

Lithospheric Profiles in Western North America

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ABSTRACT:

As we move toward a Comprehensive Test Ban Treaty for nuclear weapons, it has become increasingly clear that detailed knowledge of lithospheric structure is necessary to verification efforts. Key seismic phases which are being used as discriminants (Pn, Pg, Lg, etc.) to identify suspicious seismic signals travel exclusively in the lithosphere and are thus much affected by its structure. However, the studies needed to acquire detailed knowledge of lithospheric structure require large explosions, recorded by hundreds of seismograph systems. In the former Soviet Union, a series of Peaceful Nuclear Explosions (PNE) were exploded to provide such data. There have been very few PNE in the U.S., and these experiments took place in the 1960's and 1970's long before there were large numbers of digital seismograph systems available to provide detailed recordings. Thus, these few PNE events do not provide detailed pictures of lithospheric structure and propagation of regional phases and cannot serve as effective benchmarks for comparison with other continents. Large chemical explosions can provide suitable sources for lithospheric experiments as proven by the EARLY RISE experiment in the Great Lakes region in the 1960's and the recent Non-Proliferation Experiment at the Nevada Test site (NTS). However, we have not had an opportunity to conduct a large-scale lithospheric experiment with modern equipment except with NTS sources. The UTEP geophysics group has been conducting a series of investigations in the southwestern U.S. The most recent was undertaken in the summer of 1995 and is the closest thing to a PNE experiment that we will see taking place outside of NTS for the foreseeable future. In cooperation with the Canadian program called LITHOPROBE, we and Rice University recorded along a profile extending from Great Slave Lake to New Mexico, a distance of about 2500 km. This experiment is a unique opportunity to gather seismic data at regional distances with large numbers of modern seismograph systems. In addition to preliminary information on this 1995 experiment (termed "Deep Probe") we will present results of the May 1994 Colorado Plateau/Basin and Range transition experiment ("Delta Force"), tomographic studies of the eastern Mojave using earthquake and explosion sources, and passive seismic studies of the El Paso and Lubbock, Texas regions.

key words: western North America lithosphere

OBJECTIVE:

Determine the lithospheric structure of western North America including structure of the western Colorado Plateau/eastern Basin and Range transition, eastern Mojave Desert region, Rio Grande rift/Great Plains transition, and deep structure of Archean and Proterozoic crust of the northern and central Rocky Mountains. These objectives will be accomplished through active and passive seismic experiments in the regions of interest.

PRELIMINARY RESULTS:

Delta Force:

The May 1994 Delta Force refraction/wide angle reflection seismic project was designed to sample the eastern edge of the Basin and Range province at the latitude of Las Vegas, NV, to Blythe, CA, and into the Colorado Plateau of northwestern Arizona. A group of 474 digital instruments were installed on a single deployment covering two main lines at an average spacing of 2 km and a group of recorders were set loosely as a third line (Figure 1). Four explosive sources were set up near Hurricane, UT (Shot 1), Death Valley Junction (Shot 2), Kingman, AZ (Shot 3), and Blythe (Shot 4). The shots were fired in succession at 4 minute intervals providing in-line as well as fan-type coverage. Seismic recording occurred along Line 1 (Blythe to Death Valley Junction), Line 2 (Death Valley Junction to Kingman), and Line 3 (Hurricane to Kingman).

Preliminary results of the interpretation of Line 1 suggest Pn velocities of 7.8 km/s, which is consistent with previous studies. Upper and lower crustal velocities of 6.0 and 6.6 km/sec, respectively, are also interpreted. The crust appears to be 30 km thick. No major variation in crustal thickness is indicated along this line. The Pn crossover distance from Shot 2 along Line 2 is about 180 km, and the data indicate crustal thickening beginning at the Grand Wash Cliffs. On Line 3 the apparent Pn crossover distance is ~140 km from Shot 1.

Eastern Mojave:

We have collected travel-time data from nuclear and chemical explosions and earthquakes of magnitude > 3.0 within the eastern Mojave Desert region (Figure 2). These data have been used in a 3-D tomographic inversion to determine the velocity structure beneath the region, as well as the effects of anisotropy on wave propagation. The earthquakes and explosions used in the study were recorded by stations operated by Caltech, the University of Nevada-Reno, and the University of California at Berkeley. Travel times of P arrivals from the 1994 Delta Force and 1993 Southern Sierra Nevada Continental Dynamics seismic refraction experiments have also been incorporated into the data set. Two different starting models have been tested to see which provided the best fit with the data: a) a smooth, homogeneous model, and b) a priori velocity constraints obtained from the results of seismic refraction profiles in the Mojave and southern Basin and Range region. Preliminary inversion results suggest that anisotropy develops from both starting models, with the horizontal velocities generally being 1 to 2 % faster than the vertical velocities.

