APPARENT Q FOR UPPER-CRUSTAL ROCKS IN THE RIO GRANDE RIFT OF CENTRAL NEW MEXICO FROM THE ANALYSIS OF MICROEARTHQUAKE SPECTRA

By

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ABSTRACT

Spectra from 140 digitally recorded microearthquakes in the magnitude range -0.9 to 1.0 were used to compute apparent seismic quality factors (Q) for upper crustal rocks (0-19 km) within 45 km of Socorro. In this study apparent Q is defined as a measure of seismic wave attenuation due to intrinsic absorption and scattering. It was found that apparent Q increases with event distance for all of the stations in the digital network. This increase was successfully modeled with a laterally varying low Q, low velocity layer over a relatively high Q, high velocity half-space. It was found that:

(1) Near-surface low Q regions lying directly beneath the recording sites vary from 0.3-2.0 km in thickness and exhibit Qp and Qs values less than 50.

(2) The average Qs for the upper crust in the central Rio Grande rift, excluding the near-surface low Q region, is 535 (2 s.d. range = 374-938).

(3) Qp/Qs for events recorded by the digital network varies from 0.34 to 1.39. For earthquakes recorded at stations CM, DM, and FM, the observed Qp/Qs ratio decreased with increasing event distance. For stations CC, IC, SC, SNM, and WT, no systematic increase or decrease in Qp/Qs with distance was evident. These changes in Qp/Qs with

increasing event distance may reflect varying degrees of fluid saturation in upper-crustal rocks.

(4) At least four anomalously low Qs regions exist within 20 km southwest of Socorro. These abnormally low Q regions may reflect small magmatic intrusions or high fracture densities at depth. Two anomalous regions may lie in close proximity to microearthquake swarms at depths of 7-10 km.

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TABLE OF ABBREVIATIONS

cm	centimeters
COCORP	Consortium for Continental Reflection Profiling
D	distance wave travels through LVL
f	frequency
FFT	Fast Fourier Transform
Hz	Hertz
kHz	kilohertz
km	kilometers
LTA	long-term average
LVL	low velocity layer
m	meters, slope
MHz	megahertz
m.y.	million years
$Q, \hat{Q}$	quality factor
r	hypocentral distance
s,sec	seconds
sps	samples per second
s.d., σ	standard deviation
STA	short-term average
TERA	Terminal Effects Research Analysis
Thk	thickness
ν	Poisson's ratio
$V, \hat{V}$	apparent velocity
Vp-p	peak-to-peak voltage
t_{sta}	station correction
Δt	sampling interval

Station Names

CC	Corkscrew Canyon
CM	Chupadera Mountains
DM	Duchess Mine
FM	Fluorite Mine
IC	Indian Cave
SC	South Canyon
SNM	Socorro, New Mexico
WT	Wood's Tunnel

INTRODUCTION

Objective and Scope

The seismic quality factor, Q, is a measure of the energy lost by a seismic wave as it passes through a volume of rock. This absorption, often referred to as dissipation or seismic attenuation, represents the conversion of seismic energy into heat through a variety of loss mechanisms such as friction along cracks, interstitial fluid flow and viscous dissipation, thermoelastic relaxation, and crystal lattice changes.

Since different geological materials absorb energy in different ways, Q can be a useful parameter in delineating the composition and physical state of rocks beneath the earth's surface. Also, the magnitude of Q largely determines how the earth will filter seismic waves emanating from a natural or artificial source; Q should be known prior to computing earthquake source parameters from the spectra of short-period seismic waves.

This study was undertaken to map the seismic quality factor for upper crustal rocks in the Rio Grande rift near Socorro, New Mexico. Three major objectives of this study were:

(1) To compare Q values inside the Rio Grande rift to those observed outside the rift.

(2) To map lateral and vertical Q variations inside the rift.

(3) To evaluate the importance of site attenuation by determining the quality factor for near-surface material directly beneath the seismic stations.

The observed Q will be related to the mapped surface and inferred subsurface geology in the discussion that follows. It is hoped that this will lead to a better understanding of the absorptive behavior of particular rock types and geological structures.

General Outline of Method

In this study, apparent Q was estimated from the spectra of local microearthquakes after source, instrument and path effects (other than absorption) were taken into account. The spectra were generated by taking Fourier transforms of selected time windows from digital seismograms recorded at eight stations of the Socorro array. A flat source spectrum was assumed over the frequency range of interest (0-50 Hz) and instrumental effects were deconvolved in the frequency-domain by dividing through by the instrument response. Once instrumental effects were removed, the spectral slope (dropoff in log amplitude with frequency) was fit with a straight line. Apparent Q is inversely proportional to the slope of this line and can be easily computed from this slope if the event distance and

the average velocity along the raypath are known.

The term "apparent Q" is used here to emphasize the fact that contributions from nonabsorpive processes such as scattering are also included in the Q estimates. In this study, apparent quality factors are assumed frequency independent and represent an average Q for the entire raypath.

The 140 events used in this study were selected from a data set comprised of over 400 digitally recorded microearthquakes. The selected events exhibited relatively small errors in apparent Q and hypocenter location. These selected events were then used to determine how apparent Q varies with hypocentral distance at each station and to map lateral Q variations in the central Rio Grande rift. Multivariate linear regression was used to formulate a one-dimensional Q versus depth model. Deviations in Q from the average model were mapped for events recorded at one station and anomalously low Q regions were identified. Finally, near-surface Q values were correlated with mapped geology and rift Q values were compared with non-rift Q values.

GEOLOGICAL AND GEOPHYSICAL SETTING

The study area is located in the central Rio Grande rift near Socorro, New Mexico. The Rio Grande rift is an en-echelon series of north-trending basins and grabens extending from near Leadville, Colorado, to northern Chihuahua (Figure 1). The central part of the rift is bounded on the north by the southern Rocky Mountains, on the east by the High Plains, on the west by the Colorado Plateau and Datil-Mogollon volcanic field and on the south by the Basin and Range province.

Figure 2 shows the major physiographic/geologic features of the study area as well as the locations of seismic stations. Figure 3 comprises a general geological map of the same region also showing station locations.

The oldest rocks in the Socorro area are Middle Precambrian ($\sim$1.7 billion year old) granites, metagabbros, argillites, quartzites, and ash-flow tuffs (Condie and Budding, 1979). The Precambrian structural grain trends north-northwest and has probably influenced later faulting (Chapin et al., 1978).

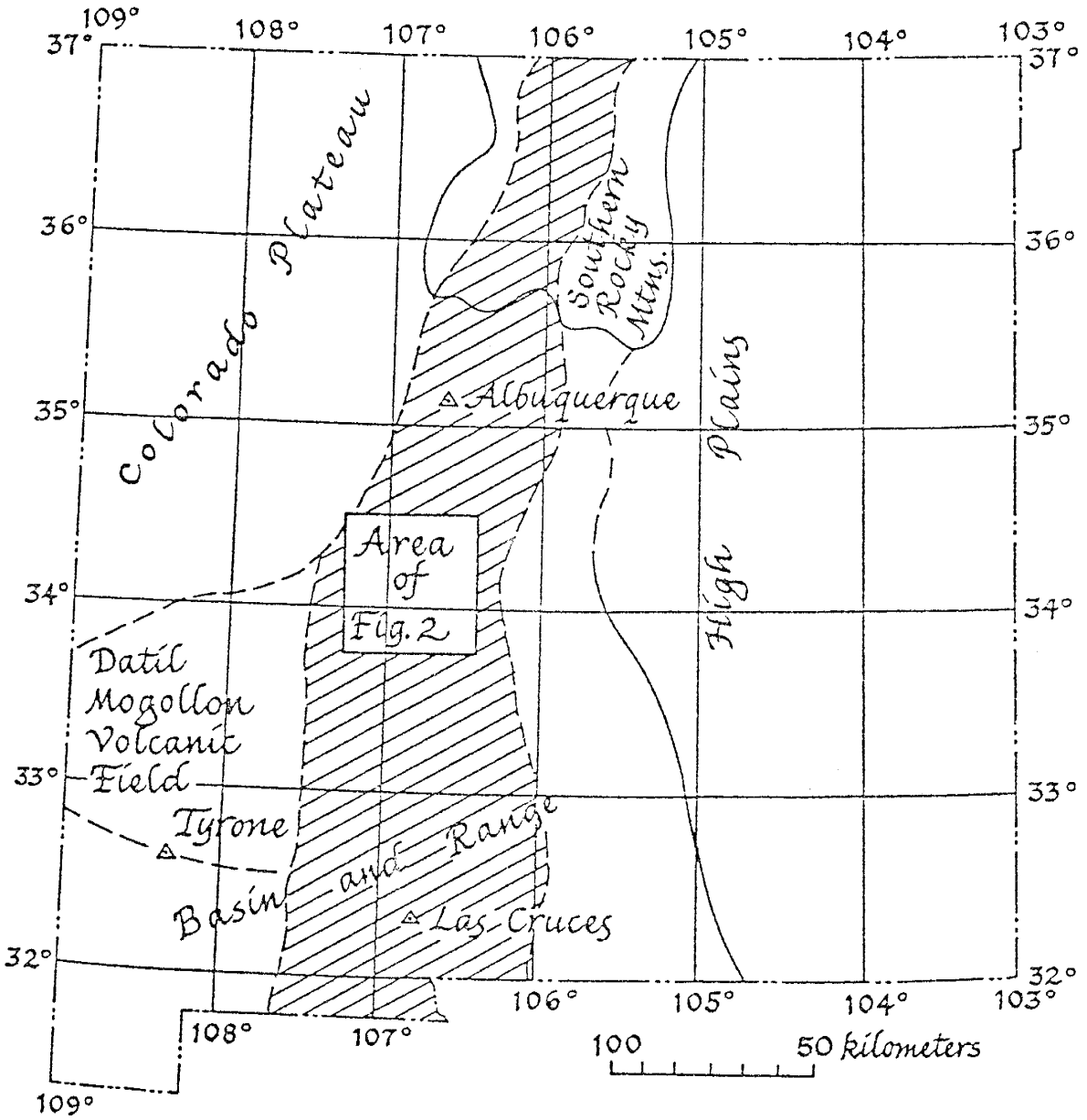


Fig. 1. Physiographic provinces in the state of New Mexico. The Rio Grande rift is shaded (after Ward, 1980).

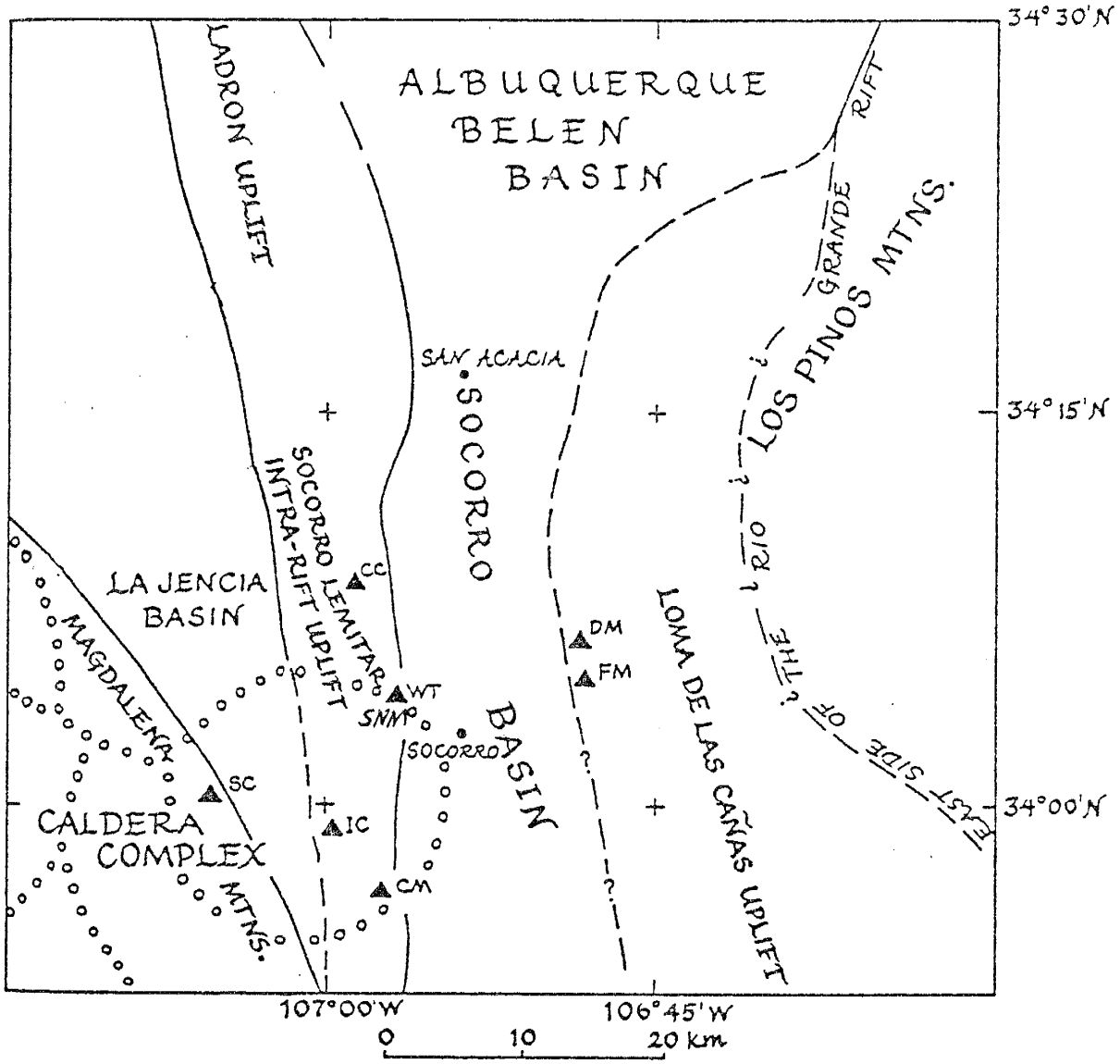


Fig. 2. Major physiographic and geological features near Socorro and the locations of the seismic recording stations (after Rinehart, 1979).

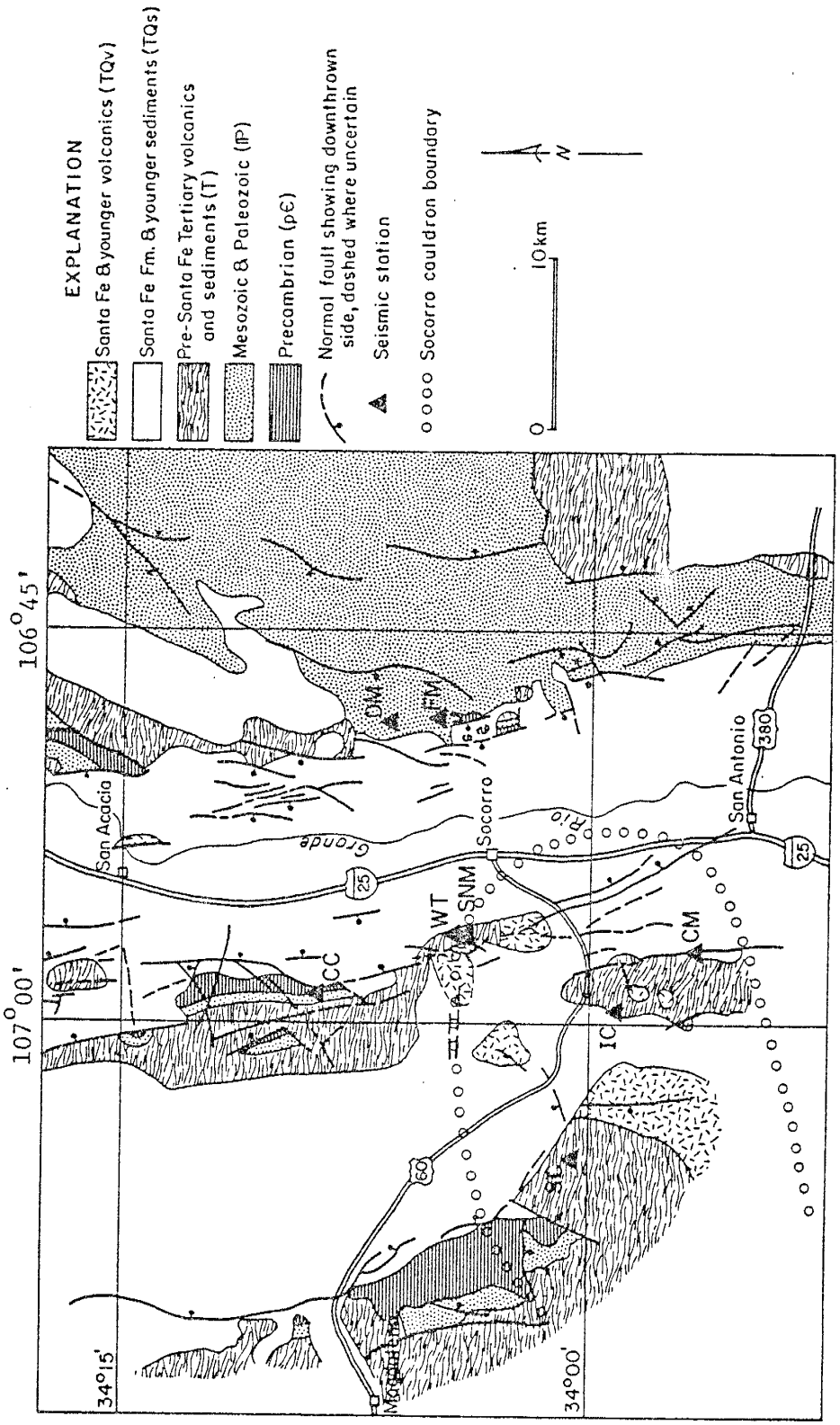


Fig. 3. Simplified geological map of the study area. Stations used for digital recording are marked with triangles (after Sanford et al., 1972).

The region experienced tectonic rejuvenation in the Late Paleozoic and underwent broad deformation during Laramide time. During the Eocene a large highland apparently existed along the west margin of the present day rift, extending from near Albuquerque as far south as Truth or Consequences (Cather, 1983). This uplift was deeply eroded, and in most areas west of the Rio Grande the Mesozoic section was removed and Tertiary rocks were deposited directly on late Paleozoic or Precambrian rocks.

Volcanic activity during the Oligocene and Miocene covered the region with voluminous calc-alkaline ash flow sheets associated with activity in the Datil-Mogollon volcanic field (Chapin and Seager, 1975). The Socorro cauldron developed about 33 million years (m.y.) ago as the northeasternmost extension of this volcanic field (Osburn and Chapin, 1983).

The beginning of rifting in the Socorro area, about 31-28 m.y. ago (Chapin and Seager, 1975), was contemporaneous with the later stages of cauldron development. Extension proceeded more or less uniformly until the mid-Miocene when there was a lull in tectonic activity. Large basins, such as the Popotosa basin, began to fill with bolson-type sediments. About 12-7 m.y. ago sedimentation was interrupted by the eruption of rhyolitic domes along the northern moat of the Socorro cauldron (Chapin et al., 1978). This ushered in a period of tectonic

rejuvenation in which the Socorro-Lemitar and Magdalena mountain blocks were uplifted and rotated (Chamberlin, 1983). As a result of this uplift, these blocks now expose cross sections of the northern and southern margins of the Socorro cauldron. Tectonic activity continues at present and has been accompanied by the intrusion and eruption of tholeiitic flood basalts during the last 4 m.y.

Significant features associated with cauldron development and rifting in the Socorro area include basins 3-5 km deep (Sanford, 1968; Chapin and Seager, 1975), Quaternary bounding faults striking north-northeast to north-northwest (Rejas, 1965; Chamberlin, 1980), and intrarift horsts such as the Socorro-Lemitar mountain block (Chapin and Seager, 1975). Seismic stations in the Socorro area lie on the raised structural margins of the rift or intrarift horst blocks. Material directly beneath the stations varies from cauldron moat deposits to Precambrian intrusive rocks. Cross sections for individual stations are presented in Figures 4 through 10.

The Socorro area is a region of high seismicity with a historical record including major earthquakes and discontinuous microearthquake activity (Sanford et al., 1979). Microearthquake swarms are common and several hundred shocks may occur during one year. First motion studies indicate the activity may be due to continuing extension along faults at depth (Wieder, 1981). Recent

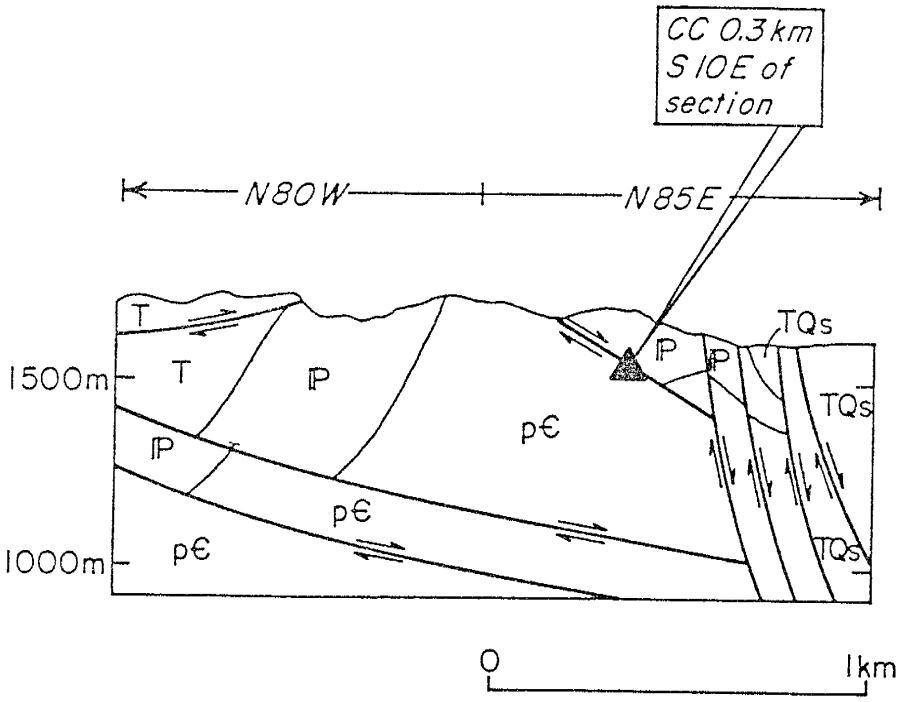


Fig. 4. Simplified geologic cross section for station CC (after Chamberlin, 1982).

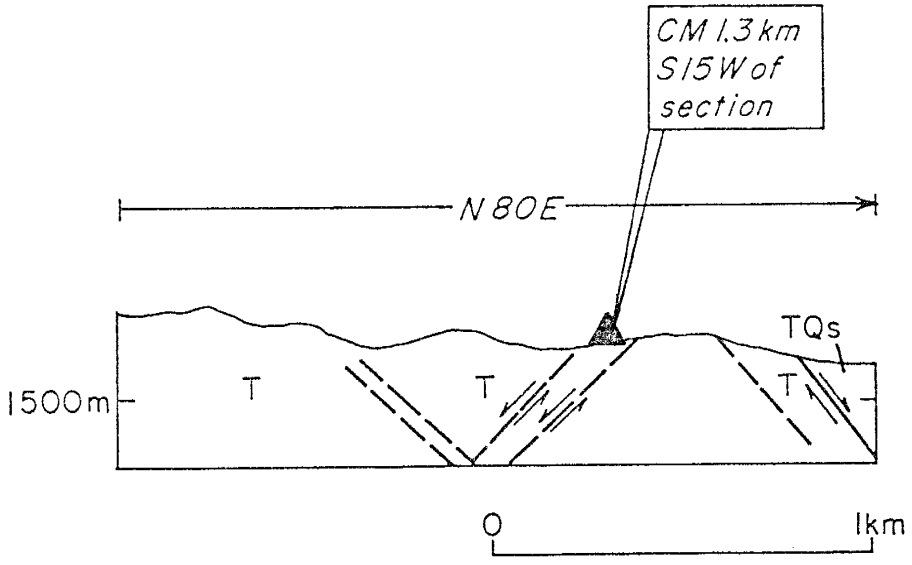


Fig. 5. Simplified geologic cross section for station CM (after Eggleston, 1982).

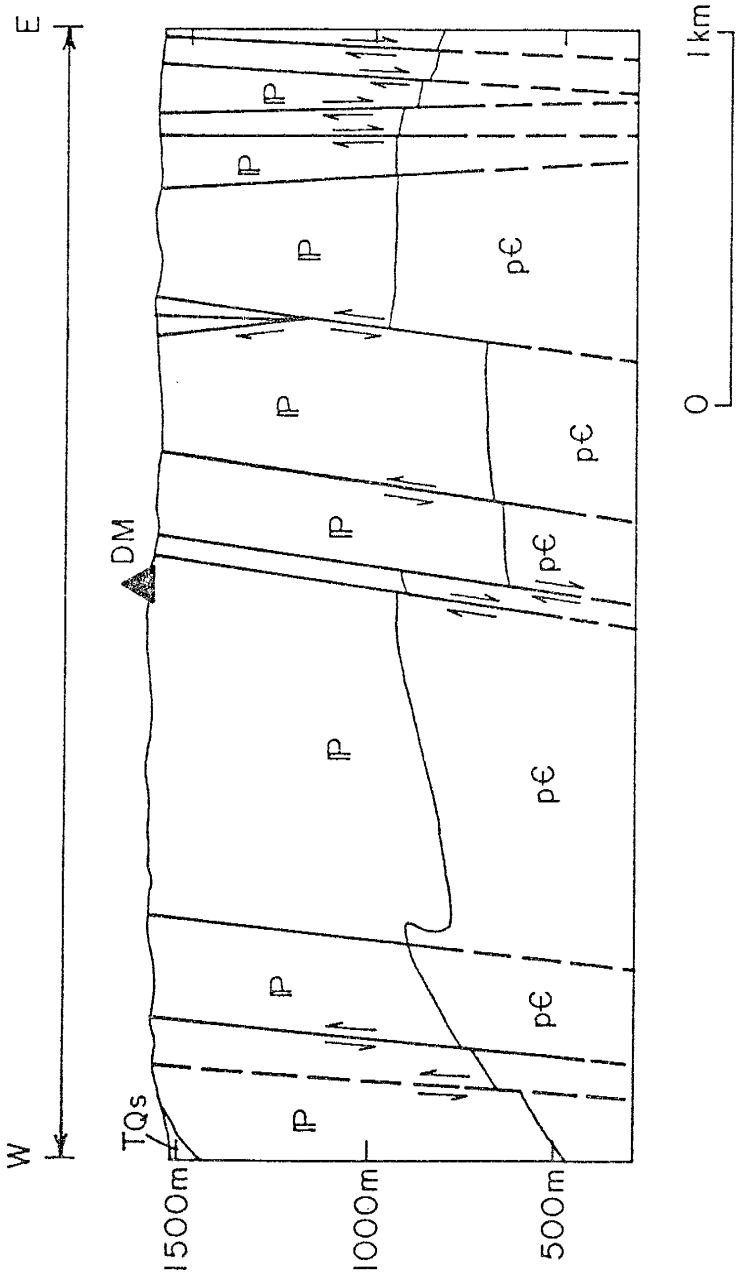


Fig. 6. Simplified geologic cross section for station DM (from Wilpolt and Wanek, 1951; Rejas, 1965).

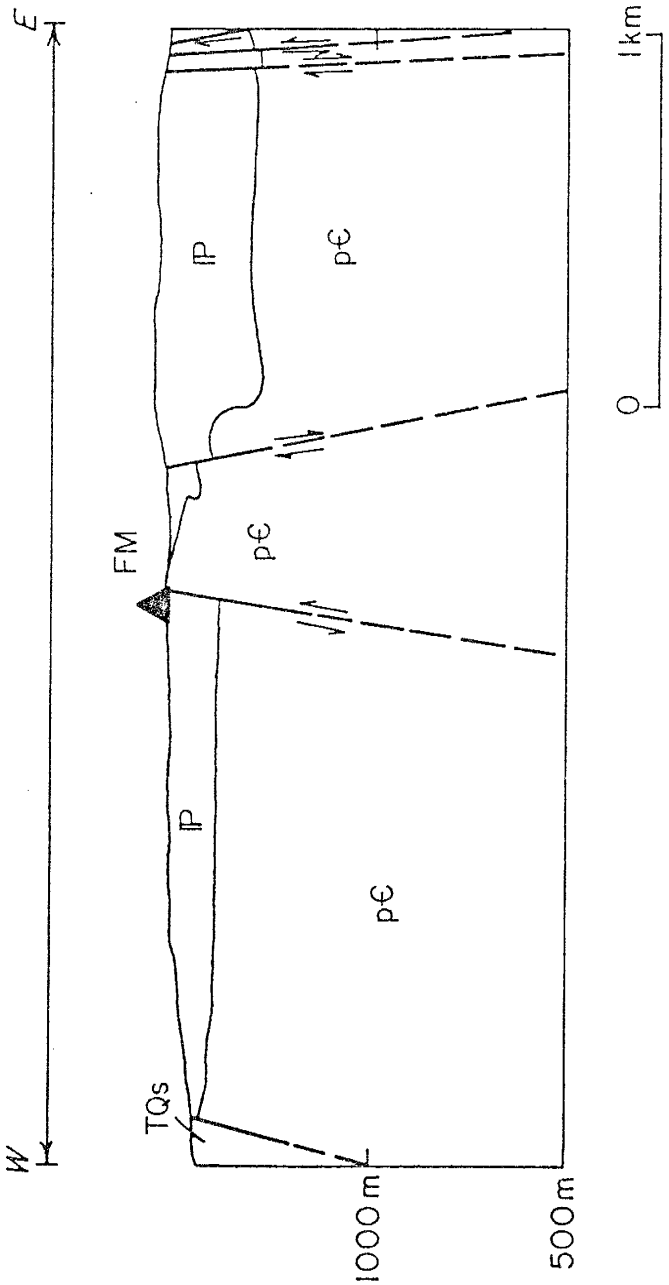


Fig. 7. Simplified geologic cross section for station FM (from Wilpolt and Wanek, 1951; Rejas, 1965).

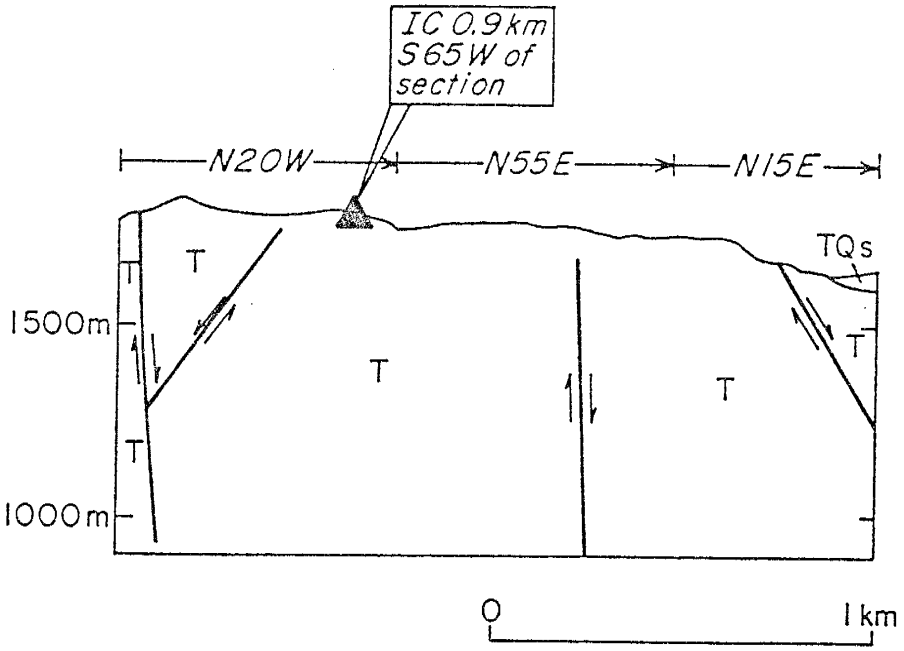


Fig. 8. Simplified geologic cross section for station IC (after Chamberlin, 1980).

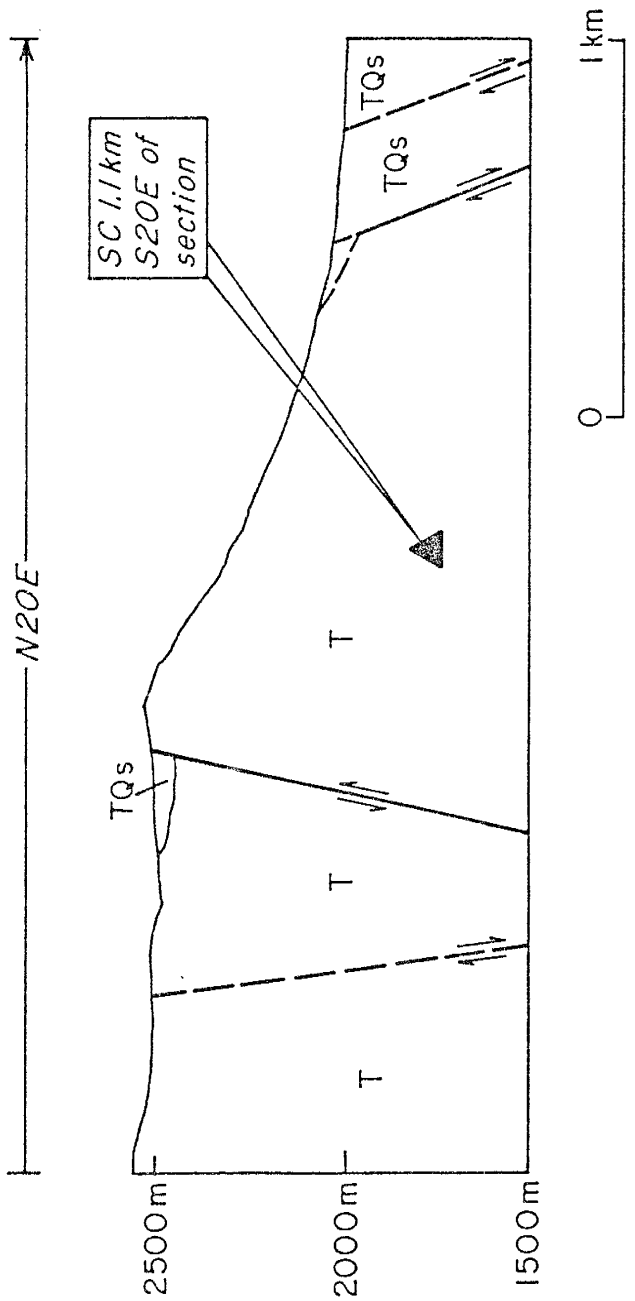


Fig. 9. Simplified geologic cross section for station SC (after Osburn, 1978).

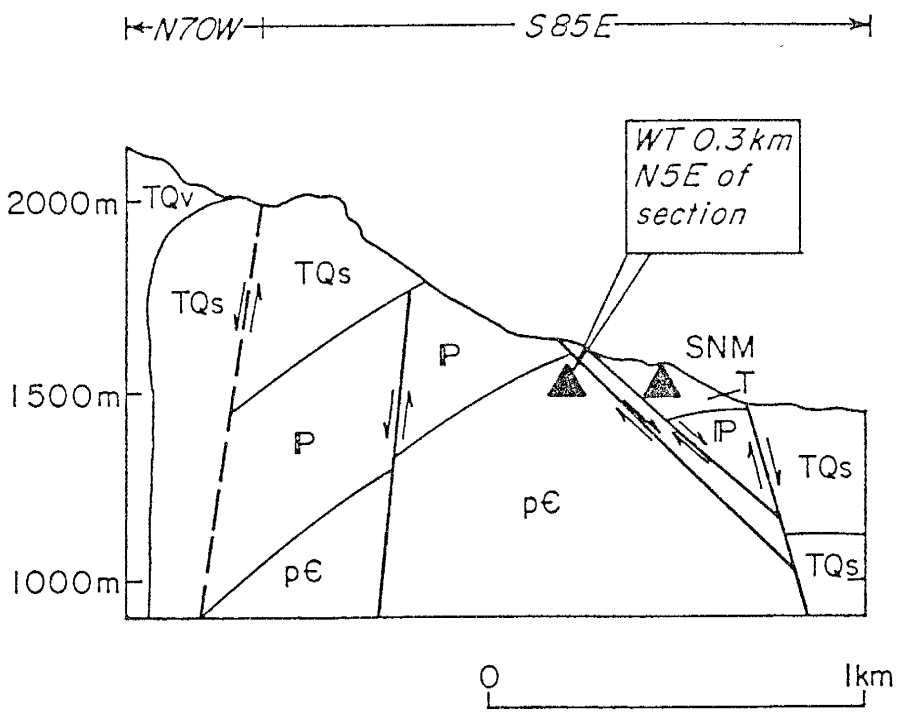


Fig. 10. Simplified geologic cross section for stations SNM and WT (after Chamberlin, 1980).

geodetic measurements, however, indicate that general crustal extension is not occurring in the areas of high seismicity (Savage et al., 1980) and most shocks are believed to be related to local extension arising from the injection of magma (Sanford et al., 1977).

On the basis of reflected S phases observed on microearthquake seismograms, Sanford and his coworkers identified and mapped the surface of a broad sill-like magma body at a depth of approximately 19 km (Rinehart et al., 1979). This mid-crustal magma body has also been identified on the reflection seismic lines of the Consortium for Continental Reflection Profiling (COCORP) north of Socorro. Figure 11 shows epicenters for over 800 shocks between May, 1975, and May, 1983, as well as an outline of the mid-crustal magma body and the location of the COCORP lines.

The occurrence of microearthquake swarms above the intersection of a transverse shear zone and the mid-crustal magma body (Chapin et al., 1978), and the association of swarms with regions of high Poisson's ratio and low velocities (Caravella, 1976; Ward et al., 1981) supports the hypothesis that many microearthquakes in the Socorro area are related to the intrusion of small magmatic bodies into the upper crust. Other regions of possible upper crustal magma accumulation have been identified through anomalous P/S amplitude ratios (Roach, 1982), S-wave screening (Shuleski, 1976; Johnston, 1978) and attenuation

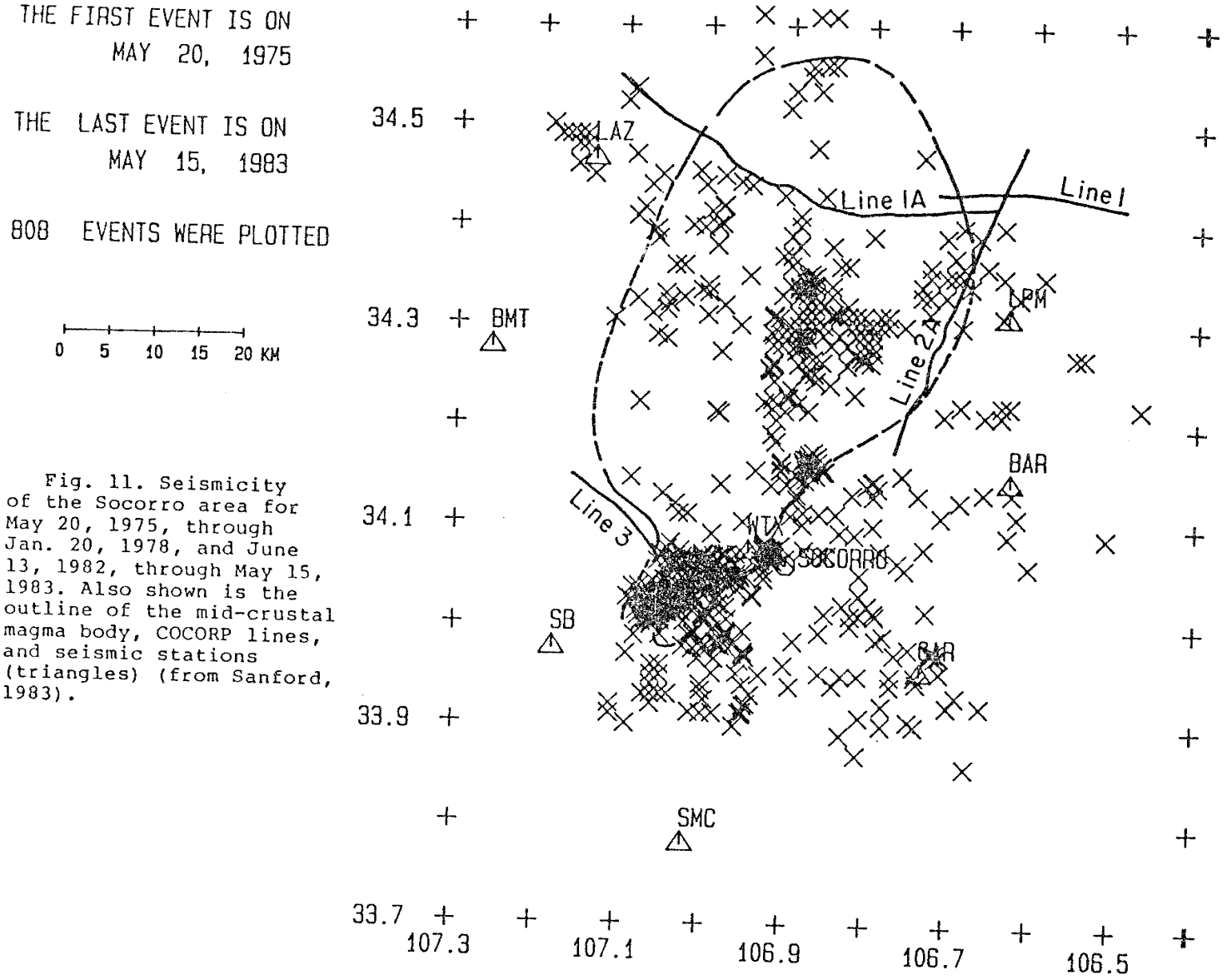


Fig. 11. Seismicity of the Socorro area for May 20, 1975, through Jan. 20, 1978, and June 13, 1982, through May 15, 1983. Also shown is the outline of the mid-crustal magma body, COCORP lines, and seismic stations (triangles) (from Sanford, 1983).

of P-waves from mining explosions (Guynn, 1978). Sanford and Schlue (1980) have reviewed these studies and believe the actual volume of molten material to be quite small, probably existing as a network of dikes and sills.

Additional evidence for upper crustal magma injection is provided by abnormally high heat flows. Near Socorro Peak, heat flows as high as 11.7 HFU have been recorded and the region has been designated a Known Geothermal Resource Area (Reiter and Smith, 1977; Sanford, 1977). Hydrothermal convection may be contributing significantly to these very elevated heat flows (Reiter et al., 1978).

Recent differential uplift has also occurred over an extensive area roughly coincident with the mid-crustal magma body (Figure 12). From recent level-line measurements, Reilinger and Oliver (1976) found uplifts of as much as 18 cm had occurred during a 40 year period near San Acacia. More recent work by Larsen and Reilinger (1983) has revealed an area of relative subsidence over the last 30 years along the southern margin of the Socorro cauldron.

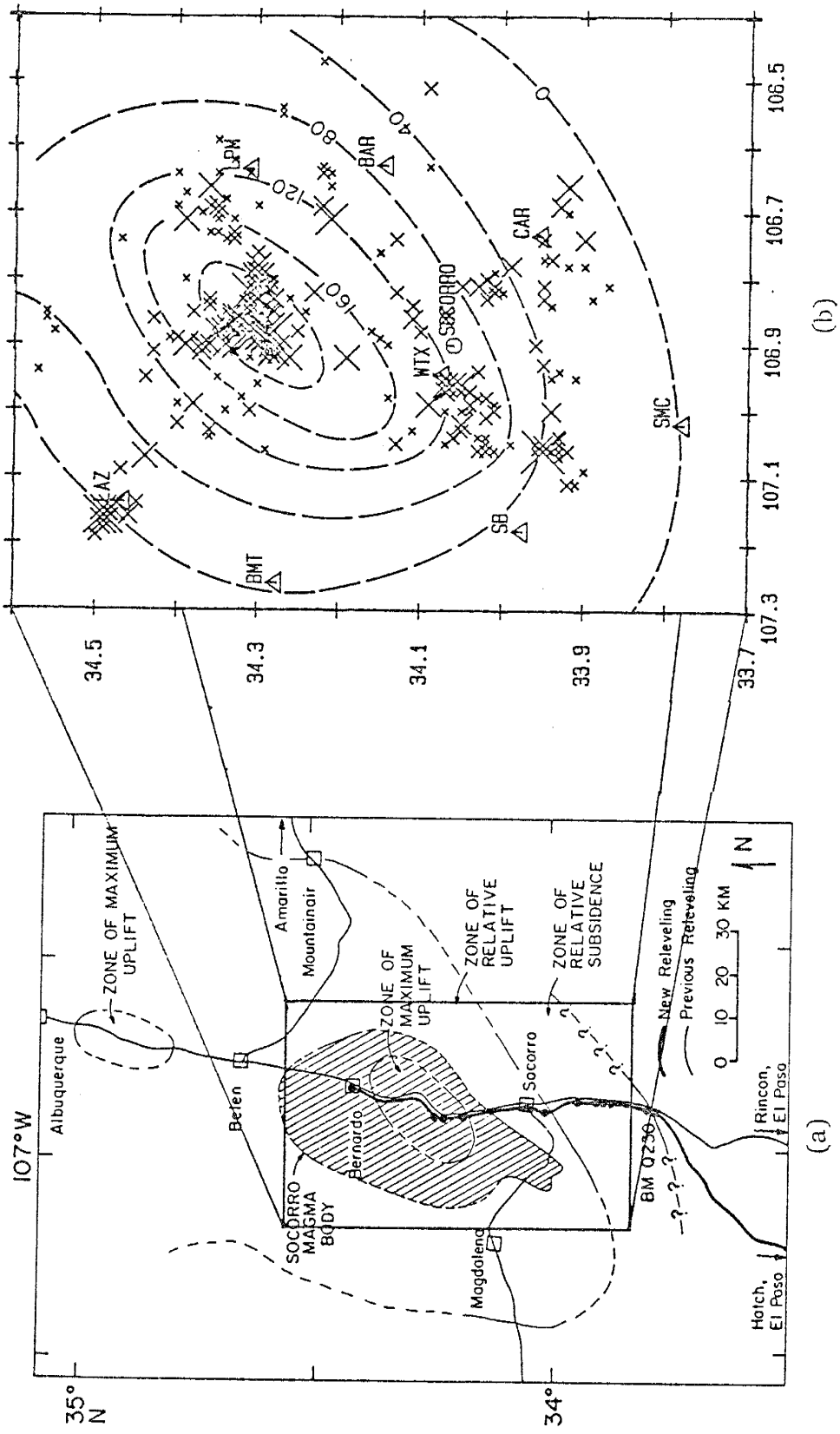


Fig. 12. (a) An area of relative uplift north of Socorro. The mid-crustal magma body is shaded (after Larsen and Reilinger, 1983). (b) An enlargement of (a) showing surface uplift in millimeters for a 40-year period with earthquake epicenters for an 11 month period (after Sanford et al., 1983b).

