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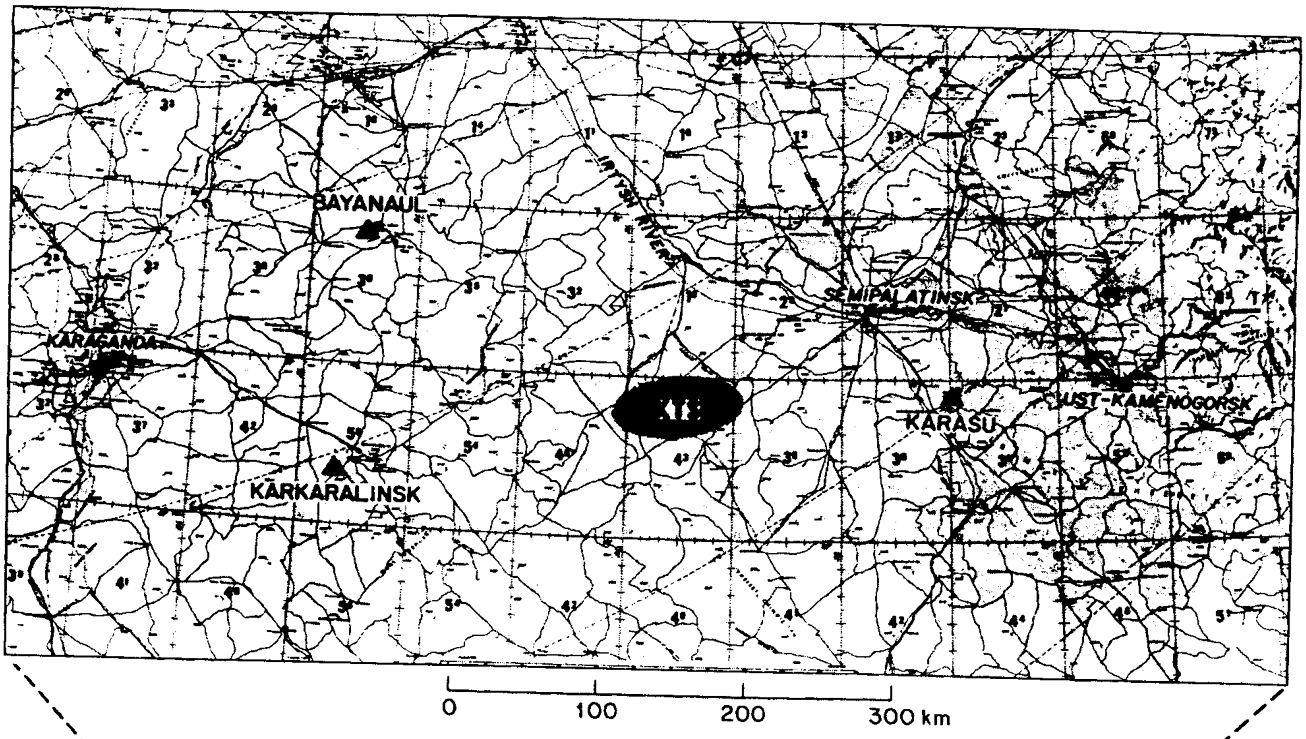

