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Seismic Data for Nuclear Explosion Monitoring in the Arabian Peninsula

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SEISMIC DATA FOR NUCLEAR EXPLOSION MONITORING IN THE ARABIAN PENINSULA

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ABSTRACT

We report results from the third and final year of our project (ROA0101-35) to collect seismic event and waveform data recorded in and around the Arabian Peninsula. This effort involves several elements. We are working with King Abdulaziz City for Science and Technology to collect data from the Saudi National Seismic Network, that consists of 38 digital three-component stations (27 broadband and 11 short-period). We have an ongoing collaboration with the Kuwait Institute for Scientific Research, which runs the eight station Kuwait National Seismic Network. We installed two temporary broadband stations in the United Arab Emirates (funded by NNSA NA-24 Office of Non-Proliferation & International Security). In this paper we present a summary of data collected under these efforts including integration of the raw data into LLNL's Seismic Research Database and preliminary analysis of souce parameters and earth structure.

OBJECTIVES

The objective of this project was to gather seismic event, arrival and waveform data for nuclear explosion monitoring calibration purposes in the Arabian Peninsula. Over the past three years we have worked with institutions in the region to gain access to unique data sets from permanent and temporary deployments of seismic instrumentation.

Data was collected and loaded into the LLNL Seismic Research Database. Organization and archival of these data facilitates analysis for nuclear explosion monitoring calibration research, such as station siting, noise studies, regional phase signal propagation and detection modeling, event source parameters (e.g depth, moment and focal mechanism) and Earth structure estimates (e.g. travel times, surface wave group velocities, receiver functions, full waveforms).

RESEARCH ACCOMPLISHED

This project provided support to collect data in the Arabian Peninsula for nuclear explosion monitoring calibration purposes. Data was archived at LLNL and loaded into the LLNL Seismic Research Database. This is an ORACLE database containing waveform and parameter data, based on extended CSS3.0 format. In the following sections we describe the various data sets we have collected.

Saudi Arabia

The Saudi Arabian National Digital Seismic Network (SANDSN) is operated by King Abdulaziz City for Science and Technology (KACST). The network consists of 38 stations (27 broadband and 11 short-period) and is described by Al-Amri and Al-Amri (1999). Figure 1 shows the configuration of the SANDSN stations. The network began operation in May 1998 and records continuous waveform data. Data is collected and events are detected and located with the Boulder Real Time Technologies (BRTT) Antelope software. Data are digitized at the stations and telemetered to KACST. All data is recorded at 100 samples/sec.

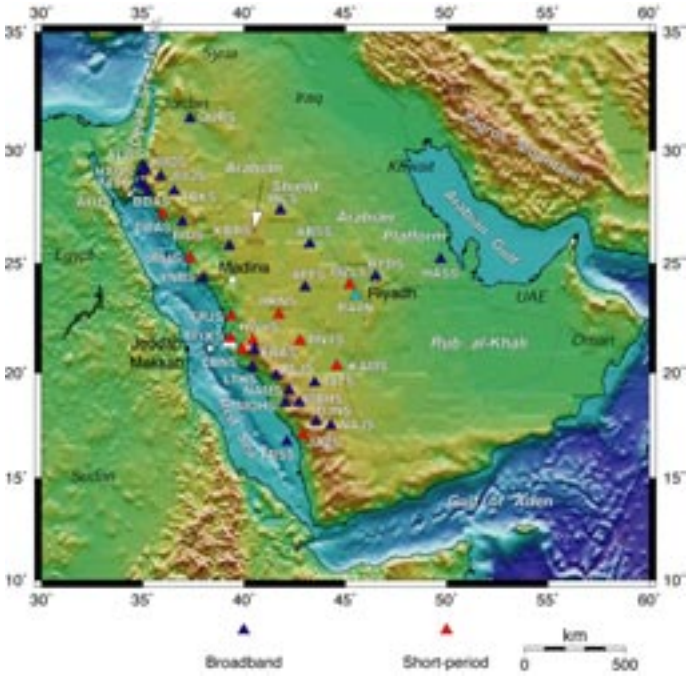

Figure 1. Stations of the Saudi Arabian National Digital Seismic Network: broadband (blue) and short-period (red) sites.

We obtained event segmented waveform data for local, regional and teleseismic events. Figure 2 shows the distributions of events. As of this writing not all data has been loaded into the LLNL Database.