PREVIOUS Q INVESTIGATIONS

Field Studies

Field measurements of Q are relatively rare. A few values from the literature are listed in Table 1 and will be discussed below.

One of the earliest in-situ Q values was obtained by McDonal et al. (1958) who measured P and S wave attenuation in a homogeneous section of Pierre shale near Limon, Colorado. In this study, an array of borehole seismometers was used to record vertically traveling P waves and horizontally traveling S waves to depths of 1.2 km. The objective of the experiment was to determine if the Pierre shale behaved as a visco-elastic material. McDonal and his co-workers found that it did not (at seismic frequencies) as they obtained frequency-independent Qp and Qs values of 32 and 10 respectively for the upper 300 m.

Tullos and Reid (1969) carried out a similar experiment in Pleistocene Gulf Coast sediments near Houston. Utilizing spectral ratios to eliminate the source spectrum produced by explosions, they found an average frequency-independent Qp of about 12 for a section of sands and clays.

TABLE 1

FIELD MEASUREMENTS OF ATTENUATION

ROCK TYPE	LOCATION	DEPTH	QP	QS	METHOD	REFERENCE
PIERRE SH.	LIMON, CO	0-0.3 KM 0-1.2	32	10 98	BOREHOLE GEOPHONES	MCDONAL ET AL. (1966)
BASALT FLOW	KANA-A, AZ	0-0.3	93‡		"	DE BREMAECKER ET AL. (1966)
SAND-SHALE	HOUSTON, TX	0-0.3	12‡		"	TULLOS AND REID (1969)
VARIOUS	STABLE INTERIOR	0-20	550‡		SURFACE-WAVE INV.	HERRMANN AND MITCHELL (1975)
VARIOUS	EASTERN U.S.	0-15 16-30	215‡ 500		"	LEE AND SOLOMON (1975)
VARIOUS	E. BASIN AND RANGE	0-25	550‡		REFRACTION LINE	BRAILE (1977)
VARIOUS	RIO GRANDE RIFT, SOCORRO	0-19	195		SPECTRAL RATIOS	GUYNN (1978)
CRYSTALLINE	RIO GRANDE RIFT, NM	0-19	625		REFLECTIVITY	BROCHER (1981)
BASALTS, ANDESITES	VIRGIN IS.	0-40	380‡	480‡	AMPL. RATIOS	FRANKEL (1982)
"	"	0-1	7		"	"
VARIOUS	GREAT PLAINS, STABLE INTERIOR	CRUST		800‡	CODA FITTING	SINGH AND HERRMANN (1983)
"	RIO GRANDE RIFT, NM	"		370‡	"	"
"	BASIN AND RANGE	"		260‡	"	"
"	WEST COAST	"		<200	"	"

‡AVERAGE VALUE

De Bremaecker et al. (1966) studied the attenuation of refracted P waves traveling through lava flows, ash flow tuffs, unconsolidated cinders, and lower-Permian Kaibab limestone near Flagstaff, Arizona. Fitting a power law to the amplitude decay with distance of a refracted P wave, and estimating peak frequencies, they were able to obtain a range of generally low (<100) Qp values for the upper 1 km.

Vertical seismic profiling has been combined with synthetic seismograms to study attenuation over generally known sedimentary sections. Schoenberger and Levin (1974), using a model with sedimentary layers a few meters thick and frequencies ranging from 0-250 Hz, found interference from intrabed multiples preferentially removed higher frequencies and concluded that "apparent attenuation due to intrabed multiples accounts for 1/3 to 1/2 of the total attenuation observed in the field data." They suggest that observed attenuation be expressed as the sum of an intrinsic absorption term and a scattering term. Spencer et al. (1982), in a synthetic seismogram model, incorporated interference from interbed multiples and obtained similar results.

In this study, the scattering term will not be separated from the absorptive term-- both will be incorporated into apparent Q. It should be noted that the most likely area for scattering is immediately beneath the station, where layered sedimentary and volcanic rocks are

found and where scattering from open and fluid-filled cracks would be greatest. Although this region comprises only a small fraction of the total raypath, it can profoundly affect apparent Q measured at the surface.

For example, Frankel (1982) showed that the response of the recording site dominates the spectra of local explosions and small earthquakes in the northeast Caribbean. He obtained an extremely low Qp ($\sim$7) for the upper 1 km of crust and attributed this low quality factor to scattering in a pile of andesites and basalts beneath the station. Whether low Q values near the surface are the result of intense scattering, incompetent material, or both, site attenuation is a factor that needs to be considered in short-period wave attenuation studies.

Scattered waves can be used to compute Q directly. Aki and Chouet (1975) used the decay of coda waves to estimate coda Q (probably Qs) for several sites in Japan and California. Singh and Herrmann (1983) utilized this technique to calculate the average coda Q for crustal rocks beneath the continental United States (Figure 13).

Very few upper crustal Q estimates exist for extensional terranes such as the Basin and Range province and the Rio Grande rift. Braile (1977) used synthetic seismograms to model velocity gradients and Q variations with depth in the eastern Basin and Range near Salt Lake City. Braile developed a one-dimensional model to explain

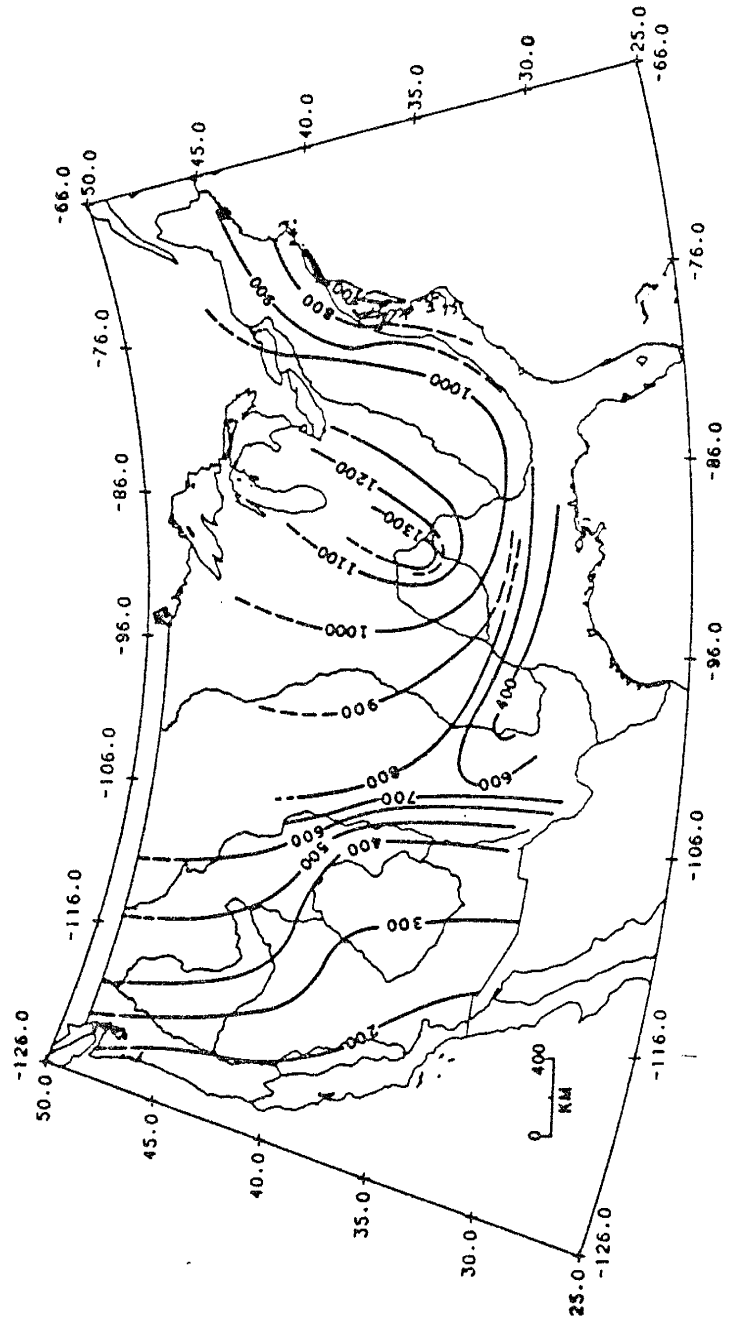


Fig. 13. Average crustal coda Q for the continental United States obtained from local and regional earthquakes over a frequency range of 0.5-3.5 Hz. Major physiographic boundaries are also shown (after Singh and Herrmann, 1983).

his observations. The model consists of a moderate Q upper crustal layer, a low Q, low velocity layer at about 10 km and a very high Q region below the Conrad, beginning at a depth of 14 km (Figure 14).

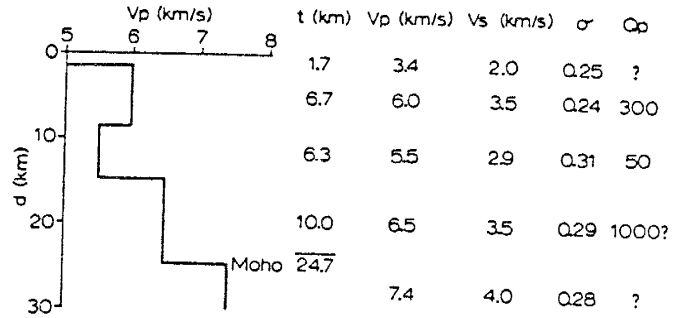


Fig. 14. One-dimensional velocity and Q model developed by Braile (1977).

Guynn (1978) applied the spectral ratio technique to distant mining explosions and obtained a Qp of 195 for upper crustal rocks in the vicinity of Socorro. Brocher (1981) used amplitudes of reflected waves generated at the mid-crustal discontinuity to estimate Qp for the upper crust at 625. His study employed a strong reflection point along COCORP Line 2A near Abo Pass on the east margin of the Rio Grande rift (Figure 11).

Laboratory/Theoretical Investigations and Attenuation Mechanisms

Wave attenuation in laboratory specimens is frequently measured as part of an ultrasonic testing procedure. Resonant bar and pulse propagation techniques are the most popular. Table 2 lists several Q values from laboratory studies. Other tabulations of laboratory Q may be found in Vasilyev and Gurevich (1962), Wyllie et al. (1962), White (1965) and Johnston et al. (1979).

In the resonant bar technique, an apparatus is used similar to that shown in Figure 15. A slender cylindrical bar, supported at its nodal points, is excited at one of its natural frequencies. Excitation is applied at one end and the resonance waveform is recorded at the other end. The sharpness of the resonance peak (in the frequency domain) is inversely proportional to Q. Alternatively, the source of the excitation can be removed and the decay of the resonant amplitude with time recorded. Q can be easily calculated from this amplitude decay curve. To determine Qp, the bar is excited longtudinally. To measure Qs, the bar is flexed or excited in a torsional mode.

A similar arrangement which may be used to measure Qs is the torsional pendulum (Figure 16). In this case, a mass at the base of a vertical rod is given an angular displacement and released; the decay in amplitude of the resulting vibration can then be used to calculate Qs.

TABLE 2

LABORATORY ATTENUATION MEASUREMENTS

ROCK TYPE	LOCATION	QP	QS	METHOD	FREQUENCY	PRESSURE	REFERENCE
GRANITE	QUINCY, MA	125	167	RESONANT BAR	0.14- 4.5 KHZ	1 ATM	BIRCH AND BANCROFT (1938)
SANDSTONE	AMHERST, OH	52		RESONANT BAR	930 HZ	1 ATM	BORN (1941)
LIMESTONE	SOLENHOFEN, BAVARIA		88-106	TORSIONAL PENDULUM	3-7 HZ	1 ATM	PESELNICK AND OUTERBRIDGE (1961)
SANDSTONE	BEREA, OH	314	92	RESONANT BAR	25 KHZ	0.41 KB	WYLLIE ET AL. (1962)
GRANITE	TUPPER LAKE, NY	60		"	90 KHZ	1 ATM	GORDON AND DAVIS (1968)
GRANITE	TUPPER LAKE, NY	1000		"	90 KHZ	1 KB	"
BASALT	NEW MEXICO	300		"	"	1 ATM	"
AMPHIBOLITE	CARRY FALLS, NY	25		"	"	"	"
DUNITE	NORWAY	700		"	"	"	"
QUARTZITE	WYOMING	850		"	"	"	"
BASALT	MT. SHASTA, CA		20	RESONANT BAR	50 HZ	1 ATM	TITTMAN (1977)
BASALT (DEGASSED)	MT. SHASTA, CA		2400	"	"	VACUUM	"
NAVAJO SS	?	7.3	6.2	PULSE	0.1-1 MHZ	1 ATM	TOKSOZ ET AL. (1979)
SANDSTONE	MASSILON, OH	143	111	RESONANT BAR	0.5-1.7 KHZ	1 ATM	WINKLER AND NUR (1979)

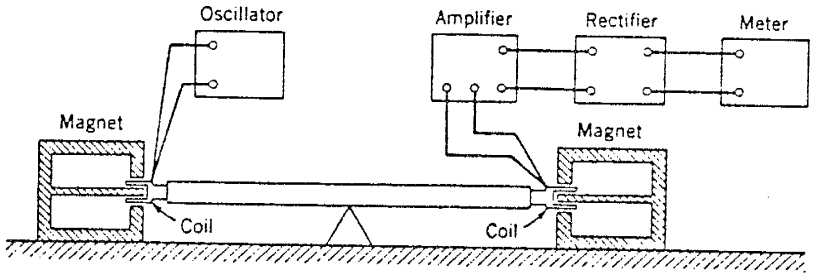


Fig. 15. The resonant bar (after White, 1965).

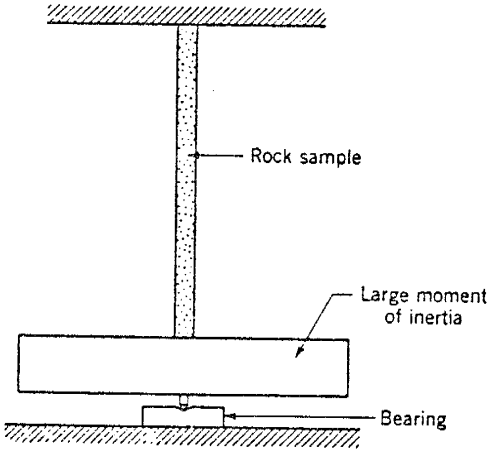


Fig. 16. The torsional pendulum (after White, 1965).

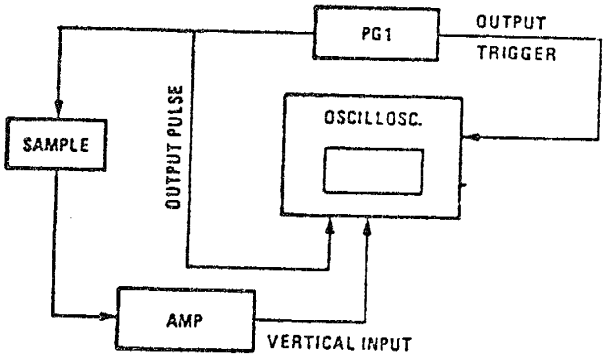


Fig. 17. A pulse-transmission system.

Finally, in the pulse transmission technique (Figure 17), a pulse (corresponding to a delta function) is passed through the specimen and recorded, either after one transit or after multiple reflections. Typically piezoelectric crystals affixed to the sample are used to apply and record the pulse. The Fourier transform of the emergent waveform is taken and Q is computed from the spectral slope.

It should be noted that laboratory determinations of Q may be unrealistic approximations to in-situ Q for several reasons:

(1) Since almost all laboratory measurements are made in the kHz-MHz frequency range, results must be extrapolated to seismic frequencies (0-250 Hz). Q may be frequency dependent over this wide frequency range and the results may not be valid for seismic waves. For example, a certain sized inhomogeneity in a sample may lead to scattering at short laboratory wavelengths but will have a negligible effect on relatively long wavelength seismic waves. In particular, fluids are very sensitive to the frequency of the excitation. At high frequencies, turbulent flow can develop whereas at low frequencies laminar flow will dominate (Biot, 1956a, 1956b, 1962). These different flow regimes dissipate energy at different rates.

(2) Rocks are often tested in a dry state in the laboratory while in the earth interstitial fluids are present and can profoundly affect Q.

(3) The samples are usually tested under pressure and

temperature conditions far different from those in the earth. In spite of these limitations, laboratory investigations can still help in defining attenuation processes. An advantage of the laboratory and theoretical approach is that one dissipative mechanism can be isolated and its relative importance evaluated, as long as it is not coupled to another mechanism.

No general agreement exists as to which physical mechanisms dominate seismic wave attenuation. Candidates include friction along cracks, thermoelastic relaxation, ionic dislocation in crystals and viscous dissipation by fluids in rocks. This section will summarize a few investigations designed to quantitatively explore these processes.

Friction between crack surfaces is intuitively appealing. Two important observations are explained by friction: (1) the commonly observed frequency independence of Q (Knopoff, 1964) and (2) higher attenuation in polycrystalline materials when compared with monocrystalline materials of the same composition (Peselnick and Zietz, 1959). Walsh (1966) made a theoretical analysis of crack friction in dry rocks. His model consisted of an isotropic homogeneous medium with randomly oriented thin elliptical cracks, all of which had the same length. The wavelength of the disturbance was assumed to be much longer than the crack length and small displacements were assumed. While Walsh

could not obtain absolute values for Qp and Qs, he did estimate $Qp/Qs \sim 0.5$ for most dry rocks. This ratio has been measured in room dry granite and limestone by Peselnick and Zietz (1959). Walsh's formulation can be extended to saturated rocks which give $Qp/Qs \sim 1$ according to Johnston et al. (1979).

Gordon and Davis (1968) measured Q at a variety of confining pressures, temperatures and strain amplitudes. For granite, they found Qp highly pressure dependent, as is shown in Figure 18. Qp, however, was not found to depend on amplitude in the seismic range (strains $< 10^{-6}$) as Figure 19 shows. Qs was found to respond in a similar manner to increased confining pressure and varying strain amplitudes. Intergranular friction was proposed by Gordon and Davis as the dominant attenuation mechanism. They noted that substantial pore pressures at depth could hold cracks open and facilitate friction along asperities despite high confining pressures.

Friction as a loss mechanism has been disputed, however, by Winkler and his coworkers. Winkler et al. (1979) studied the variation of Q with strain amplitude at kHz frequencies and found, as did Gordon and Davis, that Q is virtually independent of strain amplitude at strains less than 10^{-6}. Since typical strains associated with seismic waves are much less than 10^{-6}, they concluded that friction is probably not an important loss mechanism

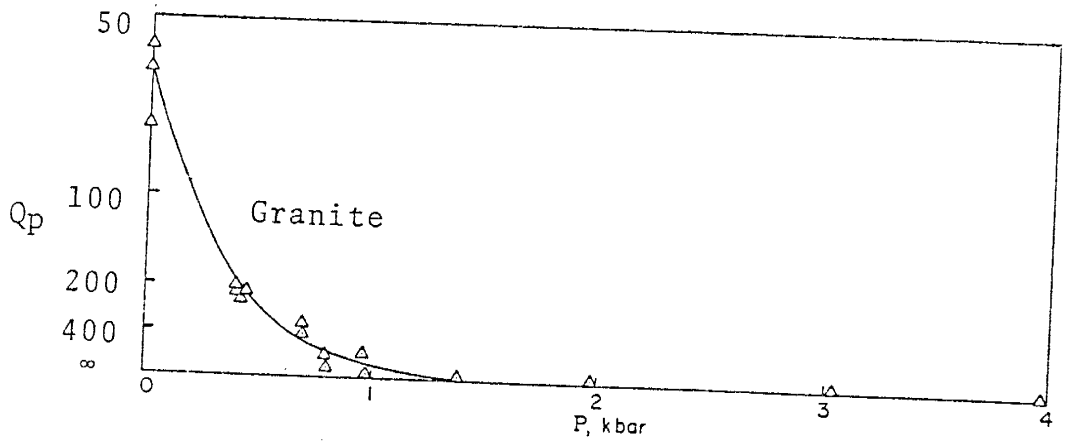


Fig. 18. Qp as a function of confining pressure for a granite specimen tested at 10 MHz (after Gordon and Davis, 1968).

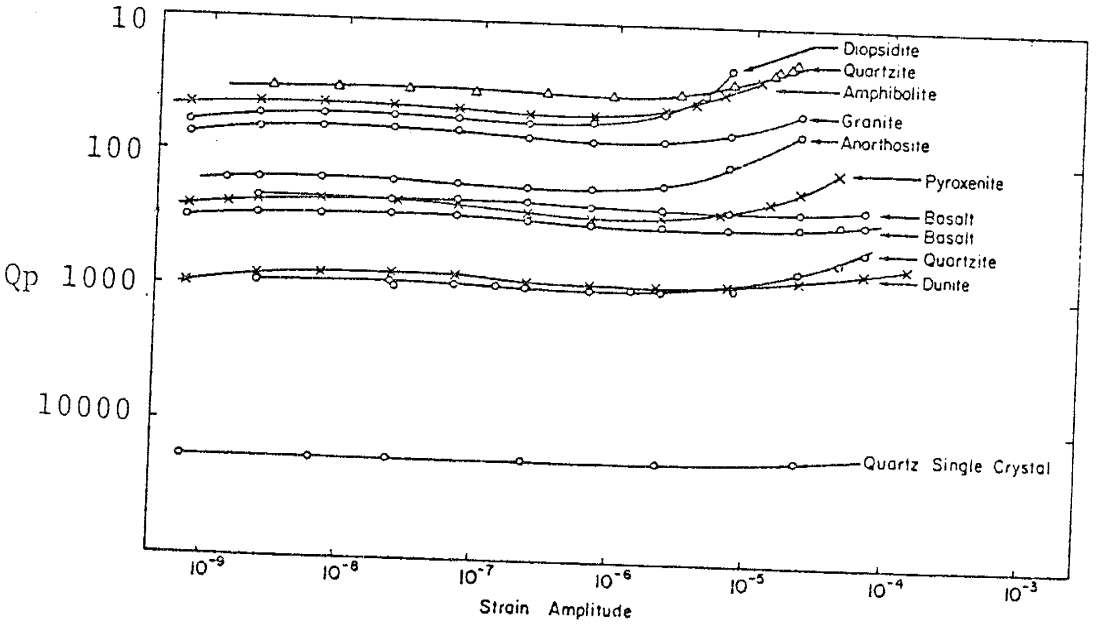


Fig. 19. Qp as a function of strain amplitude for various rock types. The resonant bar was used at a frequency of 90 kHz (after Gordon and Davis, 1968).

(assuming the work done against friction is proportional to the strain amplitude). As an alternative, they suggested viscous dissipation from fluid flow in rocks as the principal loss mechanism.

Fluids in rocks are believed to strongly dissipate seismic energy, depending on the degree of saturation. Several models that have been proposed are shown in Figure 20. While extensive tests have been made to ascertain the effect of fluids and the degree of saturation on attenuation, no general agreement exists as to which mechanisms are the most important at seismic frequencies.

Biot (1956a, 1956b, 1962) examined a model consisting of a saturated isotropic solid with interconnected pores. He divided the attenuation into two parts: (1) the anelasticity of the skeletal frame and (2) the viscous dissipation in the water moving relative to the frame. For the fluid, he found significant losses occurred at grain-fluid interfaces due to viscous drag and in irregularly shaped cavities due to pressure-gradient flow. He considered both high and low frequency acoustic waves. At the lower frequencies (seismic range) Poiseuille (laminar) flow occurs and Q was found to be proportional to f^{-1}. At higher frequencies, turbulent flow develops and Q is proportional to $f^{1/2}$. As 100 percent saturation is approached, Biot predicted attenuation would drop off sharply, as flow is inhibited.

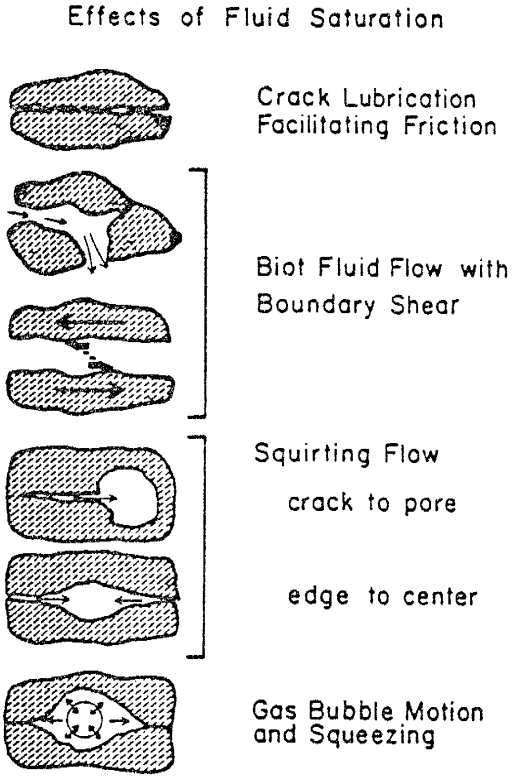


Fig. 20. Schematic illustration of several proposed attenuation mechanisms for saturated and partially saturated rocks (after Johnston et al., 1979).

Winkler and Nur (1979) tested several samples of Massilon Sandstone under saturated and unsaturated conditions. They found that both P and S wave attenuation increased as the fluid content was increased to 95% saturation. With increasing saturation, Qs continued to decrease while Qp increased. At 100% saturation, Qp > 3Qs. This behavior is consistent with Biot's prediction as discussed above. Johnston and Toksoz (1980) also studied changes in Qp and Qs with increasing saturation. Ultrasonic tests performed on a sample of Navajo Sandstone produced results similar to those obtained by Winkler and Nur (1979), although the Qp/Qs ratio was not as large at complete saturation (Figure 21).

Stoll (1974) expanded upon the work of Biot and derived expressions to allow extrapolation of high-frequency experimental data to seismic prospecting frequencies. Stoll measured a strong frequency dependence for Q in saturated sediments (kHz range) and showed the change in Q with frequency depends on porosity, permeability, frame anelasticity, and the density of the fluid and grains. For seismic prospecting frequencies (0-200 Hz), however, in sands and clays, he found that Q is essentially frequency independent.

Squirting flow is another proposed fluid loss mechanism. (Mavko and Nur, 1975; O'Connell and Budiansky, 1977). Squirting flow can occur only in partially saturated

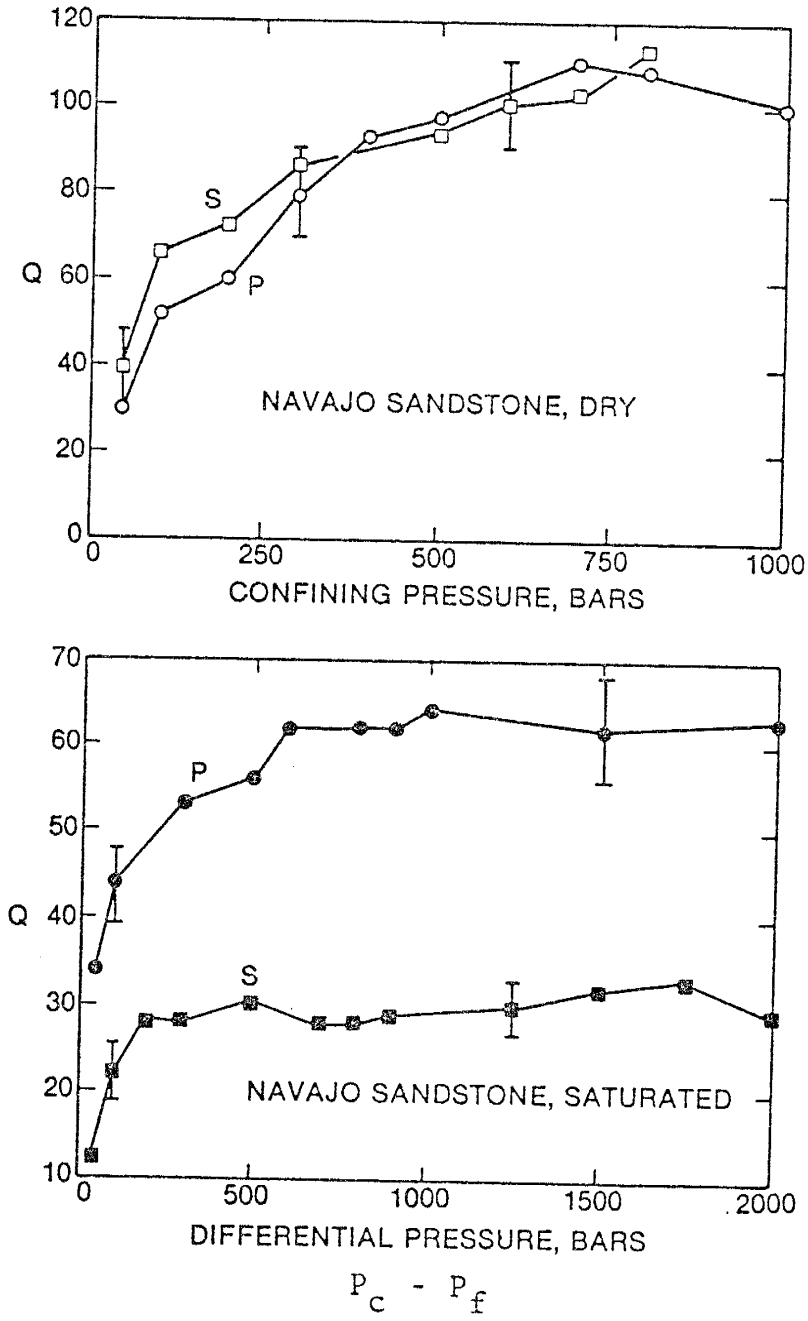


Fig. 21. Qp and Qs as functions of confining and differential pressure for dry and water-saturated Navajo sandstone at ultrasonic frequencies. Pc = confining pressure, P_f = pore pressure (after Johnston and Toksoz, 1980).

rocks. Mavko and Nur (1975) showed that in this case Q is particularly sensitive to the pore aspect ratio, being smaller for flatter pores.

Finally, White (1975) showed that pores need not be interconnected to contribute significantly to seismic wave attenuation. If pores or cavities are partially saturated, strong pressure gradients can induce rapid fluid motion with subsequent viscous dissipative losses.

Even a slight volatile content can significantly enhance attenuation. Tittman (1977) attempted to explain Q values in the range of 1000-5000 believed to exist in the earth's lower crust and mantle and in near-surface rocks on the moon as resulting from a lack of volatiles. Using sophisticated drying techniques with terrestrial olivine basalt samples and testing in a vacuum, Tittman obtained similar high Q values using the resonant bar technique at kHz frequencies. When removed from vacuum conditions, Q fell to below 100. Tittman believes that a thin layer of adsorbed water on pore or crack surfaces may explain this drop in Q. In contrast, rocks on the lunar surface or deep in the earth would be strongly outgassed.

Q is also affected by temperature. While an exact relationship between temperature and attenuation has not been defined, it has been generally observed that a strong decrease in Q occurs at temperatures approaching the melting point of rocks (Walsh, 1968, 1969; O'Connell and Budiansky,

1977; Manchnani et al., 1983). This arises from melting at grain boundaries which adds viscous losses to solid-state losses (Knopoff, 1964; Walsh, 1968, 1969). Also, geothermal regions have been shown to have abnormally low Qp values along with low compressional wave velocities (Ward and Young, 1980).

At temperatures below 200 ^{o}C, Gordon and Davis (1968) found a substantial dropoff in Q with increasing temperature for quartzite samples. They attributed this drop to the formation of cracks arising from the anisotropic thermal expansion of quartz grains. Kissell (1972), however, found that Q increased with increasing temperature below 200 ^{o}C for several rock types including quartzite. Kissell attributed this increase in the quality factor to the loss of volatiles with heating.

Unfortunately, little work has been done on how physical conditions and rock compositions affect the Qp/Qs ratio. Most studies to date have focused on relating Qp/Qs to the degree of fluid saturation in rocks. As mentioned earlier, Walsh (1966) and Johnston et al. (1979) have made calculations which show that Qp/Qs increases from 0.5 to 1.0 with increasing saturation. Mavko and Nur (1979) obtained similar results from a theoretical analysis of flow in flat partially saturated pores, noting that this is basically a compressional model of attenuation. Winkler and Nur (1979) confirmed this theoretical work when they tested samples of

Massilon sandstone ultrasonically and found that $Qp/Qs < 1$ for partially saturated rocks while $Qp/Qs > 1$ for completely saturated rocks. Johnston and Toksoz (1980), on the other hand, found that $Qp \approx Qs$ for dry rocks while $Qp > Qs$ for saturated Navajo sandstone samples (porosity ≈ 30%) tested at ultrasonic frequencies (Figure 21).

The only other factor that has been found to affect the Qp/Qs ratio is partial melting. Anderson et al. (1965) reports that $Qp \approx 9/4\ Qs$ for surface waves probing the asthenosphere, a region believed to have a very small percentage of melt. O'Connell and Budiansky (1977) suggest from theoretical calculations with crack models (< 1 percent fracture porosity) that $Qp > Qs$ in zones with a small fraction of partial melt.

While Q and velocity may be related, a quantitative relationship between the two has not been established. Many investigators, such as Winkler and Nur (1979) and Johnson (1983), have found an experimental correlation between low Q rocks and low velocity rocks. This is generally attributed to the presence of open or saturated pores or fractures which lower seismic velocities and quality factors (Figure 22). As mentioned earlier, Ward and Young (1980) found that low Q volumes correlated with low velocity volumes in the study of a geothermal system. While no clear functional relationship between velocity and Q has been determined, it appears that a general decrease in Q accompanies a decrease

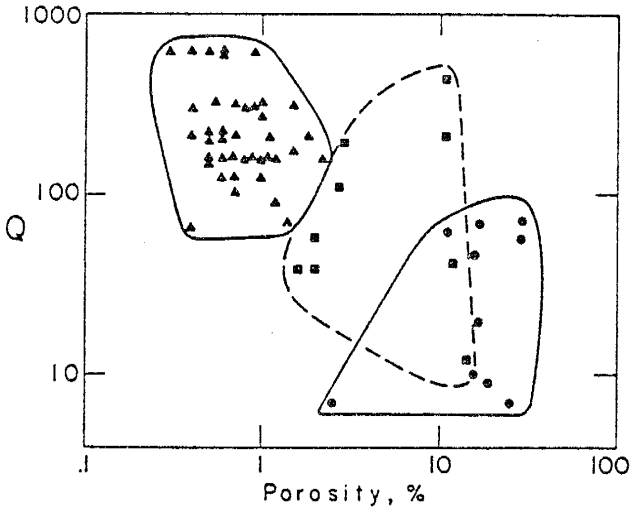


Fig. 22. Q as a function of porosity. Sandstones are shown as circles, limestones as squares and igneous/metamorphic rocks as triangles (after Johnston et al., 1979).

in velocity. In this study, a model will be proposed that links low velocity regions with low Q regions.

Attenuation in the Socorro Area

Of particular interest in the Socorro area are the effects of intense fracturing and elevated temperatures on Q. Zones of intense fracturing have been identified through geologic mapping, and inferred through seismicity maps, geochemical analyses, and tectonic modeling. Chapin et al. (1978) have defined at least three areas of intense deep-seated fracturing in the Socorro area:

(1) Major N-S trending rift faults.

(2) Cauldron ring fractures.

(3) A transverse shear zone extending from South Canyon in the Magdalena Mountains beneath Socorro Peak and to the east.

Chapin et al. (1978) notes that all of the above could provide pathways for ascending magmas. Experimental data indicates both fracturing and increased rock temperature would lead to a substantial reduction in Q for seismic waves passing through these regions (Walsh, 1966; Gordon and Davis, 1968; O'Connell and Budiansky, 1977). Also, Eggleston et al. (1983) have shown, through geochemical analyses and modeling, that meteoric waters have circulated as deep as 4 km in an ancient hydrothermal system in the southern Socorro cauldron. Chapin et al. (1978) describes

another ancient geothermal reservoir (active 12-7 m.y. ago) in permeable volcanic tuffs which are still buried in many parts of the cauldron. Loss of seismic energy to interstitial fluids in these rocks could also substantially lower the quality factor.

DATA

Digital Recording

Over 400 digitally recorded microearthquakes comprise the data for this study. These events were recorded by Sprengnether DR100 and DR100-1A digital recorders deployed intermittently among eight field stations between January, 1977, and March, 1983. Figures 2 and 3 show maps of the station locations. Table 3 lists the coordinates and elevation of each station.

The seismograms were automatically digitized at a rate of 100 samples per second (sps). The DR100 units continuously monitor the seismic background and compare a short term average amplitude (STA) to a long term average amplitude (LTA). If the STA/LTA ratio exceeds a preset value, the unit triggers and records the event on magnetic tape. 5.52 seconds is continuously being monitored; if the startup time for the recorder is subtracted from this, about 2-4 s of the pre-trigger seismic signal is recorded. So while the S phase usually triggers the unit, enough information is stored to record the P wave and a slight leader. Header information listing the event date, time and unit number precedes and follows each recording. Timing information is provided by a precision internal

TABLE 3

SEISMOGRAPH STATION LOCATIONS

STATION	LATITUDE*	LONGITUDE*	ELEVATION (m)
CC	34.1442	106.9819	1649
CM	33.9501	106.9576	1640
DM	34.1075	106.8079	1536
FM	34.0829	106.8047	1537
IC	33.9870	106.9967	1730
SC	34.0100	107.0894	2073
SNM	34.0702	106.9435	1511
WT	34.0722	106.9459	1555

*Degrees north and west

quartz-crystal chronometer. Amplitude values are stored in a 12-bit word (11 bits plus sign) with a maximum capacity of 2047 bits. One bit corresponds to an amplifier output of 5 millivolts and the maximum amplifier output that can be recorded is about 10 volts. The duration of a recorded event will be less than 20 seconds unless triggering reoccurs during recording.

Figure 23 shows a digitally recorded event. Figure 24 shows a DR-100-1A deployed in the field.

Gains were set at 6 dB increments over the range 66-90 dB. Filters were applied at various times to reduce noise. A low-cut 5 Hz filter was frequently used at stations CC and SC to reduce teleseismic triggers. A 30 Hz high-cut filter was used at IC, SNM, and WT to reduce noise from wind and electrical transmission lines. The frequency response of the recording system will be discussed in detail in the deconvolution section.

The seismometer employed through most of this study was the Mark-Products L4C (vertical component, 1 Hz natural frequency); the vertical channel of a 3-component Sprengnether S-6000 seismometer was also used for a short time at WT. The response of the seismometers and different recording units was checked by recording the same earthquake on two different units with two different seismometers at the same site. In all cases, the seismograms and spectra were identical within the accuracy of the sampling rate

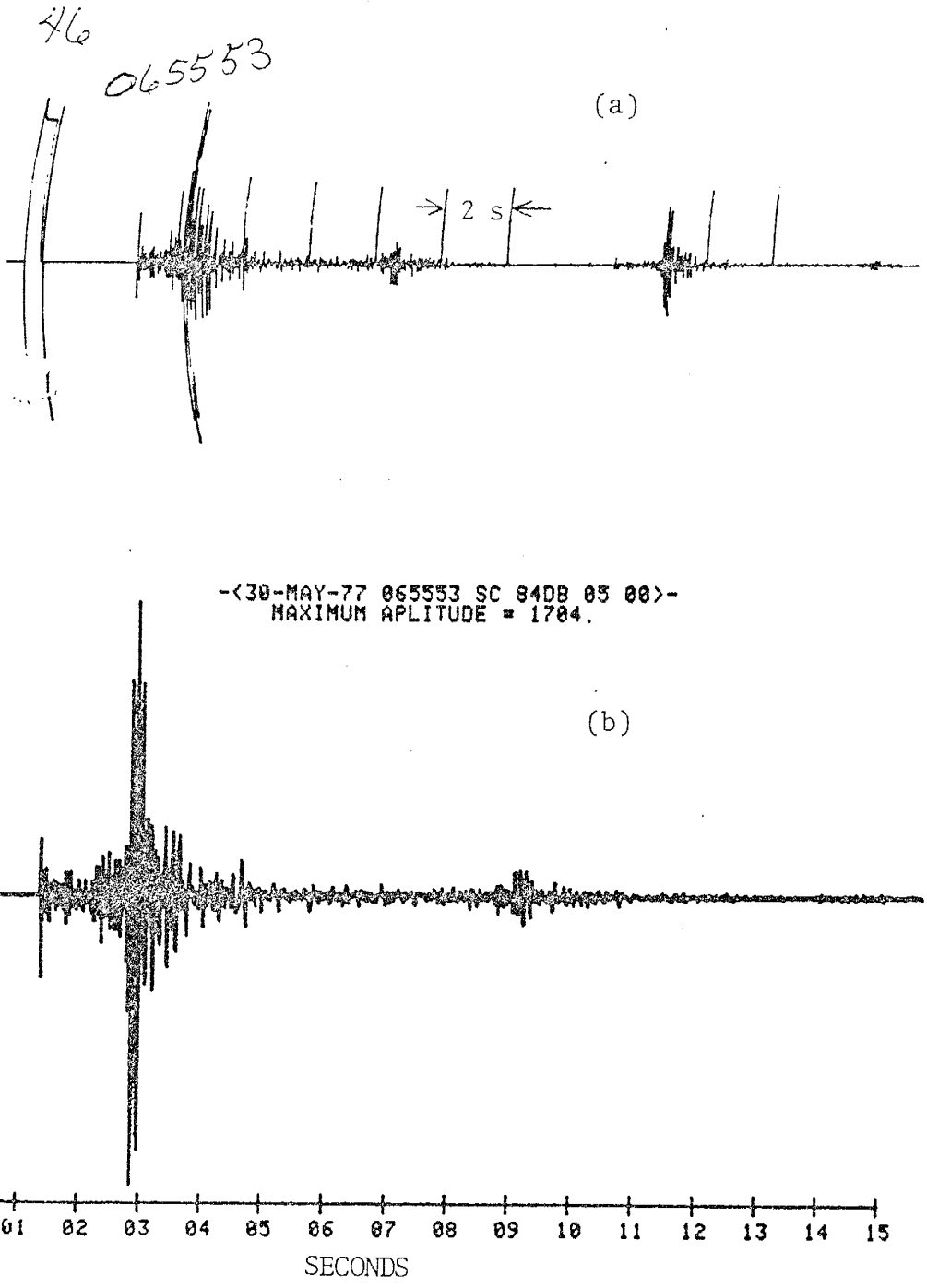


Fig. 23. (a) A digitally recorded microearthquake before initial processing. (b) The same microearthquake after initial processing.

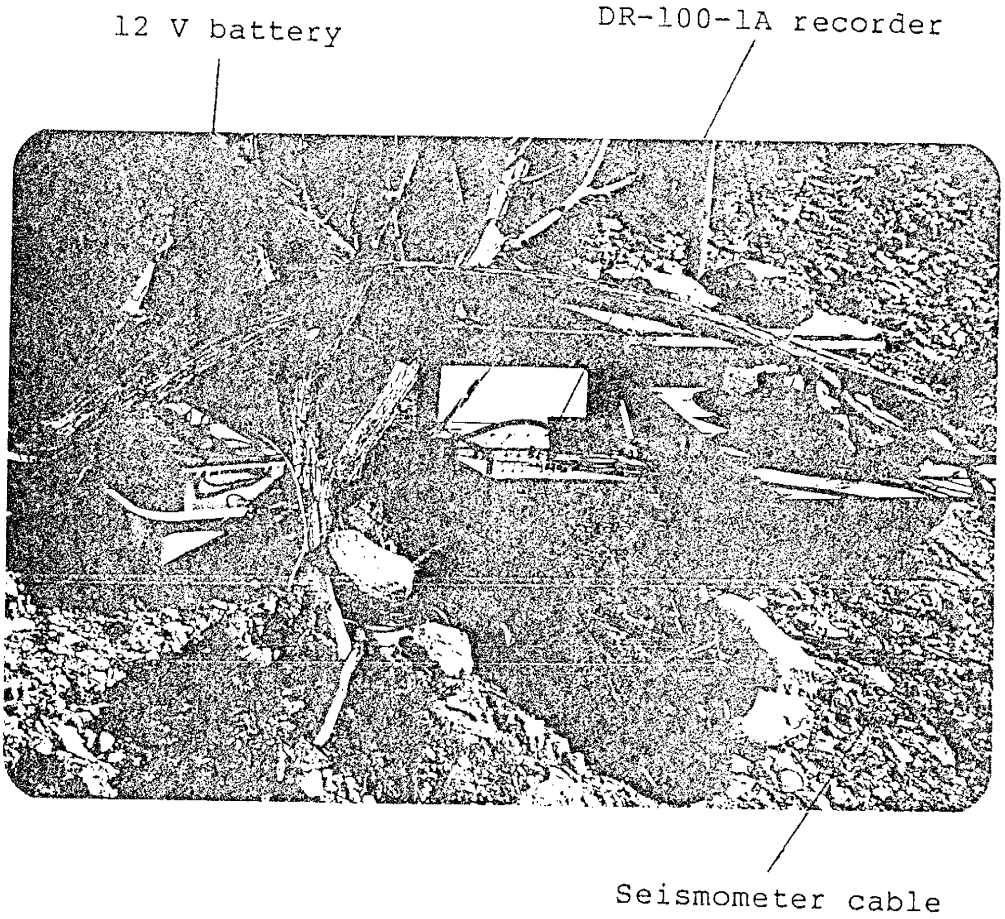


Fig. 24. A DR-100-1A digital recorder deployed in the field.