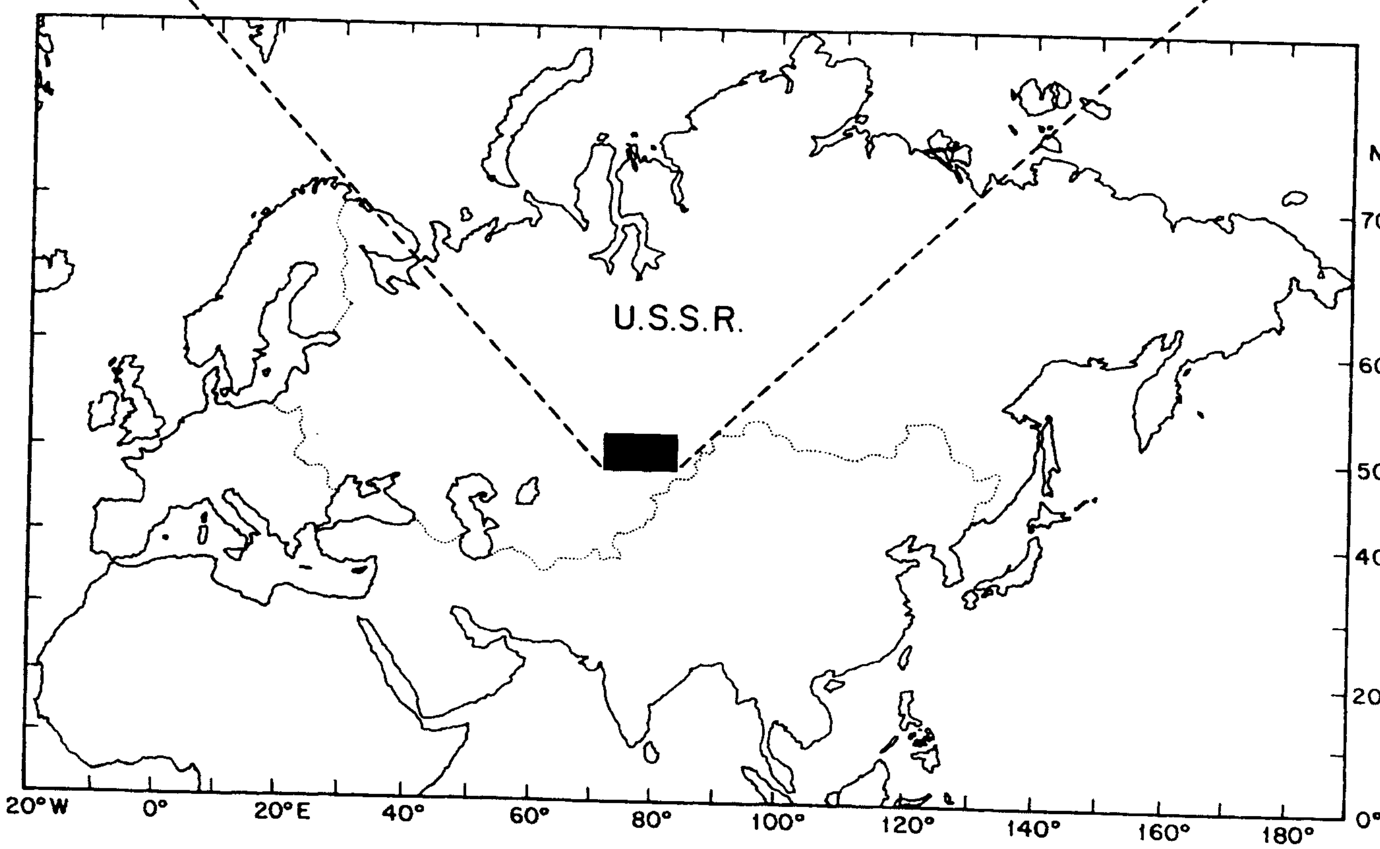

A New U.S.–U.S.S.R. Seismological Program

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Introduction

On July 9, 1986, a team of researchers from the University of California, San Diego; University of Nevada, Reno; and the University of Colorado, Boulder established the first of three seismic stations to be located in the vicinity of the Soviet nuclear test site in eastern Kazakhstan (KTS) (see cover). Under an agreement reached between the Soviet Academy of Sciences and the Natural Resources Defense Council, a nonprofit U.S. environmental organization, these stations, which are configured to meet the specifications of the proposed new global seismographic network [*Incorporated Research Institutions for Seismology (IRIS)*, 1984], will be complemented by three similarly equipped stations to be installed in the vicinity of the U.S. nuclear test site in southern Nevada (NTS). The stations are to be operated cooperatively by Soviet and U.S. personnel
(Figure 1).