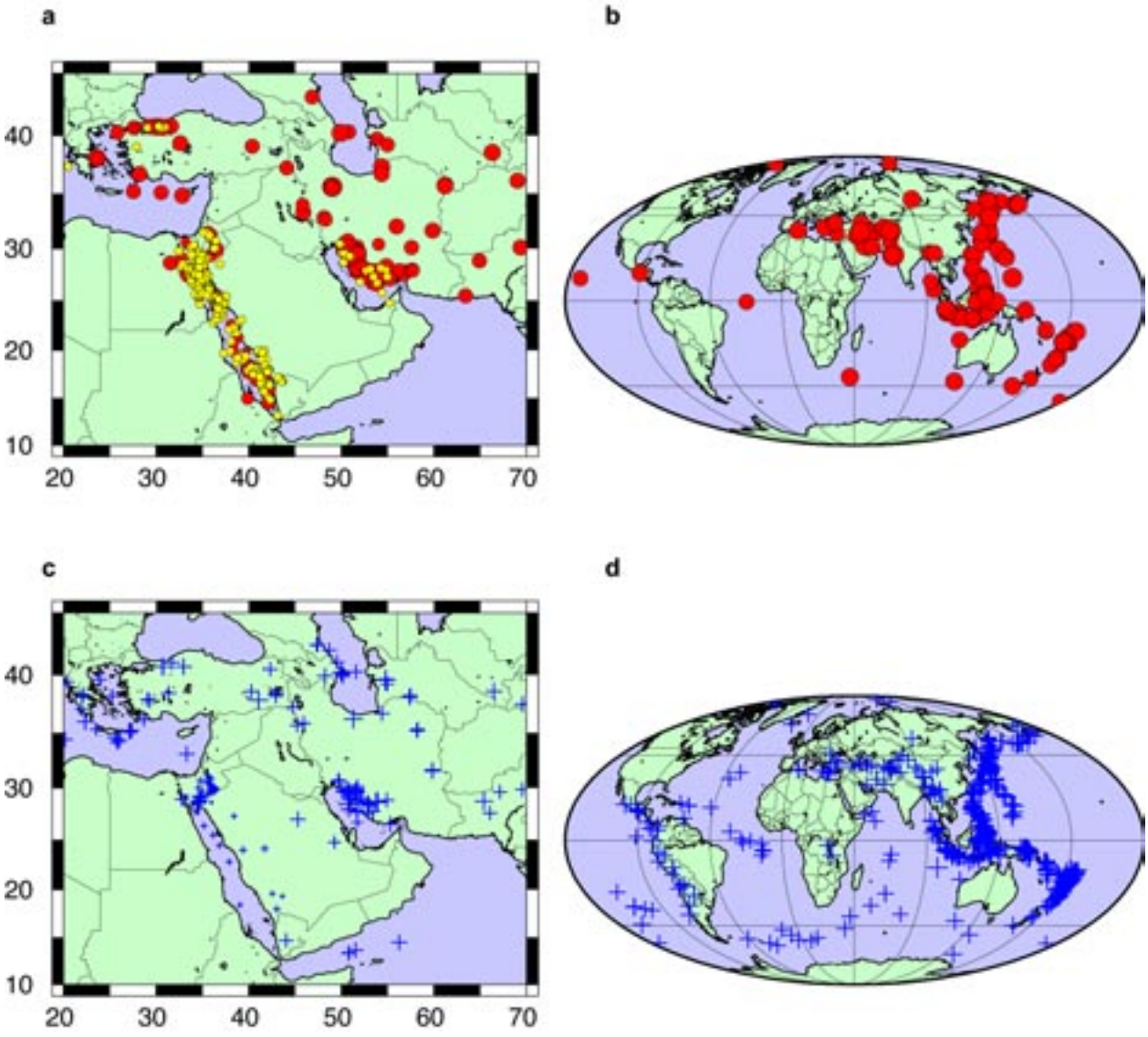

Figure 2. Events collected from the Saudi Arabian National Digital Seismic Network: (a) regional and (b) large global (M≥5) events loaded into the LLNL Seismic Research Database; (c) regional and (d) large global (M≥5) not yet loaded. Red circles and blue crosses are scaled to event magnitude, yellow circles indicate events with only a KACST local magnitude.

The SANDSN records very high-quality waveform data. Figure 3 shows waveforms we've obtained for station HILS and the associated regional events. For simplicity, we're only showing the events with body-wave magnitude, m_b, greater than or equal to 5.0. Note the extended dispersed surface waves for these paths crossing the deep sediments of the Arabian/Persian Gulf and Arabian Platform.

