United States Department of the Interior
Geological Survey

NATIONAL EARTHQUAKE INFORMATION CENTER
SEMI-ANNUAL TECHNICAL REPORT
VOLUME 2 NUMBER 1

Open-File Report 90-267
1990

National Earthquake Information Center
U.S. Geological Survey
Denver, Colorado

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RESEARCH AND DEVELOPMENT

Intensity of the Loma Prieta, California, Earthquake of October 1989

The Santa Cruz (Loma Prieta) earthquake occurred on October 18, 1989 UTC (October 17, 1989 PST). This major earthquake was felt over a contiguous land area of approximately 170,000 km^2; this includes most of central California and a portion of western Nevada. The University of California at Berkeley assigned the earthquake a local magnitude of $7.0M_L$.

USGS Hypocentral Parameters

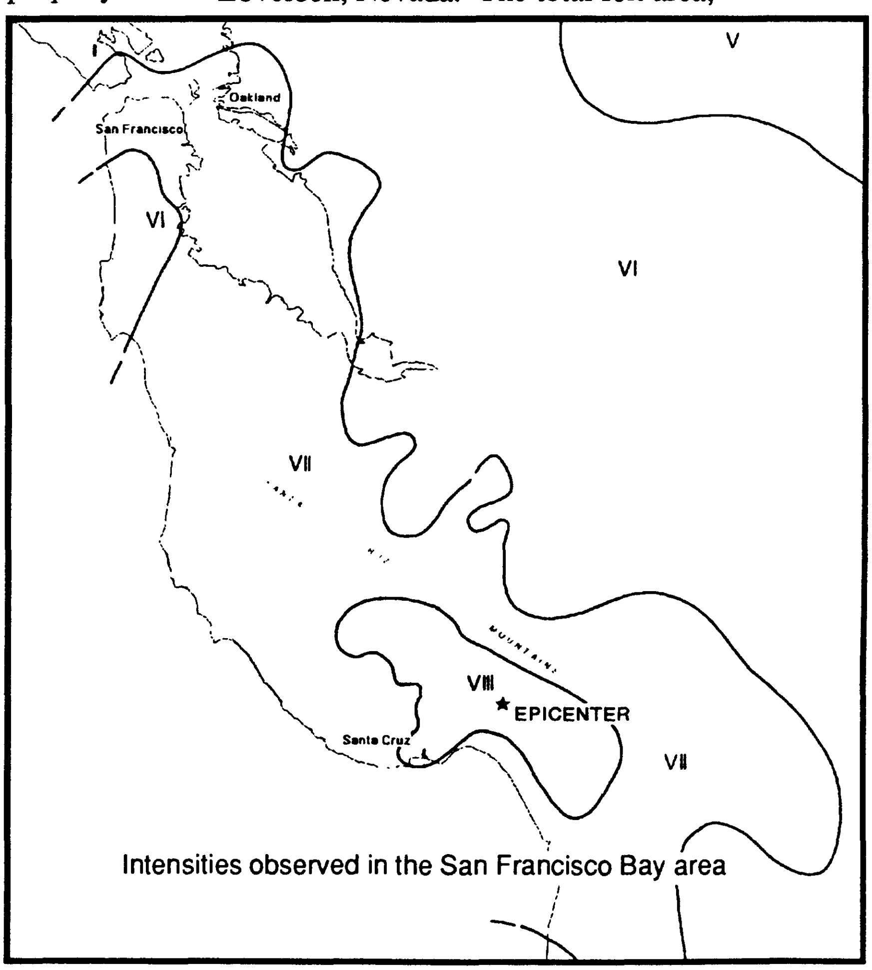
Origin Time	00:04:15.2 UTC
Location	37.0N, 121.9W
Depth	19 km
Magnitude	$6.6m_b$;$7.1M_S$

The earthquake caused at least 62 deaths, 3,757 injuries, and over $6 billion in property damage (Plafker and Galloway, 1989). The earthquake was the most damaging in the San Francisco Bay area since April 18, 1906. A major arterial traffic link, the double-decked San Francisco-Oakland Bay Bridge, was closed because a single fifty-foot span of the upper deck collapsed onto the lower deck . In addition, the approaches to the bridge were damaged in Oakland and in San Francisco. Other severe earthquake damage was mapped at San Francisco, Oakland, Los Gatos, Santa Cruz, Hollister, Watsonville, Moss Landing, and in the smaller communities in the Santa Cruz Mountains.

The earthquake has been assigned a Modified Mercalli Intensity (MMI, Wood and Neumann, 1931) of VIII in the epicentral area; an MMI of IX was assigned to San Francisco's Marina District and to four areas that experienced damage to reinforced-concrete viaducts. These areas are the Nimitz Freeway (Interstate 880, Cypress Section) in Oakland, and the Embarcadero, Highway 101, and Interstate 280 in San Francisco.

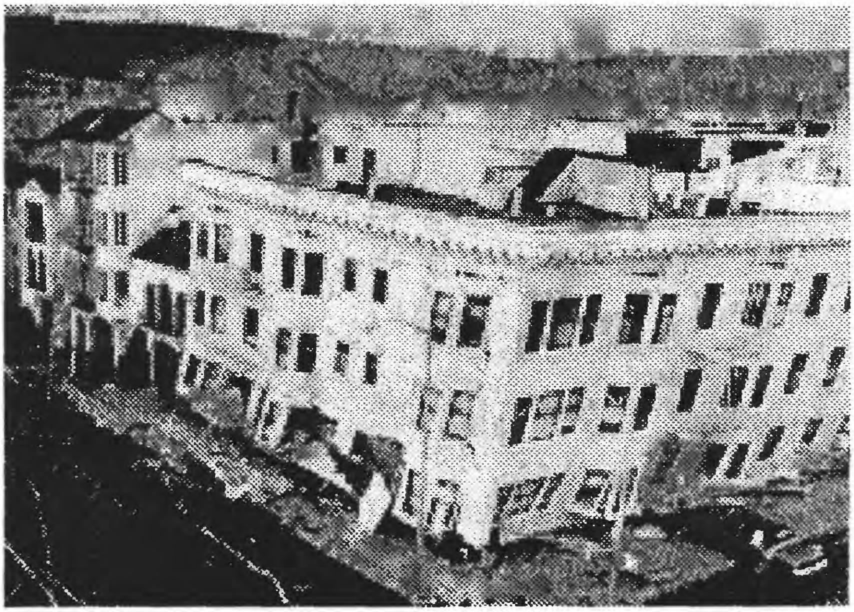
The intensities are based on data from field notes; mail questionnaires from postmasters, fire and police departments; newspaper accounts; and a damage report provided by the Scotts Valley, California fire district. These data were used by Stover et al. (1990) to prepare the isoseismal map shown below. A final version of the isoseismal map that includes the data used here will be published in the USGS Bulletin "United States Earthquakes, 1989".

The limit of perceptibility extends northward from Santa Barbara along the California coast to Fort Bragg and eastward to Lovelock, Nevada. The total felt area,



Intensities observed in the San Francisco Bay area approximately 170,000 km^2 on land, is less than one third the size of the land felt area of the 1906 earthquake, which was about 550,000 km^2.

Although the maximum intensity observed during the earthquake is MMI IX in parts of San Francisco and in Oakland, the MMI IX and MMI VIII values observed in the vicinity of San Francisco are anomalous, representing small areas of damage. Thus, no MMI VIII or MMI IX isoseismals were drawn in the northern portion of the Bay Area.

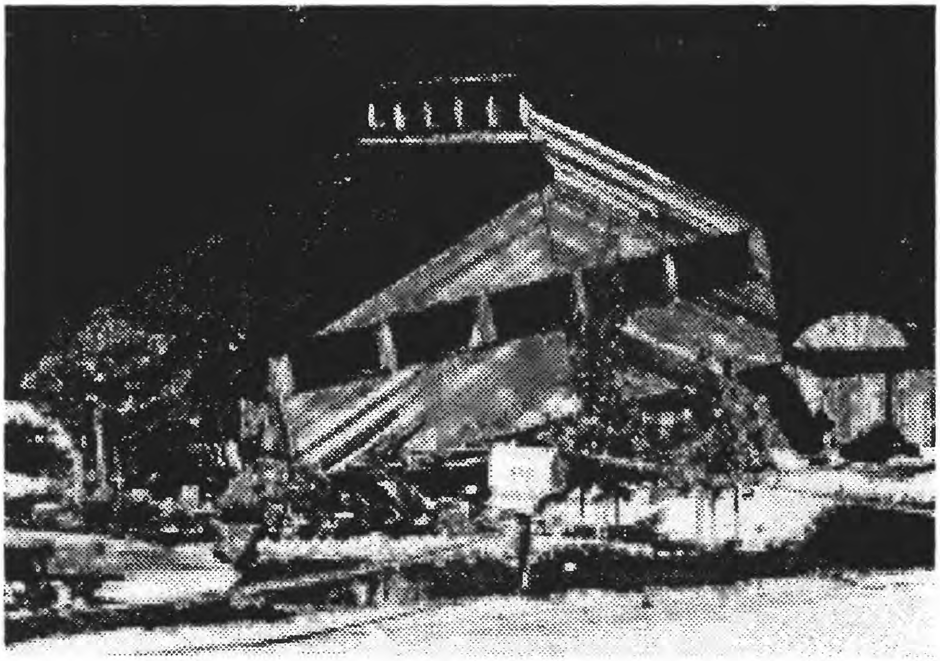


Collapsed apartment building in the San Francisco Marina District [F. Larson/S.F. Chronicle]

The maximum intensity in the epicentral area is MMI VIII. The area enclosed by the MMI VIII isoseismal is in close alignment with the fault-plane orientation of N50±8°W. The NW-SE elongation of the MMI VIII isoseismal includes the length of the inferred fault rupture that extends from State Highway 17 southeastward to the vicinity of Watsonville (Plafker and Galloway, 1989).

The general configuration of the MMI VII isoseismal encompasses most of the region west and south of San Francisco Bay southward to Monterey Bay. The southwestern part of San Francisco County and the northern area of San Mateo County that lies west of the San Francisco International Airport are outlined by the MMI VI isoseismal.

Lindie Brewer
Carl Stover
Glen Reagor
Frank Baldwin



Collapsed home near the epicenter [G. Reagor/USGS]

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Plafker and Galloway, USGS Circular 1045 (1989).

Stover, Reagor, Baldwin, and Brewer, USGS Open-File Report 90-18 (1990).

Wood and Neumann, BSSA v. 21, 277-283 (1931).

