CHAPTER II

Site Selection, Array Design, and Recording Instrumentation for the Dense Three-Dimensional Array near Garni, Armenia

R. D. Borcherdt, J. Filson, W. H. K. Lee, E. Cranswick,
C. Dietel, G. Glassmoyer, E. Sembera, and J. Mori
(U. S. Geological Survey)

L. Hakhverdian, R. Amirbekian, V. Aharonian, K. Safarian, H. Galagian, and G. Apoian
(Yerevan Seismic Station)

R. Banfill
(Small Systems Support, Big Water, Utah)

SUMMARY

Scientific objectives and logistic constraints were primary considerations in site selection and design of the dense three-dimensional array near Garni, Armenia. Principle scientific objectives concerned the need for high-frequency discrimination studies and the need to monitor seismicity for improved seismic hazard analyses for the capitol city of Yerevan with a population of 1.2 million. Principle logistic constraints concerned availability of supplies, fuel, transportation resources and site security. Instrumentation selection was based on availability of resources, familiarity, and reliability.

SITE SELECTION

The site selected for array installation was developed for geophysical monitoring purposes in the 1970s as a cooperative effort involving the USSR and Armenian Academies of Science. The facility is known as the Garni Observatory. Logistic difficulties concerned with availability of transportation vehicles and fuel were considered sufficient to preclude establishment of isolated multiple monitoring stations that might require regular visits for power maintenance.

Garni is located approximately 20 kilometers east of the capitol city of Yerevan in a moderately remote region. The location relative to other landmarks is shown at different map scales in Figures 2-1, 2-2, 2-3 and 2-4. The observatory site is located at the base of a large hill which in turn forms the boundary for a small valley used for minor agricultural farming. The area near the observatory is used primarily for the grazing of a small dairy herd.

The site consists of an elaborate two-dimensional horizontal tunnel complex (Figure 2-5) leading from the basement of the two-story observatory building (Figure 2-7), and about four hectares of property. The site is under the jurisdiction of local cooperating scientific officials and is relatively secure from vandalism. The extensive two-dimensional tunnel configuration at the observatory provided a unique opportunity to establish an array to serve as both a three-dimensional array for high-frequency discrimination studies and as an array to assist in monitoring seismicity for improved seismic hazard analyses for Yerevan.

Seismic studies conducted at this site as part of the joint U. S. - U. S. S. R. cooperative studies following the devastating earthquakes of December 7, 1988 (Borcherdt *et al.*, 1989), showed that the site is relatively well isolated from local cultural noise sources.

ARRAY DESIGN

The array design was developed to incorporate the two-dimensional configuration of the tunnel as shown in Figure 2-5. Using the length of the shortest arm of the tunnel as the minimum dimension of the array (~60 m), the array was designed within geometric constraints of the tunnel and available cable to resemble a nested tripartite configuration. The array is centered on a tetrahedron, consisting of sites G1A, G1B, G2B and G4A, with minimum distances between sensors being roughly 60 meters. Three-component sensors are located in a nested configuration with spacings of about 60, 120, 200, and 480 meters. The final vertical and horizontal apertures of the array are 87 and 823 meters, respectively. The final configuration of the array as defined by the locations of the three-component sensors is shown in Figure 2-6.

To increase the aperture of the array the initial design included an additional three sites located at distances of about 1.5 km from the center of the array. The lack of appropriate housing in the area and scarcity of available resources led to the establishment of sites G6A and G7A. The first subsequent revisit of the site a few months later showed that continued maintenance of sites G6A and G7A was also an extreme imposition on local resources. As a result these stations were withdrawn from the array.

INSTRUMENTATION

Sensors -- Three single-component velocity transducers (1 Hz, Mark Products L-4C) oriented vertical, north-south, and east-west (refer to Table 2-1 for actual sensor orientations and positions) were emplaced at each of the array nodes indicated in Figure 2-6. Each of the sensors was emplaced on a concrete pad (~ 0.5 x 0.8 x 0.1 m) prepared at each site with leveling platforms and housings (Figures 2-9 and 2-10) according to specifications used for emplacement of sensors in the Central California Network. Sensor signals were transmitted over cables to a central recording area located in a secure room (Figure 2-8) on the second floor of the observatory building (Figure 2-7). It was necessary to use locally available unshielded cable for location G4B, because one large reel of shielded U. S. supplied cable was lost in shipping.

Recording Instrumentation -- Array recording capabilities were designed to permit on-site data playback and analysis capability by local scientists and technicians. They were designed to provide redundancy in recording, playback, and event-timing capabilities. IBM compatible personal computers (PCs) were selected because of their wide availability and the local inaccessibility to other types of computer hardware. Subsequent array operation confirmed this conclusion and showed that even the replacement of common components such as hard disks was beyond the capacity of local resources.

The array was designed so that seismic-event signals are recorded simultaneously at 200 samples per second (sps) both in 16-bit digital format using GEOS and in 12-bit digital format using a PC. Two sets of three-component signals are recorded on each six-channel GEOS recorder. In addition, each set of six analog sensor signals upon being amplified and filtered for anti-aliasing by GEOS is multiplexed and recorded on the PC. Detailed performance specifications of the GEOS and the personal computer system are provided by Borcherdt *et al*. (1985), and Lee *et al*. (1988), respectively.

Timing -- Timing for the array was also designed to include redundancy. A master Omega receiver was used to establish absolute time for a master clock. In order to optimize relative timing each GEOS in the Garni Observatory was linked so as to synchronize and determine clock skew measurements with respect to the time pulse of the same master clock. The GEOS permits the clock skew measurements to be written to tape at operator selected time intervals. As an additional constraint to improve relative accuracy, the array was designed such that all signals for each event were digitized by a single analog-to-digital converter and recorded on the PC. In addition, special Omega receiver boards were designed that would have permited each GEOS to independently synchronize to Omega. Nominal GEOS clock drift rates are less than 80 milliseconds per day.

Power -- To accommodate frequent power outages and variations in voltage levels, power was supplied through an uninterrupted power supply to the PC and through batteries for the GEOS. Ungrounded power lines in the Observatory required that special provisions be implemented to minimize electronic noise pick-up on signal cables. Electronic noise was a special problem for location G4B connected via unshielded cable and was most apparent at night, when electrical lights were being used. Power outages proved to be sufficiently severe so as to eventually damage PC hard disks and reduce on-site playback capabilities.

Data Playback -- To facilitate on-site data playback, GEOS hardware and software capabilities were augmented to permit data playback via PC. Capabilities were developed for the simultaneous archival of both GEOS and PC data using two PCs networked via LANtastic. One PC is used as a data acquisition system and the other as a data playback, archival, and analysis system. Software was developed for automatic data archival using a simple multi-tasking environment. PC-compatible optical disks were selected as the medium for data archival.

Previously developed GEOS playback software (RDGEOS) used on Digital Electronic Corporation mini-computers was converted for operation on PCs (PCGEOS). GEOS software was developed to permit each GEOS unit to serve as a field playback unit via RS-232 into the portable field PCs.