Both starting models give average velocities of 6.1 to 6.3 km/sec in the upper 15 km of the crust.

Passive Seismic Studies:

We have installed broadband, digital seismographs at Lubbock and El Paso, TX, (January, 1995) and more recently at Canyon de Chelly, AZ, and Chaco Canyon, NM (June, 1995) to examine the structure of the southeastern Colorado Plateau, the eastern Rio Grande rift and western Great Plains (Figure 3). In addition to recording teleseismic data for surface wave dispersion and teleseismic receiver function studies, we have recorded a number of regional events including the April 1995 Alpine-Marathon (M~5.5) earthquake (Figure 4). Data analysis for the two Texas stations has just begun.

Deep Probe:

Collection of data for this experiment is currently underway. Figure 5 indicates the deployments in the U.S. and the shotpoints. The first deployment in Montana and southern Wyoming is scheduled for the night of August 1.

FUTURE PLANS:

The whole wavefield data for the Delta Force experiment will be modeled using the reflectivity method and a finite difference wave equation algorithm. The results will be complemented by gravity data modeling using earth structure derived from the seismic model.

Travel-time information from the University of Nevada-Reno seismic network is currently being merged with other travel-time data for the eastern Mojave region. Final results of the tomographic studies are expected by late fall.

Interpretation of broadband data collected in Texas is just beginning. We plan to continue operation of the Texas stations for at least another year. Since stations on the southeastern Colorado Plateau have only begun operation, we plan to continue data collection at these sites through at least the fall and winter of 1995.

Data from the Deep Probe experiment and preliminary interpretations will be presented at the Fall 1995 AGU meeting.