The data that are collected by this joint program are meant to be relevant to several seismological problems associated with the monitoring and verification of present and future test ban treaties. These include

• ***Determination of ambient ground noise levels as a function of frequency and time.*** The noise levels obviously control the magnitude of events that can be detected and the accuracy with which they can be characterized by any given station configuration. Initially, portable equipment was used to measure ambient noise on the surface and to locate suitable sites for the installation of more permanent equipment. The data will allow the characterization of the surface ground noise for frequencies in the band 3600 s to 100 Hz and will determine the signal-to-noise improvement over the 1–100-Hz band achieved through the use of 100-m-deep boreholes.

• ***Examination of the excitation of regional phases, including P_n, P_g, S_n, S_g, L_g, and R_g.*** The excitation efficiency and spectrum of these phases is important in the determination of source properties of events recorded at regional distances [*Evernden et al.*, 1986]. Numerous studies of these phases have been carried out for the region around the Nevada test site, but the Kazakh network will provide the first opportunity to study these phases in this region and thus reduce uncertainties due to propagation effects.

• ***Determination of the velocity and attenuation characteristics of regional phases and surface waves.*** Studies have been conducted in Nevada [e.g., *Chavez and Priestley*, 1986] and *Marshall et al.* [1979] have utilized measurements of the velocity of propagation of P_n in the Kazakh region to infer that the upper mantle attenuation is low compared to that in Nevada and is more typical of that in shield areas. It has been suggested by several authors that because of this low attenuation, the yield versus m_b relationship for nuclear explosions is considerably different for KTS than it is for NTS [*Marshall et al.*, 1979; *Sykes et al.*, 1983]. This has important bearing on current and future monitoring of the thresh-

Fig. 1. Members of the U.S.-Soviet seismological team at network headquarters, Karkaralinsk, in eastern Kazakhstan, U.S.S.R. (photograph by Ted Spiegel, Black Star).

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Cover. Locations of three Kazakh seismic stations in the Soviet Union that were established by teams of U.S. researchers from the University of California (San Diego), University of Nevada (Reno), and University of Colorado (Boulder). These stations, which will be operated cooperatively by U.S. and Soviet personnel, are part of a recent agreement between U.S. and Societ researchers. For more information, see the article "A New U.S.-U.S.S.R. Seismological Program" by J. Berger et al., page 105.