(Appendix 1).

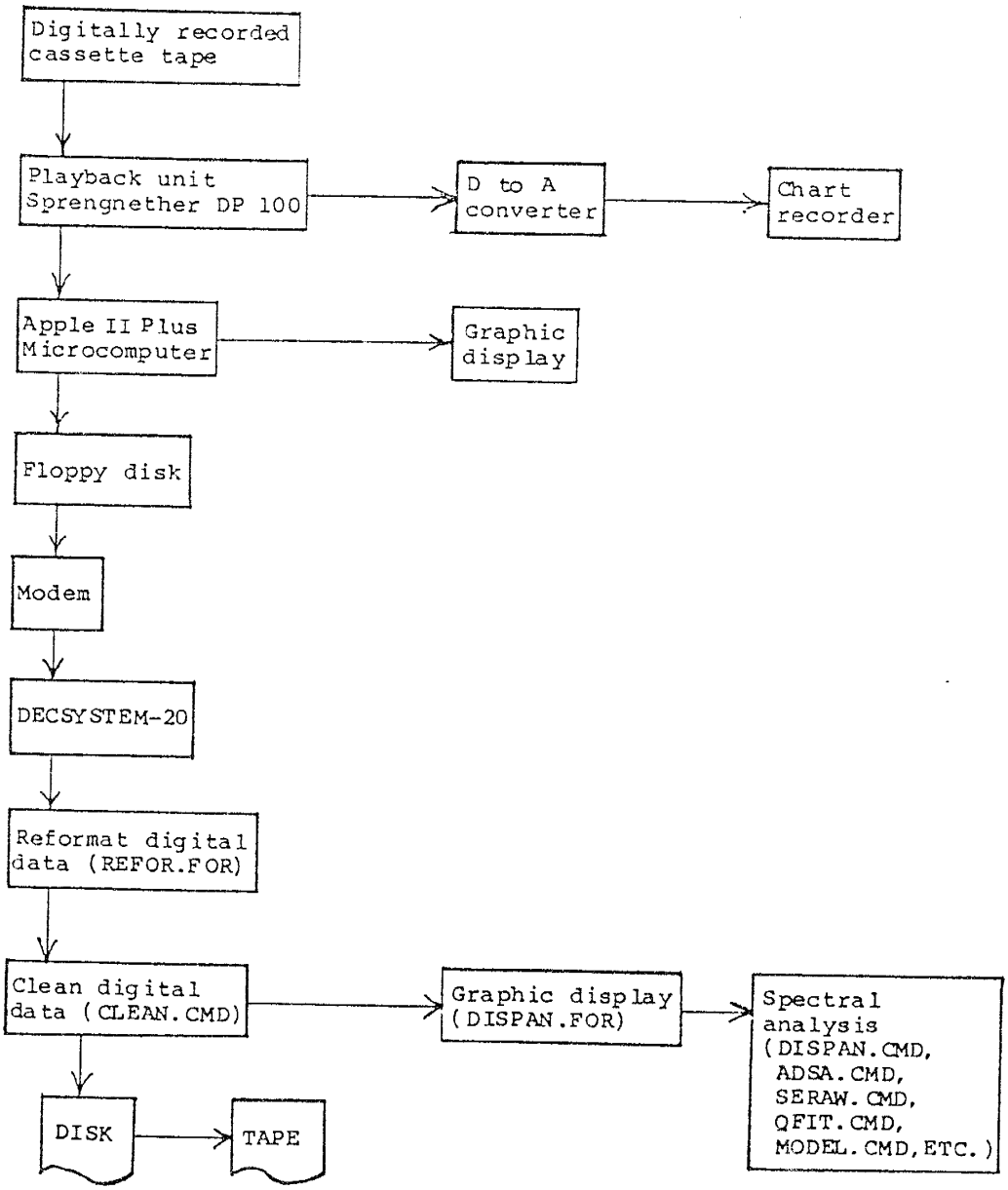
Digital Playback and Initial Processing

The playback system consisted of a Sprengnether DP-100 digital cassette tape playback unit linked to an Apple II Plus microcomputer (see Figure 25 for a schematic diagram illustrating the initial processing sequence). Figure 26 is a photograph showing the components involved. Digital amplitude values were transferred from the cassette tapes via the DP-100 to the Apple and were stored temporarily on floppy disks. The Apple was then linked to the DECSYSTEM-20 through an acoustic coupler and files were transferred to the DEC over a phone line, where they were stored on disk and magnetic tape.

Once events were transferred to the DEC, additional processing was needed to reformat digital values so that they could be read by the spectral analysis programs. Also, glitches and time marks were replaced with values interpolated from adjacent points. Figure 23 shows one event as it appears in the initial playback and after the initial processing. Programs for displaying the digitized seismograms and removing glitches, time marks, etc. are named in Figure 25 and listings are presented in Appendix 4.

FIGURE 25

DIGITAL DATA PROCESSING SEQUENCE
(Program names also shown)



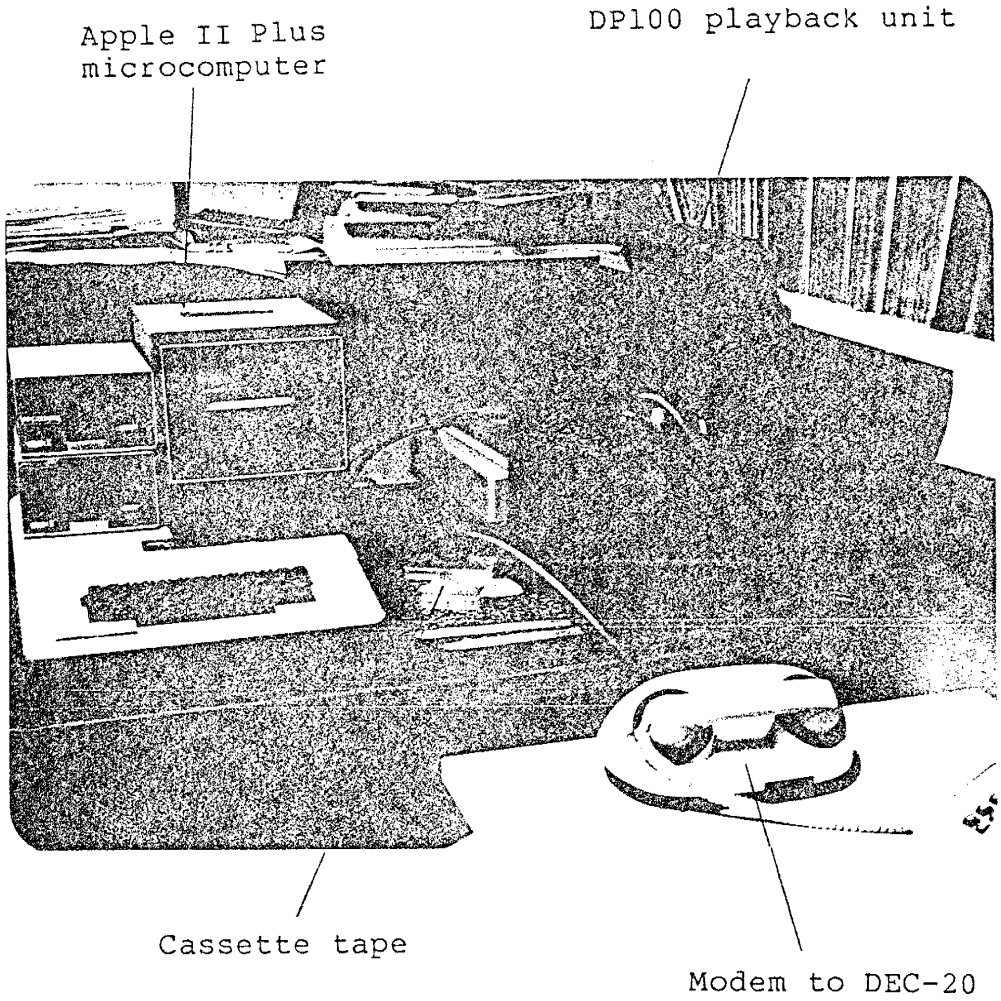


Fig. 26. The components involved in transferring the digital data from cassette tapes to the DECSYSTEM-20.

Earthquake Locations

Arrival times used to locate events in this study were routinely read from digital records, smoked paper recordings and from the hot-wire records of the NMT/USGS Socorro array. HYPO71 (REVISED) (Lee and Lahr, 1975) was used to compute hypocenter locations. A half-space velocity model was used (Vp=5.85 km/s, ν =0.25) with station time corrections to account for the varying thickness of near-surface low velocity material. Generally, arrival times from five or more stations were used to compute a solution. See Rinehart (1979) or Ward (1980) for a more detailed discussion of locating local microearthquakes.

Epicenters for all located events used in this study are listed in Appendix 2. Figure 27 shows these epicenters plotted on a map of the Socorro area, along with raypaths connecting the epicenters to the station at which they were recorded.

Distances to unlocated events used in this study were calculated using the expression

$$r = [(1.37)(S-P) - t_{sta}]\ Vp, \qquad (1)$$

where r is the hypocentral distance, Vp is the P wave velocity, (S-P) is the S-P interval, and t_{sta} is the station delay. This station delay accounts for the varying thickness of inhomogeneous low velocity material near the

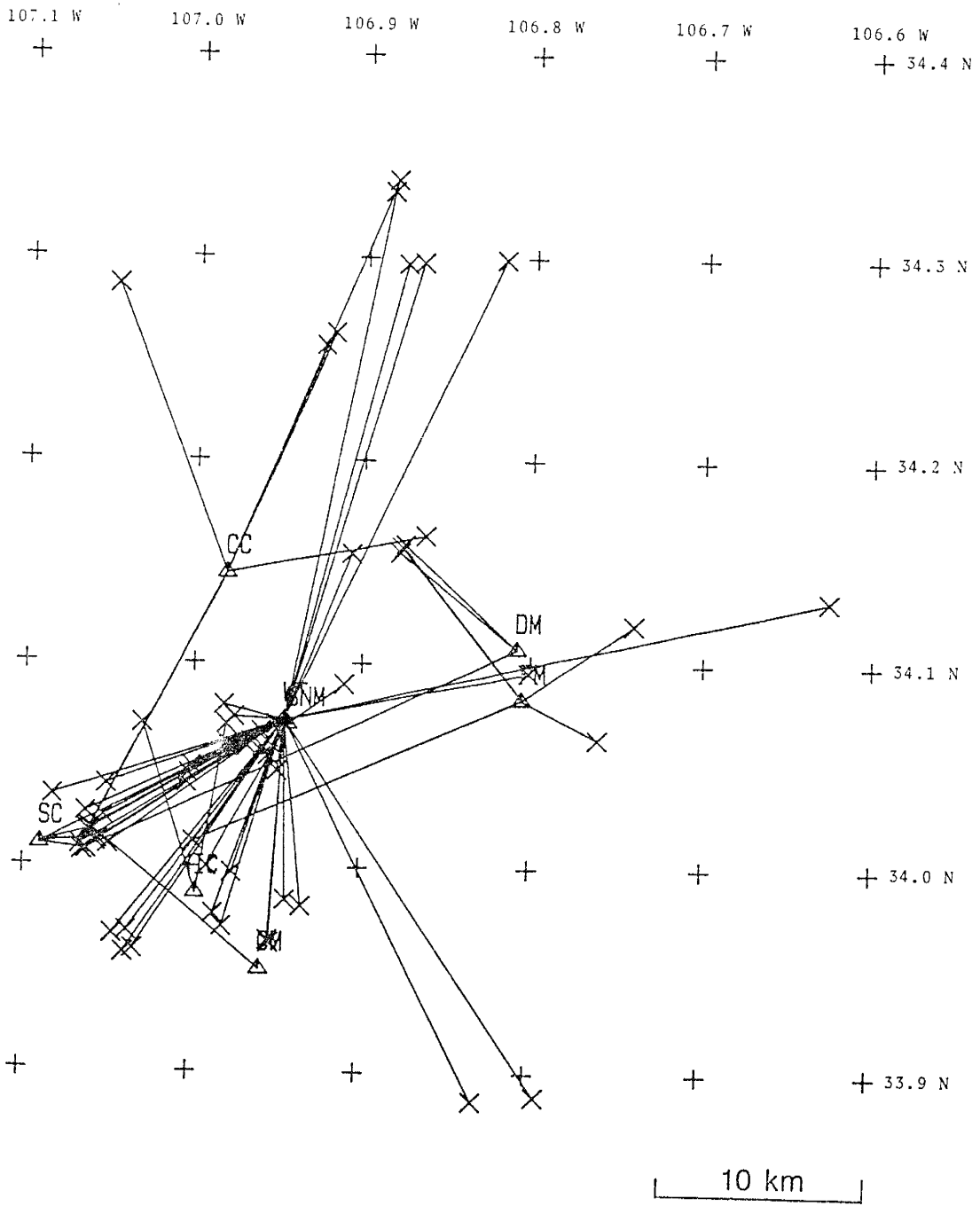


Fig. 27. Epicenter distribution for all located events used in this study. Rays connect epicenters with stations where the events were recorded.

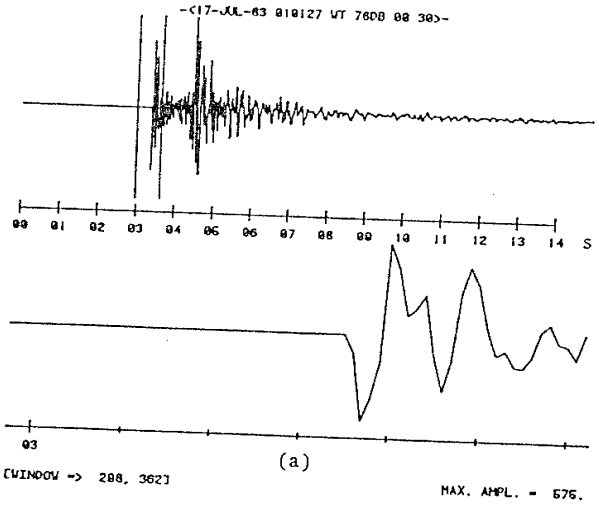
surface. Aside from the station corrections, (1) assumes a constant velocity half-space with a Poisson's ratio of 0.25.

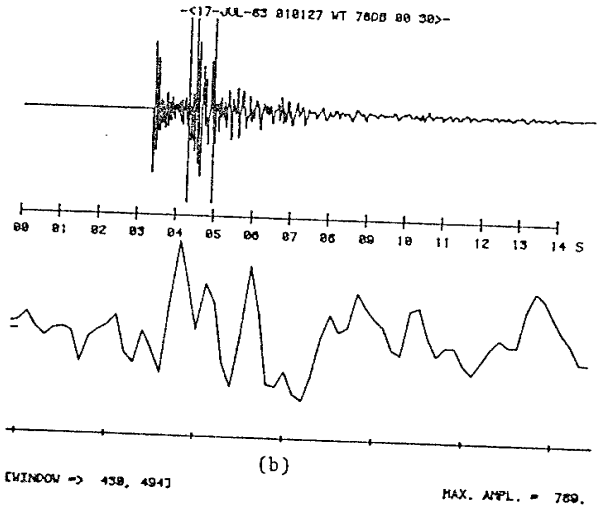
SPECTRAL ANALYSIS

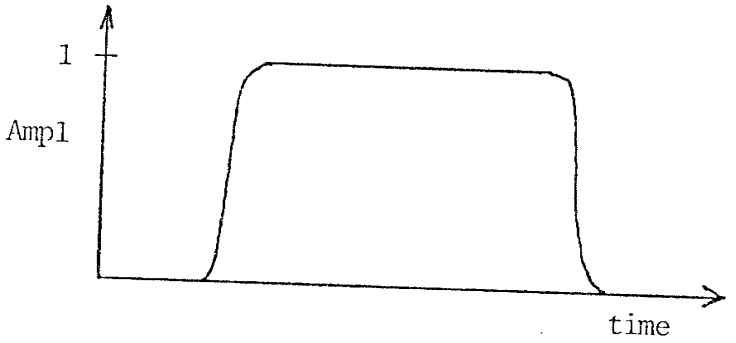
Windowing

Windows are used to select a portion of a time series for analysis. An ideal window should just enclose the oscillations of interest, should not have large sidelobes in the frequency domain, and should provide a sufficiently large number of points for spectral analysis. Windows consisting of 2^N points permit the most efficient computation of spectra with the Fast Fourier Transform (FFT) algorithm.

On the basis of these criteria, the 64-point cosine-tapered rectangular window was chosen for the analysis of the P and S waves, recorded at a sampling rate of 100 sps. For the P phases, the 64-point window encloses the prominent oscillations and a substantial amount of background (Figure 28a). For the S wave, 64 points typically spans the three to five prominent oscillations composing the primary S arrival with a minimum of coda (Figure 28b). The cosine-tapered window shape is shown in Figure 28c. Since the character and duration of these arrivals differ from station to station, as well as for events from different areas, no one window length is perfect. It is necessary, however, to use the same window







(c)

Fig. 28. Windows used for spectral analysis. (a) A typical P wave window before tapering. (b) A typical S wave window before tapering. (c) A cosine-tapered rectangular window. The first and last 10% of the window is smoothed.

length for all events since uncertainties in the Q values are largely a function of the number of spectral estimates, which is (window length)/2 + 1.

See Appendix 2 for panels showing all of the windows used in this study.

Fourier Transforms

After windows have been selected from the digitized seismograms, the time traces are converted to their frequency-domain ($\mathcal{Y}(\omega)$) representations by taking the Fourier transform of the tapered original signal (y(t)) i.e.

$$\mathcal{Y}(\omega) = \int_{-\infty}^{\infty} y(t) \exp(-i\omega t)\, dt, \qquad (2)$$

where t is time and ω is the angular frequency ($2\pi f$). In practice, an IMSL pre-packaged FFT routine is used to decompose the seismograms. The FFT is a computational device used to compute the discrete Fourier transform. Basically, the discrete Fourier transform is a numerical integration over the time window for one frequency:

$$\mathcal{Y}(n) = 1/N \sum_{k=1}^{N} y(k) \exp[-i(2\pi n/N)k], \qquad (3)$$

where N is the number of points in the window, k the time series index (1 to N) and n is the spectral estimate index

(ranges from 1 to N/2+1).

The unsmoothed spectral amplitude estimates, $\mathcal{Y}(\omega)$, as obtained above, are then used to compute Q from the slope of the spectrum. The observed amplitude of a seismic wave on a seismogram can be represented in the frequency domain as the product of several transfer functions:

$$A(\omega) = S(\omega)\ I(\omega)\ G(r)\ St(\omega)\ \exp(-\pi rf/QV), \qquad (4)$$

where f is frequency, $\omega = 2\pi f$, $A(\omega)$ is the observed spectral amplitude for each frequency, $S(\omega)$ is the source spectrum, $G(r)$ is the geometrical spreading, $I(\omega)$ represents the instrumental effects, $St(\omega)$ represents the station response, r is the hypocentral distance, V is the apparent (average) velocity along the raypath and Q is the apparent quality factor.

From (4), Q may be determined by fitting a least squares line to the log amplitude spectrum over some interval in the frequency range 0-50 Hz, providing effects introduced by source, spreading, instrument and station can be removed or accounted for, and providing that velocity and distance are known. Mathematically, this is equivalent to dividing (4) by the appropriate transfer functions and finding apparent Q from the slope of the best fit line to the spectrum, i.e.

$$A(\omega)_{corr} = A(\omega)/[S(\omega)I(\omega)G(r)St(\omega)]. \qquad (5)$$

Then,

$$A(\omega)_{corr} = A_o \exp(-\pi rf/QV), \qquad (6)$$

where A_o is a constant. Taking the $\log_e$ of equation (6) yields

$$\log_e A(\omega)_{corr} = \log_e A_o - (\pi r/QV)f, \qquad (7)$$

which is the equation of a straight line with slope = $-\pi r/QV$. Thus,

$$Q = -\pi r/(V \text{ slope}). \qquad (8)$$

Figures 29 through 31 show how Q is determined from one event. Figure 29 shows the time window. Figure 30 depicts the velocity spectrum (uncorrected for instrument) and Figure 31 shows the corrected log amplitude spectrum fit with a least squares line. There is a 95% probability the true line lies within the hyperbolic envelope.

Each of the transfer functions mentioned above will be discussed in detail in the next section. Only events which produced relatively high correlation coefficients (> 0.80) were used to define the Q structure for the Socorro area. In these cases, the high correlation coefficients showed that the linear model explained a large degree of the variability in the data and that Q for most of these earthquakes is essentially frequency independent.

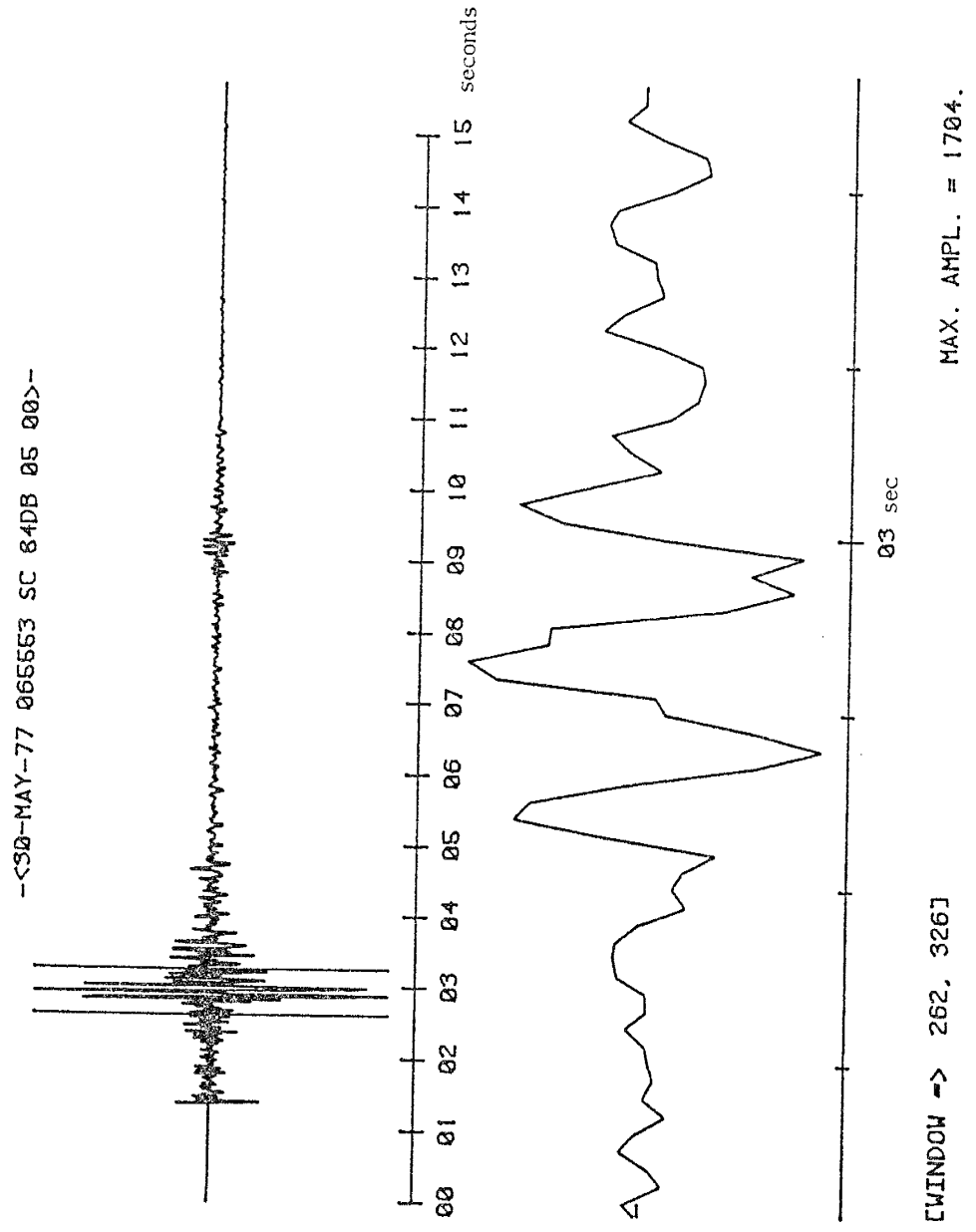


Fig. 29. S wave window for the spectra shown in Figures 30 and 31.

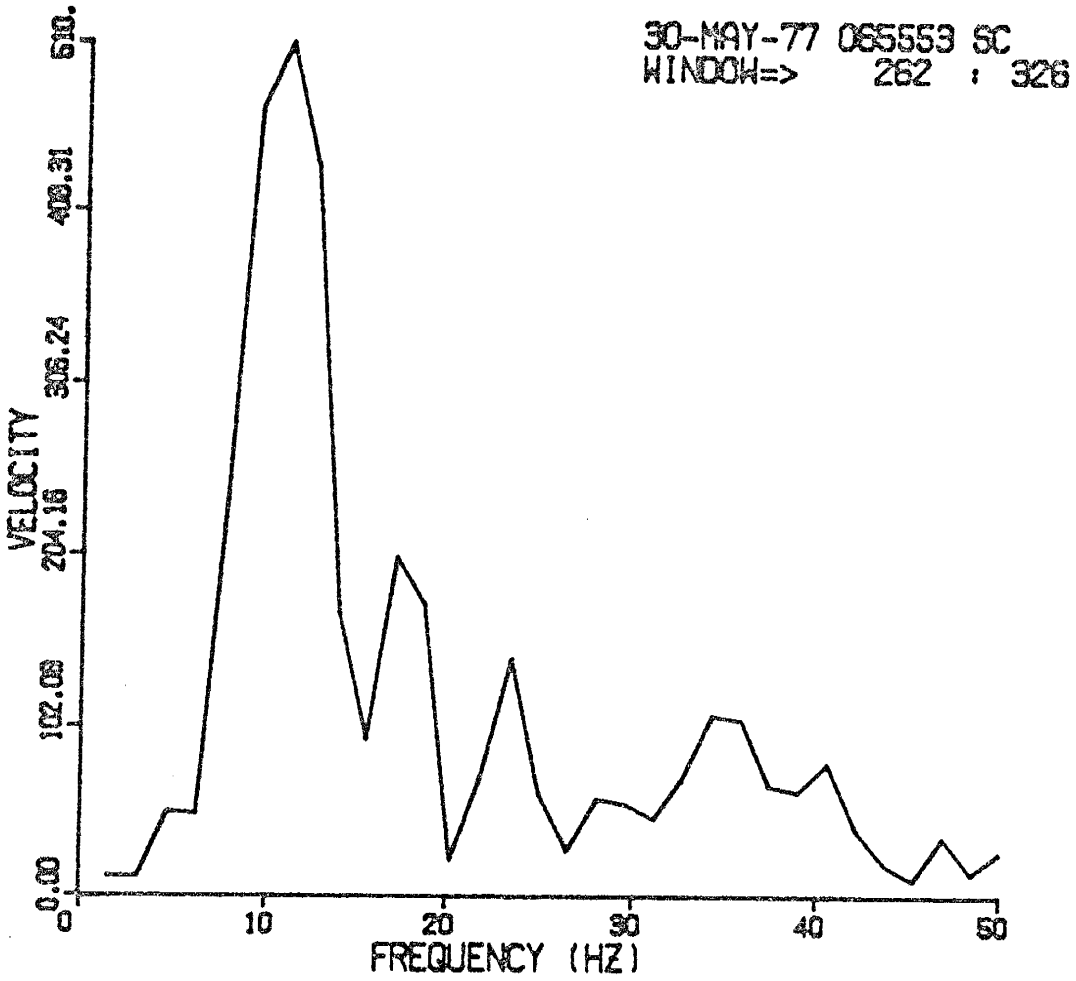


Fig. 30. Velocity spectrum for the S window shown in Figure 29.

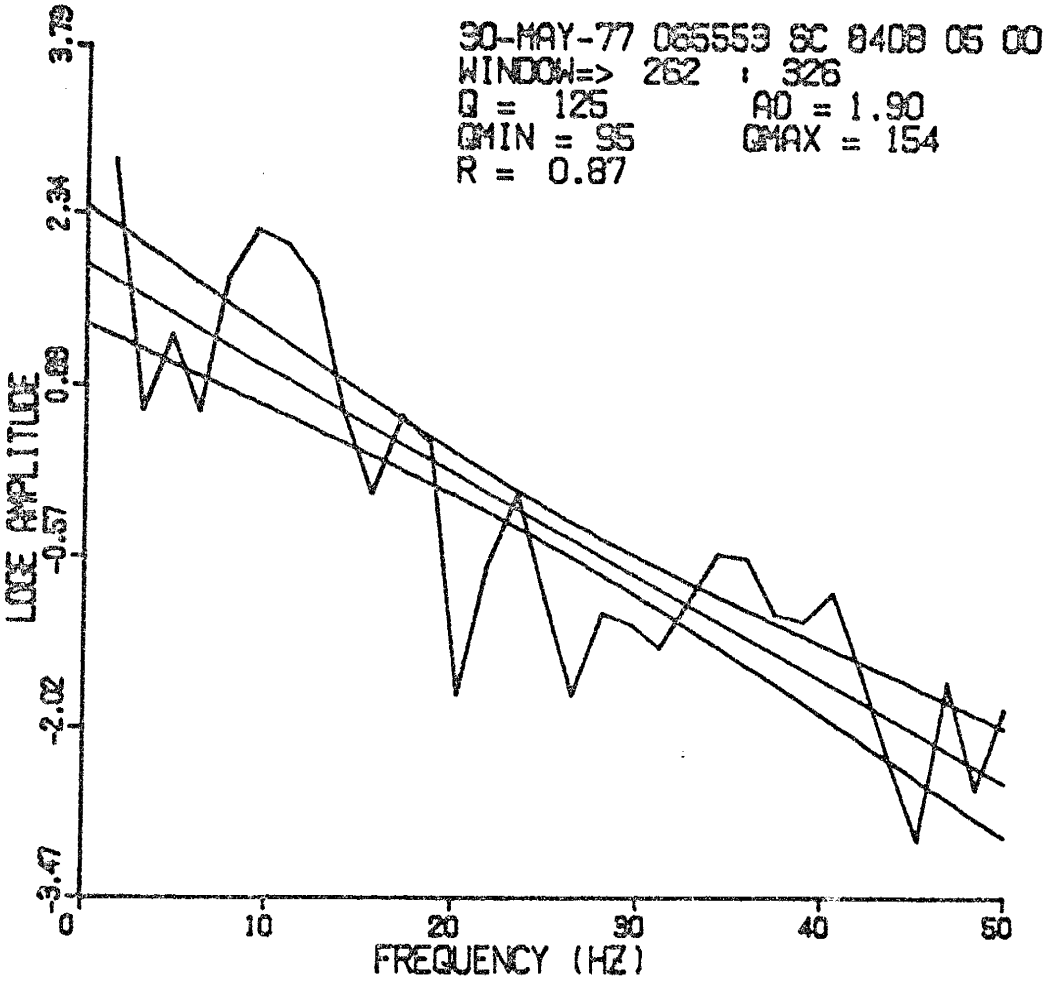


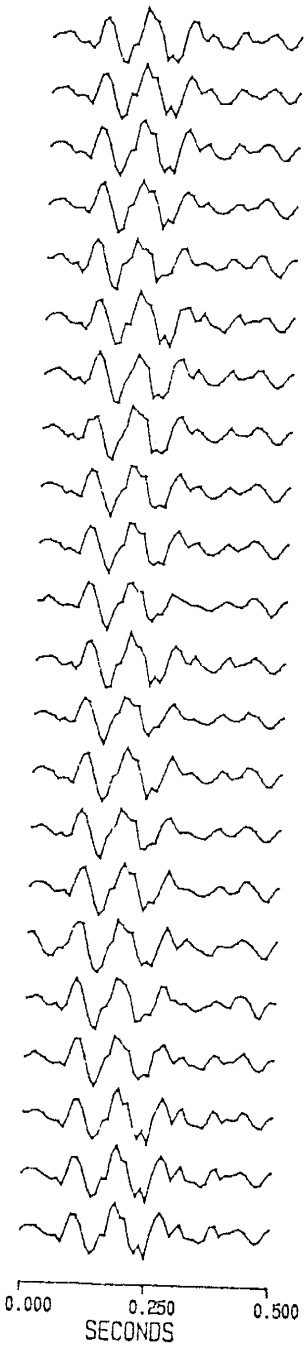
Fig. 31. Least squares fit for the corrected spectrum of the window shown in Figure 29. The hyperbolic envelope is the 95% confidence interval for the true line.

DECONVOLUTION

Source

It is generally necessary to remove the source spectrum from the observed spectrum if reliable Q values are to be computed. As the following discussion shows, a flat source spectrum over the frequency range of interest (0-50 Hz) may be assumed for the microearthquakes used in this study.

P and S waveforms from microearthquakes occurring in the same swarm in the Socorro area are often identical, even though large differences in amplitude may exist. Figure 32 shows a panel of identical S waves from one swarm in 1977. These events span a magnitude range of -0.9 to 0.3, or about a factor of 10 in amplitude. Sanford et al. (1983c) have documented this duplication for P waves from events with magnitudes less than 1.2 and for S waves from events with magnitudes less than 1.0 (Sanford et al., 1983a; A. Sanford, personal communication, 1984). All of the shocks used for Q estimates in this study lie below magnitude 1.0. This duplication shows that the frequency content of P and S waveforms is not influenced by the event strength. If the source model of Brune (1970) is adopted, this implies that these microearthquakes have corner frequencies higher than any frequencies appearing in the



Trace	Header	Ampl	XCorr
	30-MAY-77 065429	140	0.90
	30-MAY-77 065437	111	0.95
	30-MAY-77 065553	1704	1.00
	30-MAY-77 070053	646	0.94
	30-MAY-77 070207	242	0.85
	30-MAY-77 070327	147	0.93
	30-MAY-77 070339	1008	0.87
	30-MAY-77 070757	1926	0.94
	30-MAY-77 071339	613	0.97
	30-MAY-77 071533	613	0.98
	30-MAY-77 071715	252	0.95
	30-MAY-77 072805	124	0.93
	30-MAY-77 073515	155	0.95
	30-MAY-77 080257	203	0.97
	30-MAY-77 091627	417	0.93
	30-MAY-77 102733	150	0.96
	30-MAY-77 123511	406	0.90
	02-JUN-77 064555	130	0.90
	02-JUN-77 065349	177	0.96
	02-JUN-77 065523	368	0.96
	02-JUN-77 114205	179	0.97
	02-JUN-77 120709	158	0.98

Fig. 32. S windows from one swarm in May-June, 1977 recorded at SC. The header includes the event date and time followed by the amplitude and the cross-correlation coefficient (normalized with respect to the third event).

spectra (Figure 33). In the Socorro area, strong upper crustal attenuation removes the high frequency waves which would be influenced by a rolloff in the source spectrum.

This conclusion is also supported by identical first half cycles for P waves from swarms during 1977 and 1983 (Sanford et al., 1983c) which span a magnitude range from -0.6 to 1.2. In this case the width of the first half cycle is only influenced by the path and instrumental response. Frankel and Kanamori (1983) have also observed a constant first half cycle for small foreshocks and aftershocks along the San Andreas fault zone in Southern California.

It does not appear that the frequency content of emitted radiation is a function of azimuth for these events. Swarm events in which the focal plane is shifting, as evidenced by a large variation the in P/S amplitude ratios, have identical waveforms. Several of the windows shown in the panel in Figure 32 are from events which exhibit large differences in their P/S amplitude ratios. Also, no systematic distortion of the spectral slope has been observed for events with similar focal mechanisms recorded at different azimuths at one station.

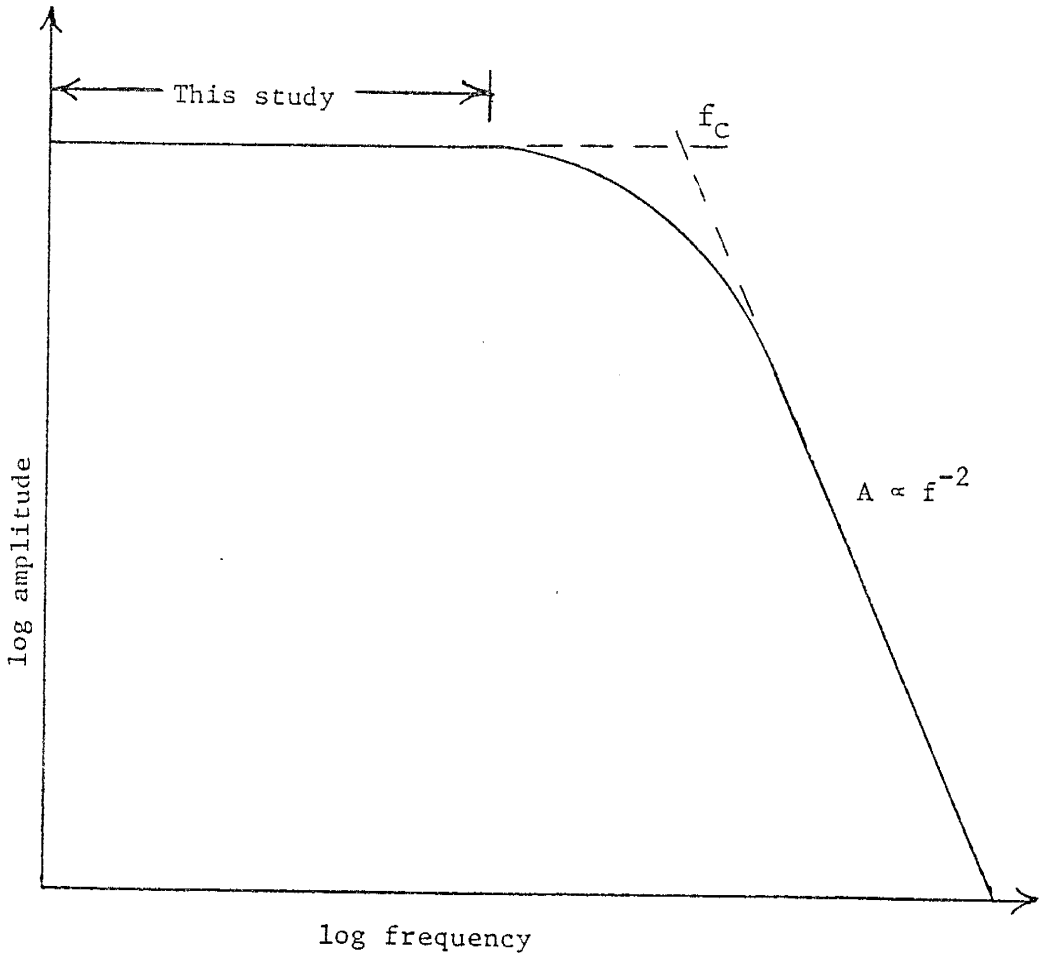


Fig. 33. Source spectrum proposed by Brune (1970) for a simple fracture. Duplication of events used in this study over the magnitude range -0.9 to 1.0 imply these events fall below the corner frequency (f_c).

Instrumental Effects

The frequency response of the DR100 system is shown in Figures 34 and 35. The system includes a Mark Products L4C vertical component seismometer, a DR-100 amplifier and two different modes of filtering. The mechanical response of the seismometer was assumed to be flat from the natural frequency to beyond the Nyquist frequency for the 100 sps sampling rate (50 Hz). Although there is some data to suggest that L4C seismometers have an abnormally low response at frequencies of about 25 Hz (L. Jaksha, personal communication, 1984), most spectra used in this study did not exhibit a sharp decline at 25 Hz. Even if a "hole" did occur in the spectra at this frequency, the reduction in Q would be minor since spectral estimates over the range 0-50 Hz are being fit with a least squares line. The system response curves shown are based on manufacturer's specifications and tests carried out by the Seismology Group at New Mexico Tech. See Appendix 1 for a detailed discussion of the calibration procedure.

These curves were digitized from analog test data and consist of 50 points (one response value per Hertz over the frequency range 0-50 Hz). The earthquake wave spectra were corrected by simply dividing each spectral estimate by an interpolated response value from the curves above.

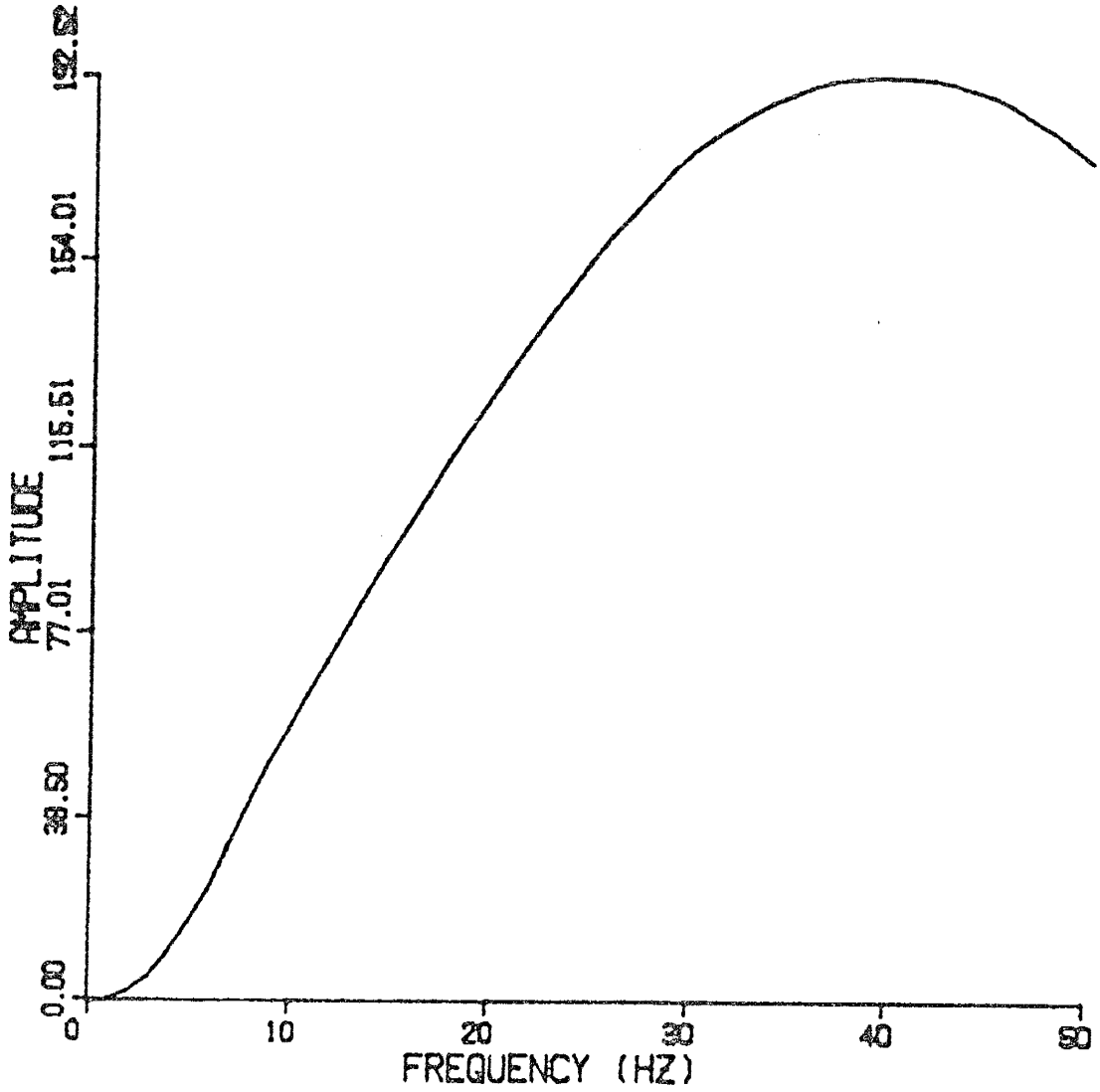


Fig. 34. Response curve for the DR100 with a 5 Hz low-cut filter.