Accelerating Energy Release preceding the 1989 Loma Prieta Earthquake

Varnes (1989) has shown that a number of foreshock sequences follow a relation of the form

$$d\Sigma E^{0.5}/dt = k/(t_f-t)^n,$$

or, as integrated,

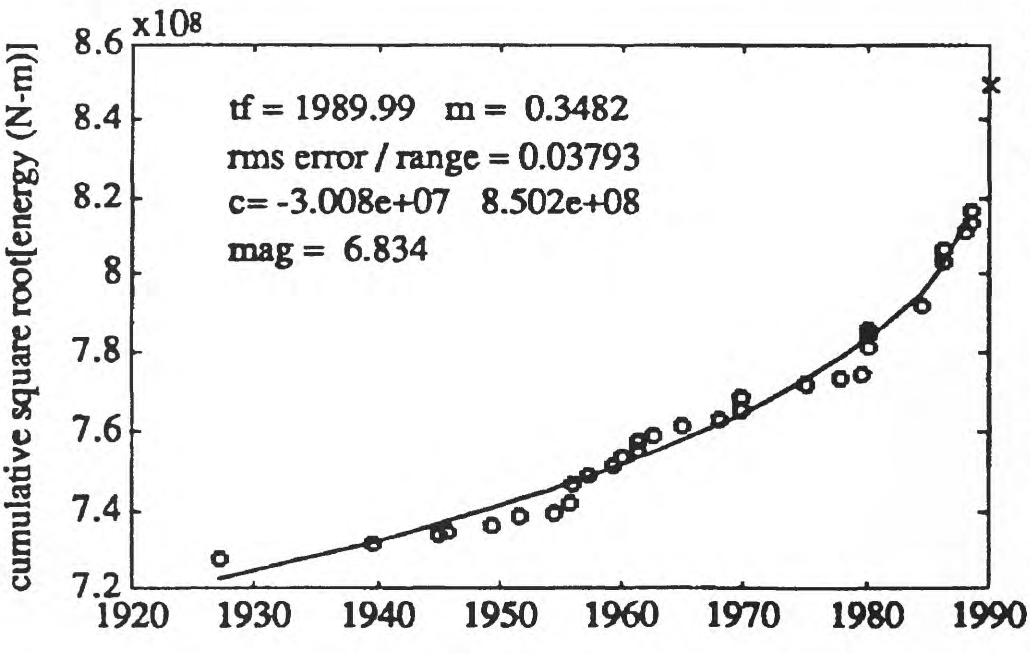
$$\Sigma E^{0.5} = \Delta + [k/(n-1)](t_f-t)^m,$$

where E is strain energy calculated from magnitude; Δ, k, and n are constants; m=1-n (n not equal to 1); and t_f is time of failure (main shock). This technique, which has application to both short-term and intermediate-term earthquake forecasting, was applied to seismicity in a large region in northern California in August, 1988, more than one year prior to the occurrence of the October 18, 1989 Loma Prieta earthquake. A best fit regression analysis, using all events of magnitude 5 and larger from 1927 through 1988, indicated that the failure curve would go "critical" by 1996. Thus a large earthquake was to be expected in the greater San Francisco Bay area within a few years.

Further analysis of these same data in 1990 using a new nonlinear inversion program shows the best fit to all pre-event cumulative square-root-of-energy data occurs when m is 0.35 and t_f is 1990.0. This date is within three months of the time of the Loma Prieta earthquake. The technique may also provide an estimate of the magnitude of the expected event at t_f. For the Loma Prieta earthquake (M_S 7.1, M_w 6.9), this estimated magnitude is 6.83. Fixing m at 0.35, we applied the analysis procedure to magnitude 5.5 and larger earthquakes in the same region from 1855 to 1903, preceding the 1906.3 earthquake (M_S 8.25, M_w 7.7). The date of projected failure was 1906.2 and the estimated magnitude was 7.64.

The occurrence of the Loma Prieta earthquake appears to satisfy the current pattern of accelerating strain energy release calculated from seismicity. However, the long-term pattern of seismicity was observed for a larger region encompassing both the San Andreas and Calaveras fault systems, and it is not possible to rule out the occurrence of additional large earthquakes on these systems in the near future.

The "time to failure" technique is being evaluated as a possible tool to test and refine estimates of seismic potential such as those developed by Nishenko (1989) for the circum-Pacific region.



Chuck Bufe
David Varnes

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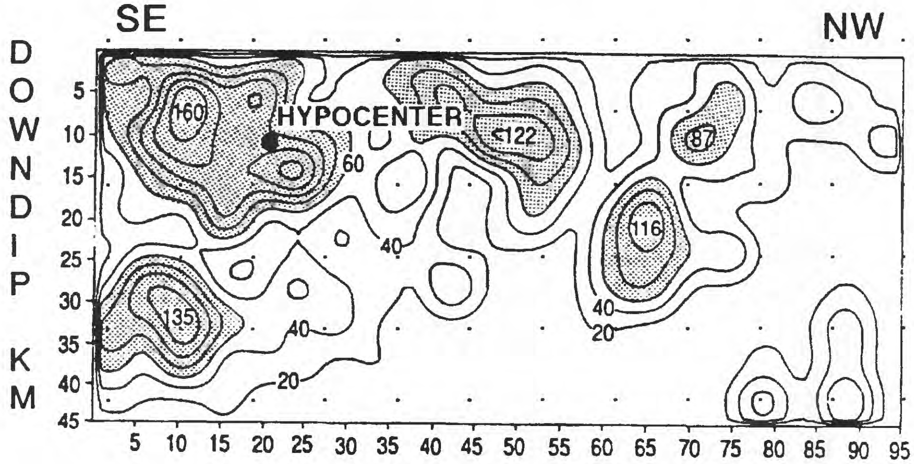
Nishenko, USGS Open-File Report 89-86 (1989).

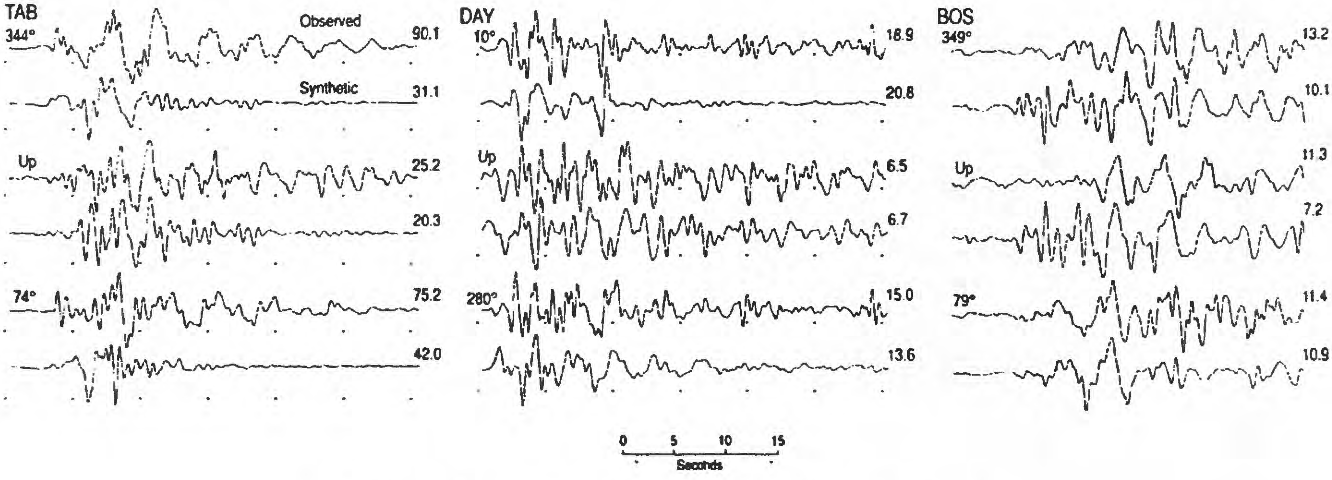
Varnes, PAGEOPH v. 130, 661-686 (1989).

Fault Slip during the September 1978 Tabas, Iran, Earthquake

The 16 September 1978 Tabas earthquake (15Hr 35Mn 56.7Sec UTC) with M_S 7.4 and m_b 6.5, is the largest event of the instrumental era to occur in Iran. Surface ruptures extended for about 85 km in a discontinuous pattern of NW-SE trending thrust segments suggesting imbricate, listric faulting (Berberian, 1982) Modified Mercalli intensites along the zone of surface rupture ranged from IX to X (Berberian, 1979). The Tabas earthquake produced one of the most complete sets of strong-motion records yet obtained for an intraplate, thrust earthquake with magnitude greater than 7. We inverted the three closest strong-motion records (TAB, DAY, and BOS) and ten teleseismic P-waveforms using a linearized, iterative, least-squares method to obtain the best-fitting slip and rupture-initiation times on a two-dimensional fault. The fault plane, which is held fixed at a strike of 330 degrees, dips at 25 degrees to the northeast from a depth of 1 km to 20 km. This geometry is consistent with the long-period teleseismic mechanism (e.g., Berberian et al., 1979; Niazi and Kanamori, 1981). The inversion method solves for the rake as a function of position on the fault. We have run successive models to determine the best-fitting hypocenter, source-time function on the fault, and initial rupture velocity. Our preferred slip model (above) has three to four distinct subevents or regions of major slip, with maximum displacements between one and two meters. These subevents are consistent with the discontinuous character of the surface ruptures and the complex teleseismic body waves. Most of the faulting occurs above a depth