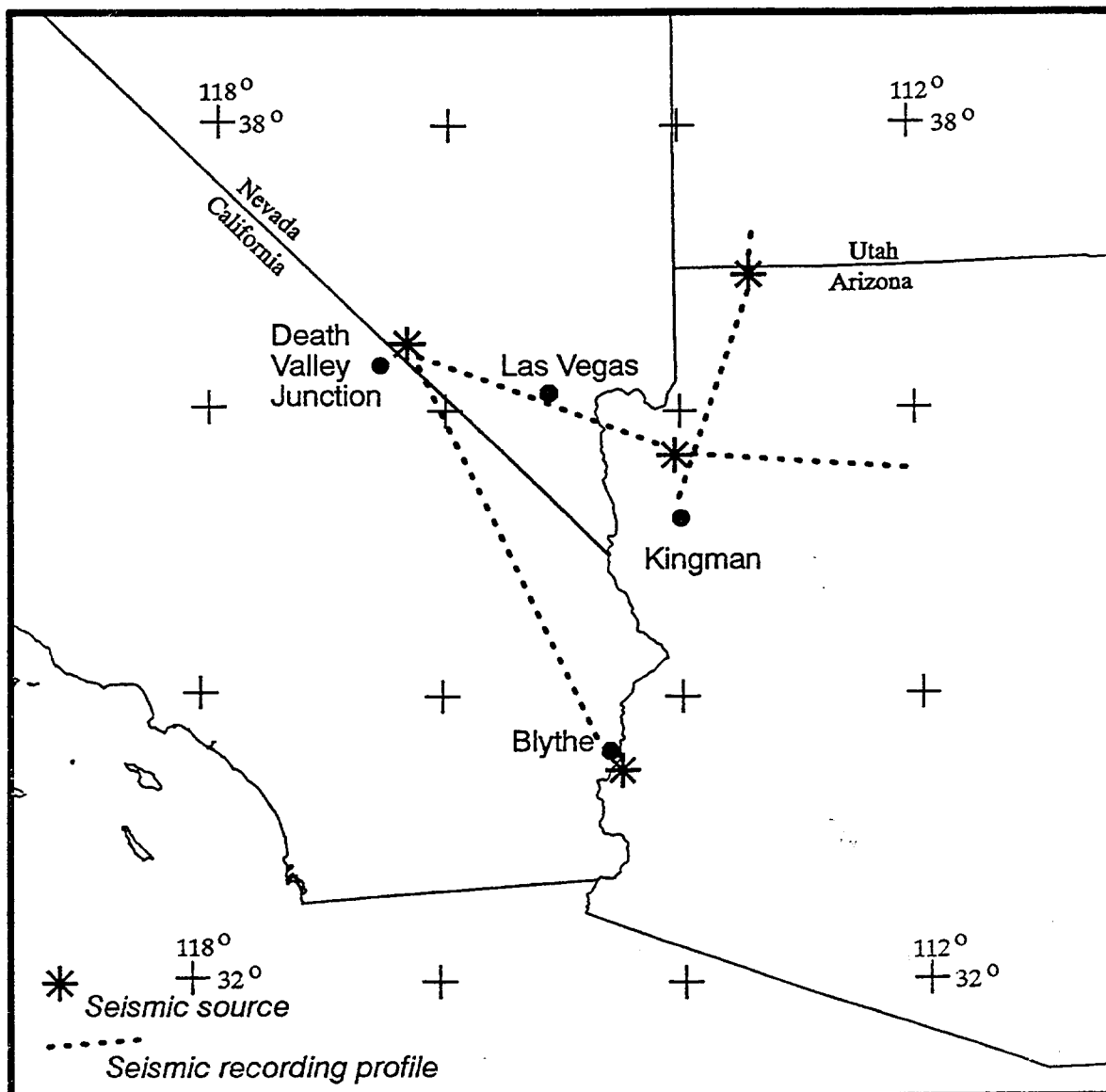


Figure 1. Index map of the Delta Force seismic experiment. Seismic sources are indicated as asterisks, receiver deployments as dashed lines.