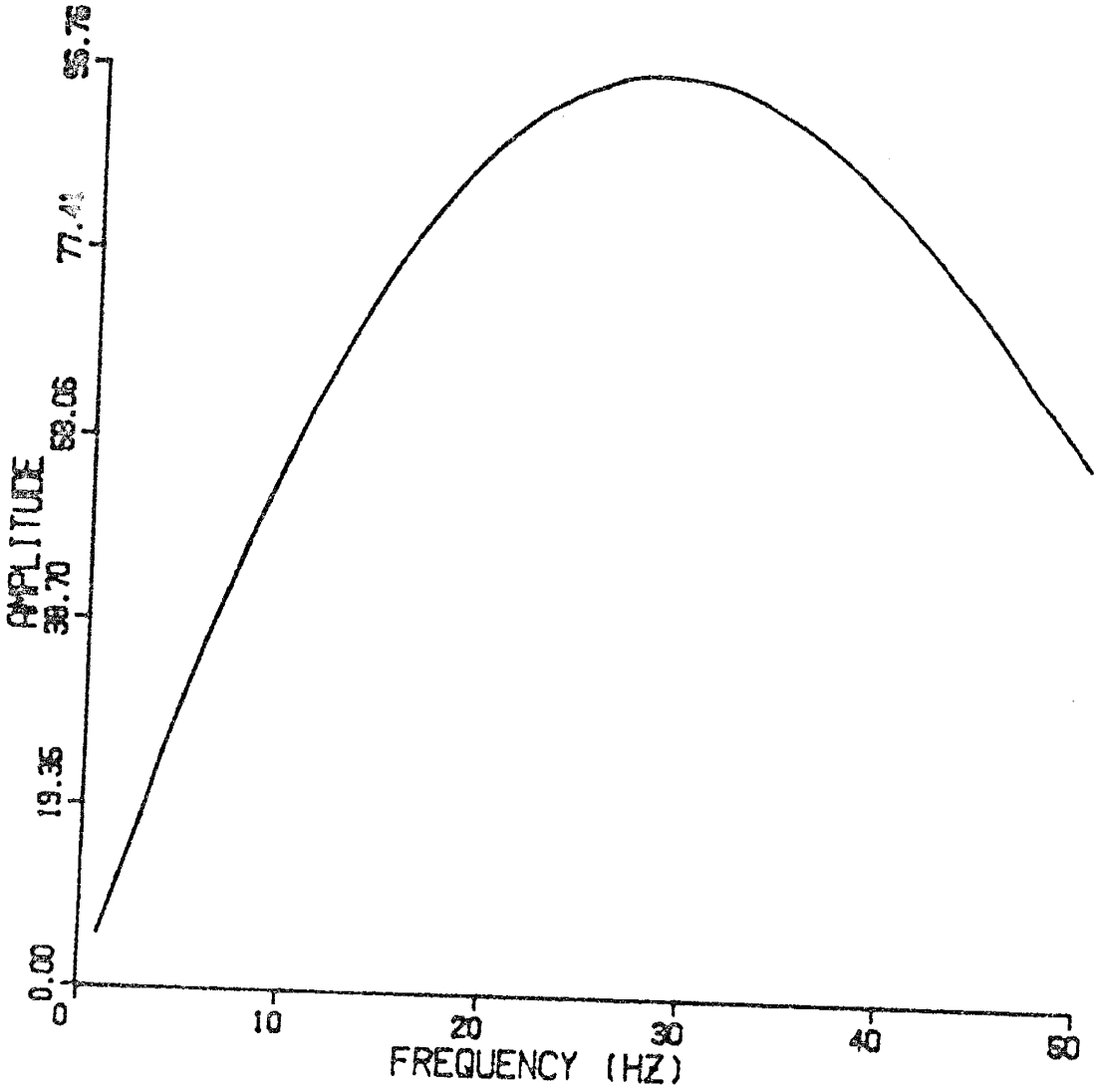


Fig. 35. Response curve for the DR100 with a 30 Hz high-cut filter.

Geometrical Spreading and Scattering

Geometrical spreading is independent of frequency and thus only affects the level of the spectrum, not the spectral slope. No correction for spreading was made, and the effects of scattering are incorporated into apparent Q.

Station Effects

Probably the most complicated transfer function to calculate is the effect of inhomogeneous incompetent material directly beneath the station. Two observations suggest that near-surface material exerts a strong influence on the character of seismic waves recorded at the surface:

(1) Surficial material has a lower velocity than basement rocks in the Socorro area and thus seismic waves spend a disproportionate share of their travel time in near-surface materials. Ward (1980) has shown near-surface rocks are the principal cause of laterally varying time delays for incoming seismic signals recorded at the seismic stations in the digital array.

(2) Small changes in receiver location lead to large changes in the character of P and S waveforms, whereas small changes in hypocenter location have virtually no effect on these waveforms (A. Sanford, personal communication, 1982).

Station effects can be divided into two broad categories. First, phases that have been multiply reflected can interfere with the primary waveform and lead to the enhancement of certain frequencies and the attenuation of others. Second, incompetent near-surface material acts as a low-pass filter. As much as 90% of the observed attenuation for earthquakes within 10 km may be due to absorption by surficial material (Frankel, 1982).

The first effect may be identified by a periodic ripple in the spectrum. This ripple arises from a time lag between the primary and interfering waveform. Analytically, this can be expressed as

$$Y(t) = X(t) + aX(t-s) \tag{9}$$

where X(t) is the original waveform, Y(t) is the observed waveform, a is a damping coefficient, and s is the time lag for the interfering waveform.

The $\log_e$ spectrum of Y(t) is composed of the spectrum of X(t) and a superimposed ripple:

$$\log_e \mathcal{Y}(\omega) = 2a\cos(\omega s) + \log_e \mathcal{X}(\omega). \tag{10}$$

Peaks or troughs in the ripple will then occur at frequencies of $f = n/2s$ and nodes at frequencies of $f = n/4s$. The cepstrum, or a spectrum of the spectrum (amplitude versus time), will show this periodicity as a peak corresponding to the delay time.

Figure 36b shows periodic oscillations in a spectrum from station SC. Figure 36c shows the cepstrum and Figure 36d shows the spectrum with part of the periodicity removed. The fit improves slightly for the filtered spectrum. This improvement, however, is felt to be too small to justify similar bandpass filtering of each spectrum.

Multiply reflected waves beneath station SC are probably interfering with the direct arrivals to produce this ripple in the seismogram. SC lies on top of a pile of cauldron deposits $\sim$1.7 km thick (Osburn, 1978) which may be the source of these reflections.

Few interfering reflections are as clear as this. Since many of the stations rest on fractured, faulted, highly inhomogeneous material, complex multiple interfering reflections abound, leading to different ripples being superimposed on the spectrum. Such multiply reflected waves are a special case of "scattered waves". Scattering generally acts like a low pass filter, with the spectral slope depending on the size distribution of the scatterers. Since all sizes of scatterers exist in this area, it is impossible to formulate an expression to correct for this. The effects of scattering are incorporated into apparent Q.

From the experimental and field data, it appears that Q near the earth's surface is quite low when compared to Q below 1 or 2 km (Gordon and Davis, 1968; Tittmann, 1977). This reflects the incompetent nature of near-surface

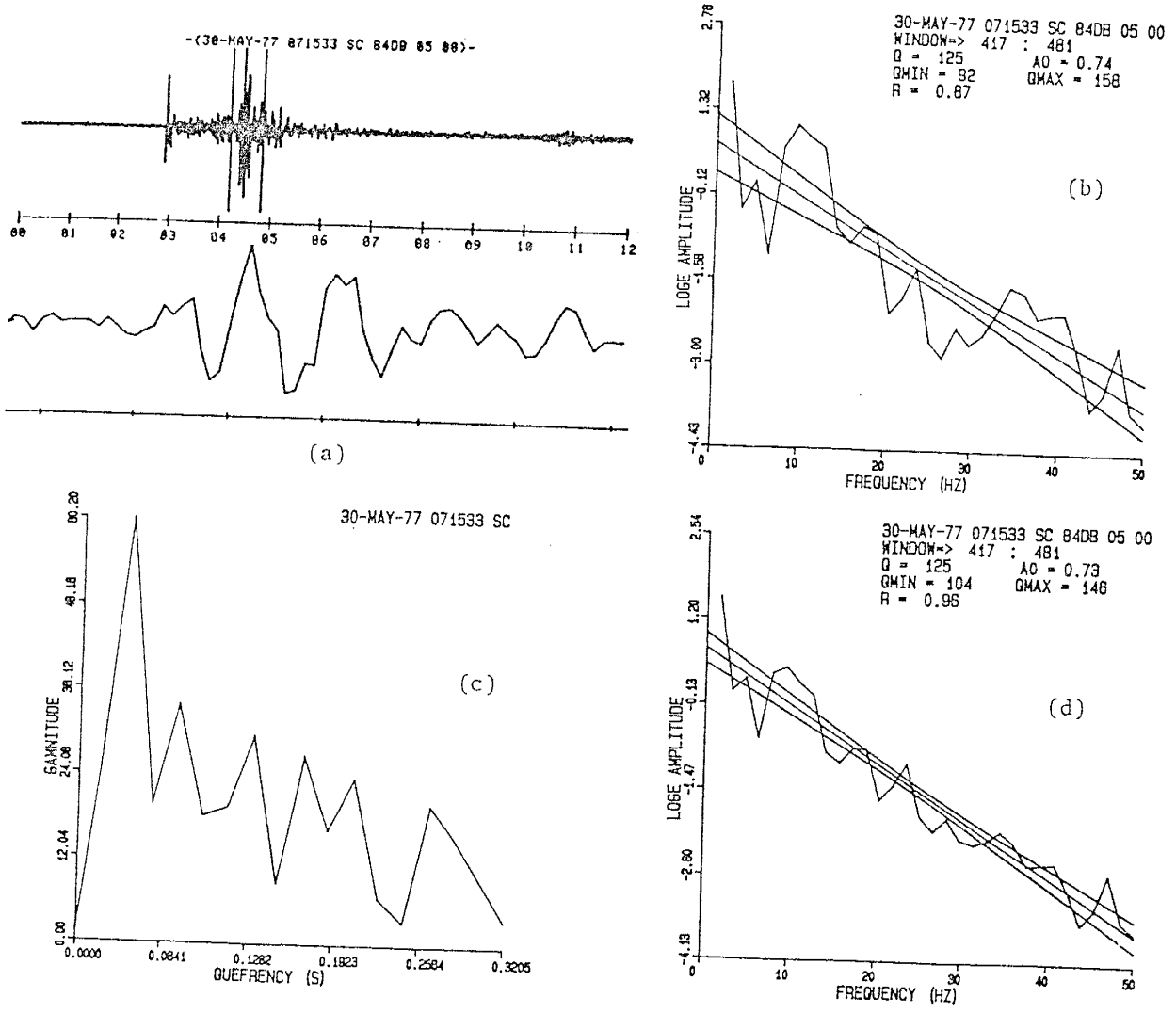


Fig. 36. Identifying and removing a reverberation. (a) The S wave window chosen for analysis. (b) The least squares fit to the spectrum of (a). (c) The cepstrum for (a). (d) The improved fit after the spectrum had been filtered with a 0.03-0.05 s band-rejection filter.

material. A crucial parameter to be discussed in the interpretation section is the magnitude of the near-surface Q which must be known if the average upper-crustal Q is to be properly computed.

ERROR ANALYSIS

Errors for all Q values were estimated from a classical error analysis of (8). It should be noted that the analysis here only considers unsystematic (or random) errors. The uncertainty in the Q estimates may be much larger if systematic errors exist in the data or calculations.

Errors in slope, event distance and velocity affect the cumulative error in each Q estimate. In general,

$$\sigma^2(u) \approx (\partial u/\partial x_i)^2 \sigma^2(x_i), \tag{11}$$

where $u(x_i)$ is a function of i independent variables, $\sigma(u)$ is the standard deviation of u, and $\sigma(x_i)$ represents the standard deviation of each variable. In the analysis that follows, the standard deviations of the means of each parameter will be used to compute the standard deviation for the mean Q for each event.

From (8), $Q = -\pi r/mV$. If we let $u(x_i)$ be Q, then from (11),

$$\sigma^2(Q) \approx (\partial Q/\partial r)^2 \sigma^2(r) + (\partial Q/\partial m)^2 \sigma^2(m) + \tag{12}$$
$$+ (\partial Q/\partial V)^2 \sigma^2(V),$$

and

$$\sigma(Q) \approx \pi/(mV) \sqrt{\sigma^2(r) + r^2\sigma^2(m)/m^2 + r^2\sigma^2(V)/V^2}, \qquad (13)$$

where r = distance, V = apparent velocity, and m is the spectral slope.

Errors in hypocentral distance were computed two ways. For located events, HYPO71 computed uncertainties from the final adjustment of the hypocenter (see Lee and Lahr, 1975). These are roughly equivalent to 2 standard deviations (s.d.) for the mean hypocenter location (J.C. Lahr, personal communication, 1984). For unlocated events, (11) was applied to equation (1),

$$r = [1.37(S-P) - t_{sta}]\, Vp,$$

with a 0.1 s error (1 s.d.) assumed in reading arrival times:

$$\sigma^2(r) \approx (1.37)(S-P)^2\sigma^2(Vp)+(1.37)Vp^2\sigma^2(S-P)+Vp^2\sigma^2(t_{sta}). \qquad (14)$$

$\sigma^2(r)$ is then used in (13) above.

The error in slope, $\sigma(m)$ can be computed from standard linear regression formulas such as those found in Volk (1956). Note that the error in individual spectral estimates contributes to the error in the slope. Any periodic ripple in the spectrum will also contribute to this error. If we ascribe much of the undulation in the spectrum to interfering multiple arrivals, we might expect that these crests and troughs would cancel each other out over a broad

range of frequencies. Thus the least squares line may be an excellent average fit even though the undulations degrade the statistical measure of this fit, namely the correlation coefficient and the standard deviation of the slope.

The error in the apparent velocity was obtained from an error analysis of

$$V = r/[D/V_1+(r-D)/V_2], \tag{15}$$

where V is the apparent velocity, r the event distance, D the distance traveled through the LVL, V_1 the LVL velocity, and V_2 the half-space velocity. A discussion of the velocities chosen for this analysis, and the uncertainty in these velocities, is presented in the next section. Errors in D were found from errors in the station delays (see next section), errors in V_1 were assumed to be 0.1 km/s (1 s.d.) and errors in V_2 0.05 km/s (1 s.d.). In general, $\sigma(V)$ was found to be less than 0.06 km/s.

For a measure of the relative importance of each of these error terms, consider an "average" microearthquake recorded at a distance of 10 km:

$$\sigma^2(r) \approx 1.0 \text{ m}^2,$$

$$r^2\sigma^2(m)/m^2 \approx 2.3 \text{ m}^2,$$

and

$$r^2\sigma^2(V)/V^2 \approx 0.1 \text{ m}^2.$$

Since each of the above terms contribute equally to the total error in Q (as shown in (13)), errors in slope are the most important, followed by errors in hypocenter location and finally errors in velocity.

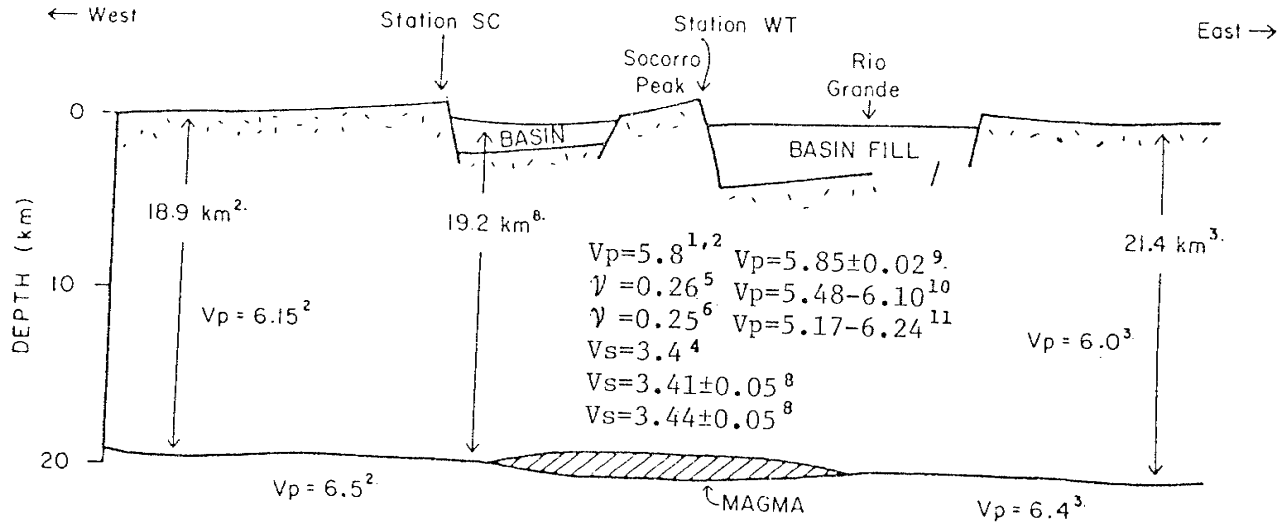
RESULTS AND INTERPRETATION

Velocity Models for the Socorro Area

In (8) above, it is necessary to know the average seismic velocity along a raypath to compute apparent Q. This section will summarize the data currently available on subsurface seismic velocities in the Socorro region of the Rio Grande rift.

Rinehart and Sanford (1981) provide an excellent summary of velocities and Poisson's ratios for the upper-crust in the Socorro area. Figure 37 shows one of their diagrams supplemented by results obtained by Ward et al. (1981).

Velocities for near-surface rocks were obtained from local explosions (Ward, 1980), refraction studies done in Wood's Tunnel near Socorro Peak (A. Sanford, personal communication, 1984), refraction lines along the east side of the Rio Grande rift (Olsen et al., 1979), and by calculating the average velocity of reflected waves passing through Phanerozoic rocks along COCORP Line 1A (Rinehart, 1979). These studies indicate a P wave velocity of 3.4 $\pm$ 0.1 km/s (1 s.d.) and an S wave velocity of 2.0 $\pm$ 0.1 km/s (1 s.d.) are reasonable average velocity estimates for near-surface rocks (depth < 2 km) beneath the seismic stations used in this study. Ward et al. (1981) found that



References

1. Sanford et al. (1973)
2. Toppozada and Sanford (1976)
3. Olsen et al. (1979)
4. Keller et al. (1979)
5. Caravella (1976)
6. Fender (1978)
7. Rinehart (1979)
8. Rinehart and Sanford (1981)
9. Ward et al. (1981)-- Average velocity to average depth of hypocenters
10. Ward et al. (1981)-- Velocity in the range 0-4 km
11. Ward et al. (1981)-- Velocity in the range 4 km-average depth of hypocenters

Vp = P-wave velocity in km/s
Vs = S-wave velocity in km/s
ν = Poisson's ratio

Fig. 37. A composite geophysical cross section of the central Rio Grande rift at Socorro, New Mexico, adapted from Rinehart and Sanford (1981). Vertical exaggeration is about two.

these near-surface low velocity rocks led to different time delays for incoming waves recorded at different stations. These time delays can be ascribed to varying thicknesses and types of low velocity material beneath each of the stations.

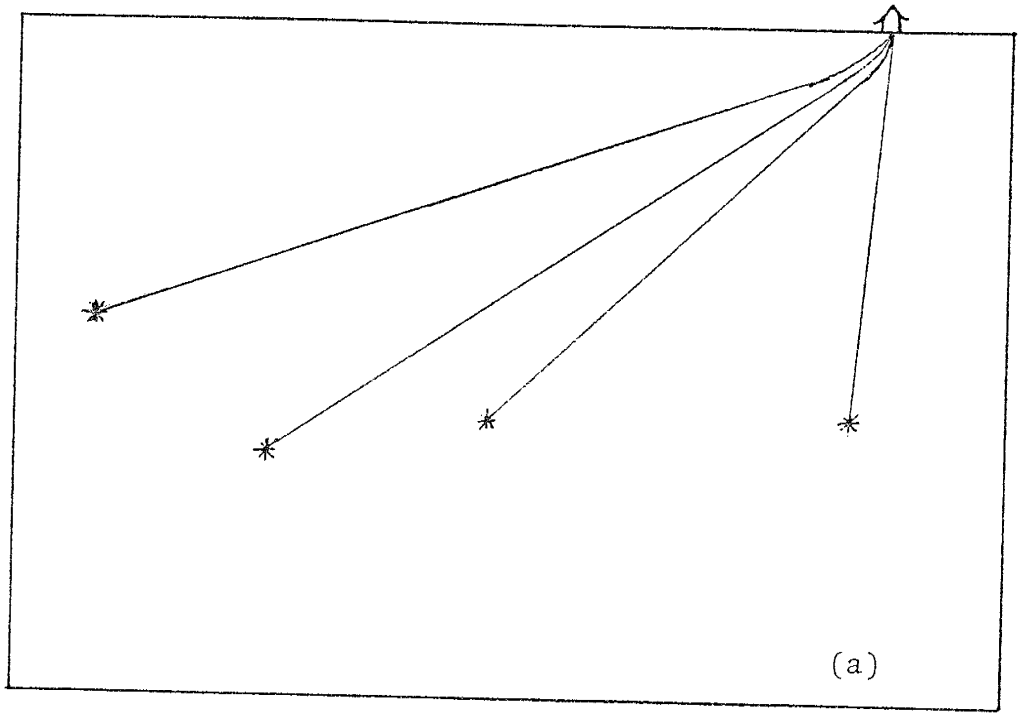
The average P and S wave velocities to be used for the half-space come from the numerous studies probing the upper 19 km of crust in the Socorro area as shown in Figure 37. In this study, a P wave velocity of 5.85±0.02 km/s (1 s.d.) (Ward et al., 1981) will be used with an S wave velocity of 3.41±0.05 km/s (1 s.d.) (Rinehart and Sanford, 1981). The standard deviations quoted in this section refer to the s.d. of each mean velocity value.

As Figure 37 shows, the P wave velocities are sharply higher below 19 km. None of the first arrivals for local events (Δ = 0-45 km) penetrate this deep. However, the region below 19 km does have to be considered in computing Q for regional events.

Near-surface Low Velocity Layers (LVL)

All of the stations in the Socorro array have station time corrections which reflect the time delay for incoming waves passing through low-velocity near-surface rocks near the seismic stations (Figure 38). The station corrections can be expressed approximately as

$$t_{sta} \approx D/V_1 - D/V_2, \qquad (16)$$



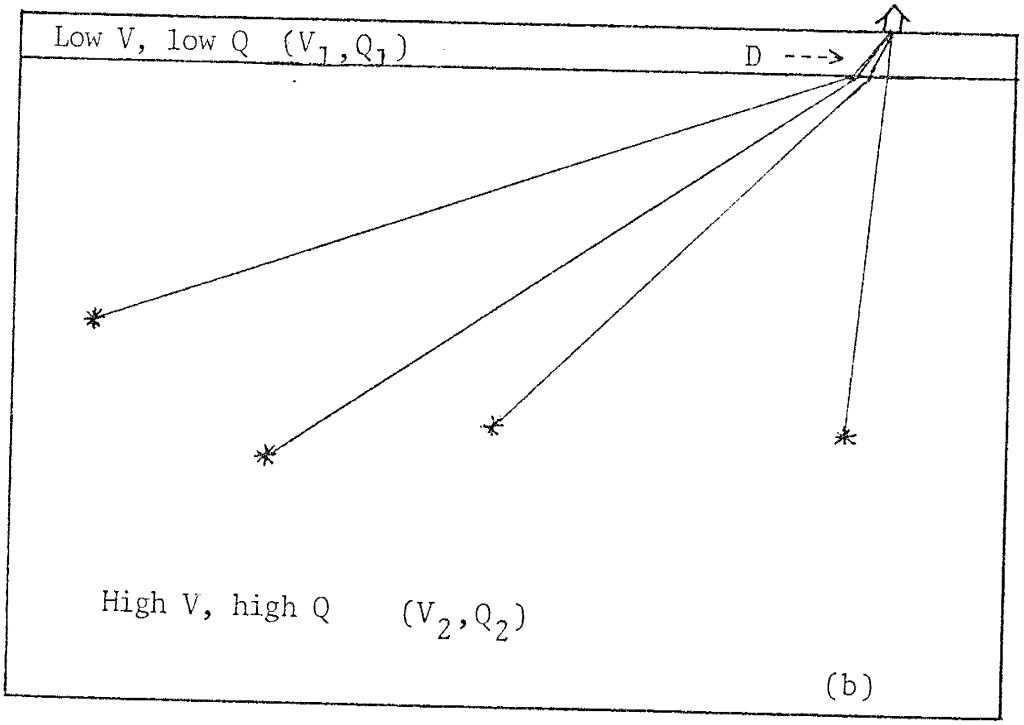


Fig. 38. Idealized microearthquake raypaths for events recorded by a station on the surface. (a) The actual raypaths for a rapid increase in velocity with depth near the surface. (b) The layer over a half-space model used to represent (a) in this study.

where t_{sta} = the observed station correction, D = the distance traveled through the LVL, V_1 = the velocity of the LVL, and V_2 = the velocity of the half-space. Note that D represents the average slant distance for waves passing through the low velocity layer, not its thickness. D may be computed by rearranging (16):

$$D = t_{sta} [1/V_1 - 1/V_2]^{-1}. \quad (17)$$

An estimate of the LVL thickness may be obtained by multiplying D by the cosine of the angle of incidence. 30^o is a good average value for the angle of incidence of incoming waves at most stations (A. Sanford, personal communication, 1984). Thus,

$$\text{thickness} \approx D \cos 30^o \approx 0.866\ D. \quad (18)$$

Uncertainties in D may be computed from a classical error analysis of (17). If 0.02 s represents the average error (1 s.d. of the mean station correction) in t_{sta} (R. Ward, personal communication, 1984), the error in each station thickness will be about 0.15 km (1 s.d. of the mean thickness).

Table 4 lists station delays, LVL thicknesses, and uncertainties for all stations at which digital recorders were deployed. The second column in Table 4 lists the station time corrections obtained by Ward (1980). The third column lists the station corrections adjusted for relative

TABLE 4

STATION CORRECTIONS AND THICKNESSES OF LOW VELOCITY LAYERS

STA	t_{sta} (Ward, 1980)	t_{corr}	t_{norm}	thick.	2 s.d.
CC	-0.15 s	-0.17 s	0.00 s	0.0 km	0.0 km
CM	0.13	0.11	0.28	2.0	0.3
DM	-0.01	-0.01	0.16	1.1	0.3
FM	0.00	0.00	0.17	1.2	0.3
IC	0.08	0.04	0.21	1.5	0.3
SC	0.15	0.05	0.22	1.6	0.3
SNM	-0.04	-0.04	0.13	1.0	0.3
WT	-0.11	-0.12	0.05	0.3	0.3

$t_{corr} = t_{sta} - \Delta Elev/(5.85\ km/s)$

$t_{norm} = t_{corr} + 0.17\ s$

elevation differences between the stations, normalized to SNM, the lowest station in the array. The fourth column lists these corrections normalized to station CC, the station with the smallest elevation corrected delay in the local array. The fifth column lists the estimated thickness of low velocity material beneath each station computed from these normalized corrections with equations (17) and (18). A P wave velocity of 3.4 km/s was used with an angle of incidence of 30^{o}. The sixth column lists the uncertainties in the LVL thicknesses (2 s.d.).

Note that in computing apparent Q, the average velocity for an earthquake wave depends on the relative fraction of the raypath in the LVL material i.e. the apparent velocity V may be found from

$$V = r/[D/V_1+(r-D)/V_2], \qquad (19)$$

where r is the hypocentral distance.

Q as a Function of Event Distance

Figures 39 through 46 show apparent Qp and Qs plotted as a function of hypocentral distance for all of the stations in the Socorro array. Error bars for Q and distance represent 2 s.d. for the mean estimates. Thus, excluding possible systematic errors, there is a 95% certainty the Q and distance estimates lie within the error bars. Only events with errors in Q less than 50 and with

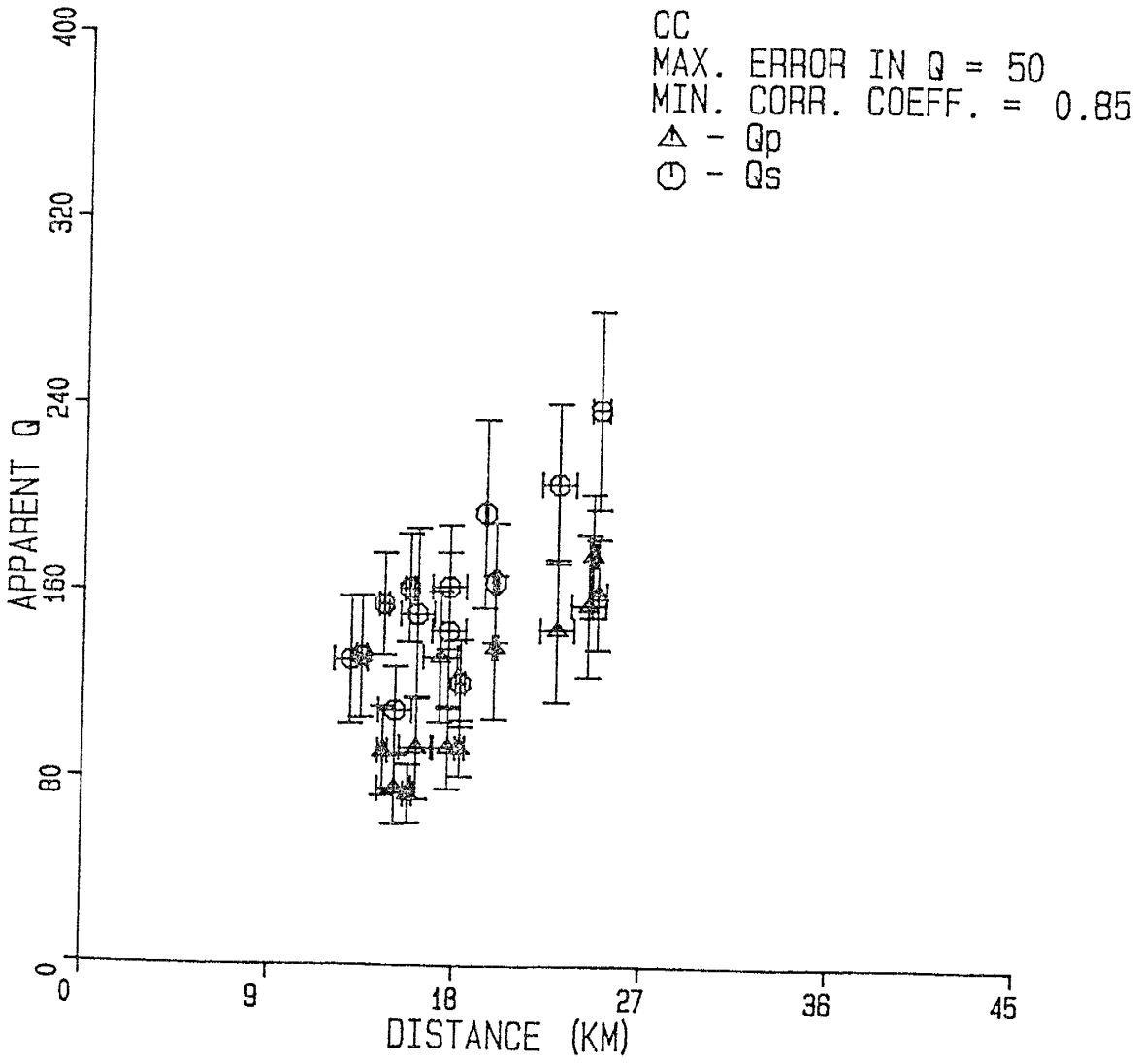


Fig. 39. Apparent Qp and Qs for events recorded at CC plotted as a function of hypocentral distance. Error bars represent 2 s.d. Events shown here have errors in Q less than 50 and spectral fit correlation coefficients greater than 0.85.

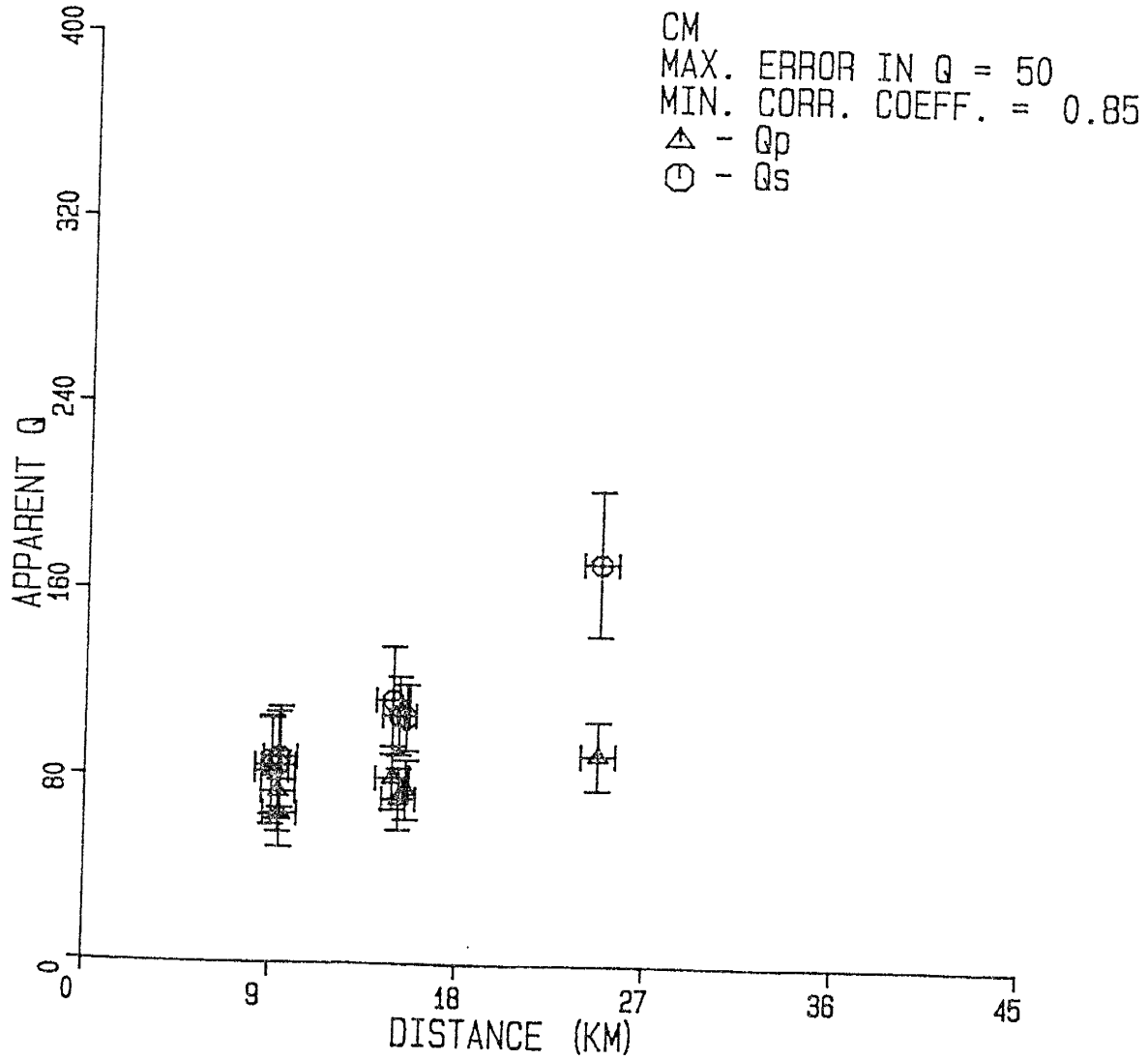


Fig. 40. Apparent Qp and Qs for events recorded at CM plotted as a function of hypocentral distance. Error bars represent 2 s.d. Events shown here have errors in Q less than 50 and spectral fit correlation coefficients greater than 0.85.

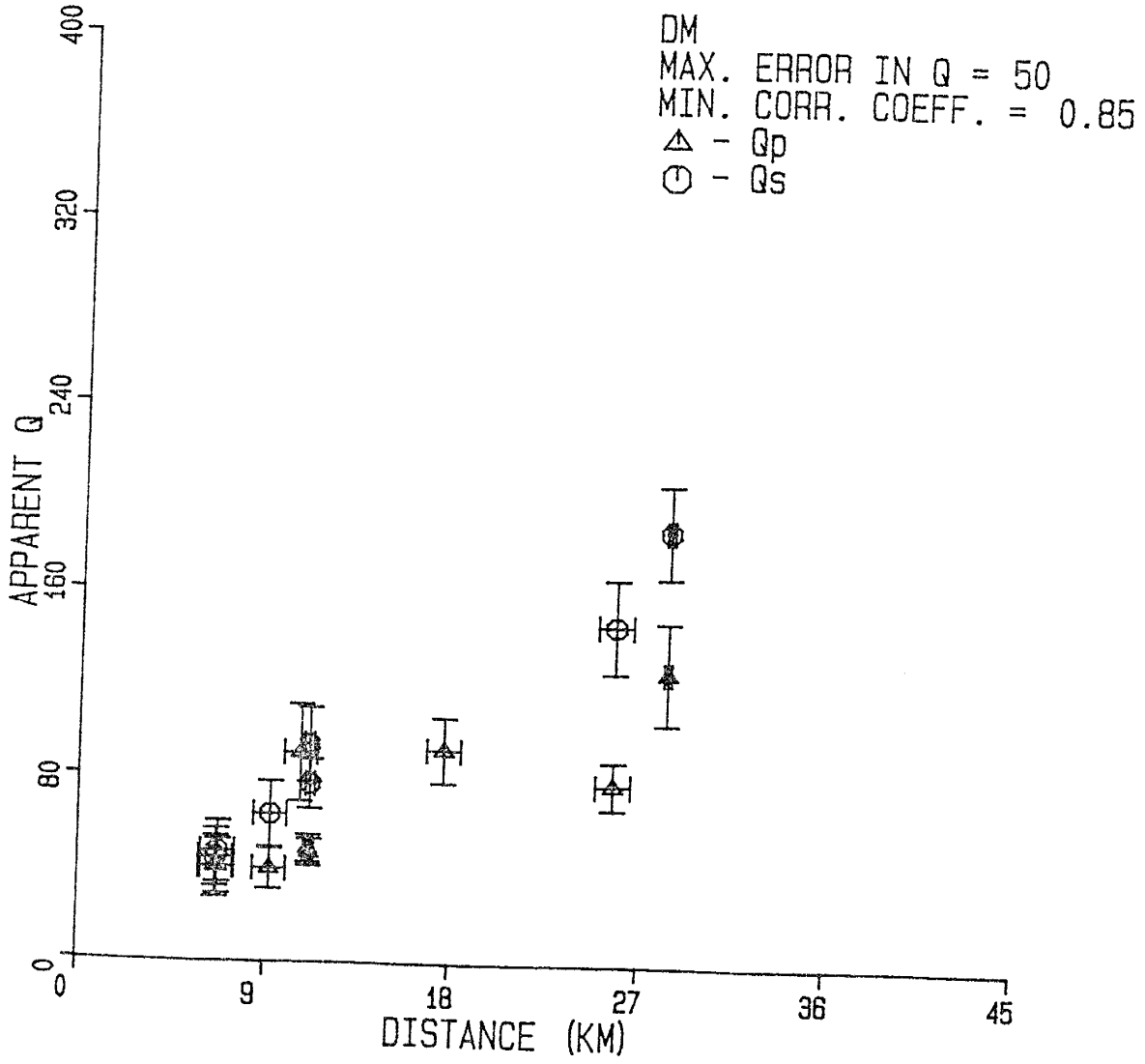


Fig. 41. Apparent Qp and Qs for events recorded at DM plotted as a function of hypocentral distance. Error bars represent 2 s.d. Events shown here have errors in Q less than 50 and spectral fit correlation coefficients greater than 0.85.

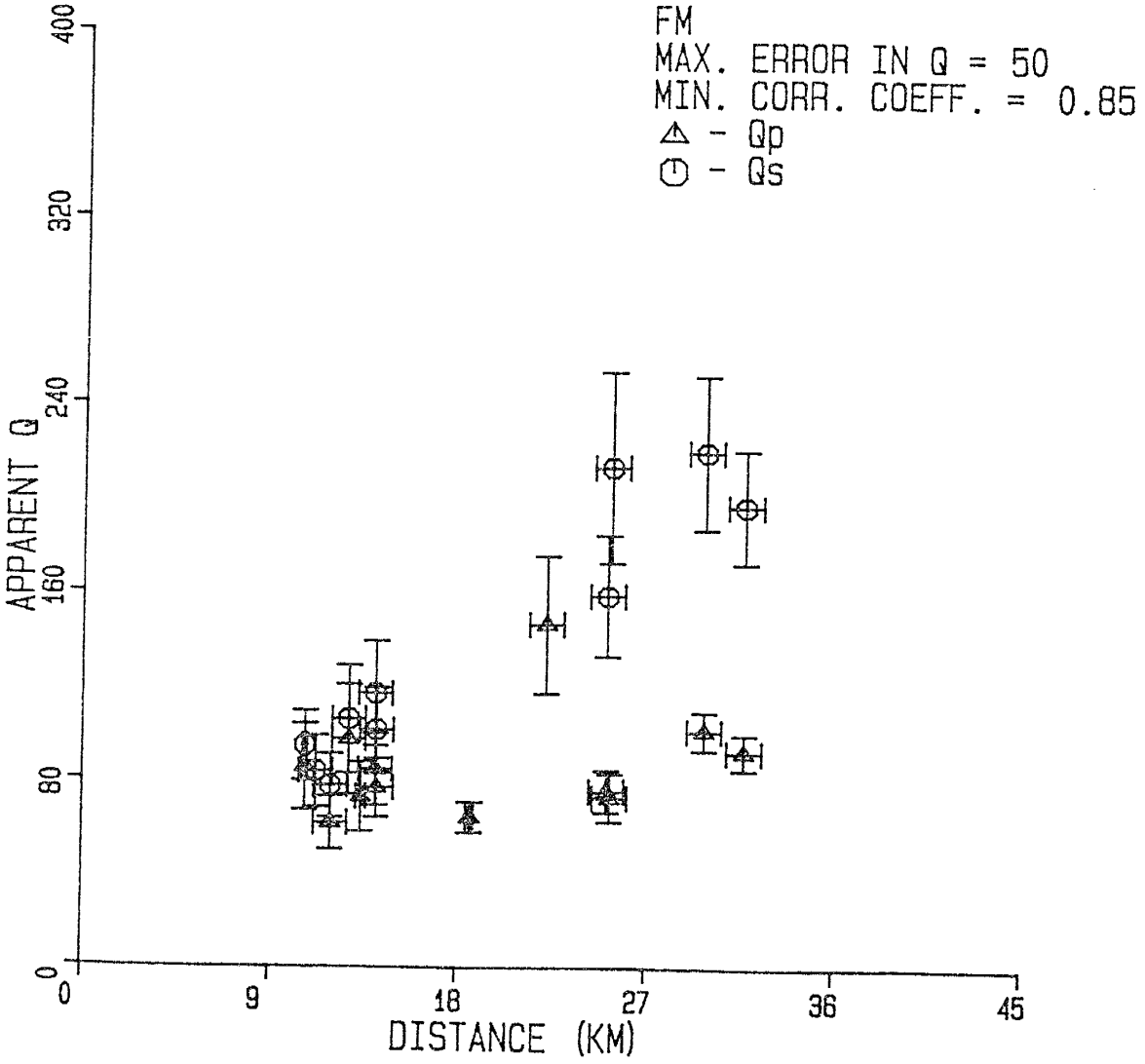


Fig. 42. Apparent Qp and Qs for events recorded at FM plotted as a function of hypocentral distance. Error bars represent 2 s.d. Events shown here have errors in Q less than 50 and spectral fit correlation coefficients greater than 0.85.

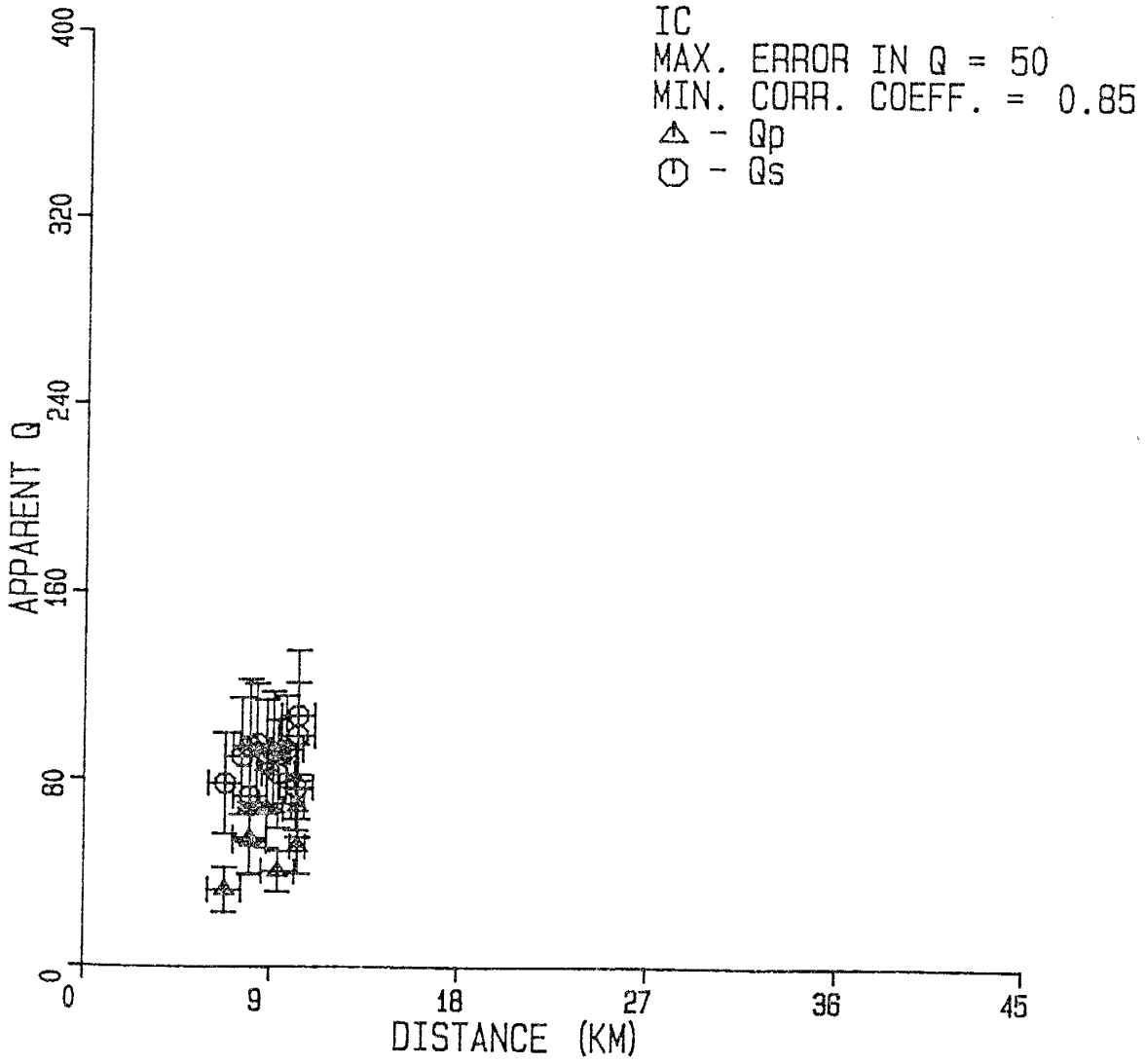


Fig. 43. Apparent Qp and Qs for events recorded at IC plotted as a function of hypocentral distance. Error bars represent 2 s.d. Events shown here have errors in Q less than 50 and spectral fit correlation coefficients greater than 0.85.