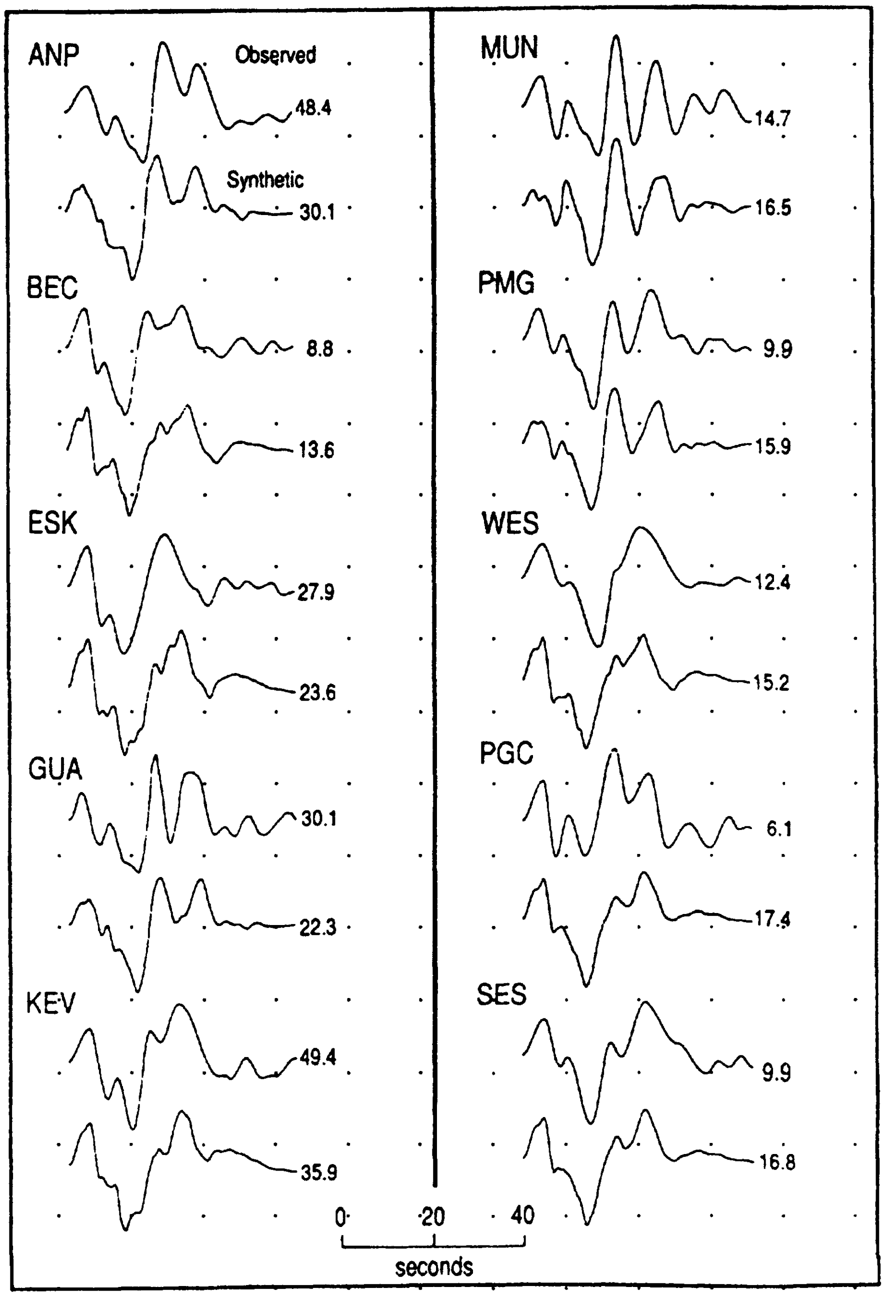


Total slip (in centimeters) along the Tabas earthquake fault



Observed strong-motion records and synthetic waveforms of 15 km. The model has a hypocenter between 5 and 10 km depth, a source risetime with a duration of 0.7 seconds, and an average rupture velocity of 2.5 km/sec. The calculated seismic moment is 5.5 X 10^{26} dyne-cm. This moment is consistent with the values obtained by other investigators using body waves but is a factor of two less than the long-period surface-wave moment. This result implies the occurrence of significant slip over a time interval greater than several tens of seconds. We stress the importance of teleseismic waveforms, used in conjunction with the strong-motion data, to add important constraints on the inversion. For the Tabas earthquake, the strong-motion data alone are not sufficent to obtain a well-constrained solution.

Carlos Mendoza
Stephen Hartzell



Observed teleseismic records and synthetic waveforms

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Berberian, BSSA v. 69, 1861-1887 (1979).

Berberian, GJRAS v. 68, 499-530 (1982).

Berberian, Asudeh, Bilham, Scholz, and Soufleris BSSA v. 69, 1851-1859. (1979).

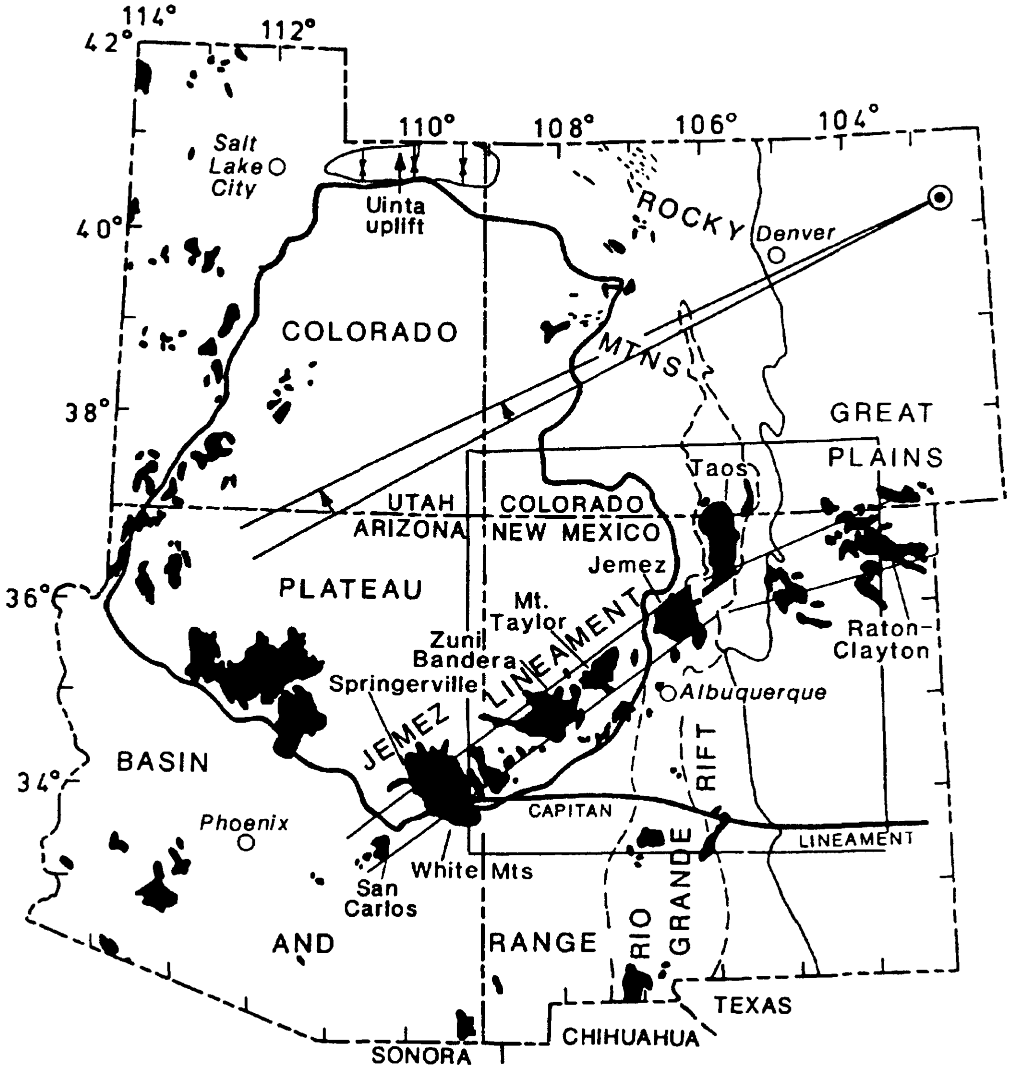
Niazi and Kanamori, BSSA v. 71, 1201-1213 (1981).

Upper Mantle Source of Magmas of the Jemez Lineament, New Mexico

The 800-km-long Jemez lineament is the most active volcanic feature in the southwestern United States. It is the southeastern tectonic boundary of the Colorado Plateau, and crosses the 950-km-long Rio Grande rift at the Jemez Mountains. The volcanism of the lineament primarily is basaltic, mostly has occurred in the last 4.5 m.y., and greatly exceeds the amount of volcanism associated with the Rio Grande rift.

To infer spatial distributions of partial melt in the upper mantle source zones for the Rio Grande rift and the Jemez lineament, we investigated the lateral variations of P-wave velocity in the upper mantle beneath these features. We used teleseismic P-wave delays recorded at a 22-station network to perform a damped least-squares, three-dimensional inversion for these lateral variations. Our technique employed velocity interpolation within a three-dimensional grid of points, rather than using blocks of constant P-wave velocity. This method allows highly realistic computation of the matrix elements in our systems of equations. Determinations of resolution of results were done in two independent ways, both of which gave consistent estimates of resolution.

In our best resolved volume (within the box shown in the accompanying map), the inversion results showed no significant concentration of relative low velocity for P-waves beneath the Rio Grande rift. However, directly beneath a 200-km long section of the Jemez lineament, there is a ~100-km-wide, 1-2% low-velocity feature in the depth range of 50-160 km. Because of the association of the low P-wave velocity with the Jemez volcanic lineament but not with the Rio Grande rift, because lowered P-wave velocity can be associated with increased partial melt, and because the volume of recent volcanism at the lineament greatly exceeds that at the



Regional map of the Rio Grande rift, the Jemez lineament, and the Colorado Plateau [adapted from Aldrich and Laughlin (1984)] rift, we infer that a large magmatic source zone exists beneath the Jemez lineament but not beneath the Rio Grande rift. This implies greater volcanic potential for the Jemez lineament than for the Rio Grande rift, in accord with the relative volcanism of these two features over the last 15 m.y. These results indicate that regional tectonics can be linked to processes in the corresponding upper mantle. Future work should include detailed mapping of the Jemez anomaly that possibly exists beneath the entire Jemez lineament, with a goal of improving estimates of the volcanic potential of this lineament.

The magmatic source zones of the Jemez lineament are best modeled by clockwise rotation of the Colorado Plateau about a pole located in northeastern Colorado. This recent rotation of the Colorado Plateau is inferred to have caused extension of the lithospere beneath the Jemez lineament, permitting concentration there of partially melted rock in the upper mantle. Consistent with this rotation, a contemporaneous compression of the northern margin of the Colorado Plateau (at the Uinta Mountains) has been demonstrated in studies by Wallace Hansen (USGS). Our interpretation supports a similar rotation of the Colorado Plateau inferred by Warren Hamilton (USGS) from largely independent data. A prior rotation of the Colorado Plateau is inferred by Hamilton to have caused much Laramide deformation in the central and southern Rocky Mountains.

In an interesting side-result, we found that the mantle source zones for the volcanics of the Jemez lineament are not overridden by, but rather move with, the North American plate. This implies that these sources are within the lithospheric plate, and that the lithosphere in this region is at least 200 km thick.

William Spence
Richard S. Gross

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Aldrich and Laughlin, JGR v. 89, 10207-10218 (1984).

This note is based on a paper submitted to the Journal of Geophysical Research.

OPERATIONS

Broadband Seismogram Analysis
The Ethiopia Double Earthquake of 20 August 1989

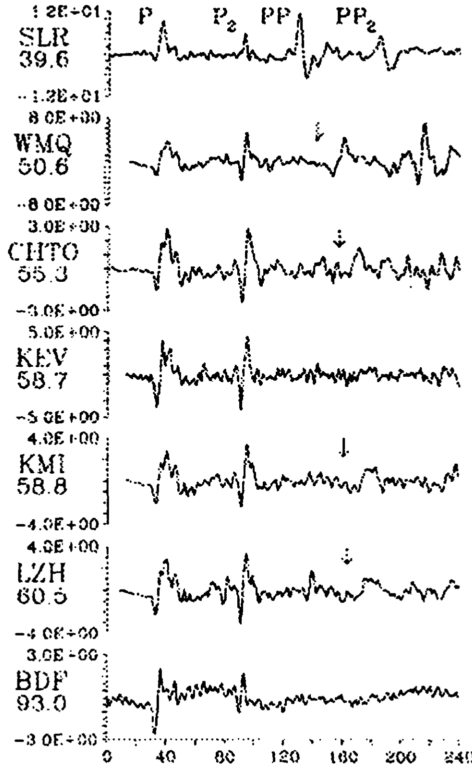
The NEIC routinely interprets broadband data from the GDSN, CDSN and other digitally recording networks that contribute to the Event Tape. Since the October 1985 Monthly Listing, the Preliminary Determination of Epicenters (PDE) has published estimates of depth from broadband seismograms. Starting with the September 1988 Monthly Listing, the PDE has incorporated polarities of pP and sP from broadband displacement and velocity seismograms in the determination of fault plane solution. Occasionally, the Comments in the Monthly Listings have also included remarks on the complexity of earthquake rupture. In each issue of the NEIC Semi-Annual Technical Report this section will be devoted to the discussion of selected earthquakes. It is the purpose of this section to describe in greater detail than is possible within the Monthly Listings the features on the broadband seismograms from which depth, fault plane solution and rupture complexity have been inferred.