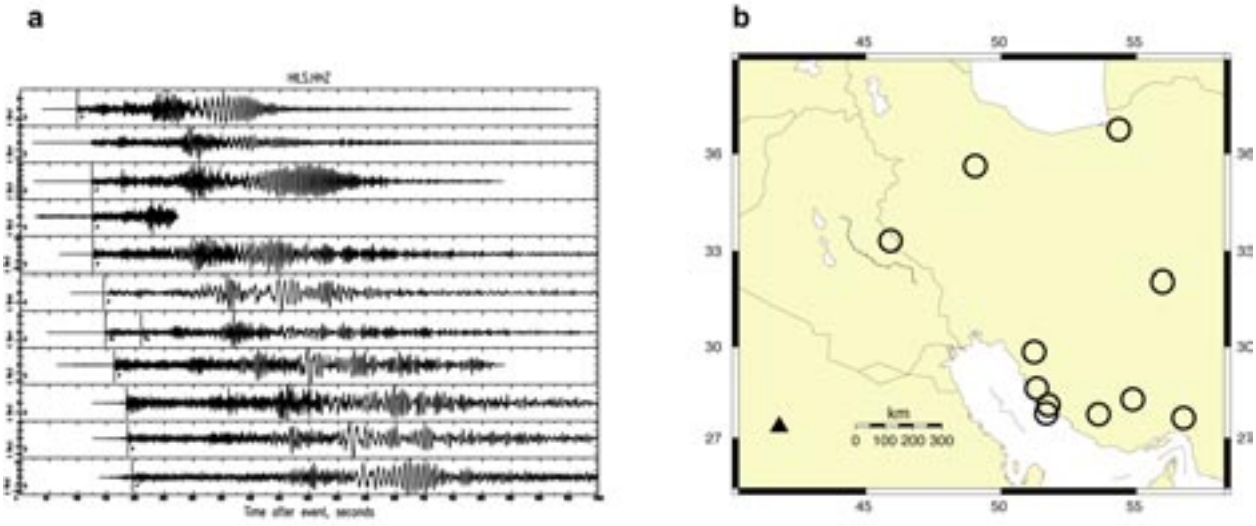

Figure 3. (a) Vertical component broadband (unfiltered) waveforms recorded at station HILS for (b) events in the Iranian Plateau.

Kuwait

The Kuwait Institute for Scientific Research (KISR) operates the Kuwait National Seismic Network (KNSN). This network consists of eight three-component stations (one broadband and seven short-period; see Al-Awadhi and Midzi, 2001), shown in Figure 4. The KNSN began operating in March 1997. The stations operate in triggered mode and transmit data when short/long term average levels exceed a pre-set threshold of six. Data are sampled at 100 samples/second with 24-bit digitization and communicated to KISR in Kuwait City via radio telemetry. An event is declared when three stations trigger within 30 seconds. The data for declared events are transferred to a PC and analyzed with the SEISAN software package, including location and magnitude estimation.

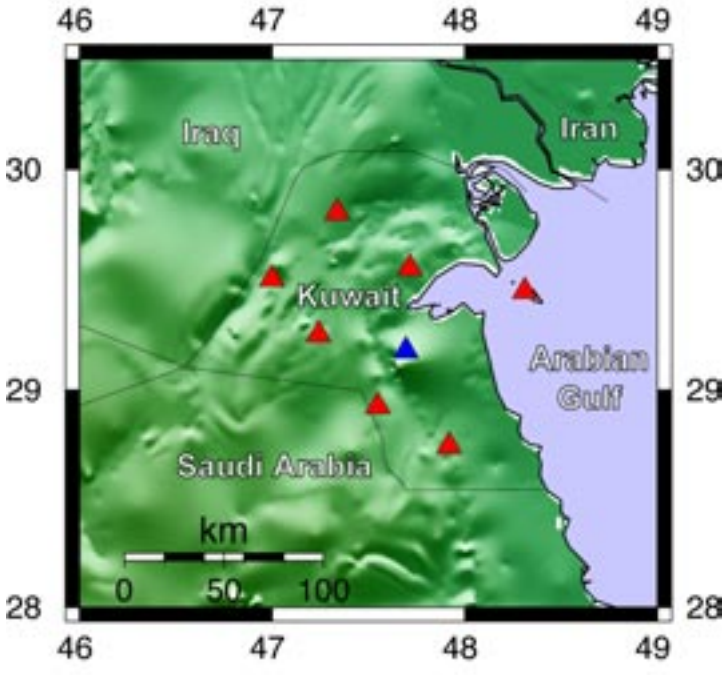

Figure 4. Stations of the Kuwait National Seismic Network: broadband (blue) and short-period (red) sites.

