DATA COLLECTION IN THE ARABIAN PENINSULA FOR NUCLEAR EXPLOSION MONITORING

Arthur J. Rodgers,[1] Hrvoje Tkalcic,[1] and Abdullah M. S. Al-Amri[2]

Lawrence Livermore National Laboratory[1] and King Saud University[2]

Sponsored by National Nuclear Security Administration
Office of Nonproliferation Research and Engineering
Office of Defense Nuclear Nonproliferation

Contract No. W-7405-Eng-48[1] and DE-FC03-01SF22418[2]

ABSTRACT

We report results from the second year of our project (ROA01-35) to collect seismic event and waveform data recorded in and around the Arabian Peninsula. This effort involves several elements. We have a temporary broadband seismic station operating near the International Monitoring System primary array site in central Saudi Arabia. We recently installed two temporary broadband stations in the United Arab Emirates, which are funded by the National Nuclear Security Administration (NNSA) Office of Nonproliferation and International Security (NA-241). We are working with King Abdulaziz City for Science and Technology to collect and analyze data from the Saudi National Seismic Network, which consists of 37 digital three-component stations (26 broadband and 11 short-period).

We will present results of these efforts including integration of the raw data into the NNSA/LLNL Seismic Research Database and preliminary analysis of event locations and source parameters and inference of earth structure.

OBJECTIVE

The objective of this project is to collect raw waveform and event parameter data for calibration of the Arabian Peninsula and surrounding regions for seismic monitoring. This effort involves several components described below. These include deployment of Lawrence Livermore National Laboratory (LLNL) equipment to the region and collaboration with seismological institutions in the region.

RESEARCH ACCOMPLISHED

During the last year we have made progress toward collecting the raw materials for seismic calibration of the Arabian Peninsula. The scope of this project covers the data collection effort and preliminary analysis. These data are integrated into the LLNL Seismic Research Database (O'Boyle et al., this Proceedings). Currently, we are not funded to analyze the data in this project though some preliminary analysis is being done for quality control. Figure 1 shows our study area and seismic stations considered. The various elements of our project are described below.

Broadband Deployment at IMS Array Site PS38

A broadband three-component seismic station was deployed near the site of the International Monitoring System (IMS) primary array site near Halban, central Saudi Arabia (PS38). LLNL and King Saud University (KSU) jointly deployed the station in January 2002 (Rodgers et al., 2001). KSU serviced the station every 6-8 weeks. Data from this site could be used as surrogate data for the IMS array. Currently the IMS array is not operating, however it is expected that testing will start later this year.

Broadband Deployment in the United Arab Emirates (UAE)

In May 2003 we deployed two broadband three-component seismic stations in the United Arab Emirates (UAE) as part of a joint research project on seismology. This project is funded by NNSA/NA-241. The stations are located near Al-Ain and Fujairah. Figure 2 shows the station locations and map of the UAE and surrounding region. The stations were deployed jointly by LLNL and UAE University in May 2003 (Rodgers et al., 2003).

Each station consists of a Guralp CMG-3T broadband seismometer and Geotech DL24 seismograph recorder. The Guralp CMG-3T seismometers have a broadband response that can sense ground motions from periods between 0.01 Hz (120 sec) and 50 Hz. We set-up the systems to record ground motion at 40 samples/sec. An anti-aliasing filter reduces the useful high frequency pass-band of the system to 16 Hz. Data are written to a 1 Gigabyte microdrive at 30 minute records. Microdrives are collected every 4-6 weeks by UAEU and a copy is sent to LLNL for archival.

Cooperation with KACST

The Saudi Arabian National Seismic Network is operated by King Abdulaziz City for Science and Technology KACST), based in Riyadh. This network features 26 broadband and 11 short-period three-component seismometers (Figure 1). We are working with KACST to improve velocity models for routine local and regional event locations. Velocity models are being developed for the main geologic/tectonic regions of the Kingdom: the Arabian Shield, Arabian Platform and the Gulf of Aqaba.

Waveform data from the KACST and Kuwait (see below) networks can be used to estimate regional velocity structure and source parameters. Figure 3 shows an example of the utility of these data for source parameter estimation. A moderate sized earthquake occurred in March of 2002 on the Musandam Peninsula in the northern UAE. Earthquakes are quite rare in this area and this event provides an opportunity to understand the seismotectonics and structure of the region.