In computing earthquake locations, the NEIC must routinely determine which of the thousands of arrival times it receives from seismograph stations around the world should be associated with an earthquake. One common problem is that of deciding whether a group of phases that arrive close together in time arises from the occurrence of a multiple earthquake or whether it arises from wave interactions with Earth structure. The advantage of using broadband data to distinguish between the two possibilities is demonstrated by our analysis of two earthquakes that occurred on 20 August 1989 in Ethiopia. As their origin times are separated by less than a minute, they are termed a "double earthquake".

The source parameters of the four largest earthquakes of an earthquake sequence that occurred in Ethiopia between 20 and 21 August 1989 are given in the table below. During the preliminary analysis of arrival time data, it was noticed that nearly one-third of the stations (about 25 out of 70) reporting a P wave for Earthquake 1 also reported an unidentified phase arriving about 1 minute later. The nature of this arrival was best determined from an examination of broadband data. Broadband displacement data (which have a flat response to displacement in the frequency range 0.01 to about 5.0 Hz) from some of the digitally recording stations used by the NEIC are shown at the top of the following page. The records are aligned by the P-wave arrival. The arrival of PP is indicated by arrows. A significant pulse arrives between P and PP that is not predicted by the travel-time curves for any of the major seismic phases. Possible interpretations of this pulse were that it was (1) an underside reflection (e.g., P_dP) from a major discontinuity at

Source Parameters of the 1989 Ethiopia Earthquakes

NO.	DATE	ORIGIN (h:m:s)	LAT (^{o}N)	LON (^{o}E)	m_b	M_S	DEPTH (km)
1	20 Aug	11:16:56.5	11.766	41.942	5.8	6.3	11.6
2	20 Aug	11:17:55.3	11.917	41.946	5.6		10.1
3	20 Aug	19:25:56.5	11.904	41.824	6.2	5.7	11.7
4	21 Aug	01:09:06.6	11.874	41.870	6.3	6.2	15.8

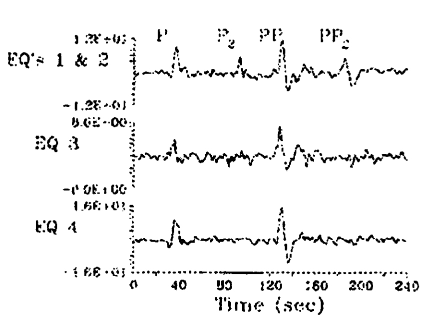


P Displacements for the Double Earthquake

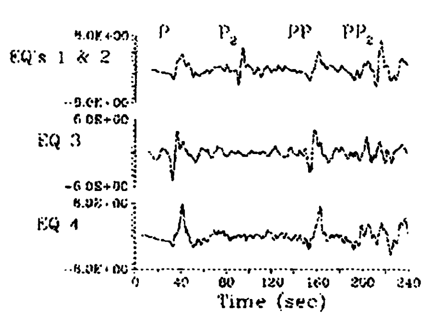
depth; (2) a phase generated by wave interaction with structure near source or near receiver; (3) a depth phase; or (4) an arrival from a second earthquake. The hypothesis of an underside reflection from a major discontinuity could be immediately discounted. The arrival did not move out with distance as, say, PP did. The hypothesis that structure near the source or receiver could generate this phase at all the stations could be easily tested by comparing seismograms at stations that recorded all four of the large earthquakes. The P-wave displacements at four such stations with very different azimuths about the epicentral region are shown below.

An unidentified strong arrival that follows the P wave of Earthquake 1, labeled P_2, is conspicuously absent in the records for Earthquakes 3 and 4. Because Earthquakes 3 and 4 occurred within kilometers of Earthquake 1, the ray paths of the P waves from all the earthquakes must have traversed nearly identical paths through the earth. Consequently, the differences between the waveforms had to arise from differences in the rupture processes of the earthquakes rather than differences along the ray paths.

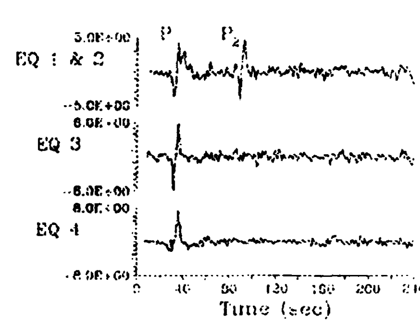
There were several strong arguments against the interpretation that the P_2 arrival was a depth phase. First, this interpretation would put the depth of the earthquake at about 130 km, a highly unlikely value for an event located in a rift zone. Moreover, an earthquake at such depth would have generated very large residuals in P arrival times at close-in stations; this was not seen in the data for Earthquake 1. Finally, the P waveform of Earthquake 1 at teleseismic distances generally consists of a distinct trough and peak. This is similar to the waveforms of the P waves generated by the Earthquakes 3 and 4, both of which were shallow earthquakes. Indeed, the signature of the P_2 arrival is also similar to those of the P waves from Earthquakes 1, 3, and 4. Our conclusion, therefore, was that the P_2 arrival was the P wave from a second earthquake. Using techniques for the analysis of broadband displacement and velocity data [as described, for instance, by Choy and Engdahl (1987), Choy and Dewey (1988), and previous issues of the Semi-Annual Technical Report] depths of 11.6 km and 10.1 km are obtained for Earthquakes 1 and 2, respectively.



P Displacements at SLR



P Displacements at WMQ



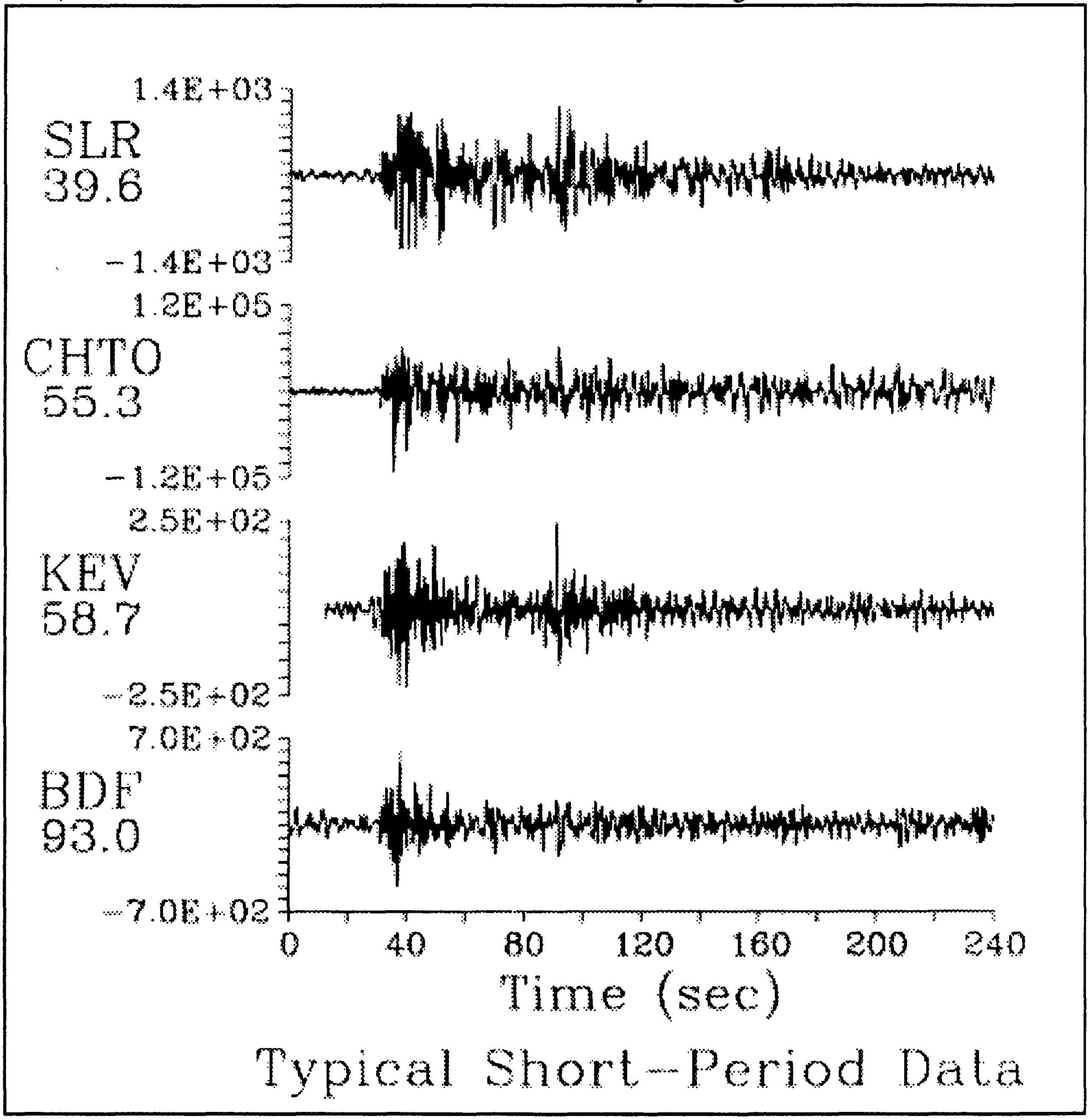
P Displacements at KEV

The use of broadband data is advantageous because broadband width provides sufficient resolution in the waveforms to distinguish source functions by direct inspection (e.g., Choy and Boatwright, 1981). The absence of this advantage limits the usefulness of conventional bandlimited data. Typical short-period records of the double earthquake are shown below. The short-period seismograms are dominated by 1.0 Hz ringing because they are recorded by instruments which have an instrument response peaked at about 1.0 Hz. At some stations (e.g., KEV) there is a distinct second arrival. At other stations (e.g., BDF) arrivals can be indentified with confidence only if the search window is known a priori. In none of the records would PP be easily indentifiable.

George L. Choy
Bruce W. Presgrave
Christina K. LaVonne

References

Choy and Boatwright, BSSA v. 71, 691-711 (1981).
Choy and Dewey, JGR v. 93, 1103-1111 (1988).
Choy and Engdahl, PEPI v. 47, 80-92 (1987).



NEIC Maps and Posters

The latest in the series of maps and posters produced by the National Earthquake Information Center (NEIC) is a unique display of world seismicity from 1979 to 1988. This large (36" x 64") poster shows three orthographic-projection "globes" on a star-covered black background. Each globe is patterned with 10 years of seismicity. Circles in three colors and sizes are used to depict earthquake hypocenters. The color of the circle varies according to the depth of the earthquake, and the size of the circle is scaled by earthquake magnitude. Over 97,000 earthquakes are represented on this poster.