We obtained event segmented waveform data for local, regional and teleseismic events. Figure 5 shows the distributions of events. Seismic events in Kuwait are clustered near some, however not all, oil production regions. The nature of these events remains to be determined in more detail. It is important to note that events in Kuwait can approach magnitude 4.0 and can be observed at regional distances.

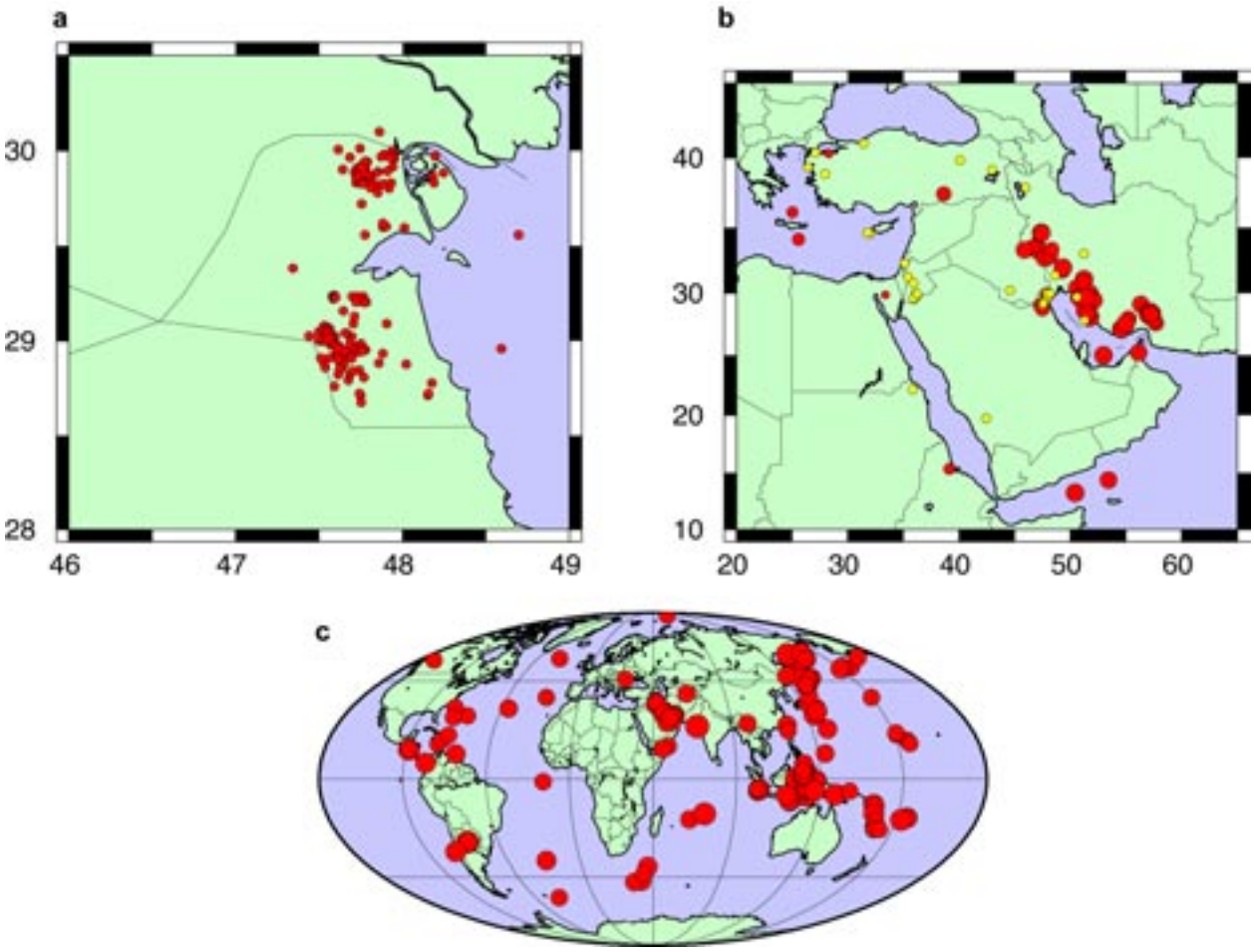

Figure 5. Events collected from the Kuwait National Seismic Network: (a) local; (b) regional and (c) teleseismic. Yellow circles in (b) indicate KISR locations.

