG's CSMIP program. The five sites are shown in Figure 1 as Yellow diamonds with small black squares within, to represent year 1 and year 2 of this project (LA00, WND, GPK, OBG, and MCS). The borehole instrumentation plan starts with rock sites around the Los Angeles basin, and then moves to soil sites within the basin. Existing and future borehole installations are shown in Figure 1.

An example of the shear-wave velocity profiles with depth collected at three sites from this project are shown in Figure 2. These sites are all located within the Santa Monica Mountains at a spacing of approx. 7km (LA00, WND, and GPK in Figure 1). While all three of these sites would be considered rock sites by engineering definition, notice that the velocity profiles are distinctly different (Figure 2). One of the questions to be addressed is how similar are the input motions over these distances, and, how far can we extrapolate the input motion for ground motion prediction in the area surrounding the borehole station.

Another highlight of the past year was having Kinemetrics Inc. redesign the old Force Balance Accelerometer downhole instrument to take advantage of its new Episensor technology. Using the new Episensor downhole technology, we are able to record from micro-g level ground acceleration to 2g. Data from the first SCEC borehole station to come on-line, the Griffith Park Observatory, was retrieved via the Internet from the SCEC data center and is shown in Figure 3. Notice the clean waveforms recorded at depth on the new Kinemetrics downhole package from a M2.6 at 25 km epicentral distance. The surface ground motion has quite a bit more ambient noise due to cultural sources that do not affect the downhole record. We can expect similar data from the remaining 4 sites, as all of these will feature the new Episensor downhole technology.

<u>References</u>

Nadeau, R. M., and T. V. McEvilly (1997). Seismological studies at Parkfield V: Characteristic microearthquake sequences as fault-zone drilling targets, *Bull. Seism. Soc. Am.,* Submitted.

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<u>SCEC Publications</u>

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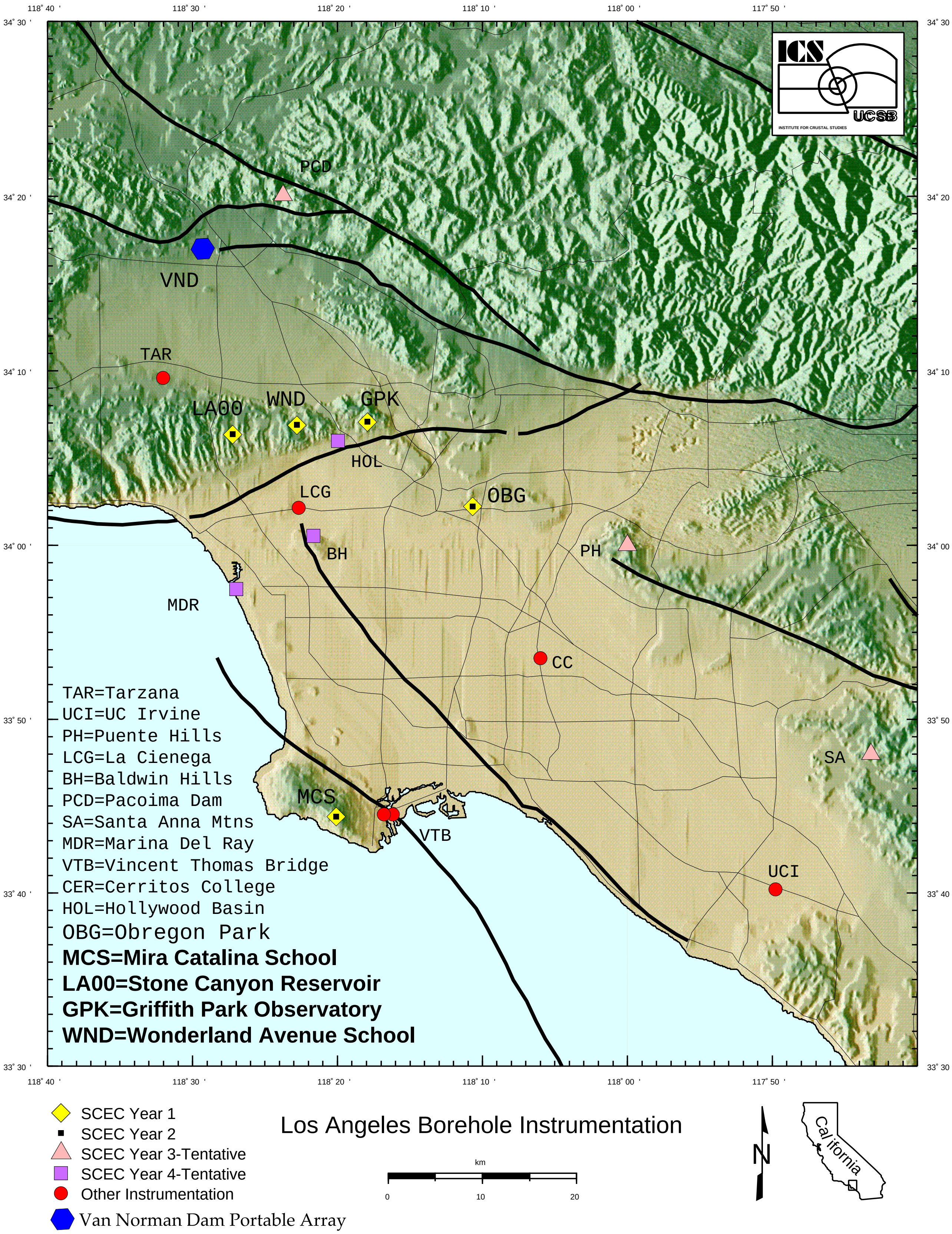