Cooperation with KISR

The Kuwait National Seismic Network is operated by the Kuwait Institute for Scientific Research (KISR). This network consists of 1 broadband and 7 short-period stations (Figure 4). Currently we have a small collection of local, regional and teleseismic events for this network. Local events are typically small, mb < 3.0. However a moderately large event occurred in southern Kuwait on December 30, 1997.

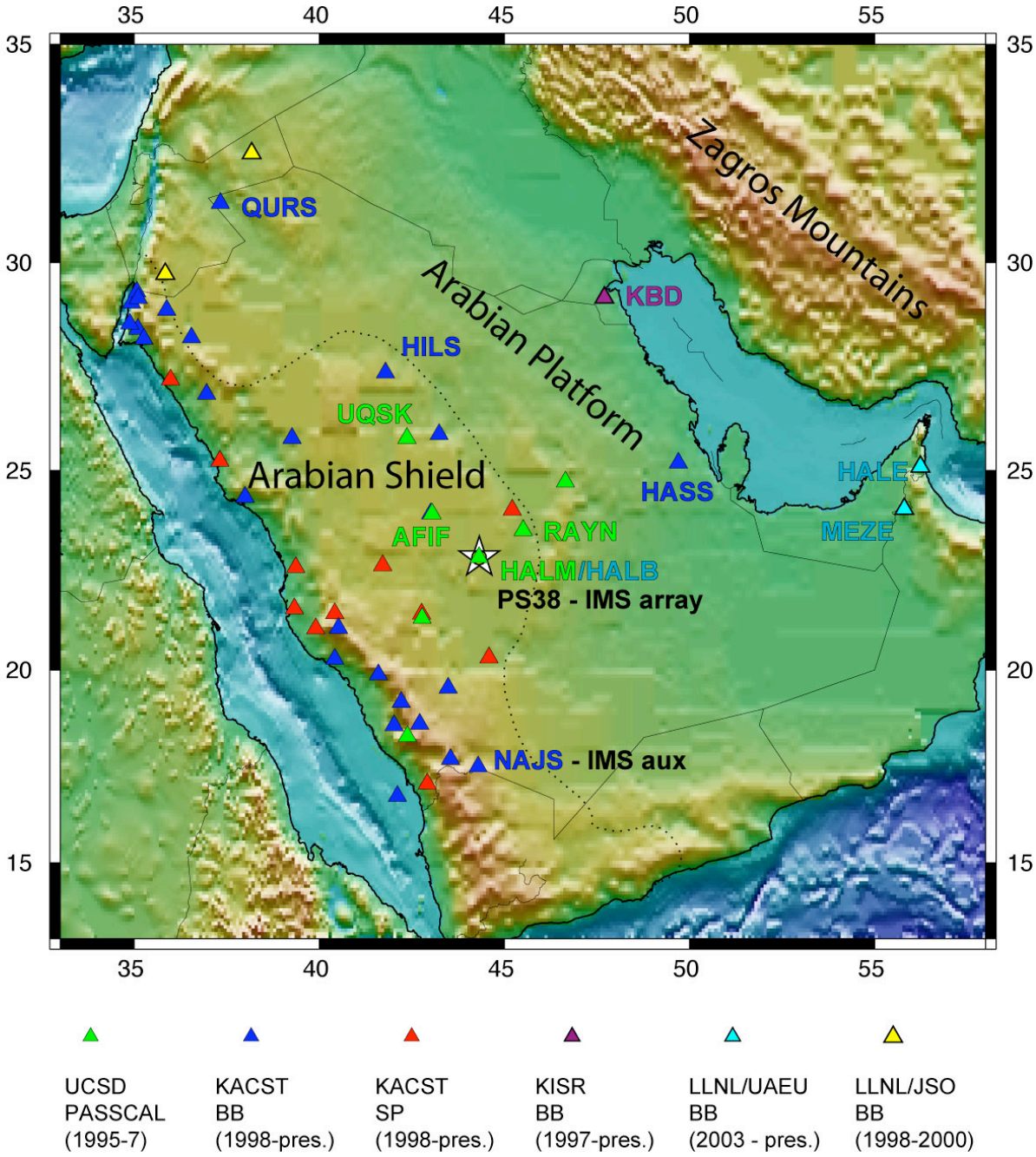

Figure 1. Map of the Arabian Peninsula showing seismic stations considered in this study.