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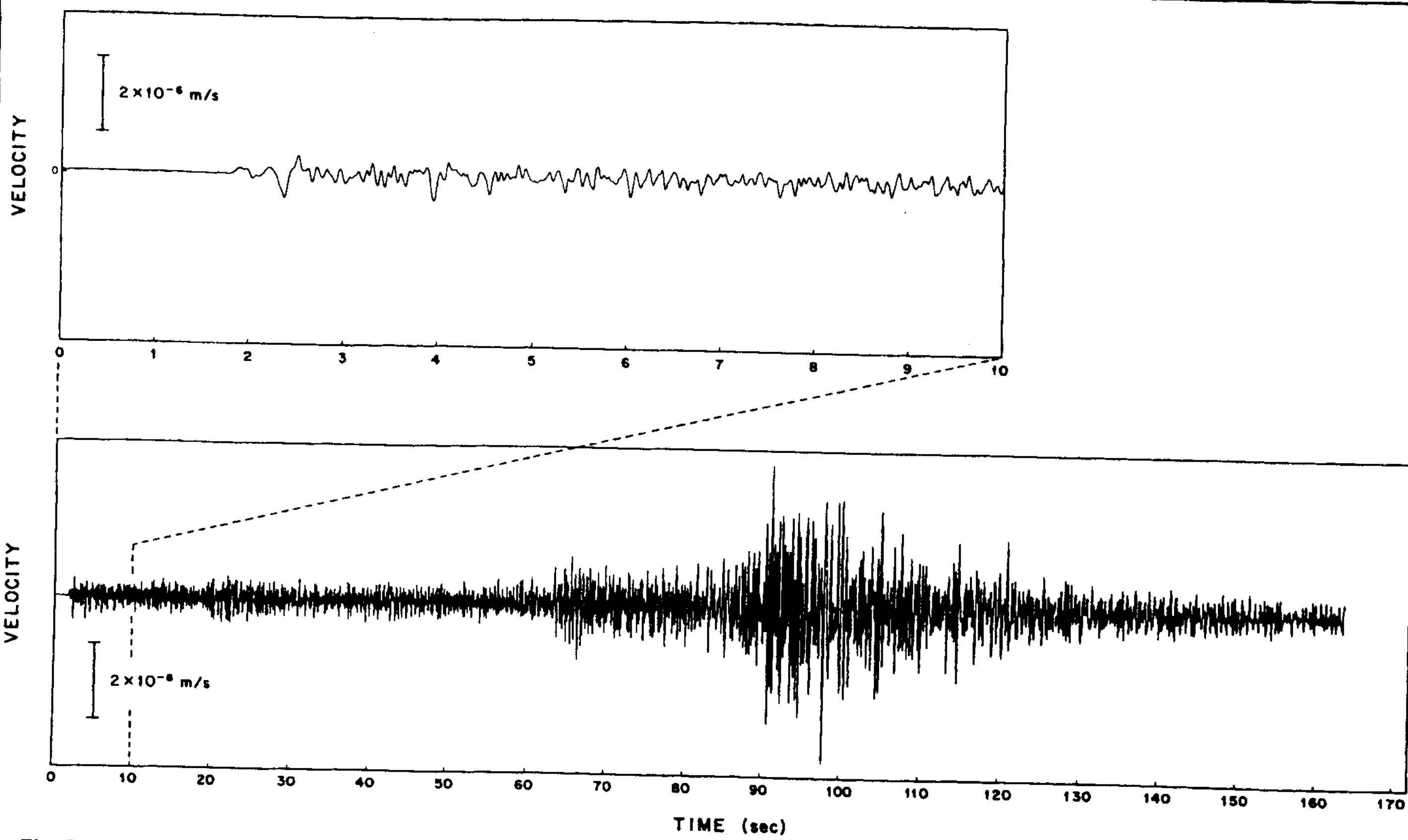

Fig. 2. Recording from Karkaralinsk station of a regional event in southeastern Kazakhstan, 44.5°N, 79.5°E, on July 21, 1986, at 22:41:56 local time. Source-receiver distance is 626 km, m_b = 4.6. The first 10 seconds of the event has been expanded to show the clear high frequencies in the P_n. Spectral analysis if the P wave train indicates energy with good signal-to-noise ratio at least up to the antialiasing filter corner at 30 Hz.

old test ban and has led to considerable controversy.

On the U.S. side, the overall science program is directed by a committee consisting of the following researchers:

- C. B. Archambeau, chairman (Cooperative Institute for Research in Environmental Science, University of Colorado, Boulder),
- S. S. Alexander (Pennsylvania State University, University Park),
- J. Berger (Institute of Geophysics and Planetary Physics (IGPP), Scripps Institution of Oceanography (SIO), University of California, San Diego, La Jolla),
- J. N. Brune (IGPP/SIO),
- D. G. Harkrider (Seismological Laboratory, California Institute of Technology, Pasadena, Calif.),
- D. V. Helmberger, alternate (Seismological Laboratory, California Institute of Technology, Pasadena, Calif.),
- E. T. Herrin (Southern Methodist University, Dallas, Tex.),
- T. H. Jordan (Massachusetts Institute of Technology, Cambridge, Mass.),
- J. B. Minster (Science Horizons, Encintas, Calif.),
- J. R. Murphy (S-Cubed, Reston, Va.),
- R. A. Phinney (Princeton University, Princeton, N.J.),
- P. G. Richards, alternate (Lamont-Doherty Geological Observatory, Palisades, N.Y.),
- S. W. Smith (University of Washington, Seattle),
- G. G. Sorrels (Teledyne/Geotech, Dallas, Tex.),
- L. R. Sykes (Lamont-Doherty Geological Observatory, Palisades, N.Y.).