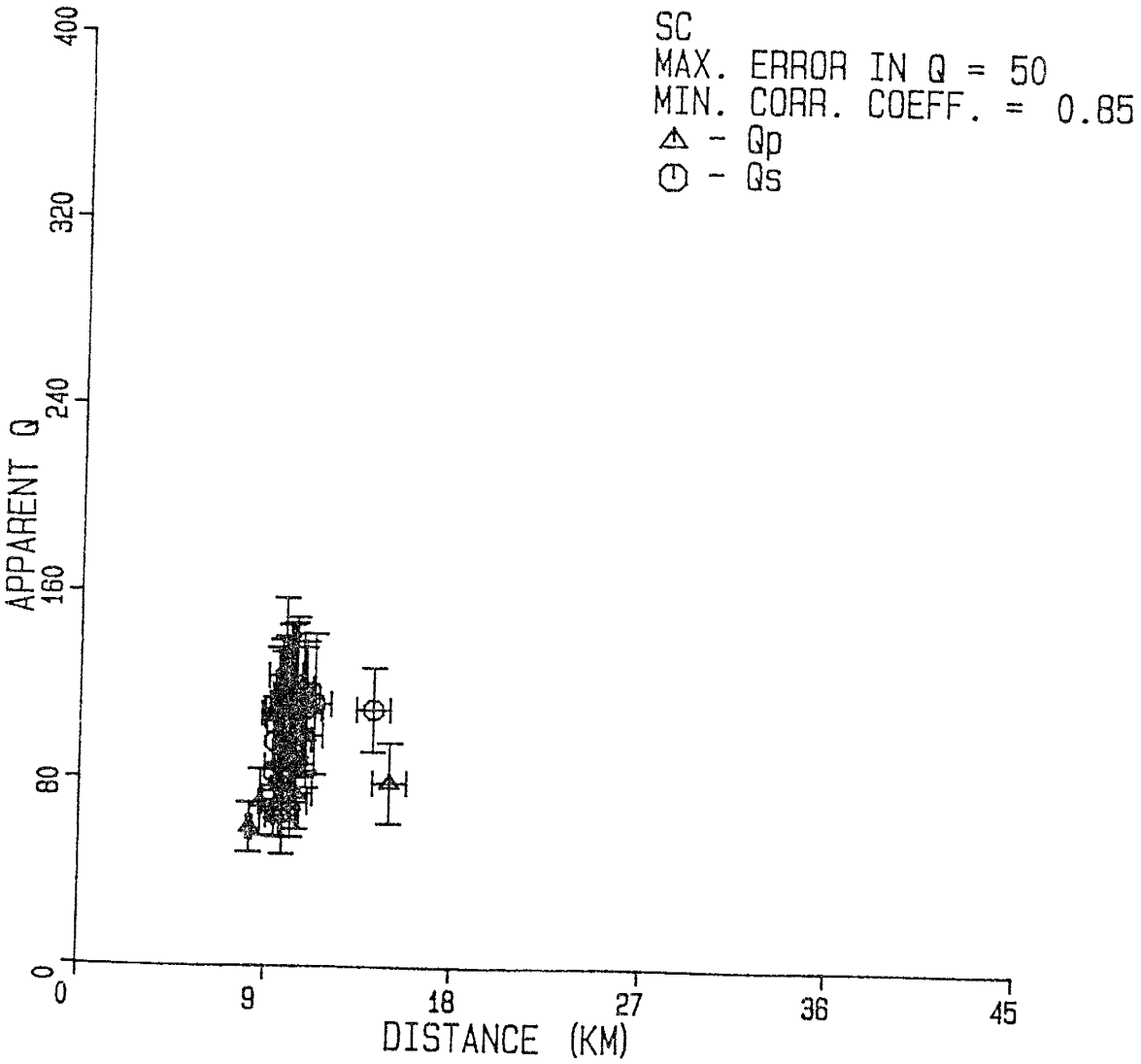


Fig. 44. Apparent Qp and Qs for events recorded at SC plotted as a function of hypocentral distance. Error bars represent 2 s.d. Events shown here have errors in Q less than 50 and spectral fit correlation coefficients greater than 0.85.

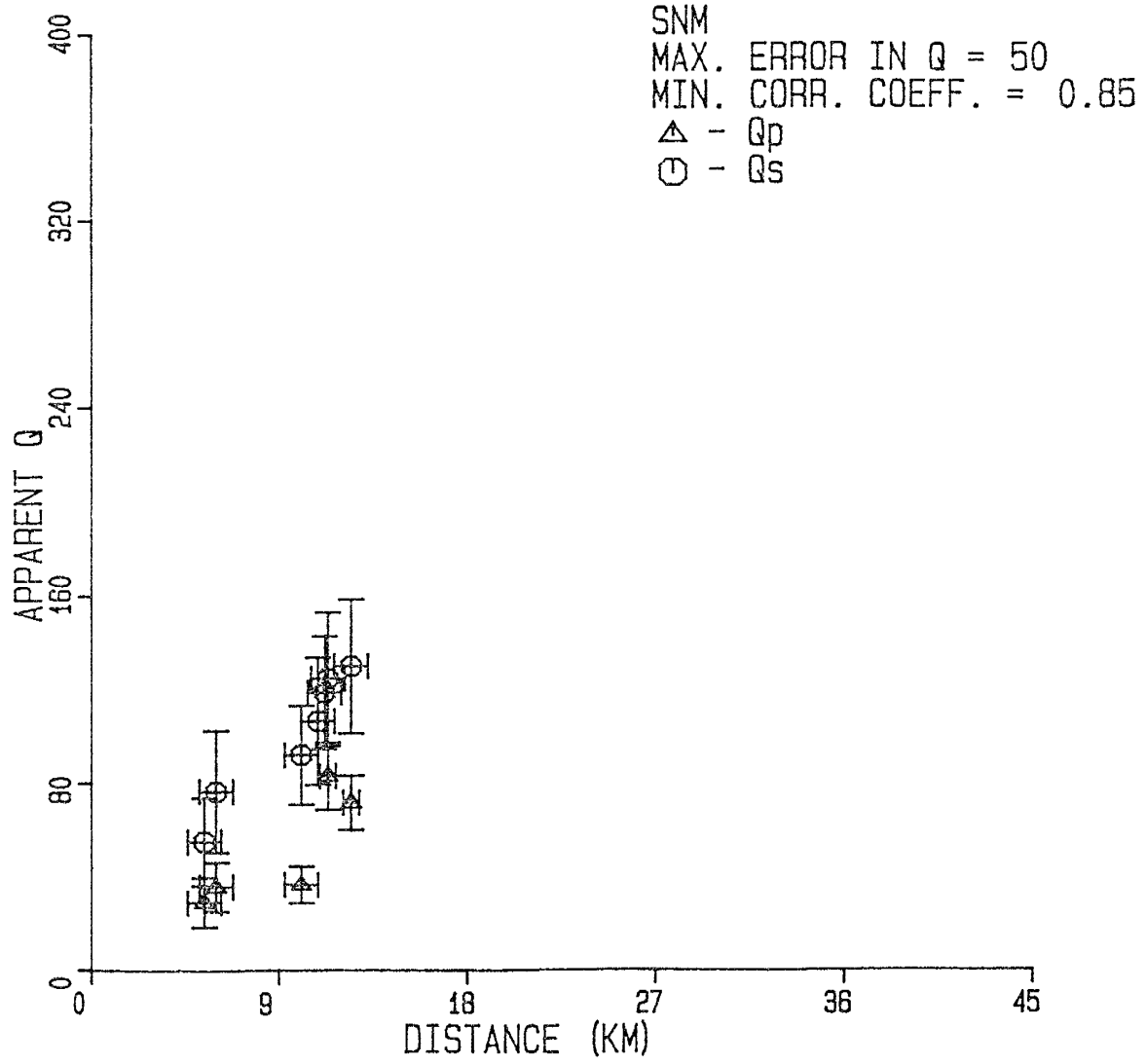


Fig. 45. Apparent Qp and Qs for events recorded at SNM plotted as a function of hypocentral distance. Error bars represent 2 s.d. Events shown here have errors in Q less than 50 and spectral fit correlation coefficients greater than 0.85.

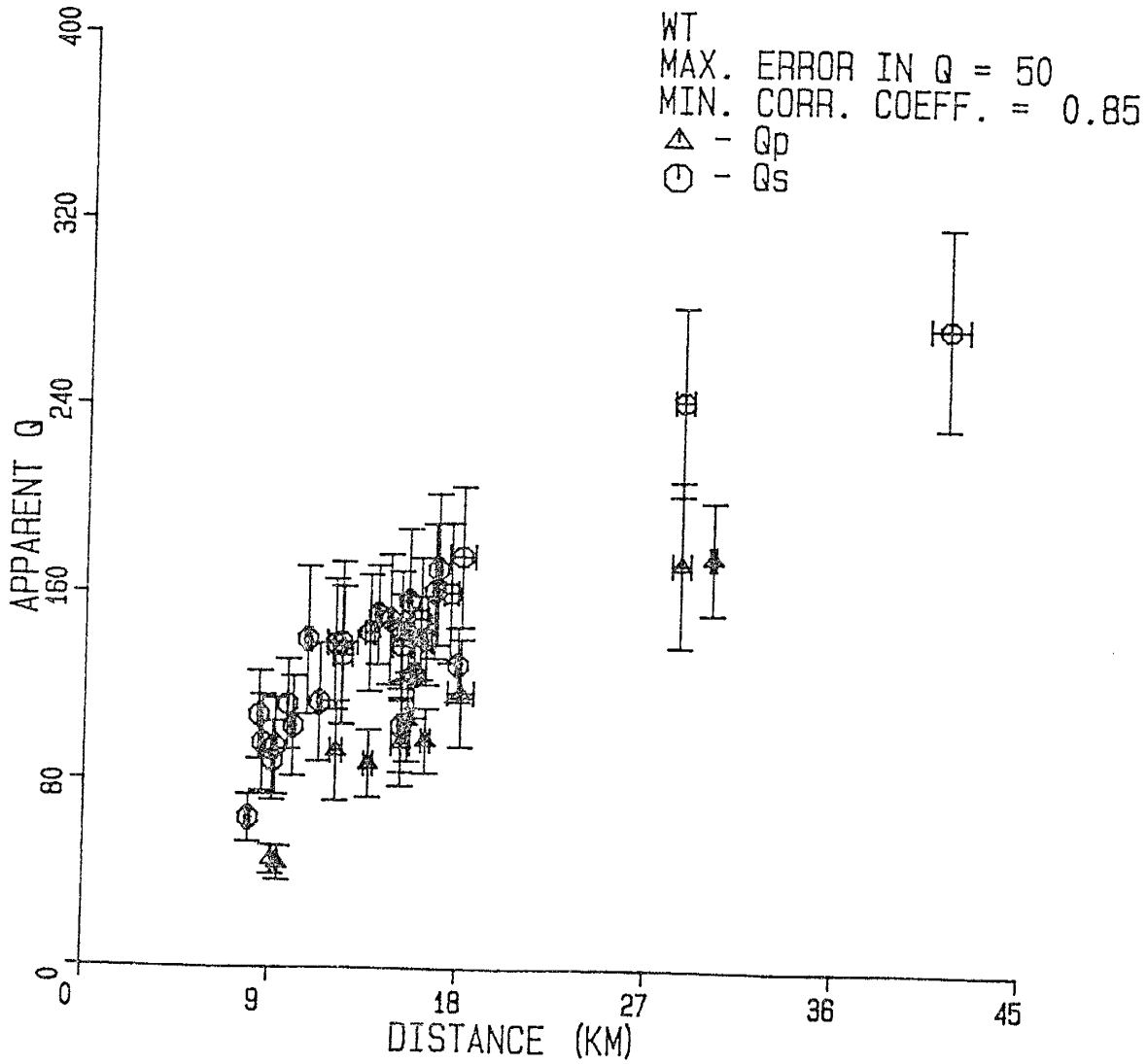


Fig. 46. Apparent Qp and Qs for events recorded at WT plotted as a function of hypocentral distance. Error bars represent 2 s.d. Events shown here have errors in Q less than 50 and spectral fit correlation coefficients greater than 0.85.

spectral fit linear regression correlation coefficients greater than 0.85 are included in these figures. While the plots for station WT show only located events, plots for all other stations include both located and unlocated events. In the case of unlocated events, distances were computed from S-P intervals as described in the location section. A focal depth of 8.5 km was assumed for these events, the average depth for all located events recorded at WT. As the best located events were recorded at WT, this is believed to be a representative focal depth for events in the Socorro area. Tables 2-1 through 2-16 in Appendix 2 list all of the events shown in these plots, with Q values, locations, uncertainties, distances, and focal depths. The windows selected for spectral analysis are also presented in Figures 2-1 through 2-16.

From these plots, it can be seen that apparent Q increases with distance at all stations. This implies Q increases with depth i.e. waves from more distant earthquakes spend more time in deeper, higher-Q rocks. Figure 38 illustrates this schematically with raypaths for a number of different earthquakes at different distances and depths.

Q Versus Depth Models

The Qs data for station WT was used to constrain a Q versus depth model analogous to the one-dimensional velocity versus depth model discussed earlier. The model consists of a low velocity, low Q layer lying above a high Q, high velocity half-space (Figure 38b). As with the velocity model, a strong Q gradient near the surface is accounted for by lumping all of the low Q material into one layer. Two general observations that support this model include:

(1) An increase in apparent Q with hypocentral distance at all stations.

(2) Qs values from reflected SxS waves which are similar to Qs values obtained from direct waves traveling an equivalent distance in the upper 12 km (Figures 47 and 48). This observation indicates that for these raypaths the average Qs between the base of the seismic zone ($\sim$12 km) and the mid-crustal discontinuity is the same as the average Qs in the upper 12 km, despite the probable existence of a plastic rheology (long time constant) beneath 12 km (Rinehart, 1979).

A bivariate regression technique was used to estimate the low velocity layer Q_1 and the half-space Q_2 from the S wave apparent Q values for station WT. The discussion below is a detailed description of the method used to determine Qs_1 and Qs_2. A short summary of the results of this regression follows this discussion.

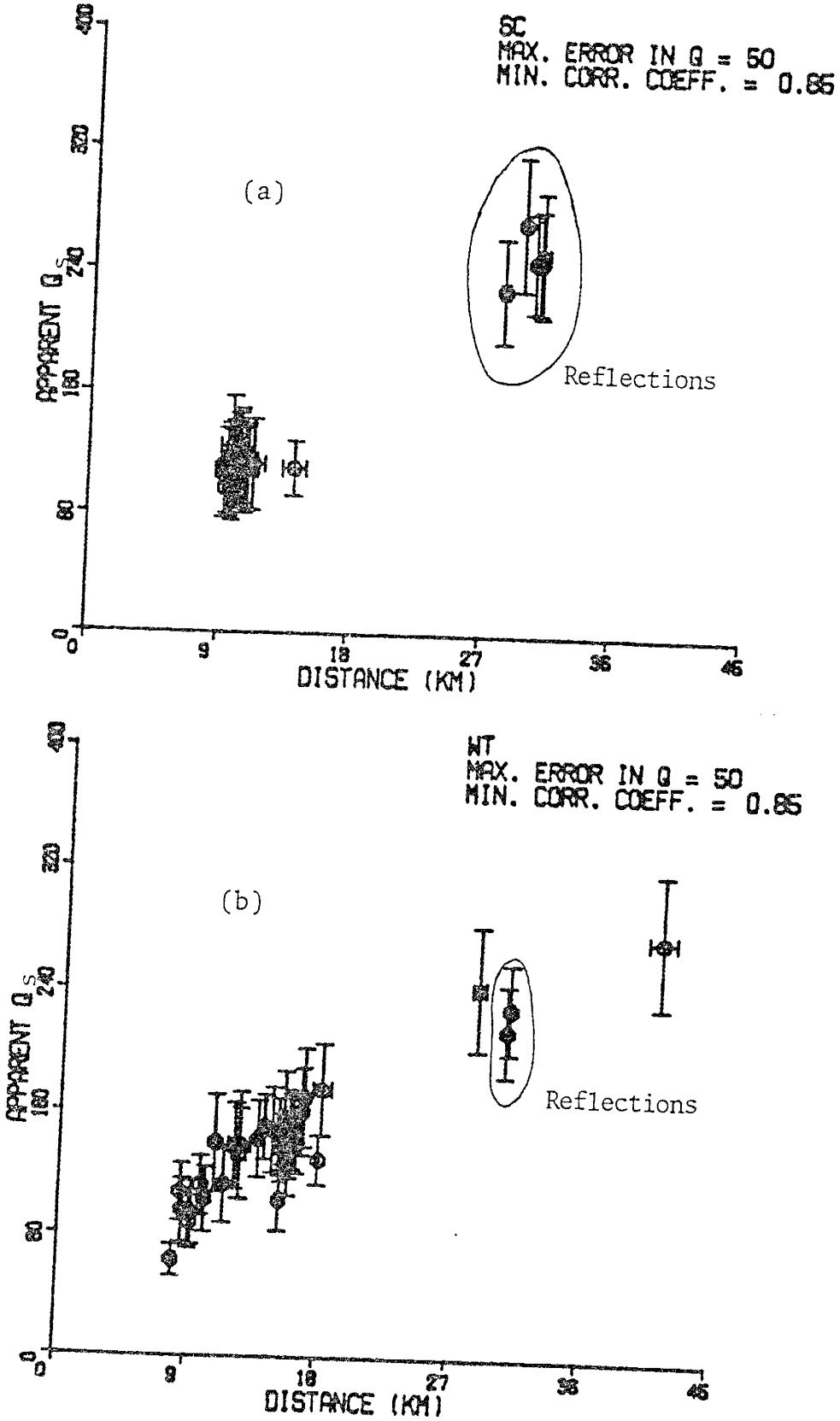


Fig. 47. Qs from direct and reflected waves plotted as a function of hypocentral distance. (a) Qs for events recorded at SC. (b) Qs for events recorded at WT.

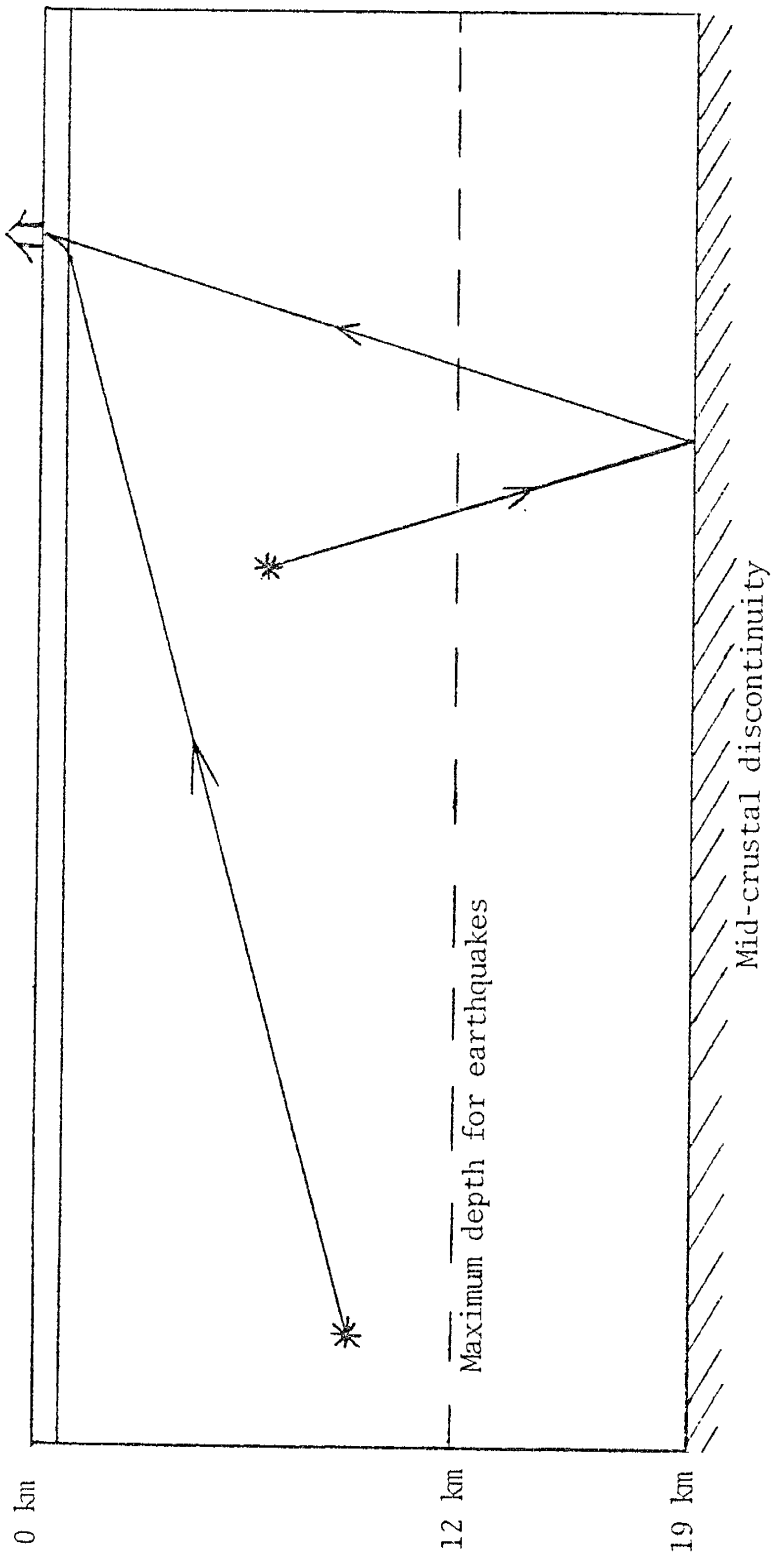


Fig. 48. Raypaths for a direct ray traveling in the upper 10 km and a reflected ray sampling the lower part of the upper crust. Both of these waves travel the same distance.

Bivariate Regression Details

In the discussion below, estimates of Qs_1 and Qs_2 are obtained from the variation in apparent Q with increasing hypocentral distance. In the model to be fit to the data, the distance traveled through the low velocity, low Q layer is known (D), as well as V_1 and V_2 (Figure 38). For WT the average distance traveled through the LVL is about 0.40 km, Vs_1 is 2.0 km/s and Vs_2 is 3.41 km/s. While in general D varies with the angle of incidence of the emerging ray, at WT such variation is less than 0.1 km over the range of possible incident angles. Thus, in the regression described below, D will be considered constant.

Qs_1 and Qs_2 are chosen so that a least squares solution is found to the system of equations

$$r_i/(\hat{Vs}_i\hat{Qs}_i) = (D/Vs_1)(1/Qs_1) + ((r_i-D)/Vs_2)(1/Qs_2), \quad (20)$$

where r_i is the hypocentral distance for each event and i represents the event index. $\hat{Vs}_i$ is the apparent S wave velocity (Vs) for each event and $\hat{Qs}_i$ is the apparent S quality factor (Qs) for each event.

Equation (20) can be written as a standard first-order linear model where Y is a function of two unknown coefficients, β_1 and β_2, and the data, $\underline{X}_1$ and $\underline{X}_2$:

$$\underline{Y} = \beta_1\underline{X}_1 + \beta_2\underline{X}_2, \quad (21)$$

where

$$\underline{X}_1 = \begin{Bmatrix} D/Vs_1 \\ D/Vs_1 \\ \cdot \\ \cdot \\ D/Vs_1 \end{Bmatrix}$$

and

$$\underline{X}_2 = \begin{Bmatrix} (r_1-D)/Vs_2 \\ (r_2-D)/Vs_2 \\ \cdot \\ \cdot \\ (r_n-D)/Vs_2 \end{Bmatrix} .$$

$\beta_1 = 1/Q_1$, $\beta_2 = 1/Q_2$,

$$\underline{Y} = \begin{Bmatrix} r_1/(\hat{Vs}_1\hat{Qs}_1) \\ r_2/(\hat{Vs}_2\hat{Qs}_2) \\ \cdot \\ \cdot \\ r_n/(\hat{Vs}_n\hat{Qs}_n) \end{Bmatrix}$$

and the Y intercept is assumed to be zero. Note that $\underline{X}_1$, $\underline{X}_2$, and $\underline{Y}$ are vectors representing n events.

Standard procedures exist for solving this system of equations. The approach and the notation used here follows Draper and Smith (1966, p. 104-124).

Estimates of β_1 and β_2 may be computed from the expression:

$$\underline{b} = C\underline{X}^T\underline{Y}, \tag{22}$$

where $C = (\underline{X}^T\underline{X})^{-1}$, the variance-covariance matrix for β, and $\underline{b}$ contains the estimates of β_i. $\underline{X}^T$ is $\underline{X}$ transpose. The uncertainties in b_i may be estimated from the diagonal elements of C:

$$\sigma(b_i) \approx \sqrt{c_{ii}s^2}, \tag{23}$$

where s^2 is the sum of the squares of the estimated residuals. The two standard deviation range in Q_1 and Q_2 can then be computed from b_i i.e.

$$Q_{imax} \approx 1/(b_i - 2\sigma(b_i)), \tag{24}$$

$$Q_{imin} \approx 1/(b_i + 2\sigma(b_i)), \tag{25}$$

where i= 1,2.

An estimate of the uncertainty in the model can be made from

$$\sigma(\underline{Y}) \approx \sqrt{s^2\ (\underline{X}^T C \underline{X}_o)}, \tag{26}$$

where the vector $\underline{X}_o$ contains the coordinates of the point where the uncertainty is to be computed. In this case,

$$\underline{X}_o{}^T = (D/Vs_1,\ (r-D)/Vs_2). \tag{27}$$

The uncertainty in the model will be incorporated into the uncertainty in Q residuals to be discussed in a later section.

Results of Regression

For S waves recorded at station WT, the average regression curve and curves generated using Q_{max} and Q_{min} with equation (20) are shown in Figure 49 along with their respective Qs_1 and Qs_2 values. These upper and lower curves are intended to show Q versus distance for the minimum and maximum limits on Qs_1 and Qs_2, i.e. the envelope within which any Qs_1, Qs_2 combination must lie, and do not represent the 95% confidence interval for the average regression model. The confidence interval for the regression model is much narrower.

Obviously, while Qs_1 is well constrained, Qs_2 is not. The inability of the S wave data to adequately determine Qs_2 may be due to several factors. First, too much scatter exists in the data (reflecting lateral Q and velocity changes) while errors have been incurred in fitting of the spectra, in hypocenter determination, and in the velocity model. Also, more earthquakes are needed at distances over 25 km to adequately determine Qs_2 (A. Gutjahr, personal communication, 1984).

Too wide a scatter in Q estimates and too few located events satisfying the error criteria preclude this type of least squares fitting for P waves recorded at WT and P and S waves recorded at other stations.

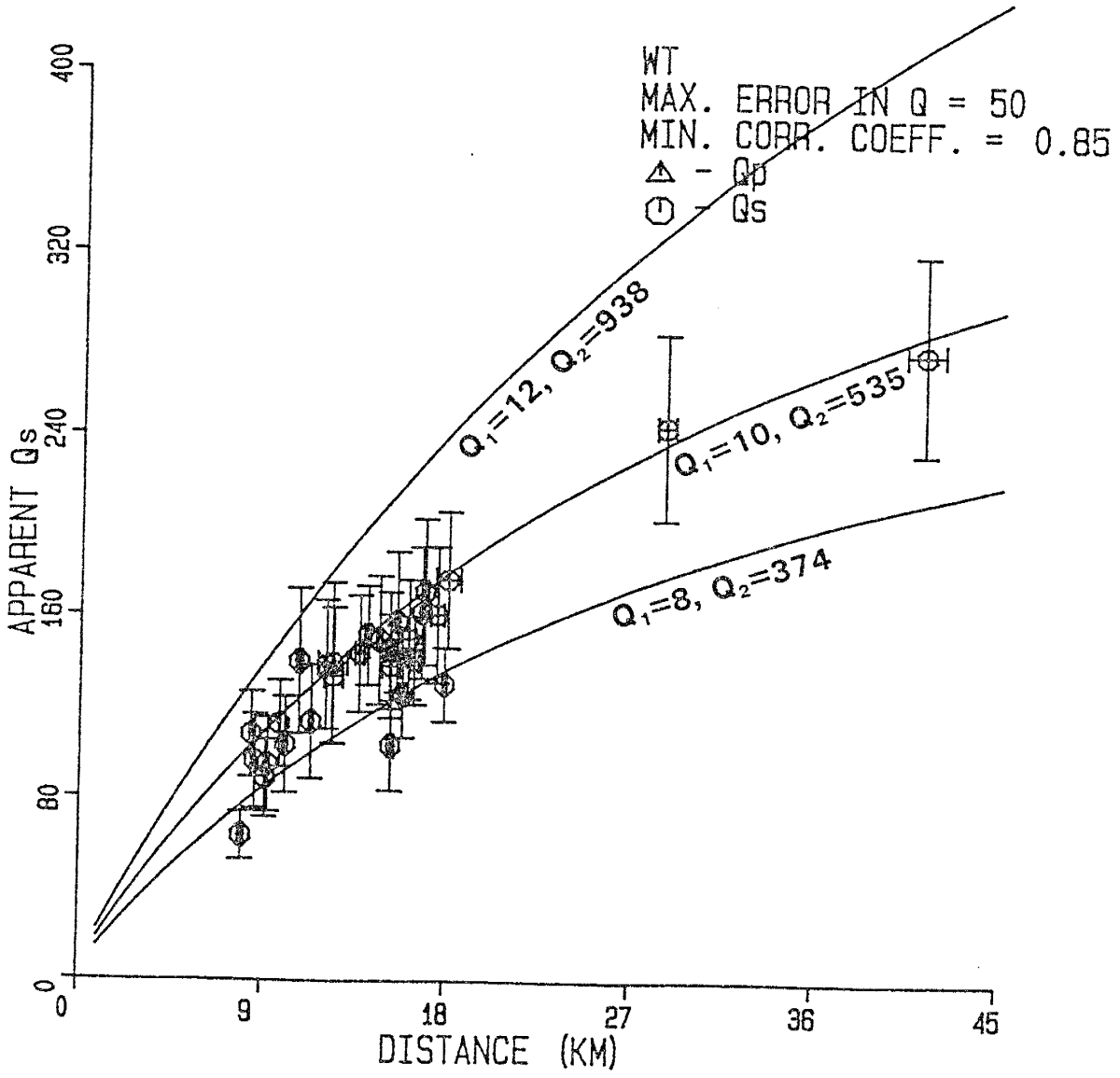


Fig. 49. Results of the least squares fitting of the layer over a half-space model to S wave data recorded at WT. The center curve is the average regression model. The upper and lower curves were computed from the maximum and minimum values of Qs_1 and Qs_2.

Q Values and Near-station Geology

Figures 3 through 10 briefly summarize the geological setting of each station. Figure 3 shows a bird's eye view of all the stations and where they are in relation to large scale tectonic features. From this map it can be seen that CC lies in Precambrian rocks on the east face of an uplifted horst block forming the Lemitar Mountains. Slightly southeast of CC, WT is located in a similar upthrown block of Precambrian just beyond the north topographic wall of the Socorro cauldron (Chapin et al., 1978). To the east, DM rests on faulted Pennsylvanian limestone, possibly near the eastern margin of the rift. Just south of DM, FM is located in an adit in an upfaulted sliver of the Precambrian Tajo pluton (Condie and Budding, 1979). Moving southwest of Socorro, IC lies near the center of the Socorro cauldron above a resurgent dome inferred by Chapin et al. (1978). CM lies above a thick sequence of Socorro cauldron moat deposits along the east edge of the Chupadera Mountains, near the MCA Mine (Eggleston, 1982). To the west, SC is located near the entrance to South Canyon in the Magdalena Mountains and also lies on thick cauldron ash-flow tuff deposits near a transverse shear zone identified by Osburn (1978). Finally, SNM rests on moat deposits of the Socorro cauldron, about 200 meters south of the northern topographic wall.

To obtain a quantitative estimate of the variation in Q_1 for these different stations, the average value of Qs_2 was removed from each apparent Qs value and Qs_1 was calculated for each station using average distances for S waves traveling through the LVL at a velocity (Vs_1) of 2.0 km/s i.e. from (20),

$$Qs_1 = D/Vs_1 \; [r/(VsQs) - (r-D)/(Qs_2Vs_2)]^{-1}, \qquad (28)$$

where D is the distance traveled through the LVL, r is the hypocentral distance, Vs_2 is the half-space velocity (3.41 km/s), Vs is the apparent velocity for the wave and Qs_2 is the average half-space Q obtained from the regression above ($Qs_2 = 535$).

Average Qs_1 values computed from (28) are listed in Table 5 and are shown in Figure 50 as a composite bar graph, which allows Qs_1 values to be compared for events recorded at different stations. The 2 s.d. range for each mean Qs_1 is also listed in Table 5. The distribution shown in Figure 50 doesn't substantially change if Qs_2max or Qs_2min is used to compute Qs_1. At these short hypocentral distances, the second term in the denominator of (28), $(r-D)/(Qs_2Vs_2)$, is very small, and has little effect on Qs_1.

These average values for Qs_1 may be compared with the near-station geology. CC is not included here since the thickness of low velocity material beneath this station was assumed to be zero, providing a base for calculating LVL

TABLE 5

Q1 ESTIMATES FOR EACH STATION

Q2 = 535.00
V1 = 2.00
V2 = 3.41

STA	# QUAKES	D (KM)	Q1AVE	2 SD Q1AVE
CC	13	0.00	-----	----
CM	7	2.30	35.93	2.92
DM	7	1.30	18.83	2.00
FM	10	1.40	24.18	2.80
IC	12	1.70	34.62	2.74
SC	16	1.80	36.95	1.77
SNM	7	1.10	24.11	2.06
WT	29	0.40	9.83	0.32

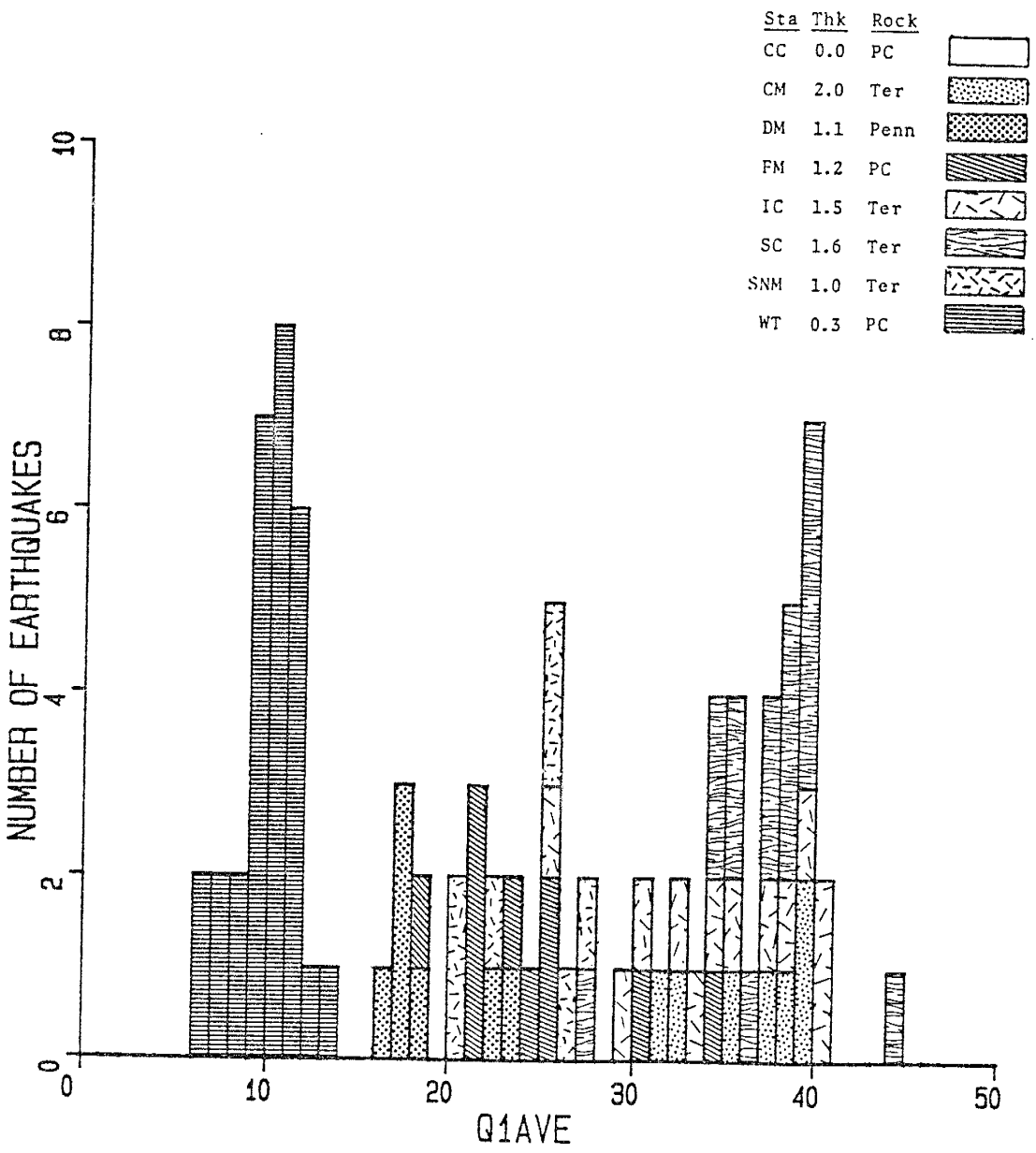


Fig. 50. Cumulative bar graph illustrating the average Qs_1 for each station computed assuming a constant Qs_2 of 535. Sta--station, Thk--thickness (km), Rock--rock type outcropping at station.

thicknesses at other stations (Table 4). From Table 5 and Figure 50 it can be immediately seen that stations with thicker LVLs have higher average Qs_1 values. Again, this reflects the smallness of the second term in the denominator on the right hand side of equation (28). Since apparent Q (Qs) is about the same for events at equivalent distances recorded at different stations, the first term in the denominator is essentially constant, and since it is much larger than the second term, Q_1 is almost a linear function of D, or equivalently, the thickness of the LVL.

Stations with thick LVLs and relatively high average Q_1 values tend to lie on cauldron facies deposits. It is rather surprising that this material produces near-surface quality factors exceeding those obtained for stations DM, FM, and WT, which lie on Precambrian and Paleozoic rocks. A close examination of the geology at WT, DM, and FM, however, reveals several reasons why Q_1 might be relatively low.

Qs_1 for WT is significantly lower than Qs_1 for other stations. Since <u>all</u> of the WT Qs_1 values are low, and since these events do not all come from one area, (Figure 51), the possibility that all of these low Q_1 events come from low-Q source regions is small. WT rests on Precambrian metasediments and intrusives (Bingler, unpublished report, 1966) and is less than 100 meters from a zone of intense normal faulting separating Precambrian quartz monzonite from Pennsylvanian limestone (Figure 10). Since only the upper

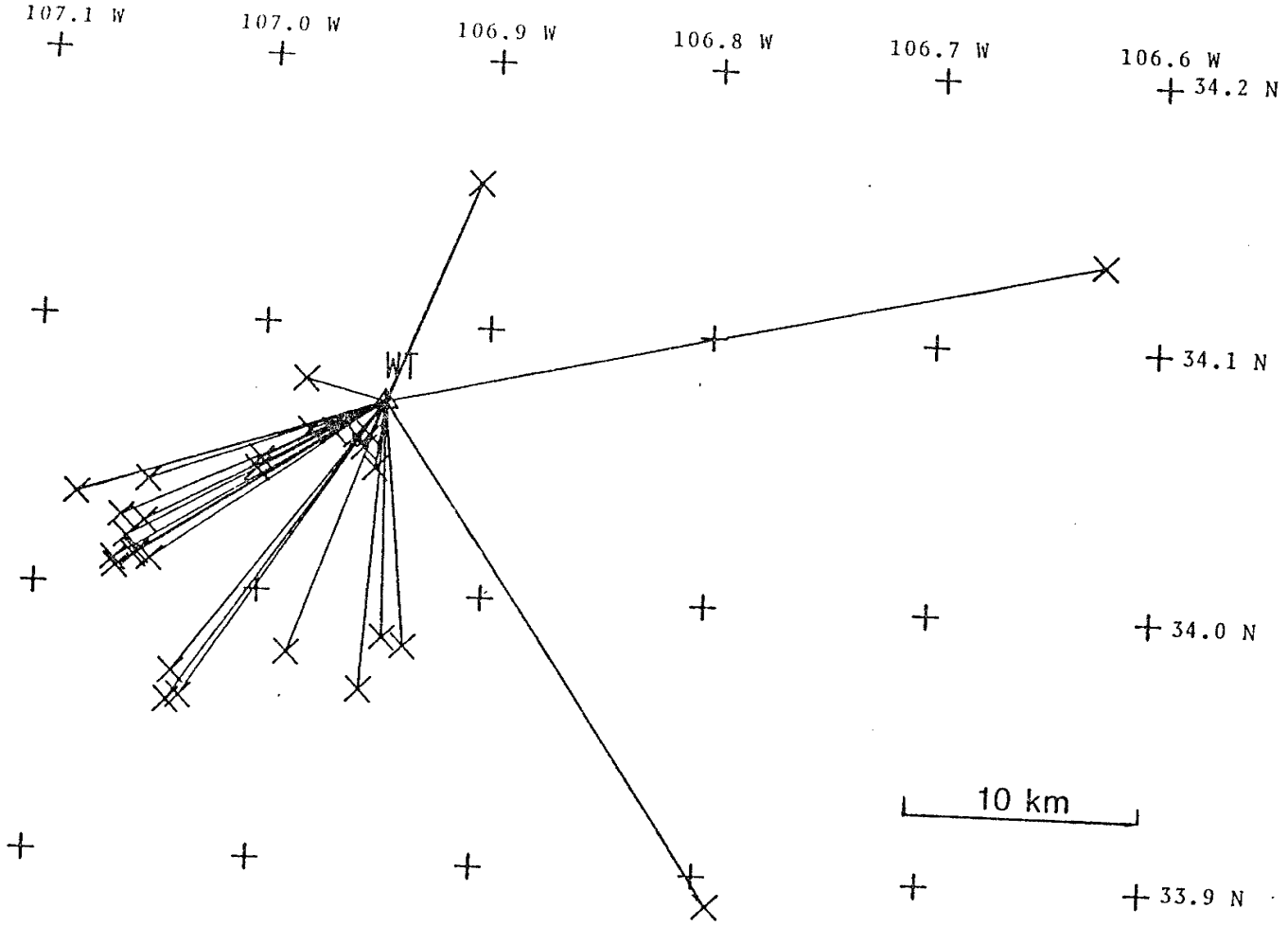


Fig. 51. Raypaths for events recorded at WT with errors in Qs of less than 50 and spectral fit correlation coefficients greater than 0.85. These events were used to fit the layer over a half-space model (Figure 49).

0.4 km of the crust is included in Q_1, this value may reflect strong attenuation resulting from incompetent fault-zone material and intense near-surface fracturing. Loss of seismic energy may also arise from scattering due to inhomogeneous structure. Finally, geothermal gradients as high as 160 ^{o}C/km have been measured within 300 m of the recording site (Reiter and Smith, 1977; Sanford, 1977), and elevated temperatures near the surface could enhance absorption (Gordon and Davis, 1968).

Station DM lies on Pennsylvanian limestone and station FM on an upfaulted sliver of the Precambrian Tajo pluton. As Figure 27 and Appendix 2 show, relatively low Qs_1 values have been obtained from events recorded at these stations at a variety of azimuths, including events near the east edge of the rift. As DM and FM lie close to fault zones, incompetent and inhomogeneous material may again be enhancing absorption near the surface.

In summary, it appears that the thickness of the LVL is the most important factor affecting Qs_1. Since events at the same hypocentral distance recorded at different stations have similar apparent Q values, thin LVLs must have relatively low Qs_1 values and thick LVLs relatively high Qs_1 values, assuming a constant Qs_2 half-space. Overburden pressure may lead to a higher average Qs_1 in thicker sections. Alternatively, the Qs_1 layer may be thinner than the Vs_1 layer, and progressively more high Q basement

material is incorporated into Qs_1 with thicker LVLs. Finally, cracks may remain open deeper in more competent rocks, enhancing scattering losses (A. Sanford, personal communication, 1984). At any rate, a comparison of near-station geology reveals that the effect of rock composition on Qs_1 is minor, given the assumptions discussed above about V_1, the LVL thickness, and Qs_2.