<u>Workshop on Reference Events on/near the Dead Sea Rift</u>

A workshop was help in Paris France October 7-9, 2002 to bring together seismologists from many institutions in Middle East with the specific goal of advancing data exchange and analysis of events along the Gulf of Aqaba and Dead Sea Rift. Participants came from Cyprus, Egypt, France, Israel, Jordan, Lebanon, Saudi Arabia, Turkey, the United Kingdom and the United States. A set of forty-six events was selected before the meeting and data from each participating institution were requested (raw waveform, arrival, event locations, magnitudes, etc…). A map of the events and stations is shown in Figure 5.

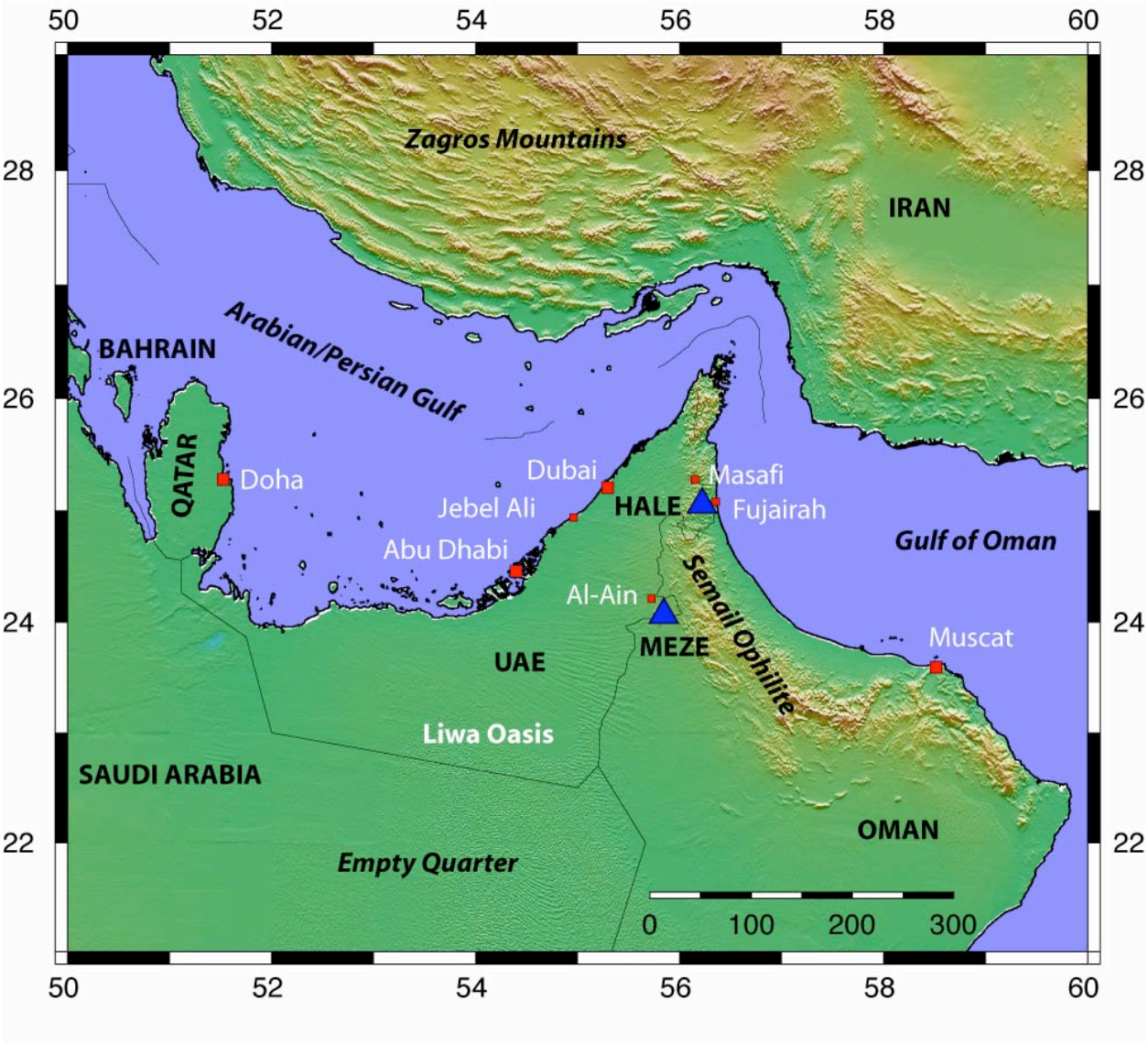

Figure 2. Map showing the locations of the two LLNL-UAEU broadband seismic stations (MEZE and HALE) in the UAE.