United Arab Emirates (UAE)

In May 2003, LLNL in cooperation with United Arab Emirates University (UAEU) deployed two broadband stations in the UAE. The deployment specifics are detailed in Rodgers et al. (2003a). A team from the Geology Department serviced the stations. Figure 6 shows the site locations. These stations recorded continuously from May 2003 – April 2004. Event segments were extracted and loaded into the LLNL Database. These stations were located within near-regional distances of the seismically active Zagros Mountains. Figure 7a shows regional and teleseismic events recorded at the stations.

Figure 6. Map of the UAE showing the locations of two LLNL-UAEU seismic stations: MEZE and HALE.

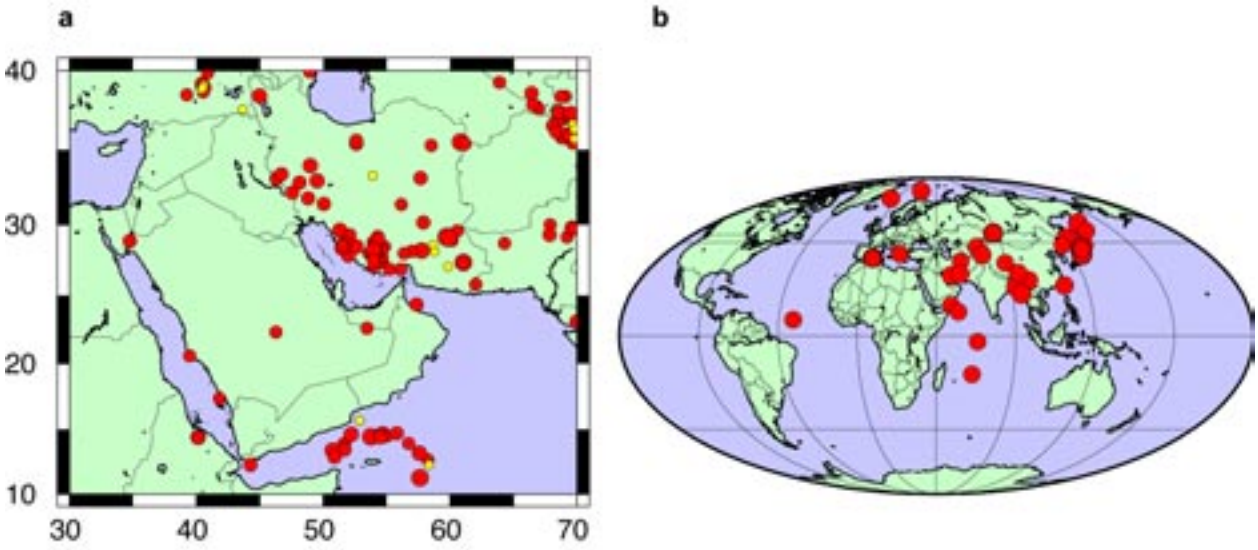

Figure 7. Events collected from the LLNL-UAEU stations: (a) regional and (b) teleseismic. Yellow circles in (b) indicate events with only local magnitudes.

The LLNL-UAEU stations provide a unique opportunity to sample local seismicity in the Musadam Peninsula. These stations were the first broadband systems to be deployed in the UAE. We will use these data to search for local events. Preliminary investigations found a local event, shown in Figure 8. Also shown in the Figure 8 is the focal mechanism of the March 11, 2002 Masafi earthquake. This event had a moment magnitude, M_W of 4.85 and was widely felt in the northern Emirates.