Qp_1 could not be estimated since a reliable Qp_2 could not be computed from the Qp versus distance plots. However, P wave first arrivals from explosions detonated by the Terminal Effects Research Analysis (TERA) group, recorded at station WT, have produced Qp values less than 20 (Table 2-18 and Figure 52). These waves pass primarily through Socorro cauldron moat deposits, and since they do not penetrate deeper than about 1 km (Sanford and Holmes, 1962), they only sample near-surface materials.

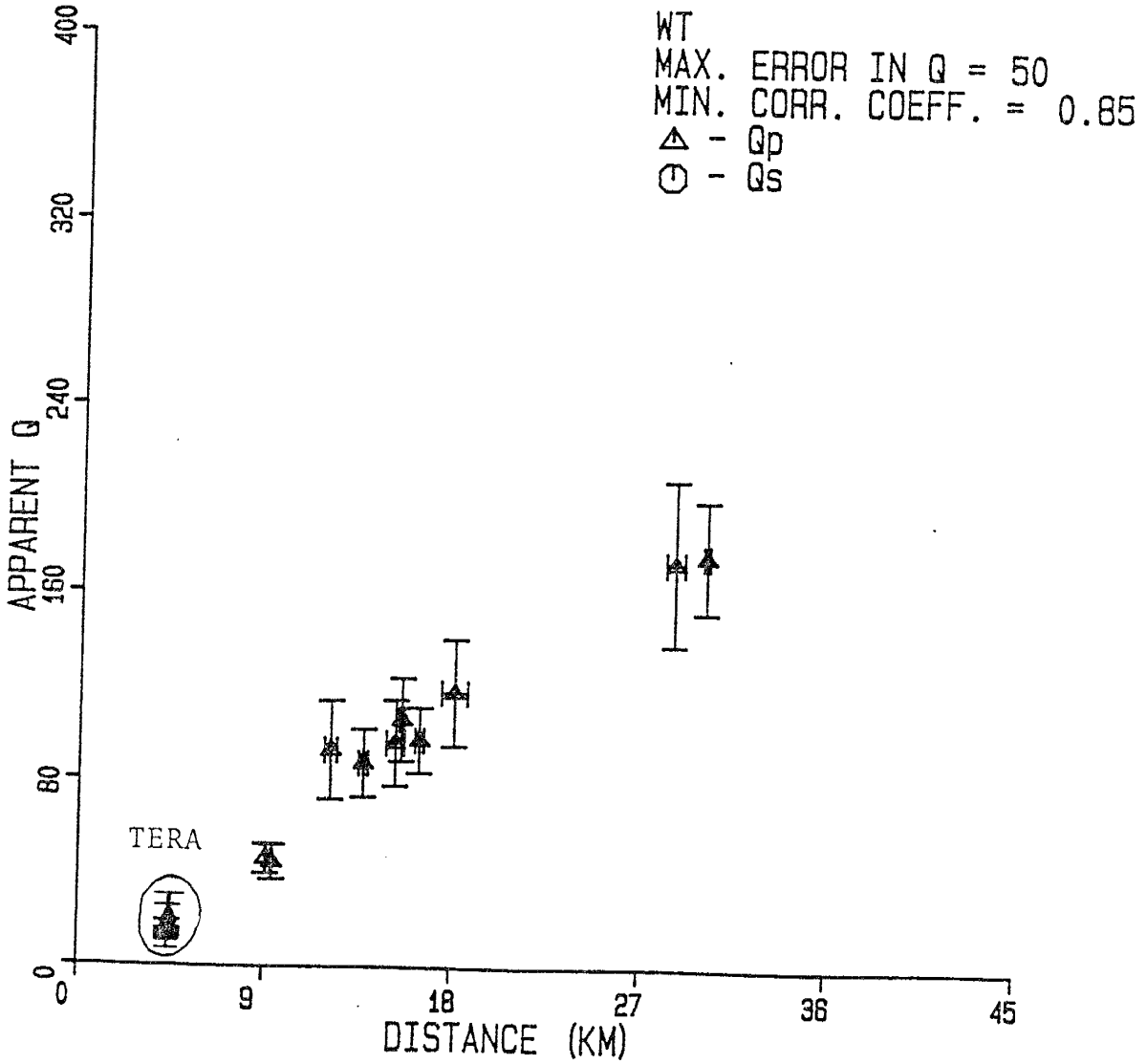


Fig. 52. Qp values from microearthquakes and TERA explosions recorded at WT. Error bars represent 2 s.d. Events shown here have errors in Q less than 50 and spectral fit correlation coefficients greater than 0.85.

Qp/Qs Ratios

Qp/Qs ratios obtained from events listed in Tables 2-1 through 2-16 are presented in Table 6. These were calculated by taking the ratio of Qp to Qs for events where both Qp and Qs met the stringent error criteria i.e. the events had errors in Q of less than 50 (2 s.d. of the mean Q) and spectral fit correlation coefficients greater than 0.85. The standard deviations listed in Table 6 represent the spread in the observed Qp/Qs ratios.

As can be seen from Table 6 and Figures 39 through 46, Qs is consistently higher than Qp for events recorded at all of the stations in the digital network. Table 6 shows that the average Qp/Qs ratio does not vary much from station to station, and the average Qp/Qs ratio for all of the events is 0.66 ± 0.08 (1 s.d. of the data), quite close to the Qp/Qs value of 0.7 obtained by Gordon and Davis (1968) from ultrasonic tests on a granite specimen. This would indicate that, in general, upper crustal rocks in the Socorro area do not exhibit an anomalous Qp/Qs ratio. However, the manner in which Qp/Qs changes with hypocentral distance varies from station to station, as does the range in Qp/Qs values.

Qp/Qs appears to decrease with increasing hypocentral distance at stations CM, DM, and FM (see Figures 40, 41, and 42). However, no systematic increase or decrease with distance is evident for events recorded at CC or WT (Figures 39 and 46). Events recorded at stations IC, SC, and SNM

TABLE 6

Qp/Qs RATIOS

Station	Ave. Qp/Qs	2 s.d.	Qp/Qs range
CC	0.66	0.22	0.45-0.83
CM	0.74	0.30	0.52-0.98
DM	0.68	0.30	0.53-0.91
FM	0.64	0.42	0.34-0.92
IC	0.57	0.26	0.42-0.74
SC	0.74	0.24	0.60-0.89
SNM	0.52	0.20	0.40-0.67
WT	0.72	0.44	0.36-1.39
WT	0.63	0.20	0.36-0.74*

*Does not include anomalous events.

(Figures 43, 44, and 45) are too closely clustered in distance to make any conclusions.

Undoubtedly a number of processes combine to produce the apparent Q versus distance plots shown above. An attempt will be made to explain these changes in the Qp/Qs ratio in terms of simple loss models below.

The change in Qp/Qs with distance for events recorded at stations CM, DM, and FM may be reflecting the degree of saturation in upper-crustal rocks along various raypaths. Previous researchers have found that $Qp/Qs < 1$ for partially saturated rocks while $Qp/Qs > 1$ for completely saturated rocks (Walsh, 1966; Johnston et al., 1979; Winkler and Nur, 1979). Fully saturated rocks probably occur near the surface, leading to $Qp > Qs$, while deeper, partially saturated and dry rocks result in $Qs > Qp$. Waves from more distant earthquakes would spend a greater fraction of their total raypath in the deeper rocks and would tend to have lower Qp/Qs ratios. These experimental interpretations, of course, do not give us a microscopic view of what is occurring in the rock as a seismic wave passes. Squirting flow may be a viable model for P wave attenuation, as it can only occur if partial saturation exists-- as total saturation is approached, and flow is inhibited, Qp increases dramatically. This has been documented by Winkler and Nur (1980), Johnston and Toksoz (1980), and Johnson (1983) in ultrasonic tests on a variety of porous rock

samples. S wave losses are more difficult to explain with this model. One scenario is that with total saturation, pores and cracks are held open, facilitating friction along asperities (Figure 20). Loss of seismic energy in fluid shear motions may also be greater. A major weakness of this flow model is that it cannot explain attenuation in dry rocks, and the fact that Qs > Qp in dry rocks.

Another model that may explain the decrease in the Qp/Qs ratio with increasing event distance for stations CM, DM, and FM is friction along fractures. Near the surface, where confining pressures are relatively small, sliding may occur along cracks, whereas at depth high confining pressures inhibit movement (assuming high pore pressures do not exist). As such sliding would be greater with shear motion, we would expect Qs < Qp near the surface and Qs ≈ Qp at depth. This model does not explain why Qs > Qp at depth and, as has been noted in a previous section, sliding friction loss models do not have much experimental support (Winkler et al., 1979).

At stations CC and WT, Qp/Qs does not vary in a systematic fashion (Figures 39 and 46). While large variations in Qp/Qs do occur, particularly for events recorded at WT, there is no general decrease in Qp/Qs with increasing event distance, as at stations CM, DM, and FM. As will be shown in the next section, some of the abnormally high Qp/Qs ratios at WT are from events occurring in

anomalously low Q source regions. Excluding these anomalous events, the Qp/Qs range for WT is diminished significantly (Table 6), and no events recorded at CC and WT have Qp/Qs ratios that exceed 0.83. Again, the above viscous loss model can be invoked to explain these observations: waves recorded at CC and WT travel primarily through dry or partially saturated rocks.

It should be noted that different sized data sets are being compared for different stations. This is especially true for station WT, where many more events were recorded representing a wider azimuthal distribution than for other stations. It will be shown in the next section that significant lateral Q differences exist in the data set for station WT-- these lateral differences in Q may mask an increase or decrease in Qp/Qs with increasing hypocentral distance.

Lateral Q Variations and Anomalous Regions

As mentioned above, it is likely that much of the scatter in the Q versus distance plots is due to lateral variations in the high Q basement. An estimate of this lateral heterogeneity may be made by examining the distribution of individual Q values about the average model.

The only area where earthquake coverage was good enough to reliably map lateral Q variations was the region southwest of WT within a radius of about 20 km. Figure 53

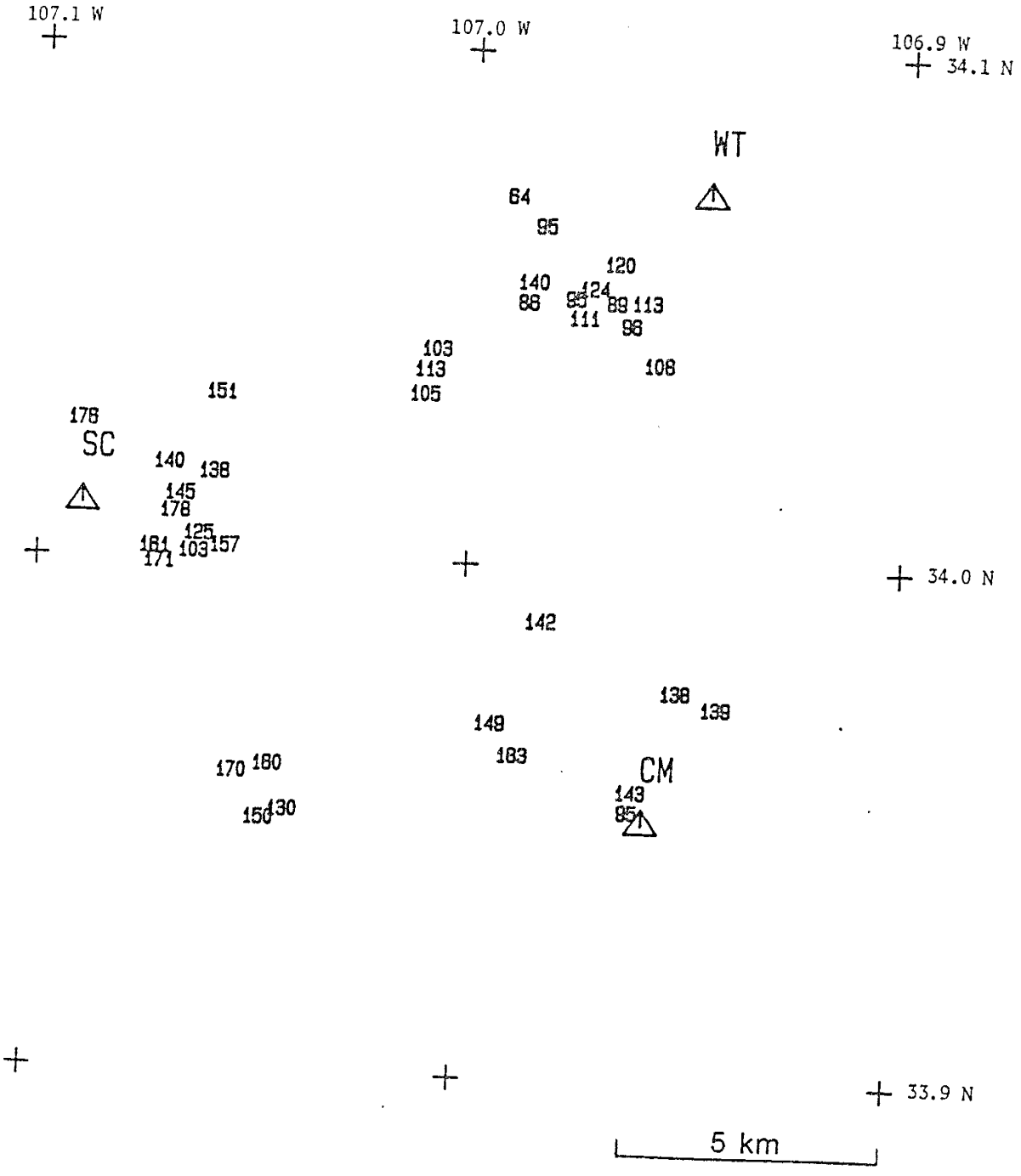


Fig. 53. A map of an active region southwest of Socorro showing Qs estimates plotted at epicenters. Events shown in this figure have errors in Qs of less than 100 and spectral fit correlation coefficients greater than 0.80.

shows Qs values plotted at epicenters in this area for events that were recorded at WT. The error criteria were relaxed somewhat to include a larger number of events than have been discussed in previous sections. Here events with errors in Q of less than 100 (2 s.d.) and spectral fit correlation coefficients greater than 0.80 are plotted. Table 2-16 lists the location of each of these events and S windows are presented in Figure 2-16. Focal depths for these events are plotted in Figure 54.

Figure 55 shows the region southwest of WT with residual Q values plotted at event epicenters. These residuals were computed by subtracting the average least squares model Q (using $Qs_1 = 10$, $Qs_2 = 535$) from each Q estimate. Figure 56 shows the residuals contoured with a Qs contour interval of 10.

The errors in the Q residuals reflect uncertainties in the regression model and uncertainties in the apparent Q. Errors in the apparent Q estimates were found from

$$\sigma(Q_{app}) = (Q_{max}-Q_{min})/4, \qquad (29)$$

where Q_{max} and Q_{min} are the upper and lower 2 s.d. bounds for each apparent (observed) Q estimate respectively.

The error in the model Q (Q_m) was computed from an error analysis of

$$Y = \pi r/(VQ_m), \qquad (30)$$

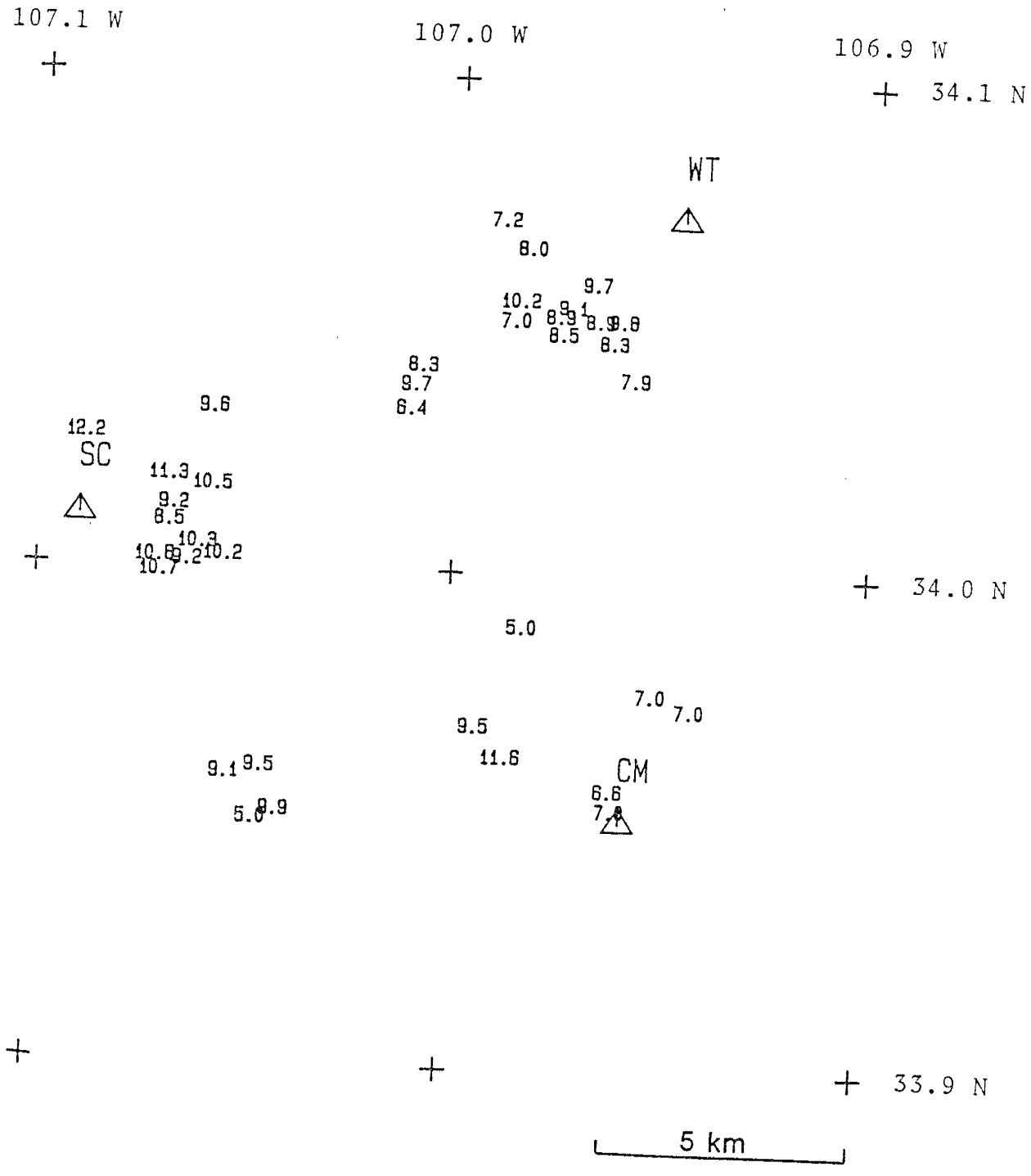


Fig. 54. Focal depths (km) for events plotted in Figure 53.

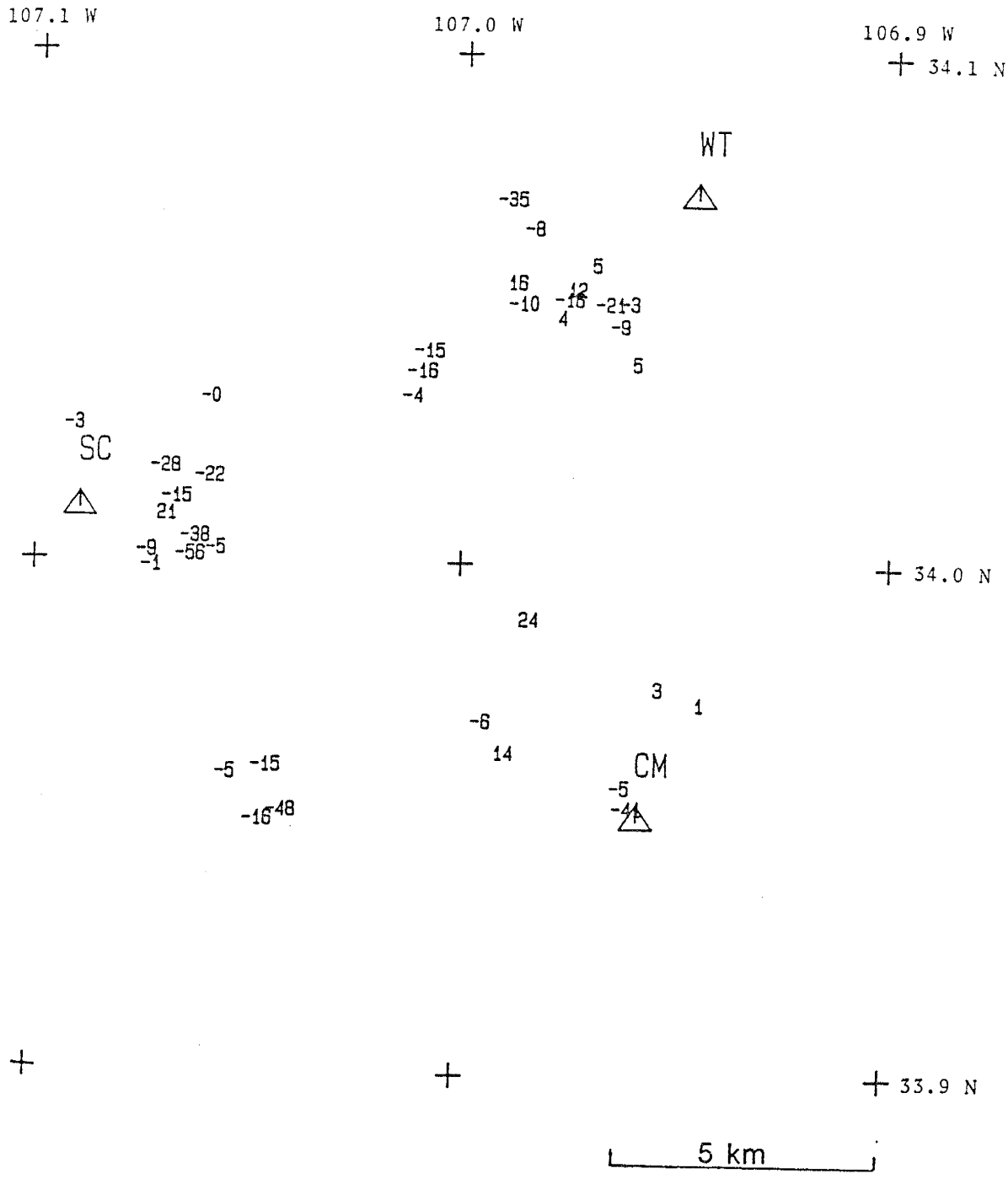


Fig. 55. Qs residuals for events plotted in Figure 53.

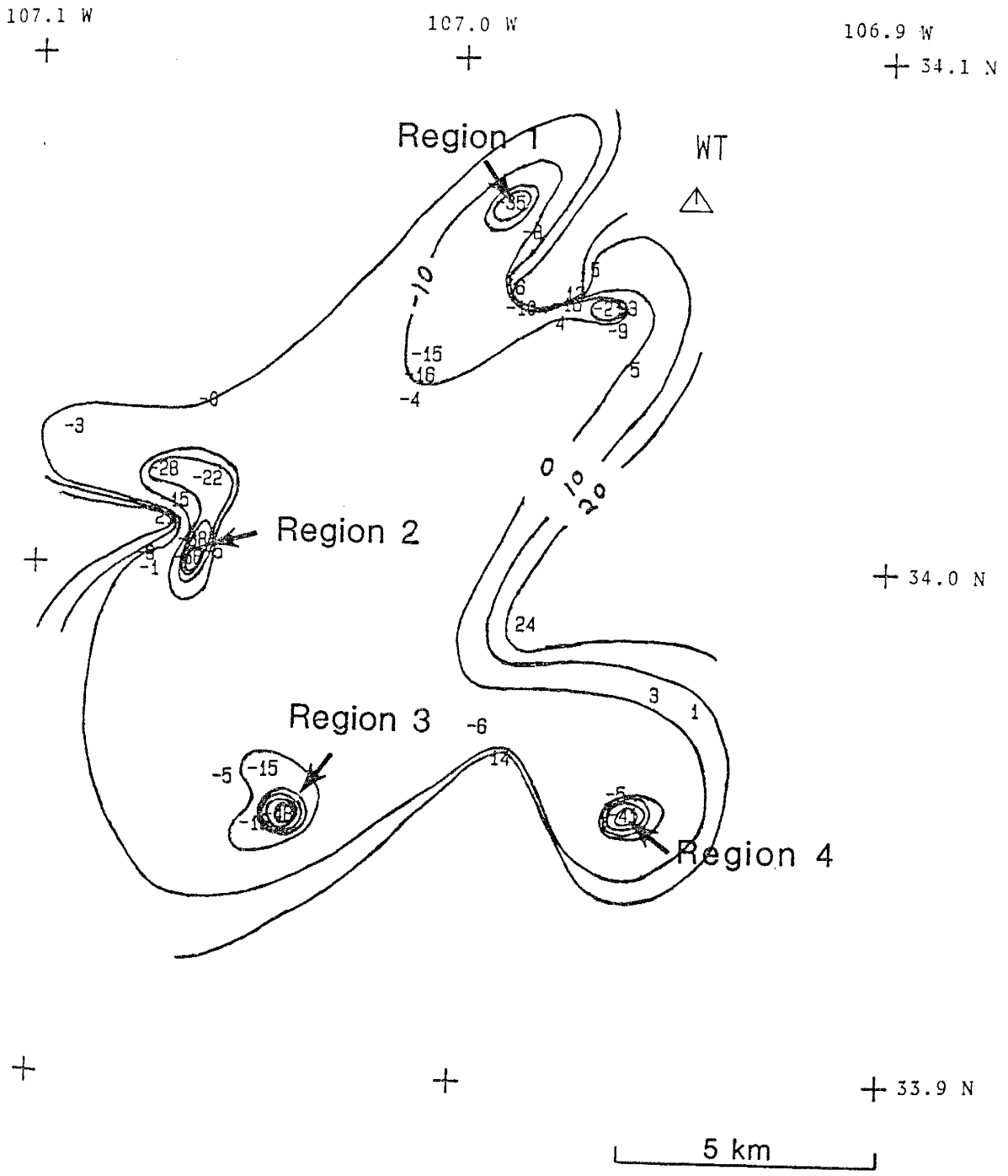


Fig. 56. The Qs residuals shown in Figure 55 are contoured here with a contour interval of 10. Regions 1 through 4 are also identified.

where Y is the spectral slope estimated by the regression model for a particular event distance. Let

$$Q_m = \pi r/(YV), \tag{31}$$

then

$$\sigma^2(Q_m) = [(\partial Q/\partial r)^2\sigma^2(r) + (\partial Q/\partial Y)^2\sigma^2(Y) + (\partial Q/\partial V)^2\sigma^2(V)] \tag{32}$$

and

$$\sigma(Q_m) = \sqrt{(1/VY)^2\sigma^2(r)+(r/Y^2V)^2\sigma^2(Y)+(r/YV^2)^2\sigma^2(V)}, \tag{33}$$

where $\sigma(Q_m)$ is the uncertainty in the model Q, V is the apparent velocity, Y is the spectral slope for a particular event distance calculated from the regression model, r is the hypocentral distance, $\sigma^2(r)$, $\sigma^2(V)$ and $\sigma^2(Y)$ represent the estimated variance in distance, velocity, and model spectral slope respectively.

These variances can be combined to yield an estimate of the uncertainty in each residual i.e.

$$\sigma(Q_{res}) = \sqrt{\sigma^2(Q_m) + \sigma^2(Q_{app})}, \tag{34}$$

where $\sigma(Q_{res})$ is the uncertainty in the Q residuals. Figure 57 shows a map of the uncertainties in the Qs residuals (2 s.d. for the mean residuals).

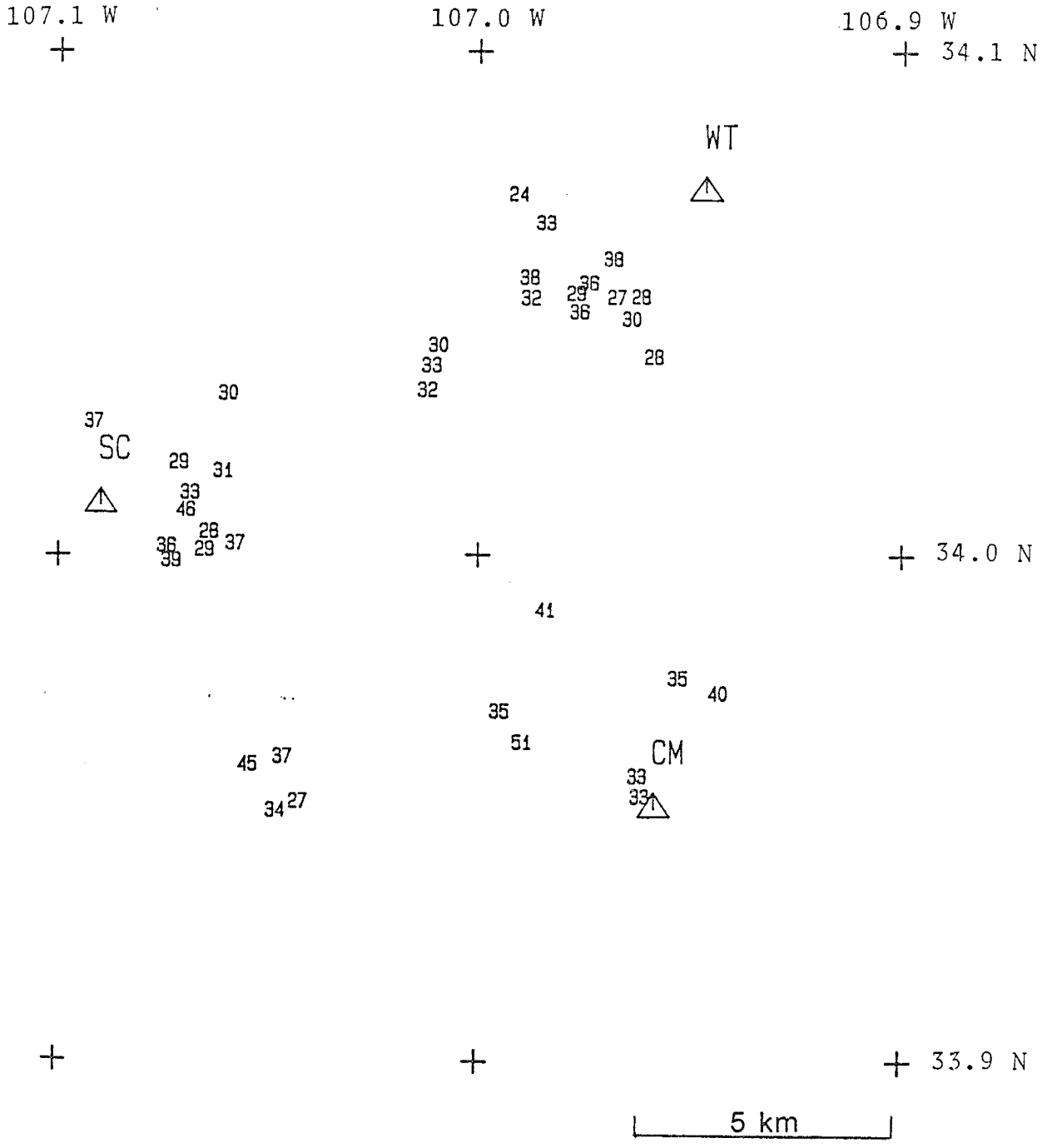


Fig. 57. Errors for the Qs residuals (2 s.d.) plotted in Figures 55 and 56.

As can be seen from Figures 55, 56, and 57, at least five events exhibit Q values that deviate significantly from the average model. These events, including windows used for the analysis of S waves, are shown in Appendix 3. The hypocentral regions of these five events will be referred to as Regions 1 through 4 below.

While the anomalous crustal volumes producing these low Q events may be located anywhere along the raypath, there is some evidence to suggest that they may lie in close proximity to the hypocenters (depths = 7-10 km):

(1) These anomalous events occur in swarms of otherwise "normal" events as can be seen in Regions 2 and 3 in Figure 56. The proximity of anomalous to normal events implies the anomalous region lies near or within the swarm (Figure 58).

(2) Only a small percentage of the rays passing through this section of crust are abnormal ($\sim$10%) and we would expect this if small anomalous volumes were in close proximity to hypocenters.

(3) Several investigators have shown a close spatial and temporal correlation between microearthquake activity and magmatic intrusion in rift areas (Shaw, 1980; Ryan et al., 1981; Sanford and Einarsson, 1982).

(4) Jarpe (1984) has found earthquakes near Socorro exhibiting compressional first motions over the entire focal sphere. This pattern implies local extension due to fluid injection at the source.

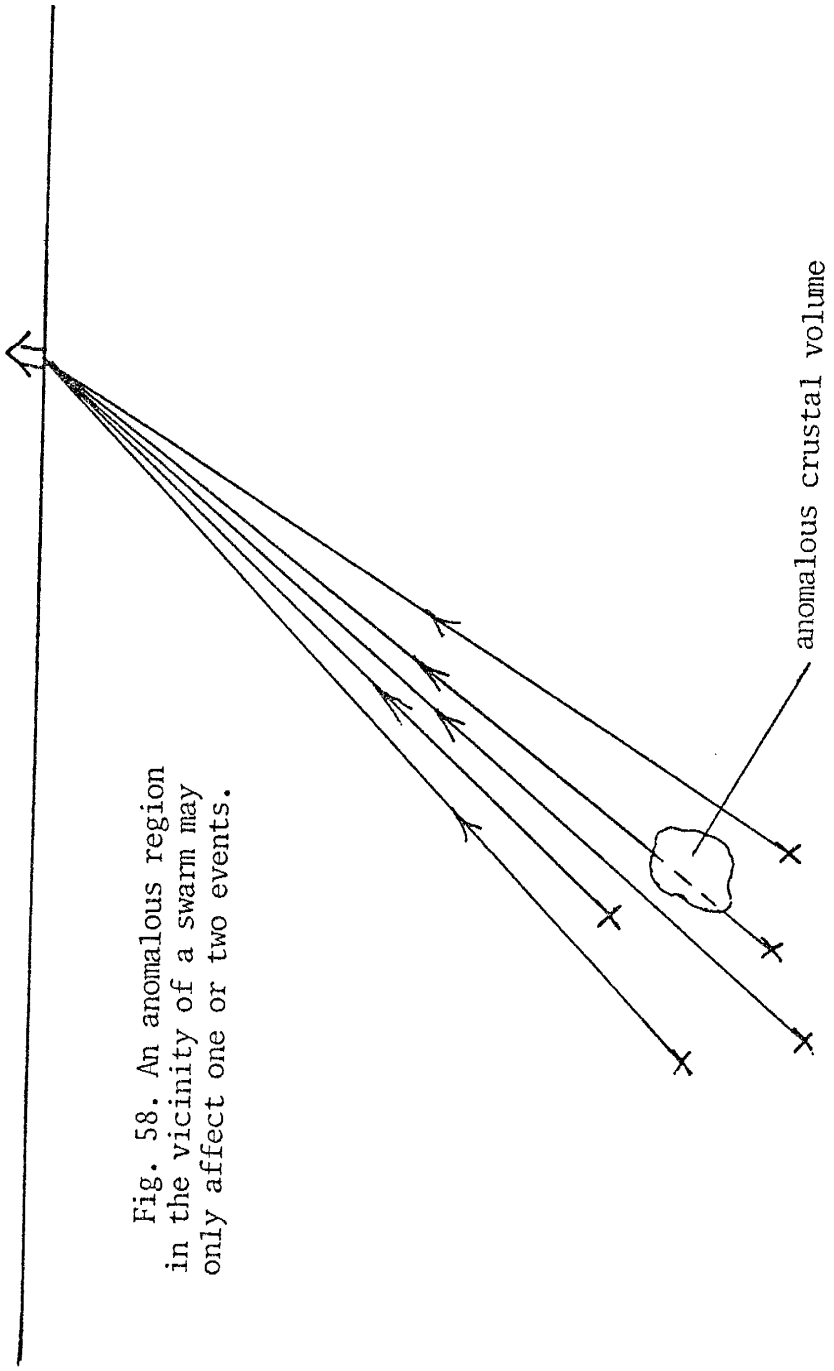


Fig. 58. An anomalous region in the vicinity of a swarm may only affect one or two events.

Figure 59 shows Regions 1-4 in relation to the surface geology and Figure 60 shows all four regions plotted on a seismicity map of the area southwest of Socorro. Region 2 falls in a zone of extremely high seismicity and Regions 1, 3, and 4 lie in areas of moderate seismicity. The correlation between anomalously low Q and high microearthquake activity in Region 2 suggests that the hypocentral region is one of intense fracturing. Such sites would also provide zones of weakness for ascending upper crustal magma intrusions; in fact, the microearthquake activity may represent release of stresses induced by intrusion (Ryan et al., 1981). If the depressed quality factors in Region 2 could be totally attributed to magma, the volume of melt would be quite small. Assuming a Qs of 0.1 for basaltic melt (Manchnani et al., 1983), a dike or sill would only need to be about 5 m thick to sufficiently attenuate S waves. If Qs for the melt were as high as 1.0, 40-50 m of magma would be sufficient. The magma chambers and conduits, however, probably cover a somewhat larger area (diameter $\sim 10^2$ m), possibly composed of "honeycombed magma-filled fracture zones" of the type inferred by Ryan et al. (1981) beneath Kilauea.

The existence of pockets of abnormally high attenuation in the upper crust southwest of Socorro offers further evidence that this is a region of severe crustal disturbance and possible magma injection. The upper crust within 20 km southwest of Socorro has been shown to exhibit abnormally

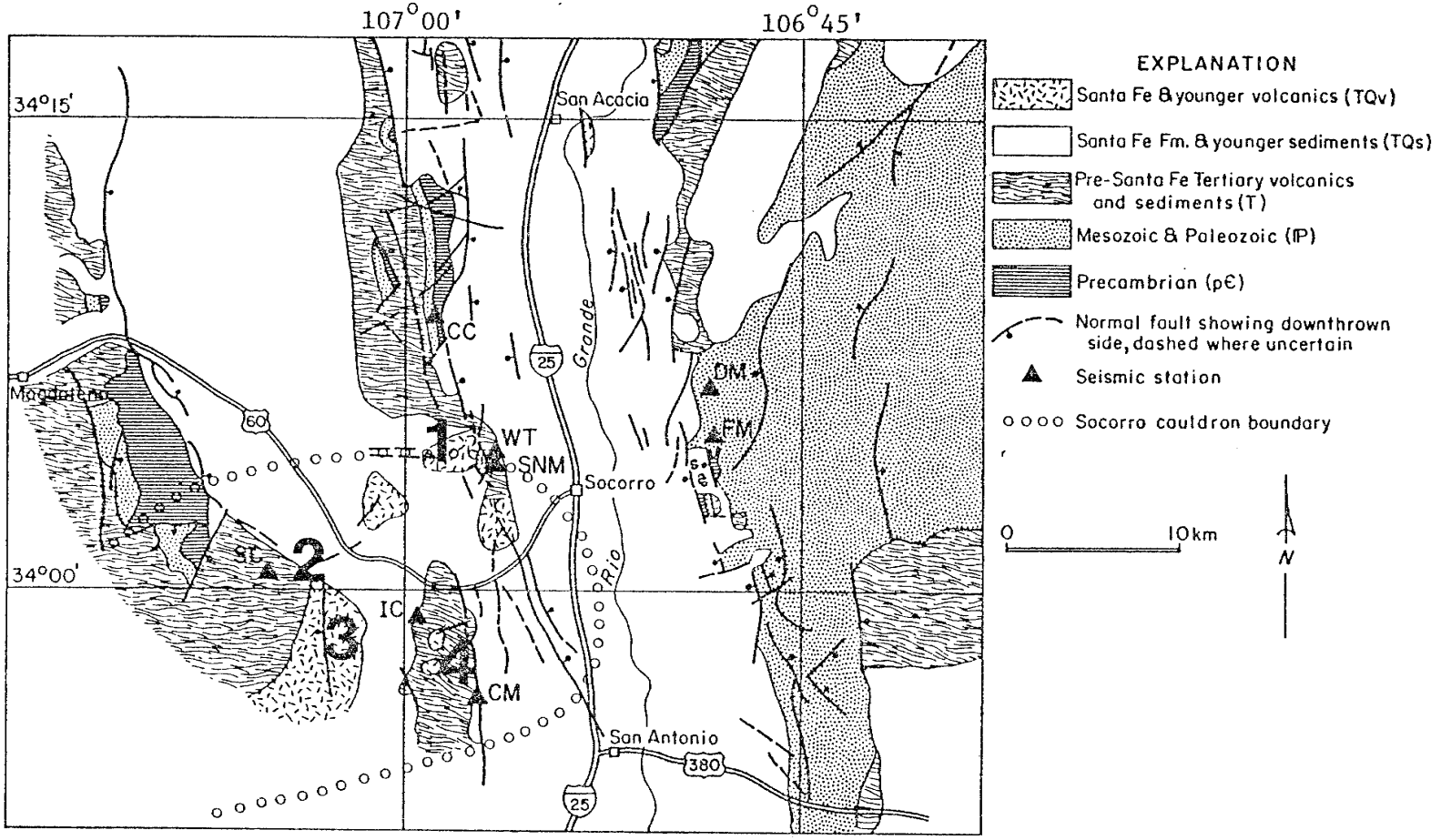


Fig. 59. A simplified geological map of the Socorro area showing Regions 1 through 4. Seismic stations are shown as black triangles (after Sanford et al., 1972).

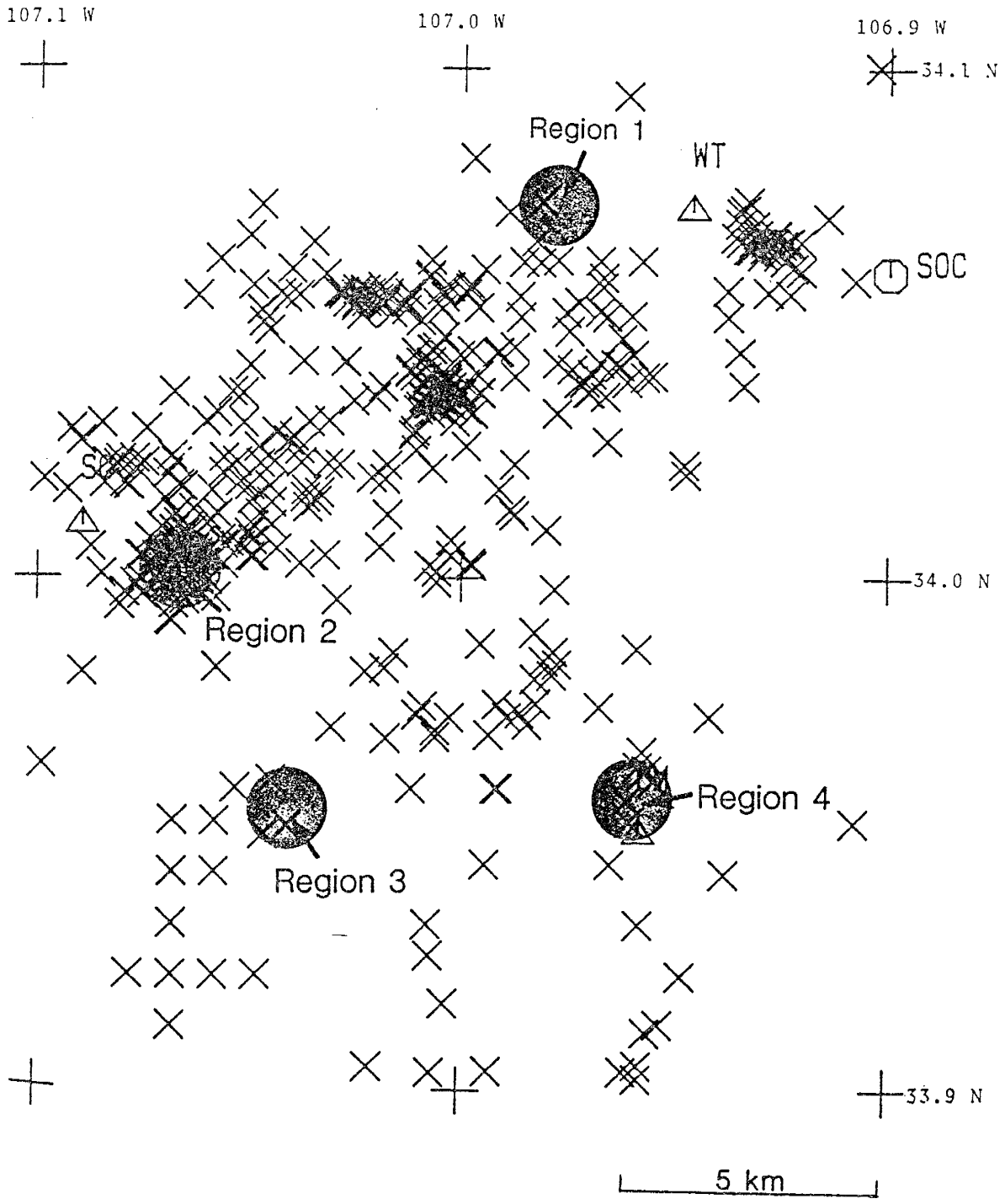


Fig. 60. Regions 1 through 4 plotted on a seismicity map of the area southwest of Socorro. This map is an enlarged portion of Figure 11 and shows events occurring over an eight year period.

high P/S amplitude ratios (Roach, 1982), anomalously low P wave velocities (Ward et al., 1981), and high Poisson ratios (>0.29) (Caravella, 1976). In particular, Region 2 lies in a volume of anomalously low P wave velocity as identified by Ward et al. (1981). Region 2 also lies within a transverse shear zone as defined by Chapin et al. (1978); this zone of surface disturbance may extend to the focal depths of these microearthquakes.