Program Status

Soviet Stations

A two-phase deployment of seismographic equipment in Kazakhstan began in early July. Phase I equipment consisted of Teledyne Geotech S-13 short-period and Kinemetrics S-1 intermediate-period seismometers (Teledyne Geotech, Garland, Texas; Kinemetrics/Systems, Pasadena, Calif.) coupled to Terra Technology 302 event-triggered data loggers sampling at 100 Hz (Terra Technology, Redmond, Wash.). These were first employed in noise surveys as part of the site selection process. When the station locations had been decided, the Phase I equipment was installed nearby while site preparation was underway for the Phase II equipment. Figure 2 shows a recording obtained early in the project of a regional event to the south, clearly indicating rich high-frequency body wave signals.

Construction of the Phase II Kazakh stations, illustrated in Figure 3, was completed in early November 1986. The sites are all located in granite massifs that rise several hundred meters above the surrounding steppe. Boreholes with diameters of 20 cm were drilled to depths of 70–100 m, cased, and sealed. Wellhead vaults were set into the surface rocks to a depth of 1.5–2 m and then covered with soil that was sloped gently to the surrounding terrain to provide both thermal

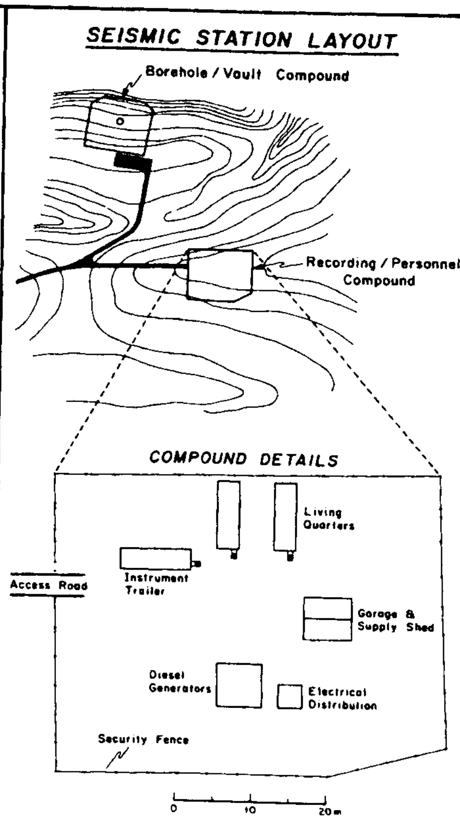

Fig. 3. Layout of the Kazakh station physical plant.

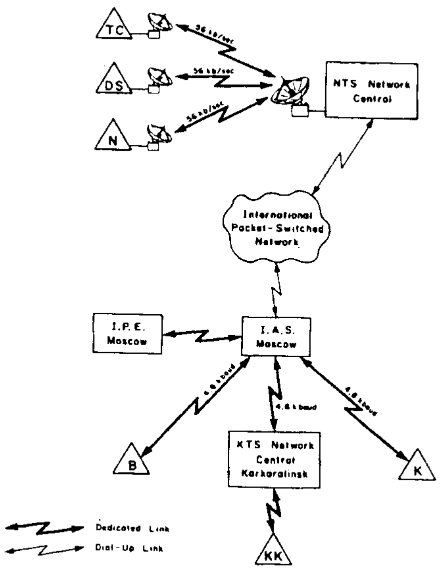

Fig. 4. Telemetry system and inter-network link for the Soviet and U.S. networks. IPE is the Institute of Physics of the Earth, and IAS is the Institute for Automated Systems.

insulation and to reduce wind resistance. The interiors of these vaults measure approximately 3 × 4 m, with a 1.2 × 2–m instrument pier situated next to the top of the borehole. Two trailers at each site provide accommodation for the Soviet personnel who will man the stations continuously and for occasionally visiting American personnel, who will be stationed at network headquarters at Karkaralinsk. A third trailer will house the recording and other instruments. High-voltage power lines have been led to each site, but because of the remoteness and climatic conditions, backup diesel generators have also been installed.