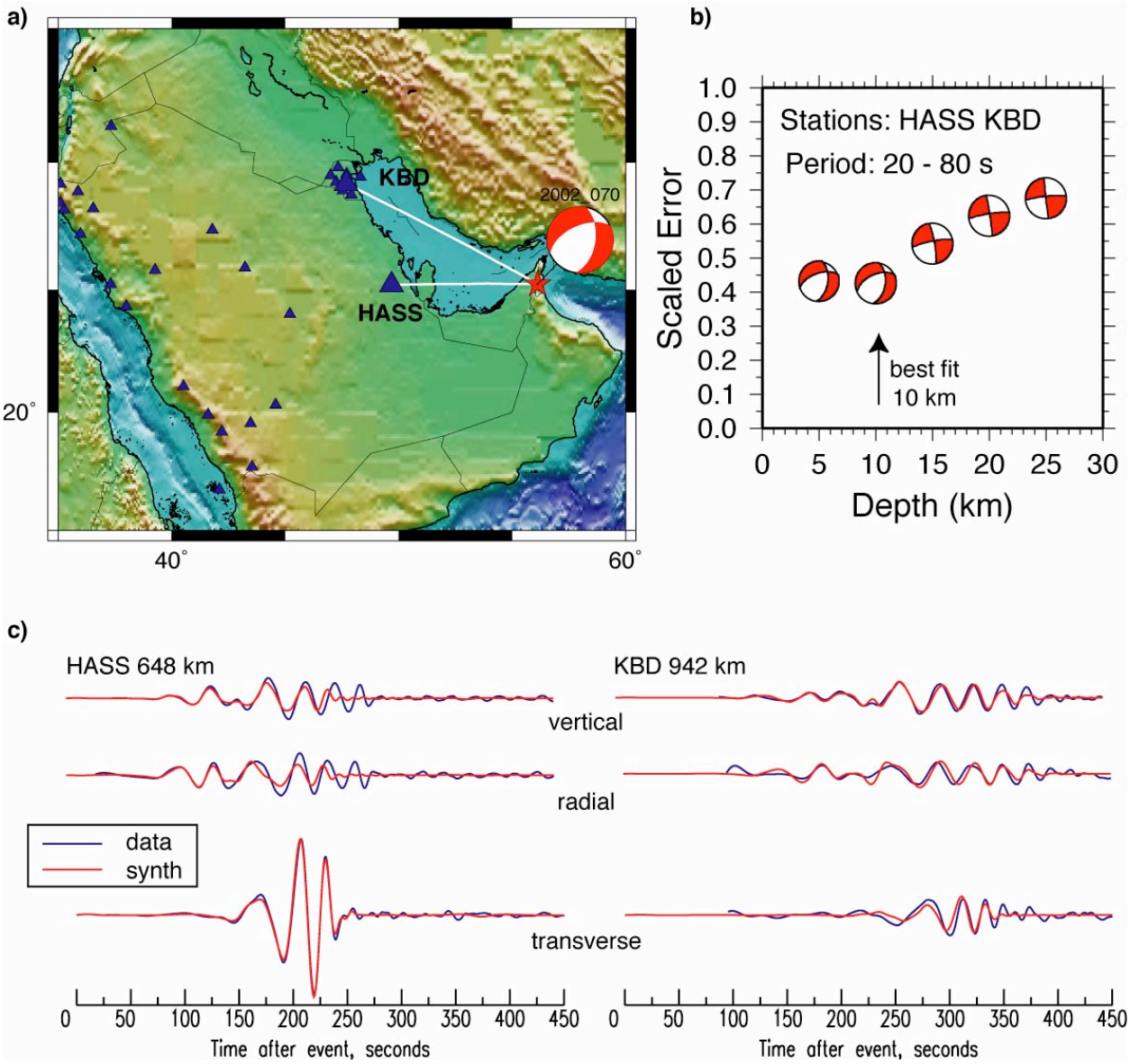

Figure 3. Analysis of the March 11, 2002 Musadam Peninsula earthquake. (a) Map showing the event location (star) from the USGS-PDE. Stations used in the source parameter estimation are shown as large triangles. Also shown are stations from the KACST network for which we have waveform data (small triangles). (b) Depth-focal mechanism-misfit curve estimated from broadband complete waveform modeling using stations HASS (eastern Saudi Arabia) and KDB (Kuwait). The best-fitting depth is 10 km. (c) Observed and synthetic waveforms for the best-fitting source model at stations HASS and KBD. Data and synthetic were filtered between 20-80 seconds.