Low Velocity Regions or Low Q Regions?

The low Q events discussed above cannot be solely the product of the S wave passing through a low velocity region. A simple calculation may be used to compute the average velocity along a raypath assuming the apparent Q fluctuations are due to velocity fluctuations. Let

$$m_{an} = -\pi r/(Q_{an}V), \tag{35}$$

where m_{an} is the spectral slope for the anomalous event, V is the average velocity used to compute Q, Q_{an} = the anomalous Q value, and r is the hypocentral distance.

The anomalous velocity that would correspond to this low apparent Q value would then be

$$V_{an} = -\pi r/(Q_{av}m_{an}), \tag{36}$$

where V_{an} = the average velocity for the raypath and Q_{av} = the average Q for this distance (from the regression model). From the above equations it was found that the average S wave velocity, for the entire raypath, would need to be lowered to 2.06 km/s to account for all anomalous Q values. In the studies listed in Figure 37, there have been no cases where an average S wave velocity this low has been observed. Also, the anomalous events do not exhibit large time residuals when being located by HYPO71 nor do they have abnormally large errors in their hypocentral locations. Thus it appears that the anomalous low Q events cannot be

explained solely on the basis of depressed seismic velocities.

Rift Versus Non-rift Q

In this study, apparent Q values recorded at the surface in the central Rio Grande rift ranged from 60 to 400. On the basis of an observed increase in apparent Q with hypocentral distance, it was proposed that low Q, low velocity rocks lie above a relatively high Q, high velocity half-space, in the depth range 0-19 km. From a least squares fit to this model, the average basement Q in the central Rio Grande rift was found to be about 535 (the 2 s.d. range for this mean value is 374-938). The veneer of low velocity, low Q material exhibited Qp and Qs values less than 50. These quality factors will be compared below to other rift Q values and Q values from other physiographic provinces.

Brocher (1981) obtained a maximum estimate for Qp of 625 from a reflection on COCORP Line 2A in the northeastern part of the study area (Figure 11). Brocher computed attenuation in rocks overlying the mid-crustal magma body by assuming the strength of reflections off the magma body's surface were only affected by attenuation in overlying rocks. Thus energy losses at interfaces were incorporated into this estimate of Q. Brocher chose the strongest mid-crustal reflection from all of the COCORP lines

(reflectivity = 0.55) and computed a Qp of 625 for a wave with a dominant frequency of 20 Hz, assuming a reflection coefficient of 1 at the mid-crustal discontinuity. Since most reflections on the COCORP lines are much weaker than the one used for this calculation, the average Qp probably is considerably less than this value. Using more typical reflectivities ($\sim$0.30), a Qp of 300 is computed using Brocher's method. This value is similar to the maximum Qp values obtained in this study.

Table 2 and Figure 13 present a few quality factors obtained by researchers for other regions of the North American continent. It can be seen that Qp and Qs values greater than 500 are common in the stable interior, but quality factors are generally smaller in the Basin and Range province and along the West Coast. The central Rio Grande rift appears to have a lower crustal Q than parts of the stable interior and a higher average crustal Q than parts of the Basin and Range and West Coast, according to Singh and Herrmann (1983). They correlate high quality factors with regions of tectonic quiescence and low quality factors with regions of tectonic activity. Singh and Herrmann believe more energy is lost to scattering from crustal heterogenieties in tectonically active regions. They base their conclusion on the measurement of higher coda Q values for waves propagating parallel to the structural grain and lower coda quality factors for waves propagating across structural trends.

Butler (1984), on the other hand, believes heat flow is the most important single parameter in determining Q for the crust and upper mantle beneath the continental United States. In comparing teleseismic P wave amplitudes (1 s) between various physiographic provinces, he found that the Rio Grande rift had the lowest crust-upper mantle Q in the continental U.S. He attributed this low Q to average temperatures in the upper 400 km being 40-90 ^{o}C higher than surrounding regions. It should be noted that the above studies utilize earthquake waves at frequencies lower than those used in this investigation. P and S waves from microearthquakes, as used in this study (frequency range 0-50 Hz), are more sensitive to small-scale inhomogeneities in the upper crust and may be "seeing" a different Q structure.

SUGGESTIONS FOR FURTHER RESEARCH

Many questions that have arisen in this study could be investigated further. A few will be discussed below.

(1) Can Qs_2 be better constrained? High-quality Q estimates from events at distances over 25 km would help constrain the bivariate regression for Qs_2 at WT. Also, a leveling out in apparent Q may occur at greater event distances; we would expect apparent Q to approach Q_2 as the distance $\dashrightarrow \infty$ unless the ray passes into another Q province.

(2) A detailed geophysical and geological investigation of station sites should be conducted. In particular, estimates of near-surface Q and velocity could be obtained using portable seismic equipment with small-scale refraction/reflection experiments.

(3) What is the source for the late P and S (scattered) arrivals that often follow the primary phases? As these waves cannot always be excluded from P and S windows, they add noise to the spectrum. A study of coda waves could be undertaken with the intention of identifying scatterers. Synthetic seismograms generated using known geology can be compared to actual seismograms and various arrivals

correlated with geological structures. This may help to identify later phases and justify their removal prior to spectral analysis.

(4) If the instrumental response can be deconvolved, an expression relating the first half-cycle of the P wave to the Qp value could be found. This idea is based on results obtained by Frankel and Kanamori (1983) in which the first half-cycle was found to be constant below a certain threshold magnitude. Below this magnitude it appears that only the path and the instrument response characteristics affect the width of the first half-cycle. A sampling rate exceeding 100 sps would be required in the Socorro area to obtain a resolution comparable to that obtained in this study (A. Sanford, personal communication, 1984) and further calibration of the DR100 amplifiers would be needed, since existing response curves only extend to 50 Hz, the Nyquist frequency for a sampling rate of 100 sps.

(5) The three-dimensional variation in Q could be statistically analyzed as a "field of Q values." Correlations between Q values for individual events could then be computed.

(6) Drilling or taking advantage of a deep drillhole in the Socorro area would increase our knowledge of subsurface structure immensely. Such a hole would allow us to compute Q over generally known intervals, to study the change in fracture density with depth, and to obtain measurements of

the geothermal gradient.

SUMMARY AND CONCLUSIONS

In this study, spectra from 140 digitally recorded microearthquakes were used to compute seismic quality factors for the Socorro area of the Rio Grande rift. The quality factors were obtained by fitting spectral slopes for each event with a least squares line after instrumental effects had been deconvolved. Source deconvolution was unnecessary as it was found that the frequency content of P and S waveforms was not affected by the event strength and thus the source spectrum was assumed to be independent of frequency for the magnitude range used in this study (-0.9 to 1.0). Near-surface reverberations were also not found to severely affect the spectra of these events, and thus no correction was made for station effects exclusive of strong near-surface attenuation.

In plotting apparent Q as a function of event distance for each station in the Socorro array, it was found that Q increases with increasing hypocentral distance. This suggests that Q increases with depth. As there is also some evidence to suggest that the average Qs beneath the base of the seismic zone ($\sim$12 km) and the mid-crustal discontinuity (19 km) does not differ substantially from the average Qs of the upper 12 km, a model was formulated consisting of a low

velocity, low Q layer lying atop a relatively high velocity, high Q half-space. The layer corresponds to laterally varying low velocity, low Q rocks and the half-space corresponds to the average basement Q for the upper crust. A bivariate least squares regression was performed on the Qs data from station WT. Qs for the near-surface layer was found to be about 10 $\pm$ 2 (2 s.d. of the mean) and the average half-space Qs was found to be 535, with a substantial degree of uncertainty (the 2 s.d. range for the mean Qs_2 is 374-938).

While least squares fits could not be used at other stations due to the sparsity of the data and the scatter in the quality factors, estimates of the near-surface Qs were obtained by assuming a value of 535 (the regression average) for the half-space Qs and using the apparent Qs to calculate the near-surface Qs. For all stations, the near-surface Qs was found to be less than 50; the magnitude of Qs_1 was found to increase with the thickness of the low velocity layer. The near-surface Qp was also found to be less than 50 from the spectra of P waves from local explosions.

Qp/Qs was found to vary from 0.34 to 1.39 among events recorded at the eight stations in the digital network. For waves recorded at three stations (CM, DM, and FM) the Qp/Qs ratio decreased with increasing event distance. Stations CC and WT showed no such trend and events recorded at stations IC, SC, and SNM were too close together to draw any

conclusions. Different changes in the Qp/Qs ratio with increasing event distance for different stations may be related to the differing degrees of saturation in upper-crustal rocks.

Also, significant lateral variations in Q were found in the Rio Grande rift near Socorro. These lateral variations were identified by plotting residual quality factors at the epicenters of individual events and noting significant deviations from the average regression model. Four anomalous low-Q regions have been identified within 20 km southwest of Socorro using this technique with microearthquakes recorded at station WT. In at least two cases, the anomalous regions appear to lie in close proximity to microearthquake swarms, at depths ranging from 7 to 10 km, beneath the southwestern La Jencia basin. As both high temperatures and high fracture densities can lead to low Q values, these regions could be zones of magma intrusion and pervasive deep fracturing. They also correlate with regions of anomalously low velocity (Ward et al., 1981) and lie in areas of suspected upper crustal magma intrusion which have been inferred on the basis of other seismic investigations (Chapin et al., 1978).

Finally, the basement Q in the Rio Grande rift was compared with basement Q values from other physiographic provinces. In general, Qs in the rift is lower than Qs in the stable interior, but higher than Qs in the Basin and

Range province and along the West Coast. Scattering from open and fluid filled fractures at depth and elevated heat flows may be responsible for this pattern.

Many questions have been raised by this investigation. Further research should focus on: (1) recording more events at greater distances to obtain more reliable half-space Q estimates, (2) undertaking field studies to delineate near-surface velocity and attenuation near recording sites, (3) identifying the sources of scattered waves, (4) relating the P wave first half-cycle to Qp, (5) analyzing the Q values in the Socorro area as a "Q field", and (6) taking advantage of any drillholes in the area in order to obtain information on subsurface Q, fracture densities and heat flows.

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APPENDIX 1

CALIBRATION DETAILS

Amplifier and Recorder Response

Response curves for the DR100 systems used in this study were originally supplied by Sprengnether. These response curves were verified by analog calibration tests conducted by the seismology group at New Mexico Tech (Rinehart, 1979). The digitally recorded amplitudes, however, will be lower than the analog amplitudes since the digitizing comb will not generally sample the waveform peaks. For low frequency waves, errors between the digitally recorded amplitude and the true amplitude will not be great. However, at high frequencies, the likelihood of sampling near a wave crest becomes small. Thus the average response of the digital recorder will decrease with frequency (Figure 1-1).

The following procedure was used to compute the average digital response. First, the smallest maximum amplitude that could be recorded for a monochromatic waveform at a particular sampling interval was calculated. This was done by moving off the wave peak by half a sampling interval ($\Delta t/2$); for a sampling rate of 100 samples per second (Δt = 0.01 s), this is 0.005 s (Figure 1-2). This corresponds to a "worst case" positioning of the digitizing comb with

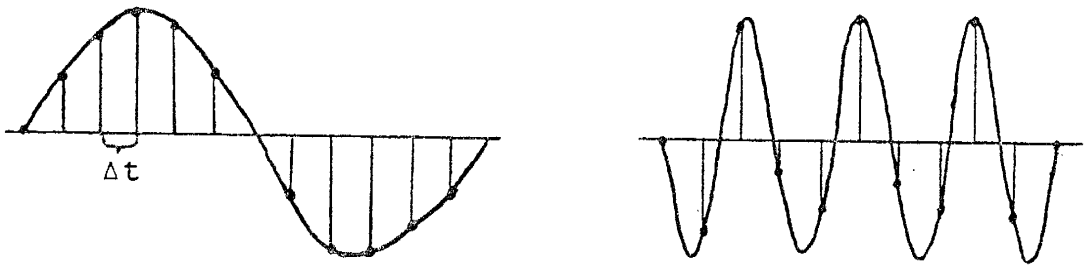


Fig. 1-1. Sampling low and high frequency waves. With the low frequency wave there is a better chance of sampling near a wave peak.

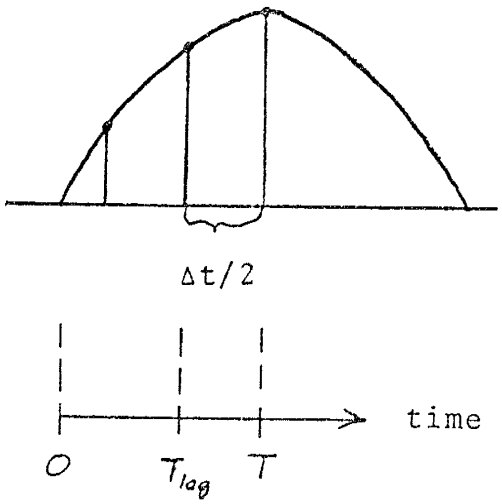


Fig. 1-2. The smallest maximum amplitude that can be digitally recorded may be found by lagging 1/2 a sampling interval behind the peak. This corresponds to the "digital worst case" or to the least fortuitous position of the digitizing comb.

respect to the waveform. Let

$$A = \sin \omega T \qquad (1\text{-}1)$$

where $\omega = 2\pi f$. For a sine wave, the maximum value will occur at $\omega T = \pi/2$, so a peak will occur at $T = \pi/(2\omega)$, or,

$$T = \pi/[2(2\pi f)] = 1/(4f) \qquad (1\text{-}2)$$

We want to lag behind the maximum value T by $\Delta t/2$ seconds, so we want to sample the waveform at

$$T_{lag} = 1/(4f) - \Delta t/2 \qquad (1\text{-}3)$$

Figure 1-2 illustrates how the waveform is sampled.

Table 1-1 shows lag times for various frequencies and the amplitude that would be recorded for a unit amplitude sine wave.

Figures 1-3 and 1-4 show the analog response curves, the worst case digital response curves, and the average of these two curves which was used to deconvolve the microearthquake spectra.

The average digital response curve for the 30 Hz high-cut filter was checked by an independent digital calibration. Sine waves with amplitudes of 0.5 Vp-p and 2.0 Vp-p were sampled and the maximum recorded amplitude plotted on the average response curve. Note that the recorded amplitudes fall near the average digital response curve, verifying this procedure.

TABLE 1-1

Times to evaluate sine function for digital worse case curve (Figure 1-2)

Freq.	T_{lag}	$A = \sin \omega T_{lag}$
1 Hz	0.2450 s	0.999
10	0.0200	0.951
15	0.0117	0.891
20	0.0750	0.809
25	0.0050	0.707
30	0.0033	0.588
35	0.0021	0.454
40	0.0013	0.309
45	0.0006	0.156
50	0.0000	0.000

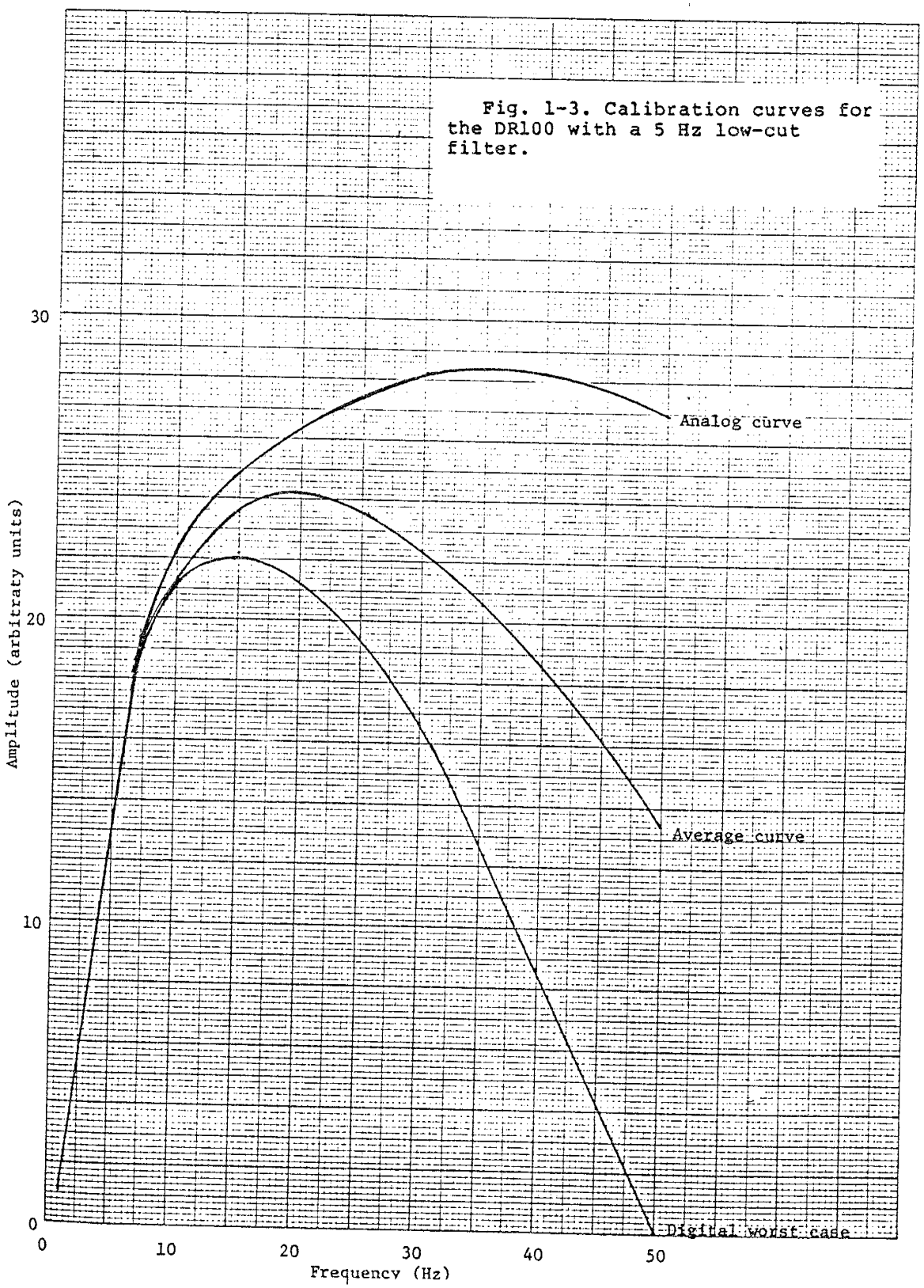


Fig. 1-3. Calibration curves for the DR100 with a 5 Hz low-cut filter.

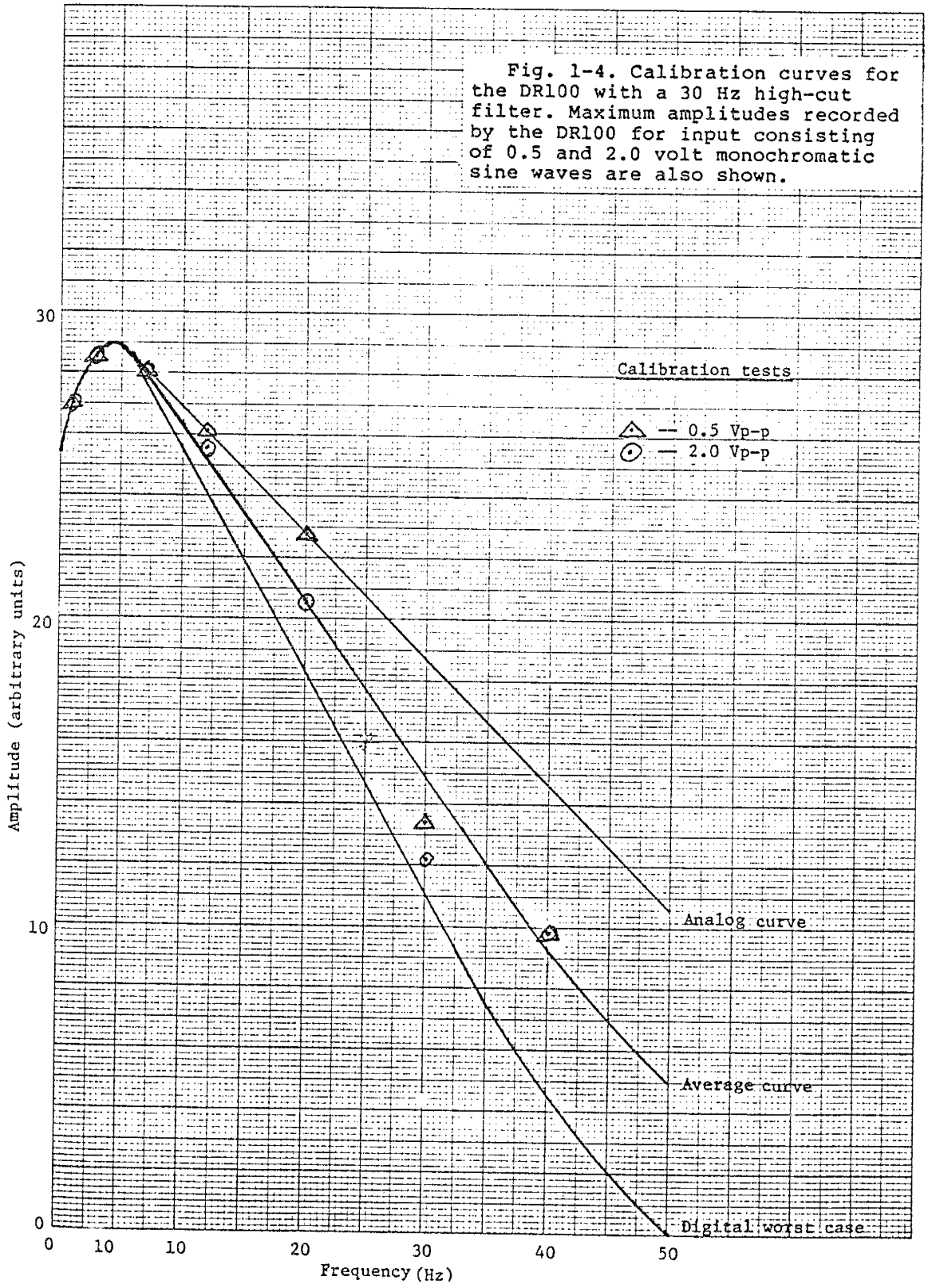
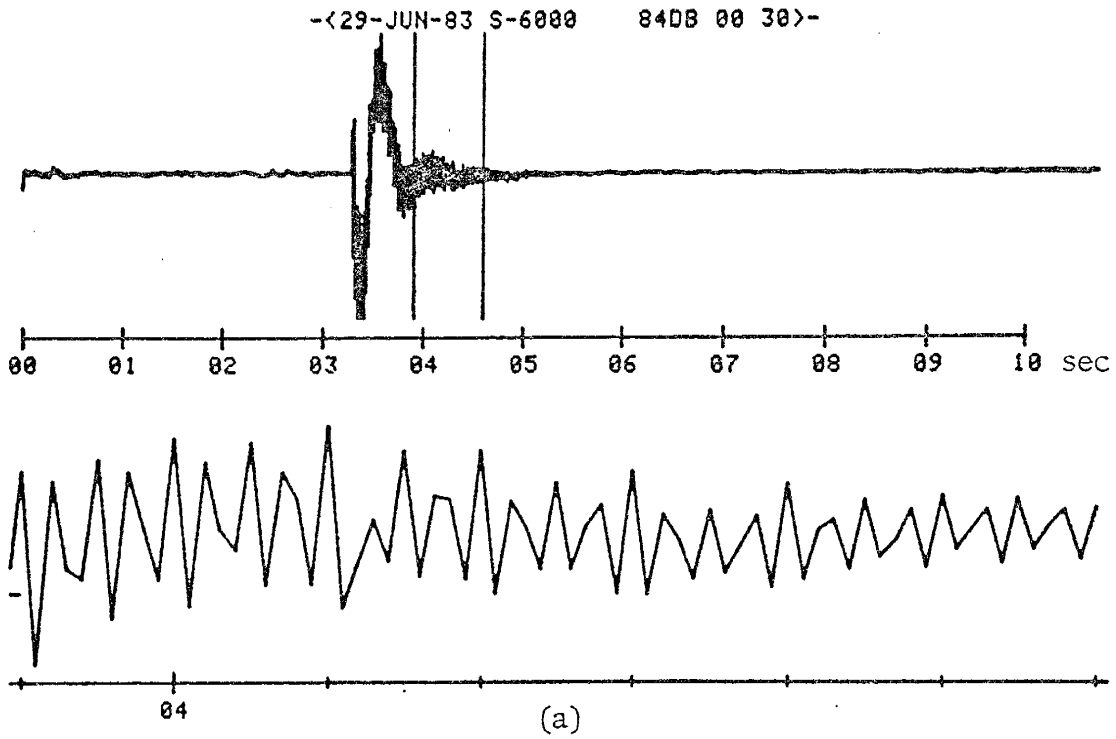


Fig. 1-4. Calibration curves for the DR100 with a 30 Hz high-cut filter. Maximum amplitudes recorded by the DR100 for input consisting of 0.5 and 2.0 volt monochromatic sine waves are also shown.

Seismometer Response

As mentioned in the main body of the text, an insensitivity to ground motion has been measured in L4C seismometers at frequencies of 25 Hz (L. Jaksha, personal communication, 1984). This insensitivity, if it exists in the seismometers used in this study, was not found to seriously affect the spectra or the Q estimates (see Figures 1-7 and 1-8).

Parasitic oscillations of the seismometers were also studied. These externally excited but totally internal flexural or torsional vibrations of the vertical seismometer spring may contaminate the ground motion signal. To generate parasitic oscillations, all of the seismometers were tapped on their sides in a quiet location. An example of the resulting waveform is shown in Figure 1-5a for a Sprengnether S-6000 and in Figure 1-5b for a Mark Products L4C. Spectra are shown in Figures 1-6a and 1-6b respectively. From the spectra it can be seen that the natural frequency for the L4C parasitic oscillations is about 20 Hz while for the S-6000 it is about 40 Hz. All of the L4Cs tested showed a strong peak near 20 Hz. To see if the parasitic oscillations had a serious impact on recorded waves, two systems were used to record the same earthquake at the same station.



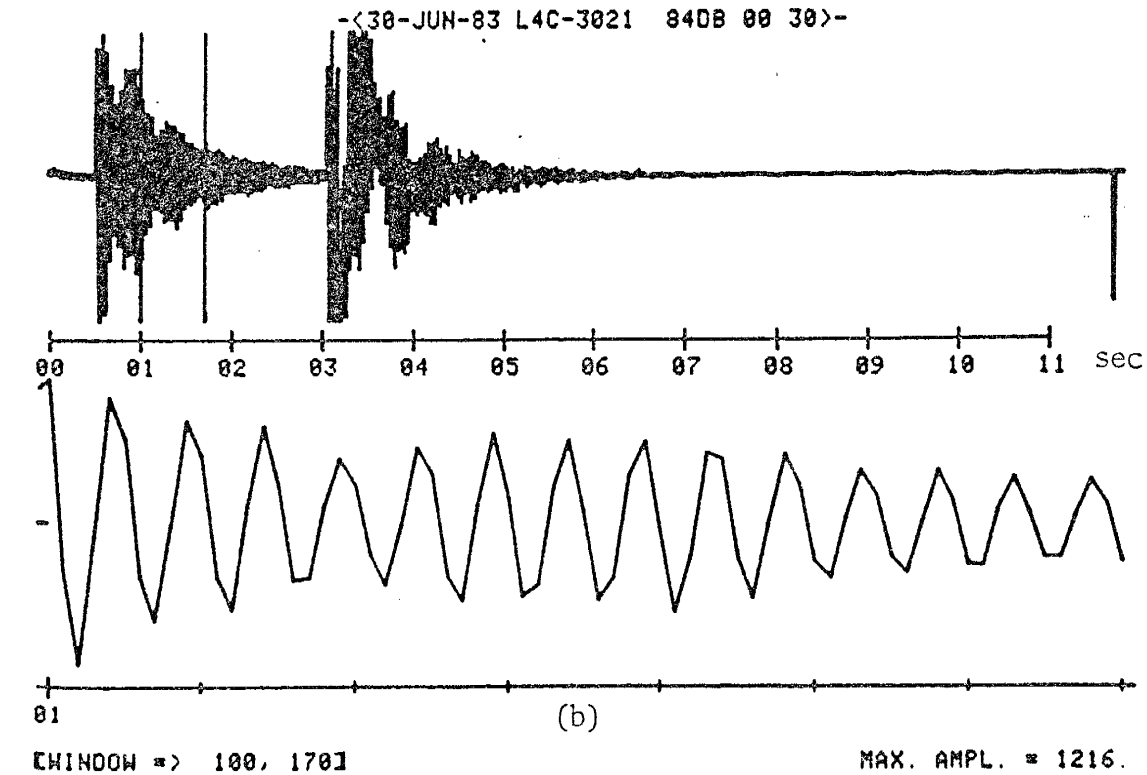
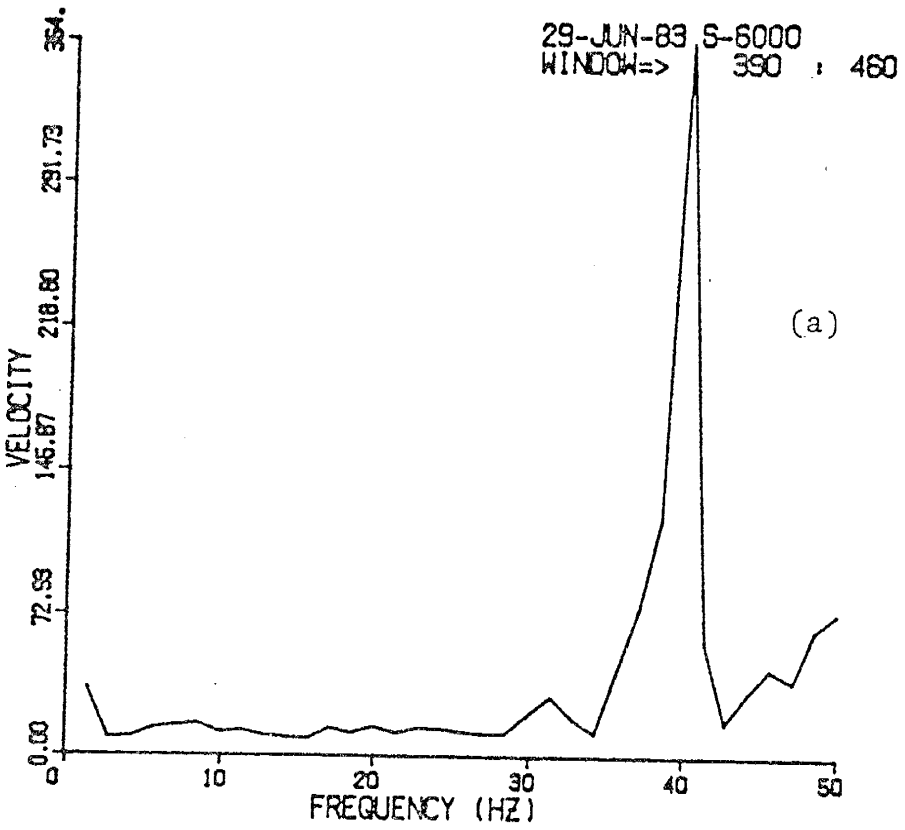


Fig. 1-5. (a) Parasitic oscillations for an S-6000.
(b) Parasitic oscillations for an L4C.



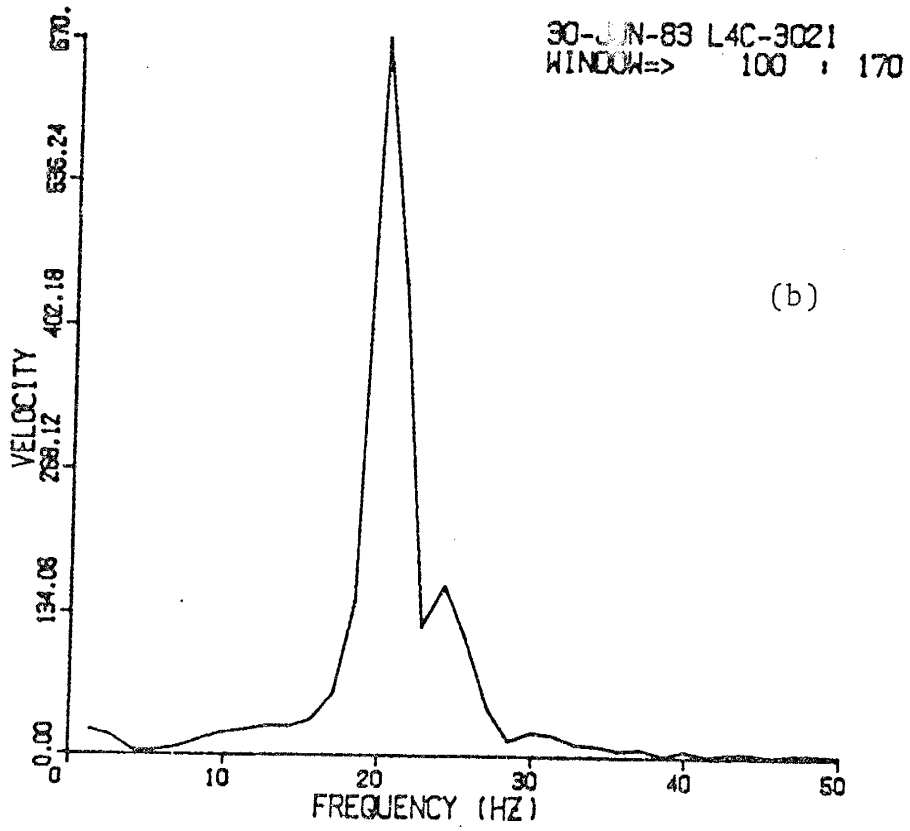


Fig. 1-6. (a) Spectrum of parasitic oscillations for an S-6000 seismometer. (b) Spectrum of parasitic oscillations for a L4C seismometer.

The first system consisted of an L4C seismometer and a DR100 recorder. The second consisted of the S-6000 seismometer with a DR100-1A recorder. Figure 1-7 shows the two seismograms produced by these two systems for an event in June, 1983. Figure 1-8 shows the spectra produced by these seismograms. As the traces and spectra are identical to within the accuracy of the sampling rate, it was concluded that parasitic oscillations are not important at typical microearthquake amplitudes. These two systems recorded other duplicate microearthquakes during swarms in 1983 with similar results.

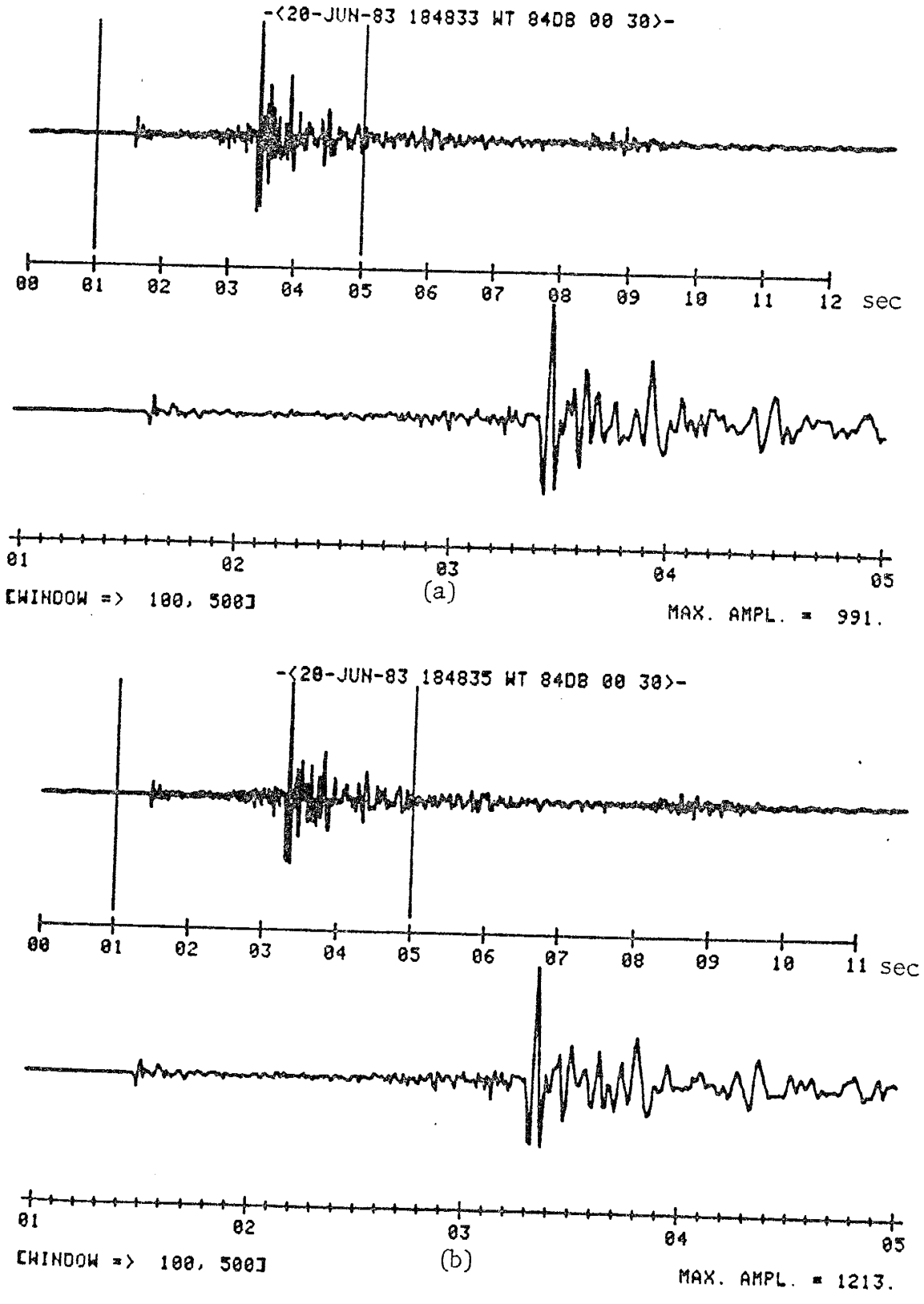


Fig. 1-7. (a) A microearthquake recorded with an S-6000 on the DR100-1A. (b) The same event recorded with an L4C on a DR100.

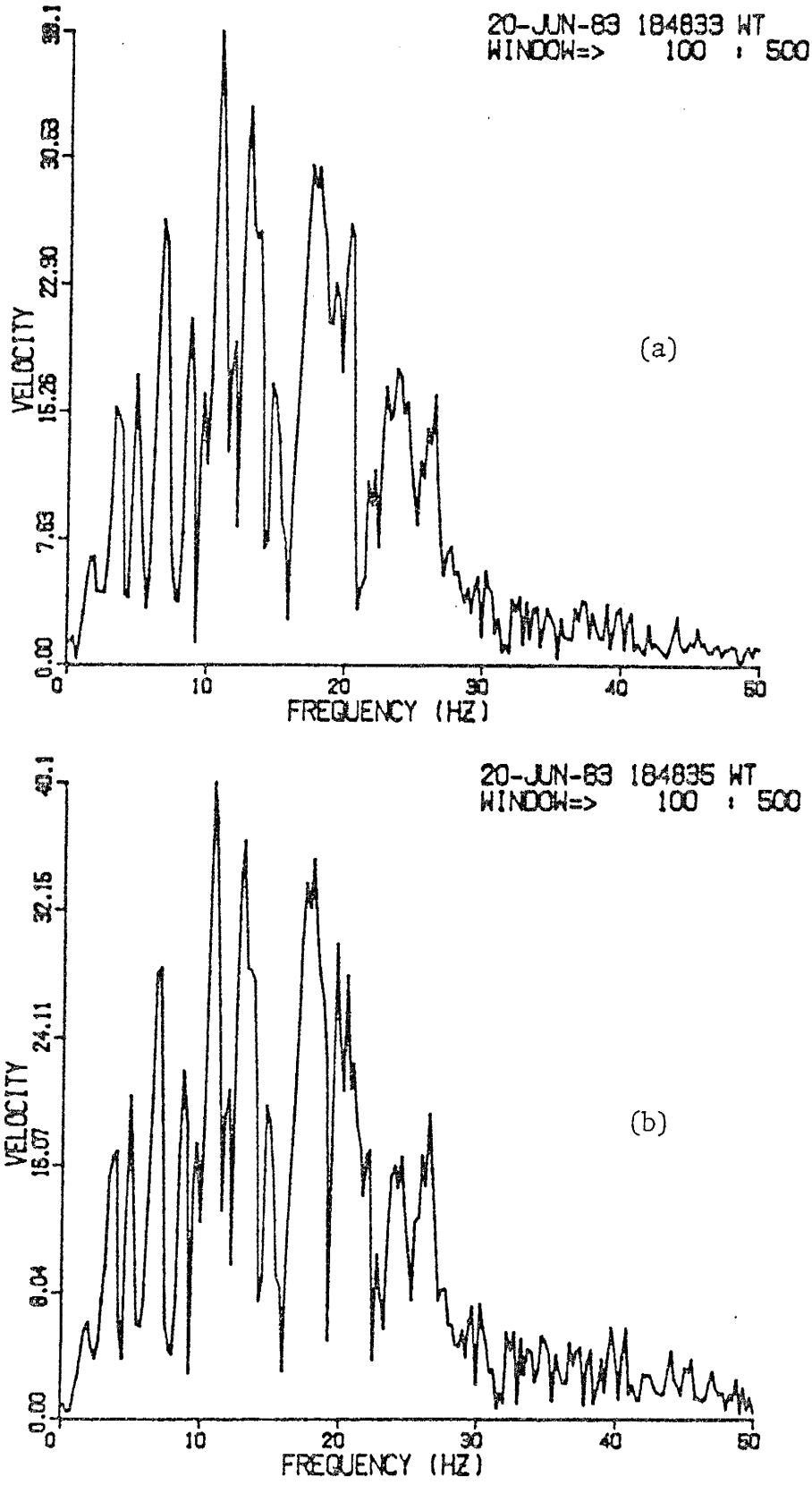


Fig 1-8. Spectra for windows shown in Figure 1-7. (a) The spectrum for an S-6000. (b) The spectrum for an L4C.

APPENDIX 2

DATA AND WINDOW PLOTS FOR EVENTS USED IN SPECTRAL ANALYSIS

In this appendix, all events included in Figures 27, 32, 39 through 46, 49, 50, and 54 are listed and the time windows used for analysis are plotted. A few notes will be included below to facilitate reading headings for tables and plots.