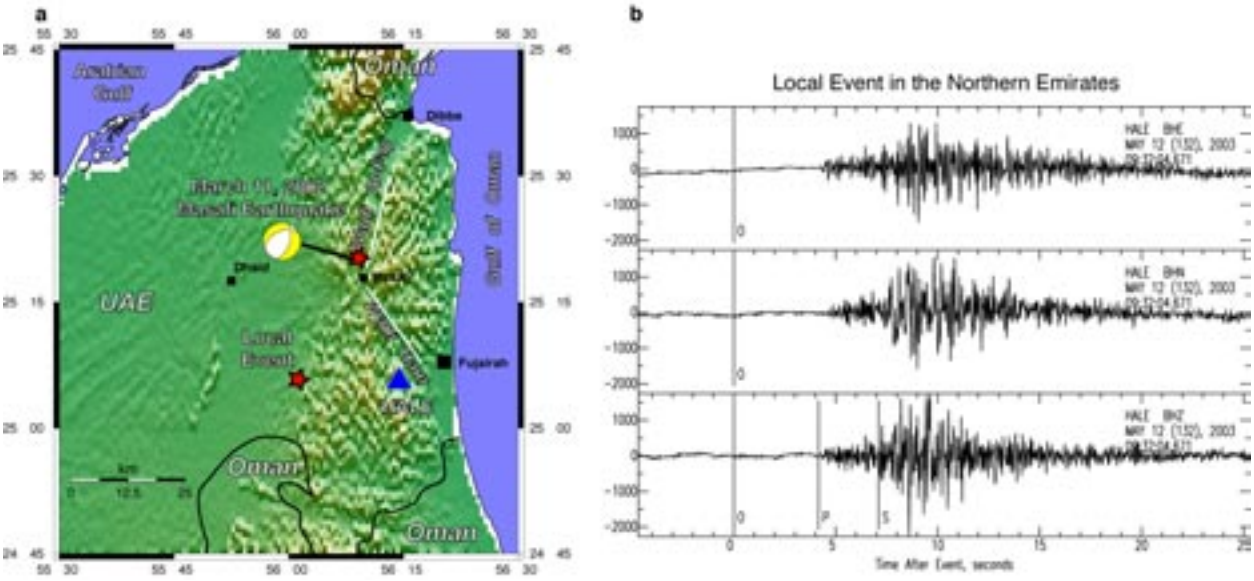

Figure 8. (a) Map of the northern Emirates showing our station HALE (blue triangle) and the estimated location of a local event (red star). Also shown is the focal mechanism of the March 11, 2002 Masafi Earthquake (M_W 4.85) and the two major faults cutting through the region. (b) The waveforms from the May 12, 2003 local event.

Regional Crustal Structure

We used data collected by this project to estimate crustal structure in the region. These efforts involve Pnl waveform modeling and joint inversions of surface wave dispersion and receiver function. Figure 9 compares estimates of crustal structure from various studies. We are able to resolve the deep sediments of the Arabian Gulf, as well as the bulk crustal velocities and thickness (e.g. Pnl waveform modeling and receiver function results). These models are compared to previous results for the Arabian Platform (Rodgers et al., 1999, 2003b) and a recent result for the Zagros Mountains (Hatzfeld et al., 2003).

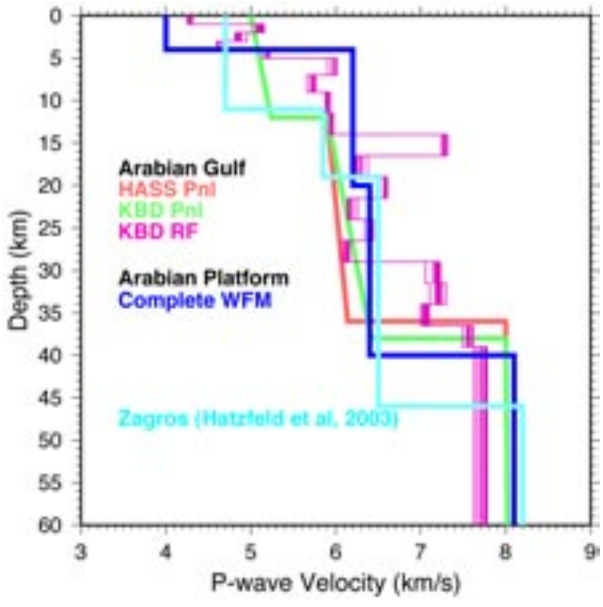

Figure 9. Comparison of crustal structure in the Arabian Gulf, Arabian Platform and Zagros Mountains (Hatzfeld et al., 2003).

CONCLUSIONS AND RECOMMENDATIONS

The data collected under this effort is valuable for calibrating wave propagation in the Arabian Peninsula and adjacent regions. When data are loaded into the LLNL Database, they are automatically associated with other origins and waveforms from the same event. This allows for data collected from all sources to be accessible to the researcher (e.g. GSN, PASSCAL, IMS, national networks, other deployments). As of this writing not all data has been loaded into the LLNL Database, however this task will be completed by August 2004. Data from this effort is being used in other projects.

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