In addition to this recent poster, the NEIC has produced several other maps in the Open-File Report series of the U.S. Geological Survey. These NEIC maps are listed below. Ordering information is available from the following address:

ATTN: Susan Goter
U.S. Geological Survey-NEIC
Box 25046, Federal Center, MS 967
Denver, CO 80225

Susan Goter

MAPS AND POSTERS AVAILABLE THROUGH NEIC

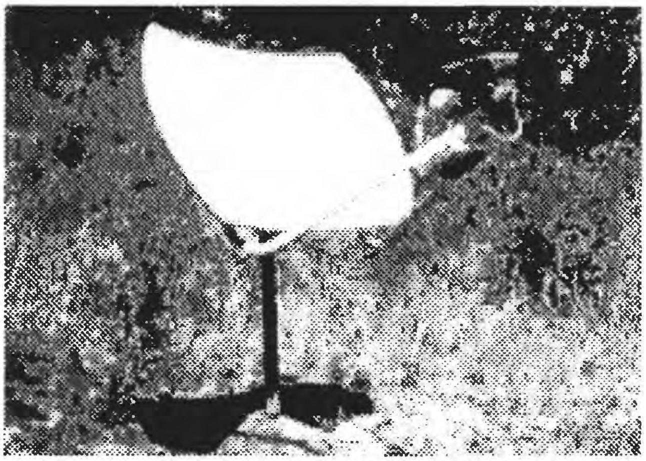
MAP	SERIES	SIZE
Seismicity of HAWAII	OFR 88-285	30" x 42"
Seismicity of CALIFORNIA	OFR 88-286	39" x 45"
Circum-Pacific Seismic Potential	OFR 89-85	25" x 35"
Seismicity of ALASKA	OFR 89-98	36" x 62"
World Seismicity	Poster-1	36" x 64"

National Seismograph Network

The U.S. National Seismograph Network (USNSN) is under development by the U.S. Geological Survey. Funding from the Nuclear Regulatory Commission supports the completion of the network east of the Rocky Mountains. Elsewhere, the Department of Defense and the Department of Energy provide funding for some additional stations. About 20 university stations, supported by state or National Science Foundation funds, consist of about 100 broadband digital seismograph stations in the conterminous states, Alaska, Hawaii, and Puerto Rico.

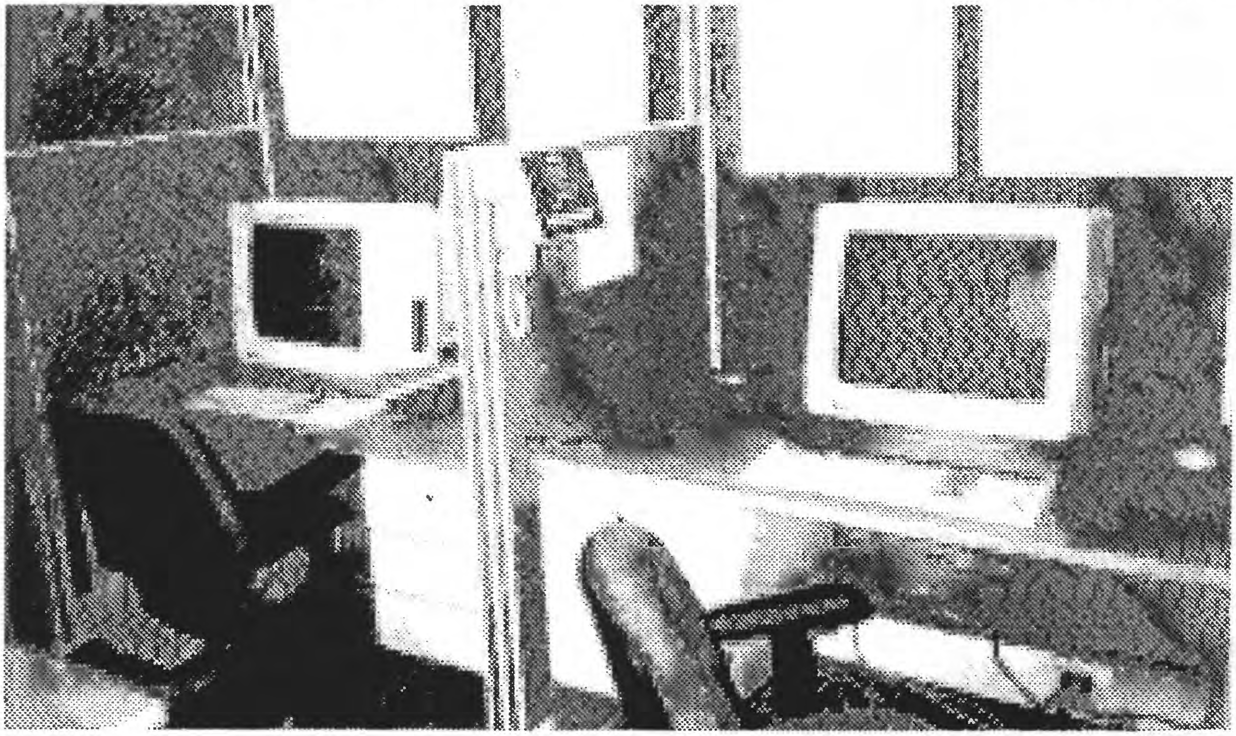
The operational goal of the USNSN is to provide the capability to locate and determine the energy release of earthquakes of magnitude 2.5 or larger in all states except for some parts of Alaska. The great dynamic range of the dual-level, 24-bit samples from the stations should provide waveform data of unprecedented quality for the investigation of earthquake source and path characteristics in the frequency range of 0.005 to 15 Hz.

Among the project accomplishments during 1989 are the following: (1) contracts for the purchase of hardware for the master station in Golden, Colorado, and for the network stations were signed; (2) software was written for handling data streams into and out of the satellite telemetry, and for processing and displaying the data at the National Earthquake Information Center (NEIC); (3) discussions and investigations of possible sites for the network stations were held in 21 states.



USNSN satellite antenna [J. McMillan/USGS]

Jim Taggart



Analyst workstations in the NEIC operations center [R. Needham/USGS]

Proposed MIDAS Network

For many Middle American earthquakes, accurate epicenter determination requires data from a network of stations that provide a greater range of distances and azimuths than that which is available from the spatially-limited national networks of individual countries. Also, in order to successfully complete earthquake hazard mitigation and disaster response programs, it is necessary to collect the seismic data quickly from stations located in the different countries and to calculate the epicenters rapidly and efficiently. With the installation of the U. S. National Seismograph Network (USNSN) by the National Earthquake Information Center (NEIC) of the U.S. Geological Survey, a system of rapid data collection from remote locations is now available. Middle American countries intend to take advantage of the USNSN program by installing digital stations that will transmit and receive seismic information to and from the NEIC and, thus, be able to monitor the earthquake activity of regional interest. For example, Mexico plans to transmit data from several independent sites to Golden, Colorado, via a U.S.-Mexico link using their Morelos satellite. This satellite link will enable Mexico to access data from any or all of the remote sites contributing to the NEIC, including U.S. stations. In this way, Mexico can monitor the seismicity of interest and acquire any of the digital data for additional or future study. Other countries have joined with Mexico and the U.S to form a Middle America Seismograph (MIDAS) consortium designed to promote the installation of a satellite-based network of high-quality digital stations in Central America and the Caribbean. This MIDAS network would allow participating countries to transmit and receive seismic data on a real-time basis.

A comprehensive Middle America program would include, but not be limited to, the following regional seismograph stations.

United States: Ten to fifteen digital, broadband, 3-component stations located along the southern boundary of the continental United States.

Mexico: At least three digital, broadband, 3-component stations; an additional long-period, 3-component station; and access to the national network of vertical, short-period stations.

Central America: Two to seven digital, broadband, 3-component stations and access to available short-period networks.

South America: The northernmost stations of the proposed South American Digital Seismic Network, consisting of broadband, 3-component systems. Also, a satellite antenna in Caracas that will collect data from the Venezuela national network of short-period stations.

Eastern Caribbean: One digital, broadband, 3-component station in Trinidad and three satellite antennas that will collect digital data from existing short-period networks in the West Indies.

Northern Caribbean: A digital, broadband, 3-component station in Puerto Rico that will collect additional data from a local network of stations distributed along the island and, possibly, from stations in the Dominican Republic.

Robert Masse
Carlos Mendoza

Global Digital Seismic Data

The Network Volumes produced by the Albuquerque Seismological Laboratory (ASL) contain data produced by the Global Digital Seismograph Network (GDSN), the China Digital Seismograph Network (CDSN), the stations of the Incorporated Research Institutions for Seismology (IRIS), and other contributing stations. These data are reformatted and written to the Network Volumes in SEED (Standard for the Exchange of Earthquake Data) format. The GDSN network includes Seismic Research Observatory (SRO), Abbreviated SRO (ASRO), and Digital Worldwide Standardized Seismograph Network (DWWSSN) stations.

Beginning with the volumes distributed in October 1989, both the amount of data and the number of stations will increase substantially. Data from four Russian stations (OBN, ARU, GAR, KIV) and from four IRIS/IDA stations (ESK, PFO, NNA, RPN) will be included on a regular basis, provided that the data arrive at the ASL in sufficient time. Network Volumes are normally produced 60 days after real time to allow for transportation from the station and processing time at the ASL. Transportation time from Russia has varied. Consequently. some of that data will be distributed as "late tapes" which are normally assembled 60 to 90 days after the Network Volumes. Initially there will be a large number of these late tapes. Delays in shipment plus converting this data to the new SEED format has resulted in a backlog of approximately 10 months of data from the Russian network. All of these data will be processed at the ASL and forwarded to the IRIS Data Management Center in Austin, Texas, where they will be available for distribution within the next 4 to 6 months.

Several new IRIS-1 stations have been added to the network. ANMO has been changed from an SRO to an IRIS-1 station effective August 29, 1989. CCM, located in Cathedral Cave, Missouri, and operated by St. Louis University, became operational on September 11, 1989. Also, an Iris-1 type seismograph station has been installed at COR effective October 29, 1989. This digital station replaces the WWSSN station at Corvallis, Oregon. In addition, the KIP station, which has experienced consistent hardware and software problems, has been fixed and has been in continuous operation since July 25, 1989.

STATIONS CURRENTLY INCLUDED IN NETWORK VOLUMES

CODE	SITE	TYPE	START
AFI	Afiamalu, W. Samoa	DWWSSN	15 May 1981
ANMO	Albuquerque, NM	IRIS-1	01 Sep 1974
ANTO	Ankara, Turkey	SRO	01 Aug 1978
ARU	Arti, Sverdlovskaya, USSR	IRIS/IDA	24 Feb 1989
BCAO	Bangui, Central Africa	SRO	12 Jun 1979
BDF	Brasilia, Brazil	DWWSSN	08 Jun 1982
BJ	Beijing, China	CDSN	Oct 1986
BGIO	Bar-Giyyora, Israel	SRO	15 Apr 1986
BOCO	Bogota, Colombia	SRO	13 Mar 1978
CCM	Cathedral Cave, MO	IRIS-1	11 Sep 1989
CHTO	Chiang Mai, Thailand	SRO	01 Jul 1977
CMB	Columbia College, CA	DWWSSN	11 Nov 1986
COL	College, AK	DWWSSN	06 Jan 1982
COR	Corvallis, OR	IRIS-1	29 Oct 1989
CTAO	Charters Towers, Australia	ASRO	09 Oct 1976