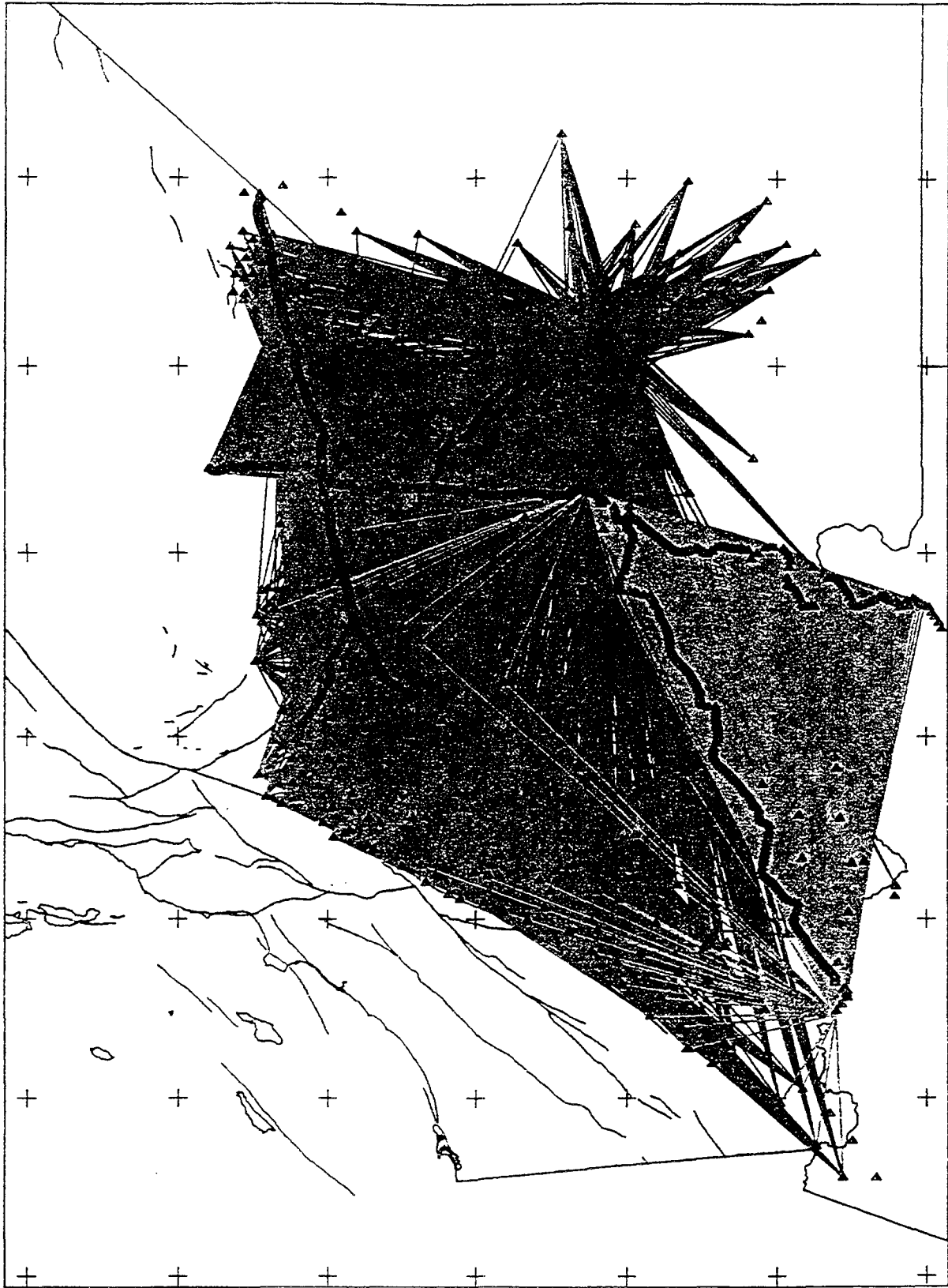


Figure 2. Index map of the eastern Mojave study region showing seismic stations (triangles) and raypath coverage.