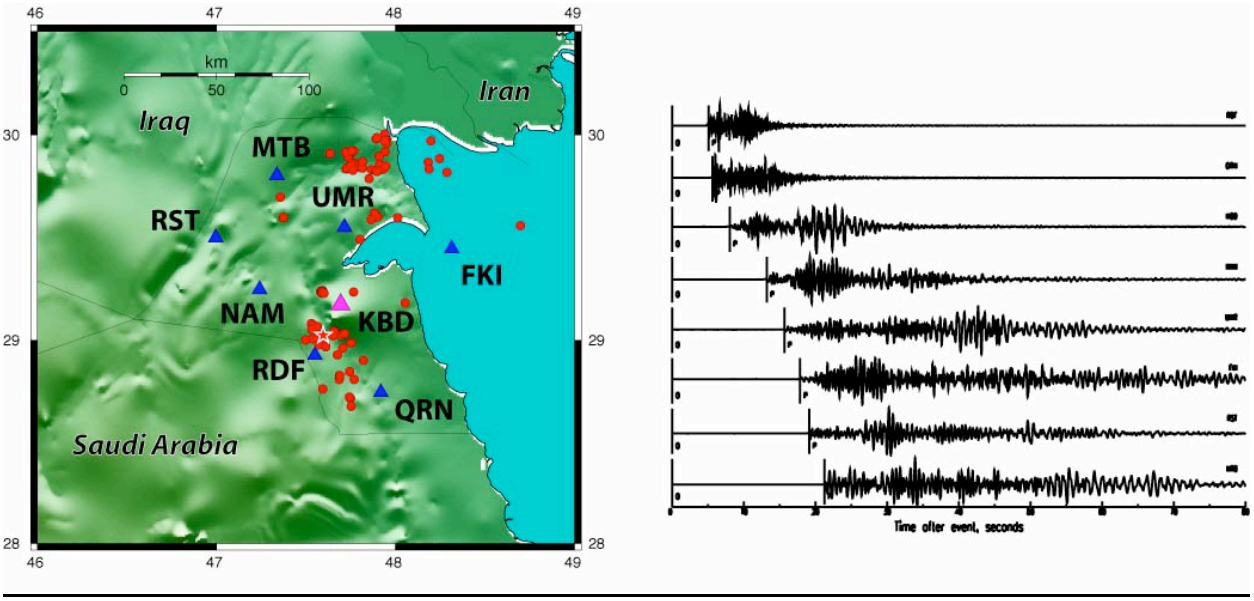

Figure 4. (left) Kuwait National Seismic Network stations (triangles). The broadband station, KBD is shown in magenta. Also shown are local events and the M 4.3 Minagaish event (Dec. 30, 1997). (right) Vertical component waveforms (unfiltered) for the Minagish event, sorted by distance.