CODE	SITE	TYPE	START
ESK	Eskdalemuir, Scotland	IRIS/IDA	16 Nov 1987
GAR	Garm, Tajik, USSR	IRIS/IDA	10 Sep 1988
GDH	Godhavn, Greenland	DWWSSN	26 Aug 1982
GRFO	Graefenberg, Germany	SRO	01 Oct 1978
GUMO	Guam, Mariana Islands	SRO	01 Dec 1975
HIA	Hailar, China	CDSN	Mar 1987
HON	Honolulu, HI	DWWSSN	21 Mar 1983
HRV	Harvard, MA	IRIS-1	01 Jan 1988
KBS	Kingsbay, Norway	DWWSSN	02 Oct 1985
KEV	Kevo, Finland	DWWSSN	14 Oct 1981
KIP	Kipapa, HI	IRIS-1	16 Aug 1988
KIV	Kislovodsk, USSR	IRIS/IDA	09 Sep 1988
KMI	Kunming, China	CDSN	Oct 1986
KONO	Kongsberg, Norway	ASRO	01 Sep 1978
LZH	Lanzhou, China	CDSN	Oct 1986
LEM	Lembang, Indonesia	DWWSSN	02 Jun 1982
LON	Longmire, WA	DWWSSN	01 Oct 1980
MAJO	Matsushiro, Japan	ASRO	15 Jun 1977
MDJ	Mudanjiang, China	CDSN	Oct 1986
NNA	Nana, Peru	IRIS/IDA	27 Jun 1988
NWAO	Mundaring, Australia	SRO	01 Apr 1976
OBN	Obninsk, Kaluzchskaya, USSR	IRIS/IDA	21 Feb 1989
PAS	Pasadena, CA	IRIS-1	03 Apr 1988
PFO	Pinon Flats, CA	IRIS/IDA	22 Dec 1987
RPN	Easter Island, Chile	IRIS/IDA	03 Jul 1987
SCP	State College, PA	DWWSSN	29 Jan 1981
SLR	Silverton, South Africa	DWWSSN	24 Oct 1981
SNZO	Wellington, New Zealand	SRO	15 Mar 1976
TATO	Taipei, Taiwan	SRO	13 May 1976
TAU	Hobart, Tasmania	DWWSSN	10 Jun 1981
TOL	Toledo, Spain	DWWSSN	03 Nov 1981
WMQ	Urumqi, China	CDSN	Oct 1986
ZOBO	La Paz, Bolivia	ASRO	10 Sep 1976

The following modifications and/or problems have been identified since the last issue of the Semi-Annual Technical Report. These changes have also been included in Appendix A, a comprehensive list of modifications that have affected the digital stations that contribute to the Network Volumes.

ANMO: Station was converted from an SRO to IRIS-1 using a modified K-36000 borehole seismometer effective August 29, 1989.

GUMO: The short-period vertical transfer function was incorrect from November 22, 1988 until May 3, 1989. The standard SRO short-period transfer function was used instead of the lower gain mass position output which is used on island sites with high noise backgrounds.

PAS: The sensitivities for all three broadband components were incorrectly listed in the header records. They were low by a factor of 10. Sensitivities for all components should read 1.0400e+09, not 1.0400e+08. The headers were corrected effective July 12, 1989. Also, the station name on the Network Volumes was changed from IPAS to PAS on February 3, 1989. Unfortunately, the station name on the data records, which has to be changed at the station, was not changed for several more weeks. This has caused some confusion when working with the PAS data.

SCP: The short-period NS component had reverse polarity from March 15, 1989 through July 27, 1989. In the Network Volumes, the azimuth was adjusted by 180 degrees during this time period to correct the problem.

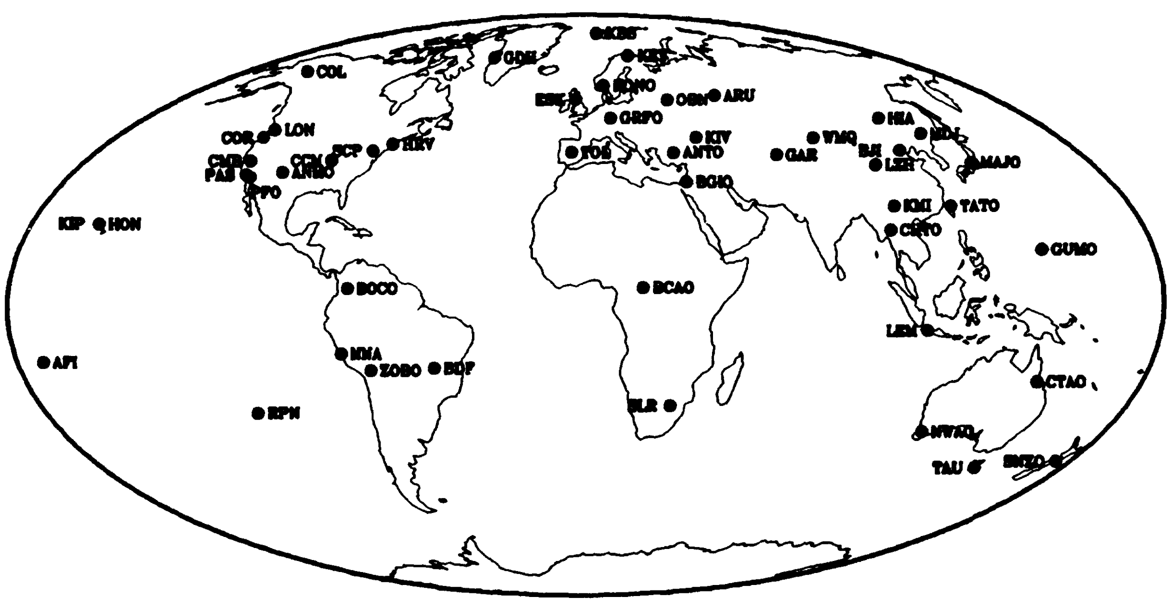
COR: The latitude for COR has been in error since installation on October 29, 1989. The correct latitude is 44.5857, not 34.5857. The correction to the Network Volumes was effective on January 1, 1990.

OBN: The latitude for OBN has been in error since installation on February 21, 1989. The correct latitude is 55.1 instead of 56.1. The correction to the Network Volumes was effective on October 19, 1989.

ARU, GAR, KIV, OBN, ESK, NNA, PFO, RPN: Several values used to calculate the sensitivities were incorrectly entered for these stations. This will be corrected shortly so that the procedure is consistent for all stations in SEED format. Until then, sensitivity values for the various components are obtained by multiplying the Normalizing Constant by the gain numbers listed in stages 1 and 2 in the station header. If there is any question regarding the calculation of these sensitivities please contact ASL.

ESK, NNA, PFO, RPN: The polarity of all components of these stations have been reversed since installation. Also, some of the poles and zeroes in the transfer functions for these stations may have an incorrect arithmetic sign. When working with data from these stations, make certain that all poles and zeroes have a negative sign.

John Hoffman



Worldwide Distribution of Digital Stations

APPENDIX A
DIGITAL STATION PROBLEMS AND MODIFICATIONS

Station	Date	Description
AFI	15 May 1981	Station installed.
	27 April 1987	Streckeisen seismometers installed.
	01 May 1987 thru 13 May 1987	Date was 24 hours ahead. To obtain the correct date, one day should be subtracted in the tape header.
	01 Jan 1988 thru 02 Jun 1988	Transfer functions were incorrect. The appropriate transfer functions can be obtained from the KEV or COL data.
	27 Apr 1987 thru 14 Feb 1989	One pole, -.838e+01, is missing from the SPZ transfer function.
ANMO	01 Sep 1974	Station installed.
	09 Dec 1975	4-pole Bessel filters replaced 4-pole Butterworth anti-aliasing filters (long-period signals).
	24 Jul 1978 thru 31 Jul 1978	Multiplexing errors occurred from 24 Jul 16:45:57.0 through 31 Jul 15:57:56.0. Channel sequence is N, E, Z.
	23 Oct 1978	Single-pole low-pass sections cornered at 16 Hz in short-period channels removed.
	30 Jul 1980	Long-period sensitivities changed: Z = 4500 counts, N-S = 5000 counts, and E-W = 5500 counts per micrometer of ground motion at a period of 25 seconds.
	13 May 1981	Clip detectors installed.
	05 Apr 1983	Horizontal short-period components installed.
	24 May 1983	The six second notch filter was removed, as were two single pole high-pass corners on the ANMO long-period filters. Pole 1 was moved from 250 seconds to 1200 seconds, and pole 2 was moved from 670 seconds to 1200 seconds.
	19 Mar 1984	22 Feb 1984 software installed. Calibration procedure revised.
	01 Oct 1984	During the first three weeks of October 1984, a new borehole was drilled close to the existing ANMO borehole. The long-period channels at ANMO became saturated during drilling operations. Drilling hours varied between 1500 and 2300 hours UTC.
	20 Feb 1985	Both short-period horizontal components were removed from the ANMO recording system to facilitate testing of a modified borehole seismometer. The SPZ component will be included with the ANMO data for the next few months.
	09 Dec 1985 thru 08 Jan 1986	Polarity reversed on the LPE channel.

	29 Aug 1989	Converted from SRO to IRIS-1 station using a modified K-36000 borehole seismometer.
ANTO	01 Aug 1978	Station installed.
	26 Feb 1979	The 4-pole Bessel anti-aliasing filter on the N-S component failed and was temporarily replaced with a 4-pole Butterworth filter on February 26, 1979. The Butterworth filter was replaced with a new Bessel filter on October 10, 1979. This was the N-S component only.
	03 Oct 1980	Long-period sensitivities changed: Z = 4500 counts, N-S = 5000 counts, and E-W = 5500 counts per micrometer of ground motion at a period of 25 seconds.
	27 Jul 1984 thru 07 Sep 1984	The time was exactly one hour fast. To obtain the correct time, one hour should be subtracted from the time listed in the tape header.
	19 Oct 1984 thru 16 Nov 1986	The time was exactly one hour fast from 16 Oct 07:40 through 19 Nov 1984 00:00 UTC. To obtain the correct time, one hour should be subtracted from the time listed in the record header.
BCAO	12 Jun 1979	Station installed.
	12 Jun 1979 thru 26 Apr 1980	Polarity reversals on both horizontal components.
	25 Sep 1980	Long-period sensitivities changed: Z = 4500 counts, N-S = 5000 counts, and E-W = 5500 counts per micrometer of ground motion at a period of 25 seconds.
	Nov 1981	The BCAO system was damaged by lightning during November 1981. When repairs to the system were completed, including a new borehole seismometer, it was found that the seismometer cable was damaged at the point where it connects to the seismometer. Only the long-period vertical component was affected, and the station has been in operation since 01 Mar 1982 without that component. On 07 Sep 1982 the cabling connections were replaced and all components are now recording data.
	29 Feb 1984	The 6 sec. notch was removed, and two single-pole high-pass corners were moved from 250 and 670 seconds to 1200 seconds.
	03 Mar 1984	Long-period transfer functions changed by removing the six second notch filters and by moving the two single-pole high-pass corners. Pole 1 was moved from 250 seconds to 1200 seconds, and pole 2 was moved from 670 seconds to 1200 seconds.
	14 Aug 1984	22 Feb 1984 software installed. Calibration procedure revised.
	14 Aug 1984	Horizontal short-period components installed.
	14 Aug 1984	Clip detectors installed.
BER	10 Aug 1981	Station installed.
	01 Sep 1984	Station closed. The digital recording system moved to Kingsbay, Svalbard (KBS).
BGIO	10 Jul 1986	Station installed.