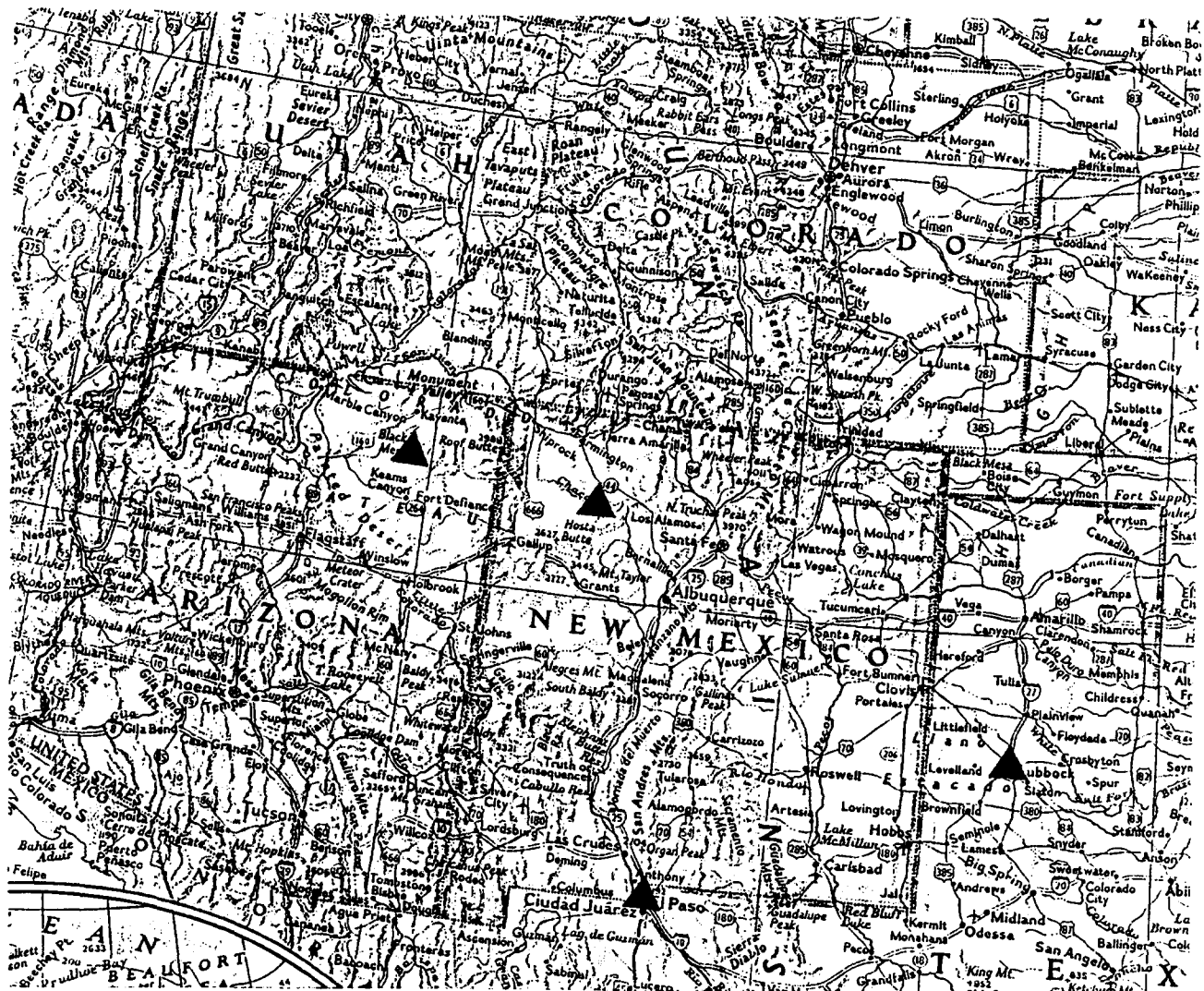


Figure 3. Index map of broadband seismograph stations (triangles) currently deployed in a passive seismic study of the southeastern Colorado Plateau, eastern Rio Grande rift and western Great Plains.

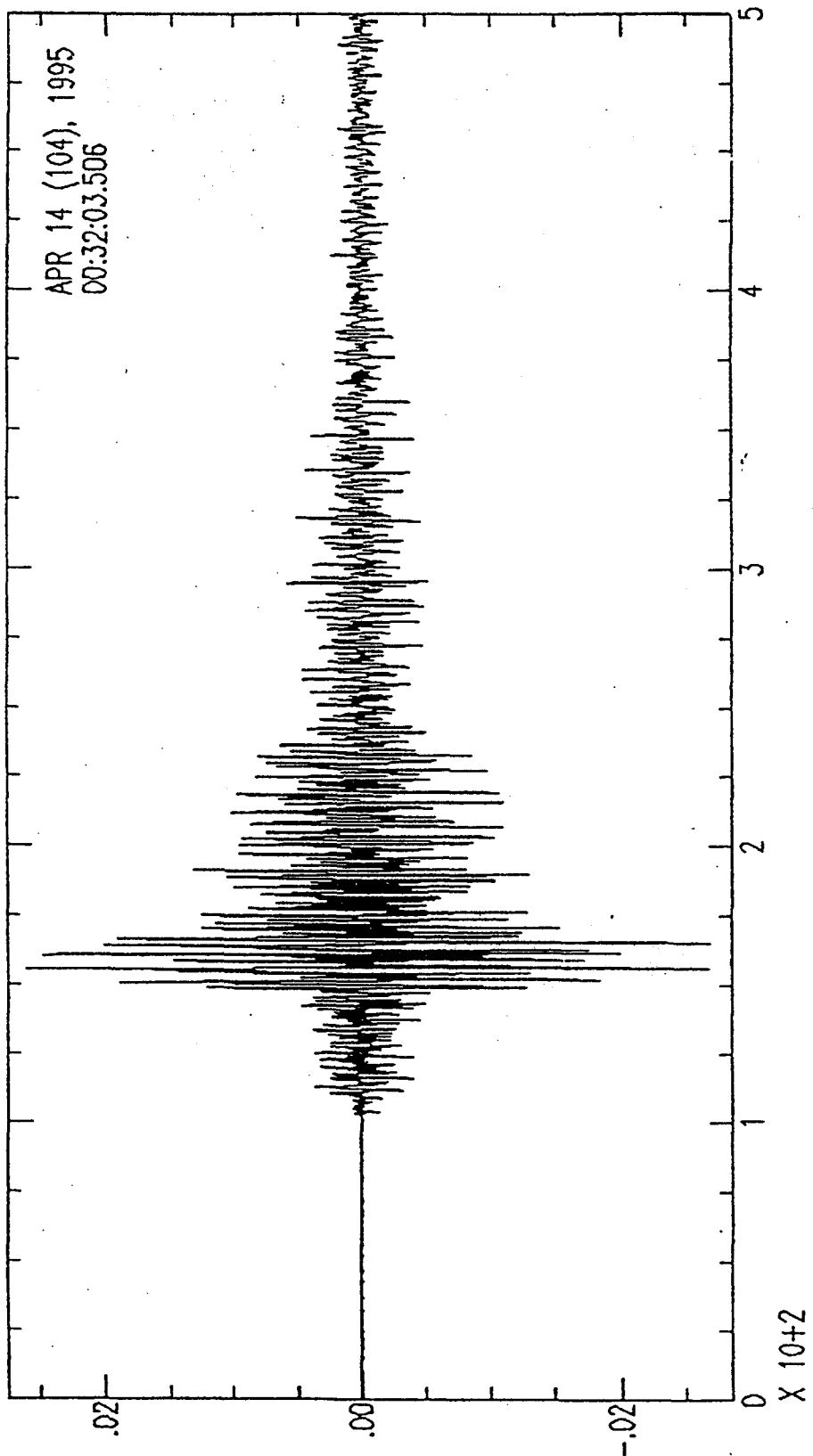


Figure 4. Seismogram of the April 13, 1994, Alpine-Marathon, Texas, earthquake (magnitude ~ 5.5) recorded in El Paso.