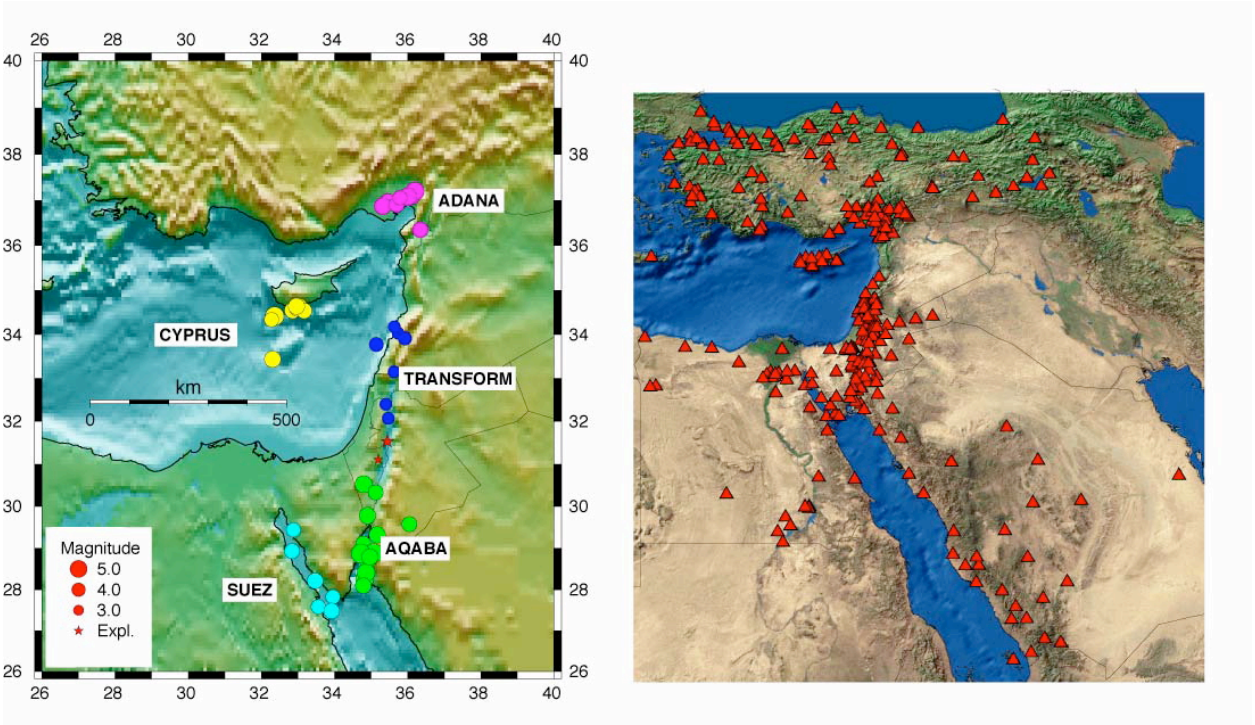

Figure 5. (left) Events selected for the Paris Workshop. (right) Stations that contributed waveform, arrival and/or location data for the Paris Workshop.

CONCLUSIONS AND RECOMMENDATIONS

Data collected in the Arabian Peninsula is a valuable resource. This region is vast yet has only a few seismic stations openly distributing data. Many studies have demonstrated the complex propagation characteristics of high-frequency regional phases, suggesting additional data will deepen understanding of regional phase behavior Rodgers et al., 1997; Mellors et al., 1999). Models exists for sediment and crustal thickness (Sandvol et al., 1998; Rodgers et al., 1999), however little broadband data has been available for evaluation of these models.

ACKNOWLEDGEMENTS

Data was integrated into the LLNL Seismic Research Database by Stanley D. Ruppert, Jennifer L. O'Boyle, Teresa (Terri) F. Hauk and Douglas A. Dodge. Keith K. Nakanishi and Cindy Lersten assisted in the planning of the UAE Deployment. Pat Lewis traveled to the UAE to deployed the two broadband stations. Donald W. Rock prepared the Lawrence Livermore seismic equipment and facilitated the loan agreements.

REFERENCES

Al-Amri, A. M. S. (1999b). The crustal and upper-mantle structure of the interior Arabian platform, *Geophys. J. Int*., **136**, 421-430.

Mellors, R., F. Vernon, V. Camp, A, Al-Amri, A. Gharib and M. Al-Dial (1999). Regional waveform propagation in the Saudi Arabian Peninsula*, J. Geophys. Res*.

O'Boyle, J., S. Ruppert, T. Hauk, D. Dodge, M. Ganzberger and F. Ryall, Middle East, North Africa and Western Eurasia Seismic Research Database, *Proceedings of the 25th Seismic Research Review*, Tucson, AZ.

Rodgers, A., J. Ni and T. Hearn (1997). Propagation characteristics of short-period Sn and Lg in the Middle East, *Bull. Seism. Soc. Am*., **87**, 396-413.

Rodgers, A., W. Walter, R. Mellors, A. Al-Amri and Y. Zhang (1999). Lithospheric structure of the Arabian Shield and Platform from complete regional waveform modeling and surface wave group velocities, *Geophys*. *J Int*., **138**, 871-878.

Rodgers, A., J. P. Lewis and A. M. S. Al-Amri (2002). Broadband seismic station deployment at Hadabat Al-Mahri, Halban Saudi Arabia. Lawrence Livermore National Laboratory Informal Document, UCRL-ID-147211.

Rodgers, A., J. P. Lewis and A. R. Fowler (2003). A Broadband Seismic Deployment in the United Arab Emirates, Lawrence Livermore National Laboratory Informal Document, UCRL-ID-153713.

Sandvol, E., D. Seber, A. Calvert and M. Barazangi (1998). Grid search modeling of receiver functions: Implications for crustal structure in the Middle East and North Africa, *J. Geophys. Res*., **103**, 26,899-26917.