	10 Jul 1986 thru 25 Jul 1986	Longitude incorrectly listed as 35.08 W (west) instead of E (east).
BJI	Oct 1986	Data included on Network-Day Tape.
	29 Apr 1987 thru 03 Aug 1987	Due to a problem with the Tape Copy System in Beijing, events triggered on the short-period and broadband records may start 2 minutes late.
BOCO	13 Mar 1978	Station installed.
	24 Oct 1978 thru 28 Oct 1978	Multiplexing errors occurred from 24 Oct 13:48:16.0 through 28 Oct 00:45:56.0. Channel sequence is N, E, Z.
	21 Nov 1978 thru 07 Dec 1978	Multiplexing errors occurred from 21 Nov 18:33:03.0 through 07 Dec 15:34:06.0. Channel sequence is E, Z, N.
	08 Mar 1979	Long-period sensitivities changed: Z = 4500 counts, N-S = 5000 counts, and E-W = 5500 counts per micrometer of ground motion at a period of 25 seconds.
CHTO	01 Jul 1977	Station installed.
	04 Feb 1979	Single-pole low-pass sections cornered at 16 Hz in short-period channels removed.
	06 Jul 1979	4-pole Bessel filters replaced 4-pole Butterworth anti-aliasing filters (long-period signals).
	10 Dec 1980	Long-period sensitivities changed: Z = 4500 counts, N-S = 5000 counts, and E-W = 5500 counts per micrometer of ground motion at a period of 25 seconds.
	May 1983	After being inoperative for more than 1 year, CHTO came on line in early May 1983 after the installation of a new power system.
	22 May 1983 thru 7 Jan 1984	Polarity reversed on all long- and short-period channels.
	21 May 1984	2-22-84 software installed. Calibration procedure revised.
	24 May 1984	Long-period transfer functions changed by removing the six second notch filters and by moving the two single-pole high-pass corners. Pole 1 was moved from 250 seconds to 1200 seconds, and pole 2 was moved from 670 seconds to 1200 seconds.
	24 May 1984	Horizontal short-period components installed.
	21 Sep 1984	Clip detectors installed.
COL	06 Jan 1982	Station installed.
	05 Feb 1987	Streckeisen seismometers installed.
	05 Feb 1987 thru 14 Feb 1989	One pole, -.838e+01, is missing from the SPZ transfer function.

COR	29 Oct 1989	Station installed.
	29 Oct 1989 thru 01 Jan 1990	The latitude given in the header is incorrect. The latitude should be 44.5837 instead of 34.5837.
CTAO	09 Oct 1976	Station installed.
	01 Jan 1980 thru 01 May 1981	A pole was not included in the original long-period transfer function listings on the network-day tapes. The pole which should be added is (-0.159E+00, -0.594E+00).
	29 Dec 1980	Long-period sensitivities changed: Z = 9000 counts, N-S = 10000 counts, and E-W = 11000 counts per micrometer of ground motion at a period of 25 seconds.
	03 Jun 1983	Short-period sensitivity was reduced from 10^5 to 10^6 counts per micrometer at one second.
	27 Sep 1987	Streckeisen seismometers installed.
	01 Jan 1988 thru 02 Jun 1988	Transfer functions were incorrect. CTAO short-period data use the intermediate-period transfer function from KEV or COL. The long-period data use the standard transfer function from KEV or COL.
GAC	26 Apr 1982	Station installed.
	30 Sep 1989	Station closed.
GRFO	01 Oct 1978	Station installed.
	03 Nov 1978 thru 11 Dec 1978	Vertical component recorded simultaneously on channels 1 and 2 from 3 Nov 1978 at 05:41 through 11 Dec 1978 at 14:53. Channel sequence is Z, Z, E.
	19 Jun 1979	Single-pole low-pass sections cornered at 16 Hz in short-period channels removed.
	08 Mar 1980 thru 03 Apr 1980	Long-period channels multiplexed incorrectly. Channel sequence is E, Z, N.
	18 Oct 1980	Long-period sensitivities changed: Z = 4500 counts, N-S = 5000 counts, and E-W = 5500 counts per micrometer of ground motion at a period of 25 seconds.
GUMO	01 Dec 1975	Station installed.
	27 Apr 1976	Short-period sensitivity reduced from 2000000 to 2000 digital counts per micrometer of ground motion at a period of 1 second. The *RESPONSE TO EARTH DISPLACEMENT* table located in the short-period data log was modified beginning on Day 326, 1981. Changes in the values for the relative amplitudes average 2%-3%. Changes in the phase angle values are more significant, averaging between 5%-10%.
	19 Dec 1979	4-pole Bessel filters replaced 4-pole Butterworth anti-aliasing filters (long-period signals).
	29 Jul 1980	Long-period sensitivities changed: Z = 4500 counts, N-S = 5000 counts, and E-W = 5500 counts per micrometer of ground motion at a period of 25 seconds.

	08 Jan 1985 thru 11 Apr 1985	Station closed on 8 Jan 1985 for replacement of the Model KS36000 borehole seismometer with the Streckeisen Model STS-I surface seismometer. New transfer functions and sensitivites are included in station and data logs. GUMO became fully operational on 11 Apr 1985.
	15 Jan 1985	22 Feb 1984 software installed. Calibration procedure revised.
	15 Jan 1985	Clip detectors installed.
	22 Nov 1988	KS36000 borehole seismometer installed.
	22 Nov 1988 thru 03 May 1989	The SPZ transfer function was incorrect. The standard SRO short-period transfer function was used instead of the lower gain mass position output that is used on island sites with high noise backgrounds.
HIA	Mar 1987	Data included on Network-Day Tape.
	27 Apr 1987 thru 20 Jul 1987	Due to a problem with the Tape Copy System in Beijing, events triggered on the short-period and broadband records may start 2 minutes late.
	Mar 1987 thru 19 Jun 1988	Polarity reversed on SPZ and SPE components
	19 Jun 1988 thru 04 Jan 1989	Polarity reversed on SPN component.
	10 Aug 1988 thru 04 Jan 1989	Polarity reversed on SPZ and SPE components
HRV	01 Jan 1988	Data included on Network-Day Tape.
	01 Jan 1988 thru 14 Feb 1989	Arithmetic sign of transfer functions was positive. This may result in reversed polarity during analysis.
	27 Oct 1988 thru 01 Jan 1989	Polarity reversed on vertical component, one zero missing from the vertical transfer function, and Cascade coefficients missing from all transfer functions.
	01 Jan 1988 thru 09 Feb 1989	Header records have incorrect azimuths for the horizontal components. The N-S azimuth should be 360°instead of 345°, and the E-W azimuth should be 90°rather than 75°.
JAS	01 Oct 1980	Station installed.
	26 Jun 1984	Station closed. Seismograph system moved to a new location. The new station code is JAS1.
JAS1	03 Jul 1984	Station installed.
	27 Jul 1984	Digital data included on network-day tapes.
	06 Nov 1986	Station closed. Seismograph system was moved to a new location. The new station code is CMB.
KAAO	10 May 1977	Station installed.

	12 Sep 1978 thru 13 Sep 1978	Multiplexing errors occurred from 12 Sep 18:32:15.0 through 13 Sep 07:33:28.0. Channel sequence is N, E, Z.
	08 Dec 1978 thru 10 Dec 1978	Multiplexing errors occurred from 08 Dec 06:02:59.0 through 10 Dec 06:10:28.0. Channel sequence is N, E, Z.
	11 Dec 1978 thru 24 Dec 1978	Time is 330 seconds fast from 11 Dec 1978 through 24 Dec 1978 at 0:700.
	01 Jan 1980 thru 01 May 1981	A pole was not included in the original long-period transfer function listings on the network-day tapes. The pole which should be added is (-0.159E+00, -0.594E+00).
	20 Jan 1981 thru 17 Feb 1982	The EW and Z components were switched.
	30 Jul 1982	Last data received. Station closed.
KEV	14 Oct 1981	Station installed.
	15 Mar 1982 thru 26 Mar 1982	The network-day tape data starting 15 Mar 1982 through 26 Mar 1982 at 06:00 UTC is approximately 15 to 20 minutes fast.
	12 Mar 1987	Streckeisen seismometers installed.
	12 Mar 1987 thru 14 Feb 1989	One pole, -.838e+01, is missing from the SPZ transfer function.
KIP	16 Aug 1988	Data included on Network-Day Tape.
	16 Aug 1988 thru 14 Feb 1989	Arithmetic sign of transfer functions was positive. This may result in reversed polarity during analysis.
KMI	Oct 1986	Data included on Network-Day Tape.
	27 Apr 1987 thru 20 Jul 1987	Due to a problem with the Tape Copy System in Beijing, events triggered on the short-period and broadband records may start 2 minutes late.
KONO	01 Sep 1978	Station installed.
	01 Jan 1980 thru 01 May 1981	A pole was not included in the original long-period transfer function listings on the network-day tapes. The pole which should be added is (-0.159E+00, -0.594E+00).
	12 Oct 1980	Long-period sensitivities changed: Z = 9000 counts, N-S = 10000 counts, and E-W = 11000 counts per micrometer of ground motion at a period of 25 seconds.
	30 May 1983	Short-period sensitivity was reduced from 10^5 to 10^6 counts per micrometer at one second. Calibration procedure for SRO/ASRO was revised.
LON	01 Oct 1980	Station installed.

	06 Apr 1981 thru 18 Jan 1982	All digital short-period vertical-component data during this time frame has reversed polarity.
LZH	Oct 1986	Data included on Network-Day Tape.
	Oct 1986 thru 24 Oct 1987	Polarity reversed on long- and short-period horizontal components.
	24 May 1987 thru 20 Jul 1987	Due to a problem with the Tape Copy System in Beijing, events triggered on the short-period and broadband records may start 2 minutes late.
MAIO	14 Oct 1975	First data distributed on Station Tape.
	24 Nov 1977 thru 27 Nov 1977	Multiplexing errors occurred from 24 Nov 7:35:30.0 through 27 Nov 5:20:59.0. Channel sequence is N, E, Z.
	11 Oct 1978	Last data received. Station closed.
MAJO	15 Jun 1977	Station installed.
	20 Nov 1977 thru 21 Nov 1977	Multiplexing errors occurred from 20 Nov 05:39:24.0 through 21 Nov 00:54:23.0. Channel sequence is N, E, Z.
	01 Jan 1980 thru 01 May 1981	A pole was not included in the original long-period transfer function listings on the network-day tapes. The pole which should be added is (-0.159E+00, -0.594E+00).
	03 Aug 1980	Long-period sensitivities changed: Z = 9000 counts, N-S = 10000 counts, and E-W = 11000 counts per micrometer of ground motion at a period of 25 seconds.
	03 Mar 1983	Short-period sensitivity was reduced from 10^5 to 10^6 counts per micrometer at one second.
	23 Aug 1988	Streckeisen seismometers installed.
MDJ	Oct 1986	Data included on Network-Day Tape.
	Oct 1986 thru 09 Aug 1988	Polarity reversed on all short-period components.
NWAO	01 Apr 1976	Station installed.
	20 Mar 1977 thru 21 Mar 1977	Multiplexing errors occurred from 20 Mar 17:25:27.0 through 21 Mar 03:00:57.0. Channel sequence is N, E, Z.
	01 Aug 1977 thru 3 Aug 1977	Multiplexing errors occurred from 1 Aug 03:23:46.0 through 3 Aug 23:49:31.0. Channel sequence is E, Z, N.
	01 Dec 1977	Single-pole low-pass sections cornered at 16 Hz in short-period channels were removed.