Table 1 lists the Phase II complement of equipment that is to be installed at the Kazakh sites. High-frequency accelerometers emplaced in the boreholes will be augmented by short-period and broadband seismometers installed in the wellhead vault. Digitization and data recording equipment will be similar to that currently operational in the Anza Network in southern California [*Berger et al.*, 1983]; data channels will be sampled at 250 Hz, with a 16-bit resolution. For both the short-period and broadband seismometers, high- and low-gain channels will be recorded to increase the dynamic range. Data will be telemetered from the wellhead vault to the recording trailer via a wireline. The equipment is designed to cover the seismic spectrum between 3600 s and 100 Hz, with resolution and system noise adequate to allow the measurement of ambient ground noise.

At each station, the MA-II data acquisition system (fabricated at IGPP by the U.S. team) will reduce the raw data rate of approximately 6 KB/s (kilobytes per second) to an average of about 75 B/s to 225 B/s by event detection and decimation to a 2-Hz sampling rate in the case of the continuously recorded broadband data streams. The data will be recorded locally on magnetic tape and forwarded to network central, which is located some 10 km from the Karkaralinsk station.

In a cooperative project with the Institute for Automated Systems (IAS) in Moscow, the three Kazakh stations will be linked together via 4.8-Kbaud dedicated land lines, as shown in Figure 4. Data from the Bayanaul and Karasu stations will be routed through the IAS facilities to network central in Karkaralinsk. A direct line will bring the data from the Karkaralinsk station to network central. The telemetry system, however, is designed to permit the collection of all data on computers at IAS and to provide access to them by scientists at the Institute of Physics of the Earth (IPE) in Moscow.

TABLE 1. Major Equipment Complement of Kazakh Stations

Item	Model	Quantity	Manufacturer
Borehole seismometer	54100	1	Teledyne Geotech, Garland, Tex.
Short-period seismometer	GS-13	3	Teledyne Geotech, Garland, Tex.
Intermediate-period seismometer	S-1	3	Kinemetrics/Systems, Pasadena, Calif.
Broadband seismometer	STS-VBB	3	Gunar Streckeisen, Pfungen, Switzerland
Remote digitizer	RT-24A	5	Refraction Technology, Inc., Dallas, Tex.
Remote interface unit	RT-44B	1	Refraction Technology, Inc., Dallas, Tex.
Data acquisition system	MA-II	1	University of California, San Diego

TABLE 2. Major Equipment Complement at the U.S. Stations

Item	Model	Quantity	Manufacturer
Borehole seismometer	54100	1	Teledyne Geotech, Garland, Tex.
Short-period seismometer	GS-13	3	Teledyne Geotech, Garland, Tex.
Intermediate-period seismometer	S-1	3	Kinemetrics/Systems, Pasadena, Calif.
Broadband seismometer	STS-VBB	3	Gunar Streckeisen, Pfungen, Switzerland
Remote digitizer	RT-97	1	Refraction Technology, Inc., Dallas, Tex.
Earth station	Gemini-56	1	M/A COM

U.S. Stations

Sites for the U.S. stations have been chosen at Deep Springs, Calif., and Nelson and Troy Canyon, Nev. Continuous data from this network will be telemetered via 56-Kb/s satellite circuits from the stations to network central, as illustrated in Figure 5. Major equipment items to be installed in the U.S. stations are listed in Table 2 and differ from those in the Soviet Union only in that the event detection function of the data acquisition system is performed at network central rather than at the individual stations. Operations of the U.S. stations are scheduled to begin in March or April 1987.

Internet connections between the U.S. and Soviet networks will be provided initially by one of the international packet-switched carriers, linking computers in La Jolla, Calif., with those at the IAS in Moscow. This internet service is designed primarily to provide limited data exchange between the two networks and to provide direct message communication between the network centers and remote stations. Experiments with more complete near–real-time data exchange are being planned.

Acknowledgments

A special acknowledgment is due to E. P. Velikhov, vice president of the Soviet Academy of Sciences, and M. A. Sadovsky, director of the Institute of Physics of the Earth, for their leadership in arranging this cooperative project. Implementation of this project has been greatly assisted by Adrian N. DeWind, chairman of the board, John A. Adams, executive director, S. Jacob Scherr, senior attorney, and the staff of the Natural Resources Defense Council.

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