Figure 1). Los Angeles Borehole Instrumentation

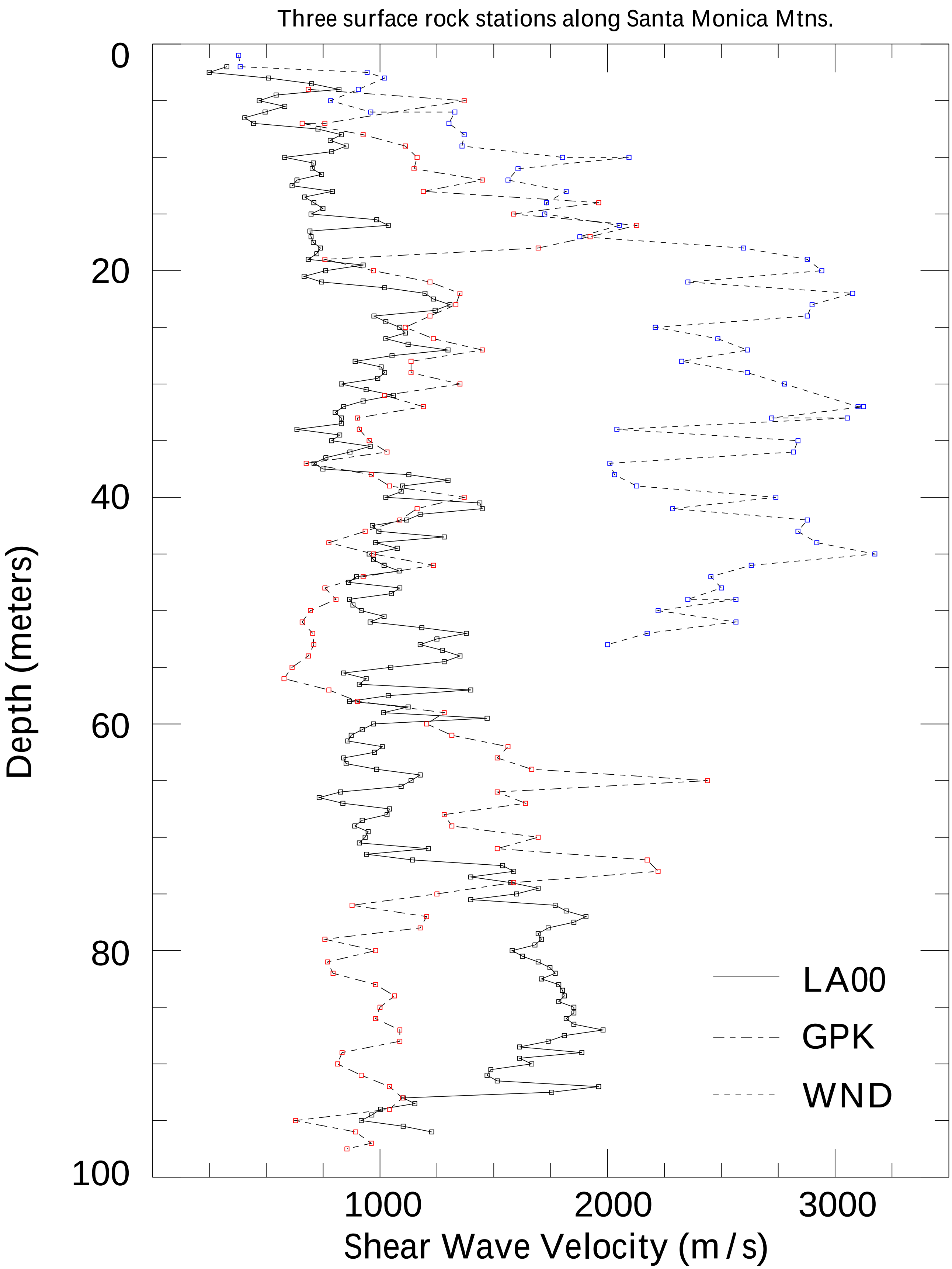

Figure 2). Near-Surface Velocity at SCEC Borehole Stations

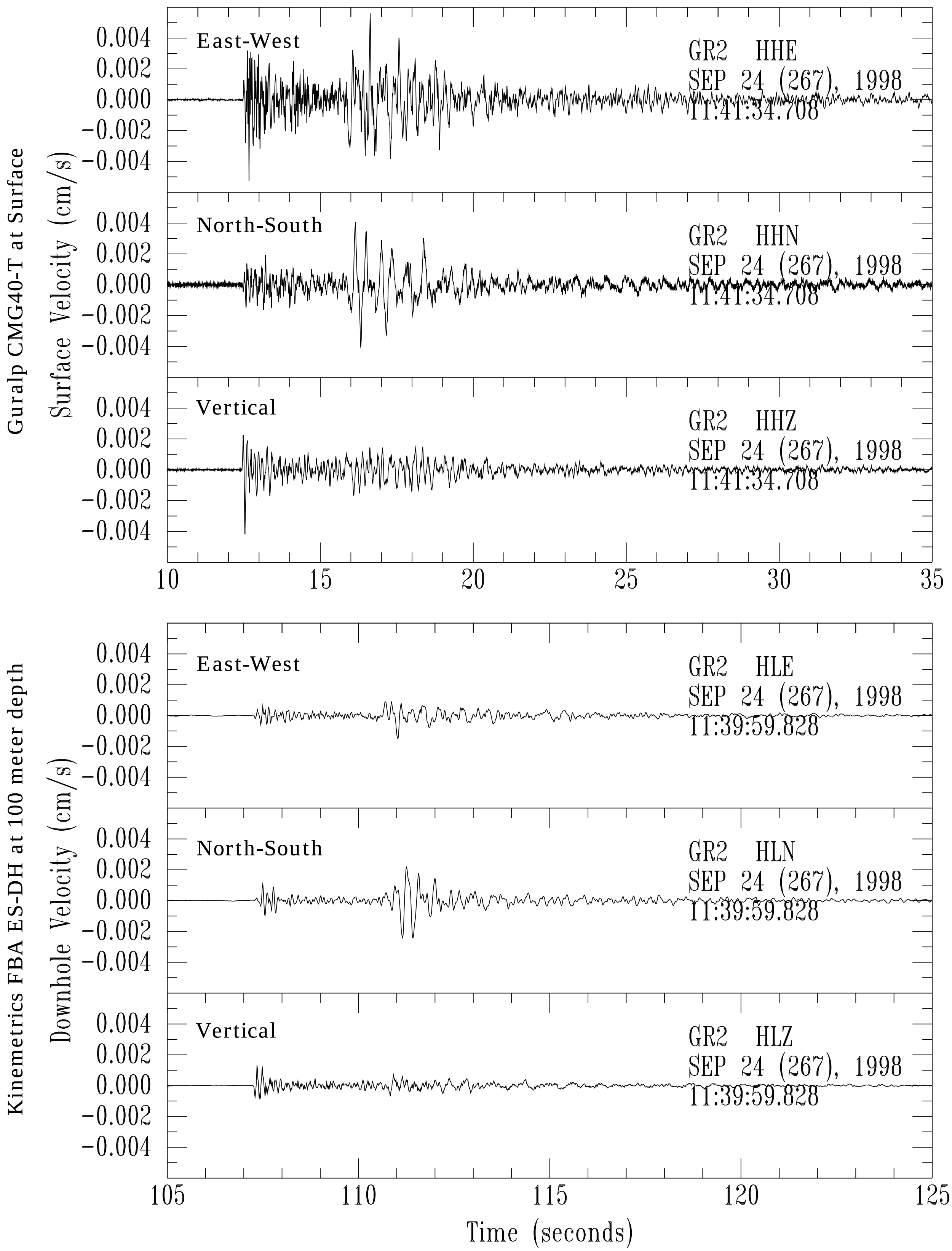

Figure 3). M2.6 @ 25km distance recorded at the SCEC Borehole Instrumentation Initiative site at GriffithPark Observatory on September 24, 1998. Surface velocity from Guralp CMG-40T shown on top, downhole velocity from new Kinemetrics Episensor downhole at 100 meters depth shown on bottom.