	05 May 1978 thru 6 May 1978	Multiplexing errors occurred from 5 May 06:30:00.0 through 6 May 07:38:59.0. Channel sequence is E, Z, N.
	13 Jun 1978 thru 14 Jun 1978	Multiplexing errors occurred from 13 Jun 07:04:14.0 through 14 Jun 04:29:30.0. Channel sequence is E, Z, N.
	30 Dec 1978	4-pole Bessel filters replaced 4-pole Butterworth anti-aliasing filters (long-period signals).
	01 Aug 1979 thru 21 Aug 1979	Long-period channels multiplexed incorrectly. Channel sequence is N, E, Z.
	24 Dec 1980	Long-period sensitivities changed: Z = 4500 counts, N-S = 5000 counts, and E-W = 5500 counts per micrometer of ground motion at a period of 25 seconds.
	21 Jan 1982 thru 01 Feb 1982	The network-day tape data starting 21 Jan 16:23 UTC through 01 Feb 00:31 UTC is 7 hours 52 minutes slow.
OBN	21 Feb 1989	Station installed.
	21 Feb 1989 thru 19 Oct 1989	The latitude given in the header is incorrect. The latitude should be 55.1 instead of 56.1.
PAS	03 Apr 1988	Data included on Network-Day Tapes.
	03 Apr 1988 thru 14 Feb 1989	Arithmetic sign of transfer functions was positive. This may result in reversed polarity during analysis.
	03 Apr 1988 thru 12 Jul 1989	Sensitivities for all three broadband components were incorrectly listed in the header records as 1.0400e+08. These should read 1.0400e+09.
RPN	03 Jul 1987	Data included on Network-Day Tapes.
	10 Jul 1987 thru 29 Nov 1987	No data recorded during this time period.
RSCP	12 Dec 1982	Data included on Network-Day Tapes.
	13 May 1985	Station modified to make the transfer functions and sensitivities identical to other RSTN stations.
	01 Apr 1985	The short-period horizontal components have been switched from the KS36000 to the S-750 borehole seismometer.
	22 Oct 1986	RSTN network temporarily closed.
RSNT	12 Dec 1982	Data included on Network-Day Tapes.
	15 Feb 1983 thru 01 Mar 1984	The short-period vertical transfer function included four incorrect poles plus the wrong sign for A0. The incorrect poles were P03, P04, P05 and P06.
	01 Apr 1985	The short-period horizontal components were switched from the KS36000 to the S-750 borehole seismometer.

	22 Oct 1986	RSTN network temporarily closed.
RSSD	12 Dec 1982	Data included on Network-Day Tapes.
	15 Feb 1983 thru 08 Jul 1984	The short-period vertical transfer function included four incorrect poles plus the wrong sign for A0. The incorrect poles were P03, P04, P05 and P06.
	01 Apr 1985	The short-period horizontal components have been switched from the KS36000 to the S-750 borehole seismometer.
	22 Oct 1986	RSTN network temporarily closed.
RSNY	12 Dec 1982	Data included on Network-Day Tapes.
	12 Dec 1982 thru 02 Mar 1984	The short-period horizontal transfer functions have listed an incorrect A0 constant plus a missing zero (Z01).
	15 Feb 1983 thru 01 Mar 1984	The short-period vertical transfer function included four incorrect poles plus the wrong sign for A0. The incorrect poles were P03, P04, P05 and P06.
	01 Apr 1985	The short-period horizontal components have been switched from the KS36000 to the S-750 borehole seismometer.
	12 Dec 1982 thru 22 Oct 1986	Seismometer orientation was in error 17°clockwise.
	22 Oct 1986	RSTN network temporarily closed.
RSON	01 Jul 1978	Data included on Network-Day Tapes.
	12 Dec 1982 thru 02 Mar 1984	The short-period horizontal transfer functions have listed an incorrect A0 constant plus a missing zero (Z01).
	15 Feb 1983 thru 01 Mar 1984	The short-period vertical transfer function included four incorrect poles plus the wrong sign for A0. The incorrect poles were P03, P04, P05 and P06.
	01 Apr 1985	The short-period horizontal components have been switched from the KS36000 to the S-750 borehole seismometer.
	22 Oct 1986	RSTN network temporarily closed.
SCP	29 Jan 1981	Station installed.
	15 Mar 1989 thru 27 Jul 1989	Polarity reversed on SPN component. Azimuth was adjusted in the Network Volumes during this time period to correct the problem.
SHIO	01 Jul 1978	Station installed.
	01 Aug 1978 thru 26 Sep 1978	Polarity reversals on both horizontal components.

	14 Sep 1978 thru 21 Sep 1978	Multiplexing errors occurred from 14 Sep 06:31:06.0 through 21 Sep 09:39:35.0. Channel sequence is E, Z, N.
	14 Sep 1978 thru 21 Sep 1978	Long-period channels multiplexed incorrectly. Channel sequence is E, Z, N.
	25 Mar 1980 thru 28 Mar 1980	Long-period channels multiplexed incorrectly. Channel sequence is E, Z, N.
	30 Nov 1980	Long-period sensitivities changed: Z = 4500 counts, N-S = 5000 counts, and E-W = 5500 counts per micrometer of ground motion at a period of 25 seconds.
	19 Feb 1984	Long-period transfer functions changed by removing the six-second notch filters and by moving the two single-pole high-pass corners. Pole 1 was moved from 250 seconds to 1200 seconds, and pole 2 was moved from 670 seconds to 1200 seconds.
	31 Mar 1985	22 Feb 1984 software installed. Calibration procedure revised.
	31 Mar 1985	Horizontal short-period components installed.
	31 Mar 1985	Clip detectors installed.
	27 May 1985 thru 18 Aug 1985	Station tapes arrived at the Albuquerque Seismological Laboratory after the network-day tapes had been written. Station day tapes have been produced containing data from SHIO only in day tape format for this period.
	03 Mar 1986	Last data received. Station closed.
SLR	24 Oct 1981	Station installed.
	14 Feb 1986 thru 01 May 1986	All data is in error by exactly 24 hours starting at 14 Feb at 04:00 until 1 May at 00:00 UTC. The data is one day late. After a power outage on 14 Feb 1986 the clock was incorrectly reset to 15 Feb 1986.
SNZO	15 Mar 1976	Station installed.
	15 Mar 1976	Short-period sensitivity reduced from 2000000 to 2000 digital counts per micrometer of ground motion at a period of 1 second. The *RESPONSE TO EARTH DISPLACEMENT* table located in the short-period data log was modified beginning on Day 326, 1981. Changes in the values for the relative amplitudes average 2%-3%. Changes in the phase angle values are more significant, averaging between 5%-10%.
	10 Nov 1978	4-pole Bessel filters replaced 4-pole Butterworth anti-aliasing filters (long-period signals).
	10 Nov 1978	Single-pole low-pass sections cornered at 16 Hz in short-period channels removed.
	07 Jan 1981	Long-period sensitivities changed: Z = 4500 counts, N-S = 5000 counts, and E-W = 5500 counts per micrometer of ground motion at a period of 25 seconds.
TATO	13 May 1976	Station installed.

	13 May 1976	Short-period sensitivity reduced from 2000000 to 2000 digital counts per micrometer of ground motion at a period of 1 second. The *RESPONSE TO EARTH DISPLACEMENT* table located in the short-period data log was modified beginning on Day 326, 1981. Changes in the values for the relative amplitudes average 2%-3%. Changes in the phase angle values are more significant, averaging between 5%-10%.
	16 Sep 1977 thru 17 Sep 1977	Multiplexing errors occurred from 16 Sep 03:12:04.0 through 17 Sep 04:02:34.0. Channel sequence is N, E, Z.
	06 Sep 1978 thru 07 Sep 1978	Multiplexing errors occurred from 06 Sep 03:24:17.0 through 07 Sep 05:37:16.0. Channel sequence is N, E, Z.
	30 Nov 1978	Single-pole low-pass sections cornered at 16 Hz in short-period channels removed.
	25 Jan 1979	4-pole Bessel filters replaced 4-pole Butterworth anti-aliasing filters (long-period signals).
	14 Sep 1979 thru 26 Aug 1980	Polarity reversals on both horizontal components.
	22 Aug 1980	Long-period sensitivities changed: Z = 4500 counts, N-S = 5000 counts, and E-W = 5500 counts per micrometer of ground motion at a period of 25 seconds.
TOL	03 Nov 1981	Station installed.
	05 Oct 1987	Streckeisen seismometers installed.
	01 Jan 1988 thru 02 Jun 1988	Transfer functions were incorrect. The appropriate transfer functions can be obtained from the KEV or COL data.
	5 Oct 1987 thru 14 Feb 1989	One pole, -.838e+01, is missing from the SPZ transfer function.
WMQ	Oct 1986	Data included on Network-Day Tape.
	13 Apr 1987 thru 18 Jul 1987	Due to a problem with the Tape Copy System in Beijing, events triggered on the short-period and broadband records may start 2 minutes late.
ZOBO	10 Sep 1976	Station installed.
	27 Dec 1977 thru 28 Feb 1978	The E-W channel was down. The N-S and E-W channels were temporarily switched from 10 Feb 1978 through 14 Feb 1978.
	10 Feb 1978 thru 11 Feb 1978	Multiplexing errors occurred from 10 Feb 16:41:06.0 through 11 Feb 12:51:05.0. Channel sequence is N, E, Z.
	06 Jun 1978 thru 14 Jun 1978	Multiplexing errors occurred from 06 Jun 18:48:02.0 through 14 Jun 14:48:33.0. Channel sequence is N, E, Z.

18 Sep 1978	During recalibration of the LPN and LPE components, incorrect motor constants were used, resulting in a sensitivity setting of 10000 digital counts per 1.4 microns of ground motion at a period of 25 seconds. LPN and LPE calibrations since that date are for an equivalent ground motion of 1.4 microns. The actual calibration for 1 micron of ground motion is approximately 7150 digital counts. The station log in the network-day tapes contained the following statement in the comment section: 'Long-period horizontal calibration values should be increased by 27%'. This statement should read: 'Long-period horizontal calibration values should be divided by 1.4'. The log comments were corrected on 10 Jun 1981. The average calibration values on the network-day tapes for the long-period horizontal components were changed on 30 Jun 1981 to their correct values (approximately 7150 counts).
01 Jan 1980 thru 01 May 1981	A pole was not included in the original long-period transfer function listings on the network-day tapes. The pole which should be added is (-0.159E+00, -0.594E+00).
11 May 1982	The station was recalibrated, and motor constants corrected. Also, the sensitivities were adjusted to coincide with those at other ASRO stations, which are Z = 9000, N-S = 10000, and E-W = 11000 digital counts per micrometer of ground motion at a period of 25 seconds.
11 Aug 1983	During a maintenance visit, the long-period sensitivities for all channels were incorrectly adjusted. The long-period sensitivities are LPZ = 10900 LPN = 9900 LPE = 10100 digital counts per micron of ground motion at a period of 25 seconds.
11 May 1984	22 Feb 1984 Software installed. Calibration procedure revised.
20 Jan 1987 thru 20 Jun 1988	Polarity reversed on LPN and LPE components.

APPENDIX B
PUBLISHED REPORTS AND STUDIES IN PROGRESS

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