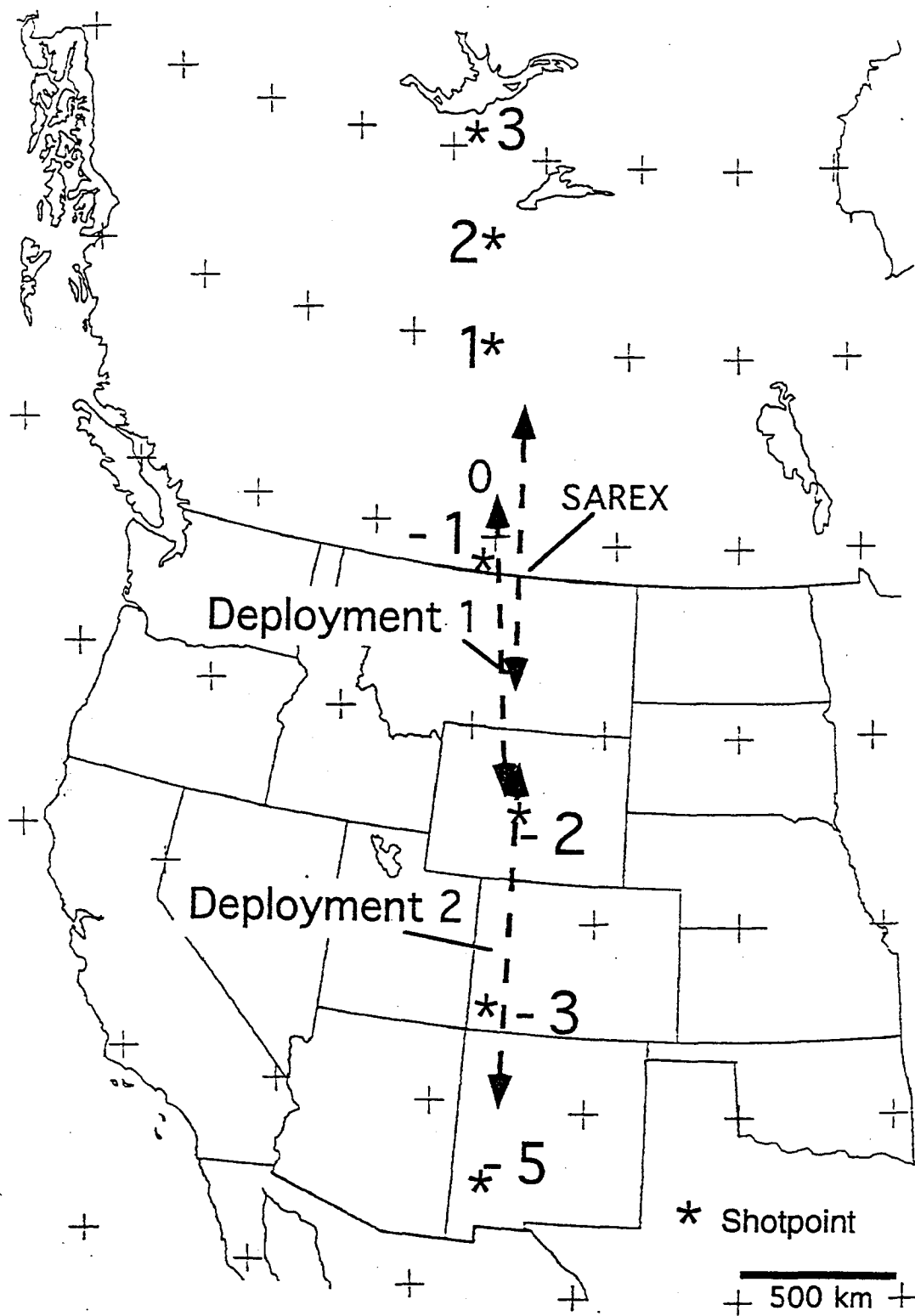


Figure 5. Index map showing U.S. deployments and all shot points for the August 1995 Deep Probe seismic experiment.