Abbreviations used in table headings:

Q	Seismic quality factor
QMAX	Upper bound for Q (2 s.d.)
QMIN	Lower bound for Q (2 s.d.)
CORR	Spectral fit correlation coefficient
DIST	Event distance (km)
DEPTH	Focal depth (8.5 km if unlocated)
LAT	Latitude in degrees (if located)
LONG	Longitude in degrees (if located)

Abbreviations used in window plots:

WINDOW	Window start and stop positions
DIST	Event distance (km)

For both of the above, the event header contains information on event date, time, and recording parameters. A header is decoded below:

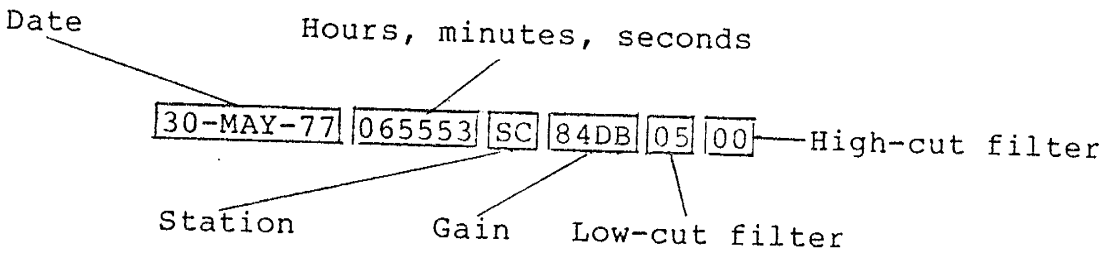


TABLE 2-1

EVENTS RECORDED AT CC USED TO COMPUTE Qp

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUN ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	17-AUG-77 155303 CC 84DB 00 00	91: 155	91.73	110.69	72.78	0.87	14.48	5.08	34.2568	106.9248
2	17-AUG-77 043655 CC 84DB 00 00	24: 88	75.68	90.79	60.56	0.91	15.06	8.50	0.0000	0.0000
3	17-AUG-77 153725 CC 84DB 00 00	241: 305	73.35	85.86	60.84	0.91	15.72	6.34	34.2628	106.9198
4	30-MAY-77 070055 CC 84DB 05 00	12: 76	93.03	114.97	71.09	0.86	16.10	8.50	0.0000	0.0000
5	16-JUN-77 092625 CC 72DB 05 30	129: 193	132.35	160.47	104.22	0.89	17.22	8.50	0.0000	0.0000
6	30-MAY-77 065553 CC 84DB 05 00	168: 232	93.22	111.06	75.38	0.91	17.62	8.50	0.0000	0.0000
7	18-AUG-77 103819 CC 84DB 00 00	186: 250	93.06	105.29	80.82	0.94	18.20	9.21	34.0182	107.0593
8	18-AUG-77 103915 CC 84DB 00 00	184: 248	136.50	167.10	105.90	0.85	19.82	10.57	34.0097	107.0648
9	17-AUG-77 120833 CC 84DB 00 00	182: 246	143.84	174.43	113.26	0.88	22.83	8.50	0.0000	0.0000
10	16-AUG-77 154927 CC 84DB 00 00	237: 301	154.50	185.09	123.90	0.89	24.35	8.50	0.0000	0.0000
11	18-AUG-77 081125 CC 84DB 00 00	180: 244	176.14	202.81	149.48	0.92	24.52	8.53	34.2268	106.8900
12	17-AUG-77 141427 CC 84DB 00 00	211: 275	159.45	183.28	135.61	0.93	24.88	8.39	34.3378	106.8830

TABLE 2-2

EVENTS RECORDED AT CM USED TO COMPUTE Qp

MAXIMUM ERROR IN Q ESTIMATES = 30.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	15-JUN-77 034715 CM 72DB 05 30	96: 160	82.13	105.09	59.16	0.86	9.02	8.50	0.0000	0.0000
2	15-JUN-77 036921 CM 72DB 05 30	122: 186	73.40	90.67	56.13	0.92	9.34	8.50	0.0000	0.0000
3	14-JUN-77 234649 CM 72DB 05 30	231: 295	64.02	78.44	49.60	0.93	9.42	8.50	0.0000	0.0000
4	09-NOV-77 071205 CM 60DB 00 00	232: 296	79.59	93.12	66.07	0.94	14.79	8.50	0.0000	0.0000
5	09-NOV-77 102909 CM 60DB 00 00	-1: 63	70.52	83.61	57.44	0.92	15.11	8.50	0.0000	0.0000
6	10-JUN-77 040451 CM 72DB 05 00	16: 88	74.40	87.09	61.71	0.91	15.47	9.96	34.0173	107.0572
7	16-JUN-77 092625 CM 72DB 05 30	169: 233	90.25	104.86	75.64	0.93	24.73	8.50	0.0000	0.0000

TABLE 2-3

EVENTS RECORDED AT DM USED TO COMPUTE Qp

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	12-SEP-77 185907 DM 84DB 00 00	269: 273	40.50	53.62	27.37	0.86	6.63	<6.63	0.0000	0.0000
2	12-SEP-77 181539 DM 84DB 00 00	244: 308	40.58	52.32	28.85	0.92	6.71	<6.71	0.0000	0.0000
3	17-SEP-77 144541 DM 84DB 00 00	241: 305	39.96	48.77	31.16	0.94	9.20	8.50	0.0000	0.0000
4	29-AUG-77 035643 DM 84DB 00 00	1345:1409	90.15	111.02	69.29	0.90	10.64	8.50	0.0000	0.0000
5	14-JUL-77 023407 DM 72DB 00 00	83: 147	49.03	54.97	43.09	0.96	11.07	7.20	34.1587	106.8758
6	14-JUL-77 113159 DM 72DB 00 00	93: 157	47.36	53.19	41.53	0.95	11.12	7.38	34.1548	106.8778
7	29-AUG-77 035643 DM 84DB 00 00	210: 274	91.47	105.75	77.19	0.95	17.61	8.50	0.0000	0.0000
8	29-AUG-77 014231 DM 84DB 00 00	226: 290	77.54	87.64	67.44	0.96	25.71	8.50	0.0000	0.0000
9	26-AUG-77 103313 DM 84DB 00 00	226: 290	125.87	148.02	103.71	0.90	28.24	10.69	34.0068	107.0637

TABLE 2-4

EVENTS RECORDED AT FM USED TO COMPUTE Qp

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	25-FEB-84 190415 FM 66DB 00 00	173: 237	85.34	103.69	66.99	0.86	10.70	8.60	34.1200	106.7400
2	25-OCT-77 125225 FM 66DB 00 00	256: 320	61.61	72.92	50.30	0.95	11.94	8.50	0.0000	0.0000
3	29-OCT-77 104137 FM 66DB 00 00	185: 249	96.99	120.34	73.64	0.87	12.82	8.30	0.0000	0.0000
4	15-NOV-77 190247 FM 66DB 00 00	52: 116	72.68	87.33	58.03	0.88	13.41	8.24	34.1505	106.8855
5	06-NOV-77 030501 FM 66DB 00 00	30: 94	84.14	99.37	68.92	0.93	14.11	8.50	0.0000	0.0000
6	18-NOV-77 142219 FM 66DB 00 00	249: 313	76.32	88.72	63.92	0.95	14.17	13.40	34.0637	106.7603
7	26-FEB-84 205621 FM 66DB 00 00	338: 402	63.66	70.15	57.16	0.97	18.60	7.81	34.0248	106.9935
8	18-NOV-77 165947 FM 66DB 00 00	237: 301	146.07	175.33	116.82	0.89	22.20	8.50	0.0000	0.0000
9	09-NOV-77 070101 FM 66DB 00 00	230: 294	75.36	84.28	66.44	0.97	25.09	8.50	0.0000	0.0000
10	09-NOV-77 071207 FM 66DB 00 00	229: 293	72.64	82.72	62.56	0.95	25.25	8.50	0.0000	0.0000
11	12-OCT-77 212033 FM 66DB 00 00	251: 315	100.79	109.08	92.49	0.99	29.81	8.50	0.0000	0.0000
12	12-OCT-77 210017 FM 66DB 00 00	248: 312	91.85	99.45	84.25	0.99	31.74	8.50	0.0000	0.0000

TABLE 2-5

EVENTS RECORDED AT IC USED TO COMPUTE Qp

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	27-JUN-81 024403 IC 78DB 00 30	248: 312	32.54	42.04	23.05	0.91	6.81	<6.81	0.0000	0.0000
2	17-JUN-81 213707 IC 72DB 00 30	135: 199	54.72	69.98	39.46	0.89	8.01	<8.01	0.0000	0.0000
3	18-JUN-81 014235 IC 72DB 00 30	130: 194	53.37	67.69	39.04	0.90	8.01	<8.01	0.0000	0.0000
4	05-JUL-81 112259 IC 72DB 00 30	135: 199	67.23	83.92	50.54	0.91	8.82	8.50	0.0000	0.0000
5	28-JUN-81 162247 IC 72DB 00 30	257: 321	40.59	49.39	31.78	0.94	9.38	8.50	0.0000	0.0000
6	18-JUN-81 101925 IC 72DB 00 30	249: 313	68.69	82.13	55.24	0.89	10.34	8.00	34.0700	106.9800
7	22-JUN-81 024115 IC 72DB 00 30	257: 321	51.37	63.06	39.69	0.86	10.34	7.00	34.0700	107.0300

TABLE 2-6

EVENTS RECORDED AT SC USED TO COMPUTE Qp

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	02-JUN-77 114205 SC 84DB 05 00	-1: 63	59.28	69.97	48.59	0.90	8.19	7.73	34.0117	107.0603
2	02-JUN-77 065523 SC 84DB 05 00	54: 118	70.09	84.40	55.78	0.87	8.70	8.22	34.0117	107.0587
3	02-JUN-77 065041 SC 84DB 05 00	73: 137	65.32	75.12	55.52	0.93	9.38	9.00	34.0073	107.0610
4	08-OCT-77 050309 SC 66DB 00 00	98: 162	71.17	87.24	55.09	0.93	9.63	8.50	0.0000	0.0000
5	30-MAY-77 091627 SC 84DB 05 00	42: 106	85.63	109.60	61.66	0.85	9.71	8.50	0.0000	0.0000
6	05-OCT-77 051727 SC 66DB 00 00	102: 166	64.53	81.13	47.92	0.88	9.79	8.50	0.0000	0.0000
7	30-MAY-77 123511 SC 84DB 05 00	184: 248	91.78	116.54	67.82	0.86	10.11	8.50	0.0000	0.0000
8	30-MAY-77 071533 SC 84DB 05 00	251: 315	70.19	85.08	55.30	0.93	10.19	8.50	0.0000	0.0000
9	04-OCT-77 234419 SC 66DB 00 00	117: 181	96.76	121.52	72.00	0.88	10.35	8.50	0.0000	0.0000
10	30-MAY-77 071339 SC 84DB 05 00	23: 87	73.94	89.08	58.79	0.94	10.43	8.50	0.0000	0.0000
11	16-OCT-77 081637 SC 72DB 00 00	93: 157	98.67	116.64	80.70	0.90	10.71	10.33	34.0117	107.0590
12	28-MAY-77 172133 SC 84DB 05 00	50: 114	98.57	120.73	76.42	0.91	10.91	8.50	0.0000	0.0000
13	05-OCT-77 001527 SC 66DB 00 00	11: 75	78.35	95.55	61.15	0.89	15.00	8.50	0.0000	0.0000

TABLE 2-7

EVENTS RECORDED AT SNM USED TO COMPUTE Qp

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	29-MAR-81 065935 SNM60DB 00 30	301: 365	28.96	39.52	18.41	0.86	5.45	<5.45	0.0000	0.0000
2	30-MAR-81 065934 SNM60DB 00 30	291: 355	35.50	45.95	25.04	0.95	6.01	<6.01	0.0000	0.0000
3	17-JUN-81 230729 SNM72DB 00 30	303: 367	36.51	44.43	28.59	0.93	10.10	8.50	0.0000	0.0000
4	16-JUN-81 064955 SNM72DB 00 30	299: 363	82.89	97.14	68.64	0.92	11.38	7.00	34.0900	106.9100
5	16-JUN-81 051341 SNM72DB 00 30	141: 205	71.55	83.03	60.08	0.93	12.50	8.00	34.0800	106.9900

TABLE 2-8

EVENTS RECORDED AT WT USED TO COMPUTE Qp

MAXIMUM ERROR IN Q ESTIMATES = 100.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.60

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	20-JUL-83 004155 WT 72DB 00 30	304: 368	45.84	52.05	39.64	0.94	9.09	0.90	34.0590	106.9583
2	14-MAY-83 010830 WT 84DB 00 30	303: 367	44.44	51.82	37.06	0.91	9.38	9.14	34.0618	106.9650
3	18-AUG-83 153511 WT 72DB 00 30	305: 369	76.19	94.29	58.10	0.84	10.05	8.35	34.0495	107.0005
4	18-AUG-83 152859 WT 72DB 00 30	305: 369	73.47	90.24	56.71	0.85	11.32	9.73	34.0455	107.0020
5	04-JUL-83 145843 WT 84DB 00 30	258: 314	92.88	114.00	71.76	0.86	12.14	0.61	33.9630	106.9522
6	26-AUG-77 103553 WT 84DB 00 00	215: 279	87.39	101.75	73.03	0.92	13.70	6.61	33.9642	106.9528
7	30-JAN-84 011932 WT 84DB 00 30	198: 262	97.63	121.09	73.37	0.83	14.10	9.59	34.0400	107.0503
8	11-JUN-83 120423 WT 84DB 00 30	288: 352	95.99	114.23	77.75	0.90	15.24	10.45	34.0245	107.0515
9	21-JAN-77 163817 WT 66DB 00 00	123: 187	95.31	118.62	72.01	0.83	15.25	9.16	34.0112	107.0558
10	01-SEP-77 215853 WT 84DB 00 00	239: 303	105.95	123.65	88.26	0.91	15.34	10.21	34.0102	107.0485
11	14-MAY-83 010216 WT 84DB 00 30	209: 273	135.84	175.91	94.17	0.81	16.87	13.48	34.0738	107.0405
12	11-JUN-83 114310 WT 84DB 00 30	302: 366	97.89	110.98	83.20	0.93	16.40	11.31	34.0262	107.0620
13	19-SEP-83 111406 WT 84DB 00 30	73: 137	107.27	132.35	82.19	0.84	16.51	11.65	33.9708	106.9803
14	18-AUG-77 103915 WT 84DB 00 00	176: 240	223.45	284.18	162.73	0.80	16.75	10.37	34.0097	107.0648
15	11-JUN-83 125737 WT 84DB 00 30	117: 181	117.67	148.78	94.56	0.89	18.05	12.22	34.0343	107.0823
16	17-AUG-77 085341 WT 84DB 00 00	52: 116	220.51	280.87	160.15	0.80	19.90	7.25	33.9110	106.9988
17	28-JUL-83 135852 WT 72DB 00 30	303: 367	173.59	208.98	138.21	0.88	28.55	12.10	33.8887	106.7932
18	22-SEP-77 052035 WT 96DB 00 00	241: 305	176.33	200.12	152.55	0.94	30.07	6.41	34.3322	106.8850

TABLE 2-9

EVENTS RECORDED AT CC USED TO COMPUTE Qs

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	26-MAY-77 173551 CC 84DB 05 00	224: 288	130.95	158.35	103.56	0.91	12.89	8.50	0.0000	0.0000
2	17-AUG-77 060323 CC 84DB 00 00	419: 483	132.41	158.72	106.10	0.88	13.41	7.40	34.1630	106.8630
3	17-AUG-77 155303 CC 84DB 00 00	300: 364	155.06	177.02	133.11	0.94	14.48	5.00	34.2568	106.9248
4	17-AUG-77 043655 CC 84DB 00 00	265: 329	109.10	128.10	90.11	0.94	15.06	8.50	0.0000	0.0000
5	17-AUG-77 153725 CC 84DB 00 00	450: 514	161.73	184.73	138.72	0.94	15.72	6.34	34.2620	106.9190
6	30-MAY-77 070055 CC 84DB 05 00	249: 313	150.87	187.50	114.25	0.86	16.10	8.50	0.0000	0.0000
7	30-MAY-77 065553 CC 84DB 05 00	411: 475	143.58	177.06	110.10	0.86	17.62	8.50	0.0000	0.0000
8	11-AUG-77 095451 CC 84DB 00 00	490: 554	162.25	188.64	135.87	0.94	17.62	8.50	0.0000	0.0000
9	18-AUG-77 103819 CC 84DB 00 00	433: 497	121.11	140.01	102.22	0.92	18.20	9.21	34.0182	107.0593
10	17-AUG-77 022025 CC 84DB 00 00	450: 514	193.85	234.33	153.36	0.87	19.31	9.34	34.2860	107.0487
11	18-AUG-77 103915 CC 84DB 00 00	430: 494	164.18	189.67	138.68	0.92	19.82	10.57	34.0097	107.0648
12	17-AUG-77 120833 CC 84DB 00 00	500: 564	206.85	241.07	172.63	0.93	22.83	8.50	0.0000	0.0000
13	17-AUG-77 141427 CC 84DB 00 00	531: 595	238.50	280.78	196.23	0.91	24.80	8.39	34.3378	106.8838

TABLE 2-10

EVENTS RECORDED AT CM USED TO COMPUTE Qs

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	15-JUN-77 054715 CM 72DB 05 30	257: 321	84.65	105.93	63.37	0.90	9.02	8.50	0.0000	0.0000
2	15-JUN-77 030921 CM 72DB 05 30	281: 345	84.63	107.83	61.43	0.87	9.34	8.50	0.0000	0.0000
3	14-JUN-77 234649 CM 72DB 05 30	391: 455	88.23	110.02	66.45	0.90	9.42	8.50	0.0000	0.0000
4	09-NOV-77 071205 CM 60DB 00 00	470: 534	112.96	136.15	89.77	0.91	14.79	8.50	0.0000	0.0000
5	09-NOV-77 102909 CM 60DB 00 00	239: 303	106.23	123.20	89.26	0.95	15.11	8.50	0.0000	0.0000
6	10-JUN-77 040451 CM 72DB 05 00	254: 318	105.51	119.86	91.16	0.94	15.47	9.96	34.0173	107.0572
7	16-JUN-77 092625 CM 72DB 05 30	522: 586	172.64	204.07	141.22	0.91	24.73	8.50	0.0000	0.0000

TABLE 2-11

EVENTS RECORDED AT DM USED TO COMPUTE Qs

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.65

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	12-SEP-77 185907 DM 84DB 00 00	316: 380	44.41	56.84	31.98	0.94	6.63	<6.63	0.0000	0.0000
2	12-SEP-77 181539 DM 84DB 00 00	350: 414	46.98	60.14	33.82	0.93	6.71	<6.71	0.0000	0.0000
3	17-SEP-77 144541 DM 84DB 00 00	408: 472	63.55	77.87	49.23	0.94	9.20	8.50	0.0000	0.0000
4	14-JUL-77 023407 DM 72DB 00 00	433: 497	93.68	109.75	77.60	0.91	11.07	7.20	34.1587	106.8750
5	14-JUL-77 113159 DM 72DB 00 00	268: 324	76.85	87.47	66.23	0.94	11.12	7.38	34.1548	106.8778
6	29-AUG-77 014231 DM 84DB 00 00	575: 639	145.87	166.46	125.28	0.95	25.71	8.50	0.0000	0.0000
7	26-AUG-77 103313 DM 84DB 00 00	580: 644	186.81	206.98	166.65	0.96	28.24	10.69	34.0068	107.0637

TABLE 2-12

EVENTS RECORDED AT FM USED TO COMPUTE Qs

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	25-FEB-84 190415 FM 66DB 00 00	315: 379	94.34	109.12	79.57	0.92	10.70	8.60	34.1200	106.7400
2	25-OCT-77 150331 FM 66DB 00 00	403: 467	83.47	98.67	68.26	0.96	11.22	8.50	0.0000	0.0000
3	25-OCT-77 125225 FM 66DB 00 00	443: 507	77.37	90.77	63.98	0.96	11.94	8.50	0.0000	0.0000
4	29-OCT-77 104137 FM 66DB 00 00	403: 467	105.53	128.53	82.54	0.90	12.82	8.50	0.0000	0.0000
5	06-NOV-77 030501 FM 66DB 00 00	250: 314	116.58	139.05	94.12	0.92	14.11	8.50	0.0000	0.0000
6	18-NOV-77 142219 FM 66DB 00 00	407: 471	100.85	119.07	82.64	0.94	14.17	13.40	34.0637	106.7603
7	09-NOV-77 070101 FM 66DB 00 00	578: 642	158.56	184.62	132.49	0.93	25.09	8.50	0.0000	0.0000
8	09-NOV-77 071207 FM 66DB 00 00	582: 646	213.41	254.03	172.78	0.90	25.25	8.50	0.0000	0.0000
9	12-OCT-77 212033 FM 66DB 00 00	660: 724	219.63	252.55	186.72	0.94	29.81	8.50	0.0000	0.0000
10	12-OCT-77 210017 FM 66DB 00 00	657: 721	196.32	228.65	171.98	0.96	31.74	8.50	0.0000	0.0000

TABLE 2-13

EVENTS RECORDED AT IC USED TO COMPUTE Qs

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	27-JUN-81 024403 IC 78DB 00 30	360: 424	78.12	99.99	56.25	0.93	6.81	<6.81	0.0000	0.0000
2	17-JUN-81 203031 IC 72DB 00 30	346: 410	89.79	114.96	64.61	0.90	7.61	<7.61	0.0000	0.0000
3	18-JUN-81 014235 IC 72DB 00 30	259: 323	94.19	122.66	65.72	0.85	8.01	<8.01	0.0000	0.0000
4	18-JUN-81 101937 IC 72DB 00 30	270: 334	72.67	92.63	52.71	0.89	8.01	<8.01	0.0000	0.0000
5	17-JUN-81 213651 IC 72DB 00 30	370: 434	95.33	120.89	69.76	0.89	8.34	<8.34	0.0000	0.0000
6	05-JUL-81 112259 IC 72DB 00 30	270: 334	90.88	114.10	67.66	0.90	8.82	8.50	0.0000	0.0000
7	22-JUN-81 024057 IC 72DB 00 30	408: 472	91.65	117.52	65.78	0.86	9.14	7.00	0.0000	0.0000
8	20-JUN-81 162247 IC 72DB 00 30	413: 477	82.38	105.59	59.17	0.86	9.38	8.50	0.0000	0.0000
9	19-JUN-81 182847 IC 72DB 00 30	263: 327	92.57	115.69	69.46	0.89	9.78	8.50	0.0000	0.0000
10	22-JUN-81 024345 IC 72DB 00 30	402: 466	76.36	94.95	58.16	0.90	10.26	8.50	0.0000	0.0000
11	18-JUN-81 101925 IC 72DB 00 30	413: 477	98.51	121.20	75.83	0.91	10.34	8.00	34.0700	106.9800
12	22-JUN-81 024115 IC 72DB 00 30	412: 476	107.11	134.82	79.41	0.87	10.34	7.00	34.0700	107.0300

TABLE 2-14

EVENTS RECORDED AT SC USED TO COMPUTE Qs

MAXIMUN ERROR IN Q ESTIMATES = 50.0
MINIMUN ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	02-JUN-77 065041 SC 84DB 05 00	237: 301	96.09	115.01	77.18	0.88	9.38	9.00	34.0073	107.0610
2	30-MAY-77 070757 SC 84DB 05 00	256: 320	107.98	136.11	79.86	0.88	9.55	8.50	0.0000	0.0000
3	30-MAY-77 015039 SC 84DB 05 00	229: 293	107.07	136.09	78.04	0.86	9.71	8.50	0.0000	0.0000
4	30-MAY-77 091627 SC 84DB 05 00	202: 266	108.80	139.42	78.19	0.85	9.71	8.50	0.0000	0.0000
5	30-MAY-77 070327 SC 84DB 05 00	1322:1386	104.88	134.22	75.54	0.85	9.79	8.50	0.0000	0.0000
6	30-MAY-77 072805 SC 84DB 05 00	258: 322	124.06	157.34	90.77	0.87	9.87	8.50	0.0000	0.0000
7	30-MAY-77 080257 SC 84DB 05 00	271: 335	112.16	140.89	83.43	0.88	9.95	8.50	0.0000	0.0000
8	30-MAY-77 065553 SC 84DB 05 00	262: 326	115.44	145.90	84.99	0.87	10.11	8.50	0.0000	0.0000
9	30-MAY-77 071533 SC 84DB 05 00	417: 481	115.63	146.02	85.25	0.87	10.19	8.50	0.0000	0.0000
10	04-OCT-77 234419 SC 66DB 00 00	282: 346	116.11	146.61	85.61	0.87	10.35	8.50	0.0000	0.0000
11	30-MAY-77 071339 SC 84DB 05 00	187: 251	118.29	149.13	87.44	0.87	10.43	8.50	0.0000	0.0000
12	30-MAY-77 102733 SC 84DB 05 00	267: 331	114.19	142.11	86.26	0.89	10.75	8.50	0.0000	0.0000
13	17-JUN-81 230721 SC 72DB 00 30	457: 521	109.86	136.20	83.52	0.89	10.83	8.50	0.0000	0.0000
14	28-MAY-77 172133 SC 84DB 05 00	225: 289	110.41	138.76	82.07	0.87	10.91	8.50	0.0000	0.0000
15	17-JUN-81 203033 SC 72DB 00 30	446: 510	112.14	142.17	82.10	0.85	11.31	8.50	0.0000	0.0000
16	16-JUN-81 212729 SC 72DB 00 30	453: 517	109.70	127.76	91.64	0.95	14.19	7.00	34.0700	106.9500

TABLE 2-15

EVENTS RECORDED AT SNM USED TO COMPUTE Qs

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	29-MAR-81 065935 SNM60DB 00 30	421: 485	54.67	73.41	35.93	0.91	5.45	<5.45	0.0000	0.0000
2	30-MAR-81 065934 SNM60DB 00 30	469: 473	76.18	102.40	49.96	0.86	6.01	<6.01	0.0000	0.0000
3	17-JUN-81 230729 SNM72DB 00 30	458: 522	91.86	113.05	70.67	0.91	10.10	8.50	0.0000	0.0000
4	16-JUN-81 120437 SNM72DB 00 30	331: 395	106.26	133.40	79.12	0.87	10.90	8.50	0.0000	0.0000
5	22-JUN-81 024345 SNM72DB 00 30	327: 391	118.38	142.58	94.18	0.93	11.22	8.50	0.0000	0.0000
6	16-JUN-81 064955 SNM72DB 00 30	481: 545	124.22	152.80	95.64	0.90	11.38	7.00	34.0900	106.9100
7	16-JUN-81 051341 SNM72DB 00 30	324: 388	129.70	158.57	100.83	0.90	12.50	0.00	34.0000	106.9900

TABLE 2-16

EVENTS RECORDED AT WT USED TO COMPUTE Qs

MAXIMUM EPROR IN Q ESTIMATES = 100.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.00

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	08-JUN-83 075808 WT 84DB 00 30	362: 426	86.36	109.76	62.96	0.82	7.77	7.00	34.0598	106.9787
2	20-AUG-83 053418 WT 72DB 00 30	252: 316	63.54	73.85	53.22	0.92	7.95	7.19	34.0795	106.9817
3	26-JUL-83 192432 WT 72DB 00 30	440: 504	107.89	126.61	89.17	0.91	8.41	7.93	34.0472	106.9493
4	09-JUN-83 083936 WT 84DB 00 30	366: 430	95.16	120.98	69.35	0.80	8.45	8.00	34.0738	106.9752
5	17-JUL-83 024248 WT 78DB 00 30	431: 495	95.98	116.65	75.31	0.86	8.59	8.33	34.0547	106.9547
6	14-MAY-83 144318 WT 84DB 00 30	390: 454	111.38	140.71	82.05	0.81	8.85	8.51	34.0592	106.9672
7	09-JUN-83 062951 WT 84DB 00 30	330: 394	104.80	129.03	80.58	0.85	8.98	6.37	34.0407	107.0030
8	20-JUL-83 004155 WT 72DB 00 30	434: 498	88.50	105.45	71.55	0.89	9.09	8.90	34.0590	106.9583
9	16-JUL-83 061207 WT 78DB 00 30	430: 494	94.55	115.17	73.93	0.86	9.20	8.86	34.0598	106.9680
10	14-MAY-83 010830 WT 84DB 00 30	427: 491	123.92	152.90	94.94	0.84	9.30	9.14	34.0618	106.9650
11	14-JUL-83 055229 WT 90DB 00 30	422: 486	120.41	152.04	88.78	0.81	9.78	9.68	34.0667	106.9592
12	17-JUL-83 010127 WT 78DB 00 30	430: 494	112.57	131.63	93.52	0.91	9.78	9.65	34.0592	106.9525
13	18-AUG-83 153511 WT 72DB 00 30	445: 509	103.32	124.60	82.04	0.87	10.05	8.35	34.0495	107.0005
14	24-MAY-83 225333 WT 84DB 00 30	343: 407	141.86	177.57	106.15	0.84	10.07	4.96	33.9970	106.9750
15	14-MAY-83 024142 WT 84DB 00 30	402: 466	139.99	171.60	108.38	0.85	10.71	10.18	34.0605	106.9790
16	18-AUG-83 152859 WT 72DB 00 30	445: 509	113.46	138.60	88.32	0.86	11.32	9.73	34.0455	107.0020
17	01-JUN-83 144239 WT 84DB 00 30	312: 376	138.40	166.39	110.41	0.89	12.06	7.00	33.9837	106.9432
18	04-JUL-83 145843 WT 84DB 00 30	465: 529	95.01	120.37	69.66	0.81	12.14	7.00	33.9630	106.9522
19	28-SEP-83 015137 WT 84DB 00 30	320: 384	139.13	173.96	104.30	0.86	12.37	7.00	33.9808	106.9337
20	28-JUL-77 120735 WT 78DB 00 00	270: 334	133.61	163.29	103.94	0.87	12.41	7.68	34.1543	106.9068
21	26-AUG-77 103553 WT 84DB 00 00	244: 308	143.27	168.39	118.16	0.91	13.70	6.61	33.9642	106.9528
22	30-JAN-84 011932 WT 84DB 00 30	375: 439	151.13	172.46	129.81	0.94	14.10	9.59	34.0400	107.0503
23	25-SEP-83 010739 WT 84DB 00 30	320: 384	149.18	177.06	121.30	0.89	14.66	9.46	33.9770	106.9857
24	19-AUG-77 035103 WT 84DB 00 00	430: 494	177.80	218.69	136.92	0.85	14.90	8.52	34.0168	107.0603
25	18-AUG-77 103853 WT 84DB 00 00	260: 324	144.64	169.93	119.34	0.91	15.18	9.21	34.0182	107.0593
26	11-JUN-83 120423 WT 84DB 00 30	488: 552	137.83	160.20	115.46	0.93	15.24	10.45	34.0245	107.0515
27	21-JAN-77 163817 WT 66DB 00 00	315: 379	103.22	122.84	83.59	0.89	15.25	9.16	34.0112	107.0558
28	01-SEP-77 215853 WT 84DB 00 00	450: 514	157.17	187.06	126.47	0.88	15.54	10.21	34.0102	107.0405
29	21-JAN-77 164345 WT 66DB 00 00	280: 344	125.37	143.95	106.79	0.93	15.83	10.33	34.0125	107.0547
30	27-AUG-83 103824 WT 72DB 00 30	288: 352	170.16	215.00	125.32	0.81	15.94	8.31	34.0960	106.8008
31	02-JUL-83 090044 WT 84DB 00 30	497: 561	149.52	175.62	123.42	0.91	16.12	4.98	33.9575	107.0385
32	11-JUN-83 114310 WT 84DB 00 30	502: 566	140.23	159.31	121.14	0.94	16.40	11.31	34.0262	107.0620
33	19-SEP-83 111406 WT 84DB 00 30	298: 362	182.96	229.03	136.90	0.83	16.51	11.65	33.9700	106.9803
34	18-AUG-77 103915 WT 84DB 00 00	388: 452	161.31	190.04	132.58	0.90	16.75	10.57	34.0097	107.0648
35	26-AUG-77 103301 WT 84DB 00 00	213: 277	170.56	202.66	138.45	0.89	16.89	10.69	34.0068	107.0637
36	22-SEP-83 120740 WT 84DB 00 30	315: 379	170.46	210.33	130.59	0.85	17.49	9.15	33.9665	107.0452
37	22-SEP-83 110855 WT 84DB 00 30	511: 575	160.49	190.33	130.65	0.90	17.52	9.50	33.9680	107.0368
38	22-SEP-83 171232 WT 84DB 00 30	330: 394	129.85	145.86	113.84	0.95	17.90	9.92	33.9592	107.0330
39	11-JUN-83 125737 WT 84DB 00 30	319: 383	175.91	205.87	145.95	0.92	18.05	12.22	34.0343	107.0823
40	14-JUL-83 124242 WT 90DB 00 30	422: 486	355.65	454.85	257.25	0.89	23.78	4.94	33.8868	106.8300
41	12-SEP-83 102919 WT 90DB 00 30	355: 419	383.08	478.72	287.45	0.84	27.00	7.00	34.2977	106.8667
42	09-JUN-83 090558 WT 84DB 00 30	303: 367	326.64	416.18	237.09	0.88	27.50	9.65	34.2978	106.8762
43	16-MAY-83 063326 WT 84DB 00 30	310: 374	381.43	472.93	289.92	0.84	28.16	4.38	34.2992	106.8178
44	28-JUL-83 135852 WT 72DB 00 30	704: 768	243.43	284.03	202.83	0.91	28.55	12.10	33.8887	106.7932
45	22-SEP-77 052035 WT 96DB 00 00	635: 699	274.64	331.18	218.10	0.87	30.07	6.41	34.3322	106.8858
46	22-JAN-77 071309 WT 84DB 00 00	320: 384	276.03	319.23	232.83	0.93	41.20	7.00	34.1323	106.6255

TABLE 2-17

SxS REFLECTIONS RECORDED AT STATIONS SC AND WT

MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

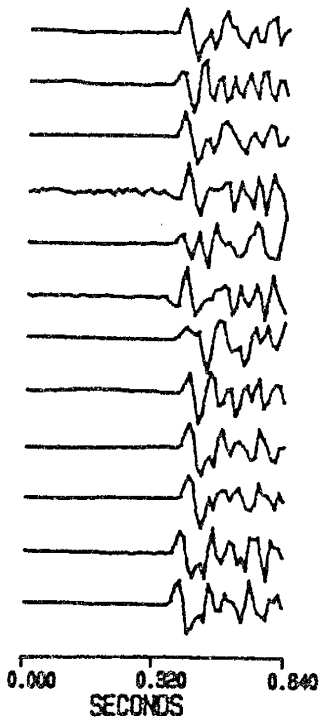
	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH	LAT	LONG
1	02-JUN-77 065041 SC 84DB 05 00	858: 922	261.61	306.41	216.81	0.91	29.52	9.00	34.0073	107.0610
2	02-JUN-77 065523 SC 84DB 05 00	859: 923	224.87	249.02	199.12	0.96	30.31	8.22	34.0117	107.0587
3	02-JUN-77 114205 SC 84DB 05 00	782: 846	268.65	318.31	219.00	0.90	30.79	7.73	34.0117	107.0603
4	02-JUN-77 120709 SC 84DB 05 00	729: 793	252.71	296.45	208.96	0.91	30.69	7.83	34.0120	107.0600
5	18-OCT-77 081637 SC 72DB 00 00	870: 934	224.61	259.25	189.96	0.93	28.21	10.33	34.0117	107.0590
1	18-AUG-77 103915 WT 84DB 00 00	989: 973	229.83	259.03	200.64	0.95	30.71	10.57	34.0097	107.0648
2	01-SEP-77 215853 WT 84DB 00 00	944:1008	240.68	272.06	209.30	0.94	30.53	10.21	34.0102	107.0485

TABLE 2-18

TERA EXPLOSIONS USED TO COMPUTE Qp

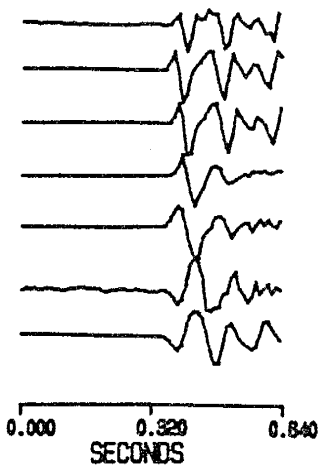
MAXIMUM ERROR IN Q ESTIMATES = 50.0
MINIMUM ACCEPTABLE CORRELATION COEFFICIENT = 0.85

	EVENT	WINDOW	Q	QMAX	QMIN	CORR	DIST	DEPTH
1	23-MAY-83 170036 WT 84DB 00 30	231: 295	13.31	14.51	12.10	0.97	3.00	0.00
2	13-JUN-83 202728 WT 84DB 00 30	284: 348	14.46	15.83	13.09	0.97	3.00	0.00
3	13-JUN-83 173323 WT 84DB 00 30	288: 352	13.55	14.73	12.37	0.97	3.00	0.00
4	08-SEP-83 185830 WT 72DB 00 30	216: 280	16.46	19.31	13.60	0.90	3.00	0.00
5	29-SEP-83 175807 WT 84DB 00 30	278: 342	12.36	13.80	10.92	0.95	3.00	0.00



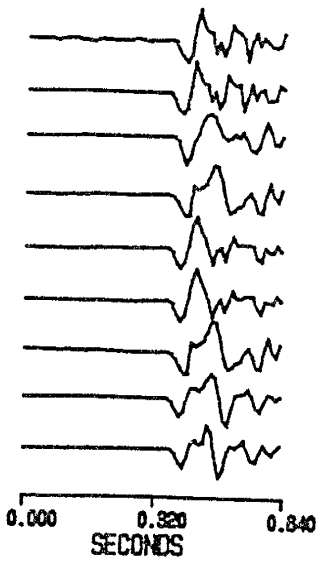
Trace	Header	Window		Dist
	17-AUG-77 155303 CC 84DB 00 00	91	155	14.48
	17-AUG-77 043655 CC 84DB 00 00	24	88	15.08
	17-AUG-77 153725 CC 84DB 00 00	241	305	15.72
	30-MAY-77 070055 CC 84DB 05 00	12	76	16.10
	16-JUN-77 092625 CC 72DB 05 30	129	193	17.22
	30-MAY-77 065553 CC 84DB 05 00	168	232	17.62
	18-AUG-77 103819 CC 84DB 00 00	186	250	18.20
	18-AUG-77 103915 CC 84DB 00 00	184	248	19.82
	17-AUG-77 120833 CC 84DB 00 00	182	246	22.83
	16-AUG-77 154927 CC 84DB 00 00	237	301	24.35
	18-AUG-77 081125 CC 84DB 00 00	180	244	24.52
	17-AUG-77 141427 CC 84DB 00 00	211	275	24.80

Fig. 2-1. P windows for events recorded at CC (Table 2-1).



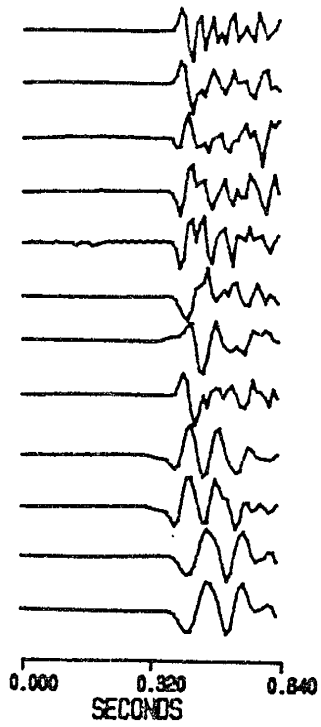
Trace	Header	Window		Dist
	15-JUN-77 054715 CM 720B 05 30	96	160	9.02
	15-JUN-77 030921 CM 720B 05 30	122	186	9.34
	14-JUN-77 234649 CM 720B 05 30	231	295	9.42
	09-NOV-77 071205 CM 600B 00 00	232	296	14.79
	09-NOV-77 102909 CM 600B 00 00	-1	63	15.11
	10-JUN-77 040451 CM 720B 05 00	16	80	15.47
	16-JUN-77 092625 CM 720B 05 30	169	233	24.73

Fig. 2-2. P windows for events recorded at CM (Table 2-2).



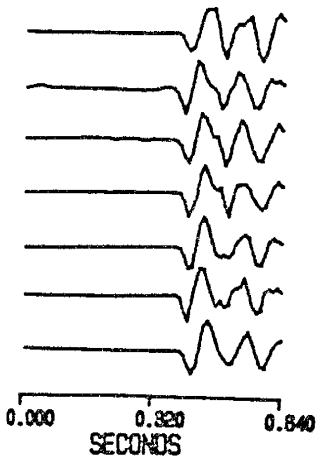
Trace	Header	Window	Dist
	12-SEP-77 185907 DM 84DB 00 00	209 273	8.63
	12-SEP-77 181539 DM 84DB 00 00	244 308	8.71
	17-SEP-77 144541 DM 84DB 00 00	241 305	9.20
	29-AUG-77 035843 DM 84DB 00 00	210 274	10.84
	14-JUL-77 023407 DM 72DB 00 00	83 147	11.07
	14-JUL-77 113159 DM 72DB 00 00	93 157	11.12
	29-AUG-77 035843 DM 84DB 00 00	210 274	17.61
	29-AUG-77 014231 DM 84DB 00 00	226 290	25.71
	26-AUG-77 103313 DM 84DB 00 00	226 290	26.24

Fig. 2-3. P windows for events recorded at DM (Table 2-3).



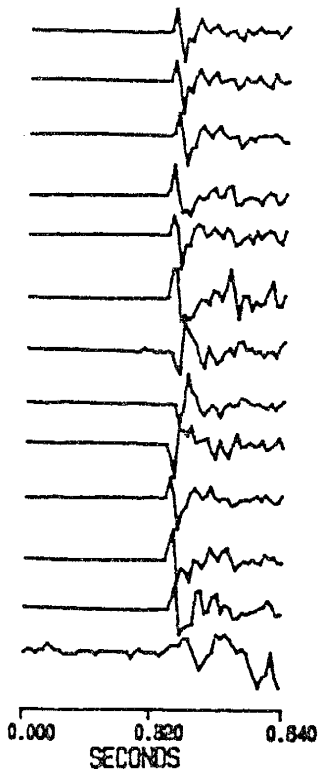
Trace	Header	Window	Dist
	25-FEB-84 190415 FM 6808 00 00	173 237	10.70
	25-OCT-77 125225 FM 6808 00 00	256 320	11.94
	29-OCT-77 104137 FM 6808 00 00	185 249	12.82
	15-NOV-77 190247 FM 6808 00 00	52 116	13.41
	06-NOV-77 030501 FM 6808 00 00	30 94	14.11
	18-NOV-77 142219 FM 6808 00 00	249 313	14.17
	26-FEB-84 205621 FM 6808 00 00	338 402	18.60
	18-NOV-77 185947 FM 6808 00 00	237 301	22.20
	09-NOV-77 070101 FM 6808 00 00	230 294	25.09
	09-NOV-77 071207 FM 6808 00 00	229 293	25.25
	12-OCT-77 212033 FM 6808 00 00	251 315	29.81
	12-OCT-77 210017 FM 6808 00 00	248 312	31.74

Fig. 2-4. P windows for events recorded at FM (Table 2-4).



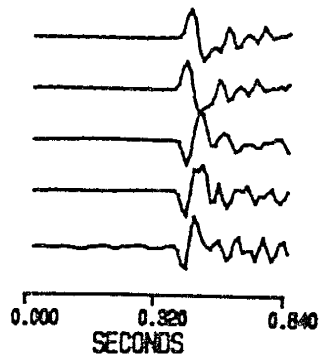
Trace	Header	Window	Dist
	27-JUN-81 024403 IC 780B 00 30	248 312	8.81
	17-JUN-81 213707 IC 720B 00 30	135 199	8.01
	18-JUN-81 014235 IC 720B 00 30	130 194	8.01
	05-JUL-81 112259 IC 720B 00 30	135 199	8.82
	20-JUN-81 162247 IC 720B 00 30	257 321	9.38
	18-JUN-81 101925 IC 720B 00 30	249 313	10.34
	22-JUN-81 024115 IC 720B 00 30	257 321	10.34

Fig. 2-5. P windows for events recorded at IC (Table 2-5).



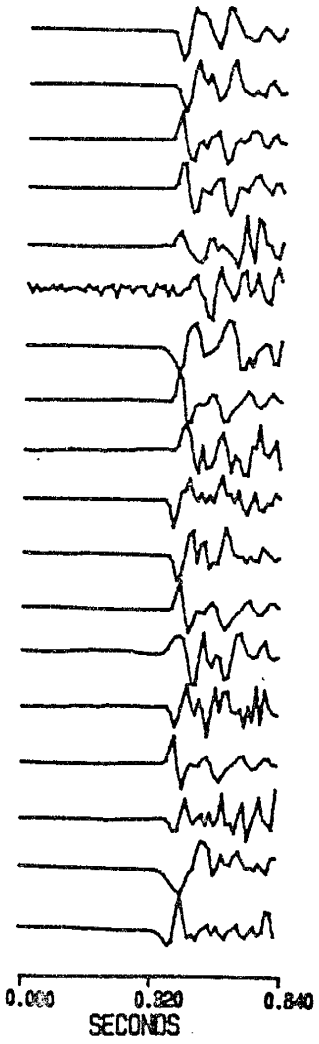
Header	Window		Dist
02-JUN-77 114205 SC 84DB 05 00	-1	83	8.19
02-JUN-77 065523 SC 84DB 05 00	54	118	8.70
02-JUN-77 085041 SC 84DB 05 00	73	137	9.38
08-OCT-77 050309 SC 66DB 00 00	98	162	9.63
30-MAY-77 091627 SC 84DB 05 00	42	106	9.71
05-OCT-77 051727 SC 66DB 00 00	102	166	9.79
30-MAY-77 123511 SC 84DB 05 00	184	248	10.11
30-MAY-77 071533 SC 84DB 05 00	251	315	10.19
04-OCT-77 234419 SC 66DB 00 00	117	181	10.35
30-MAY-77 071339 SC 84DB 05 00	23	87	10.43
18-OCT-77 081637 SC 72DB 00 00	93	157	10.71
28-MAY-77 172133 SC 84DB 05 00	50	114	10.91
05-OCT-77 001527 SC 66DB 00 00	11	75	15.00

Fig. 2-6. P windows for events recorded at SC (Table 2-6).



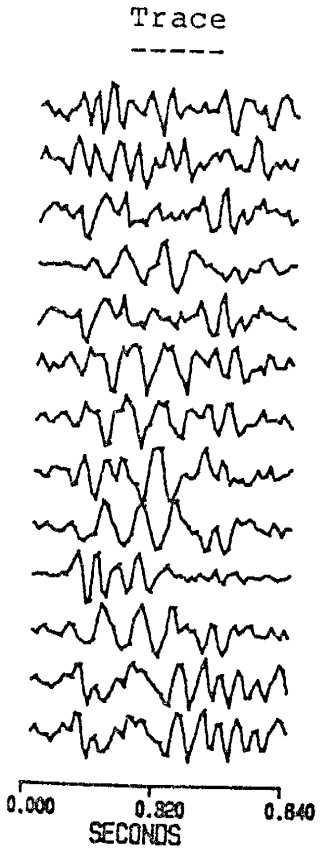
Trace	Header	Window	Dist
	29-MAR-81 085935 SNM60DB 00 30	301 365	5.45
	30-MAR-81 085934 SNM60DB 00 30	291 355	6.01
	17-JUN-81 230729 SNM72DB 00 30	303 367	10.10
	16-JUN-81 084955 SNM72DB 00 30	299 363	11.38
	16-JUN-81 051341 SNM72DB 00 30	141 205	12.50

Fig. 2-7. P windows for events recorded at SNM (Table 2-7).



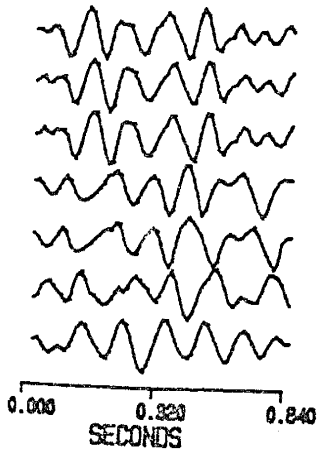
Trace	Header	Window	Dist
	20-JUL-83 004155 WT 72DB 00 30	304 368	9.09
	14-MAY-83 010830 WT 84DB 00 30	303 367	9.38
	18-AUG-83 153511 WT 72DB 00 30	305 369	10.05
	18-AUG-83 152859 WT 72DB 00 30	305 369	11.32
	04-JUL-83 145843 WT 84DB 00 30	250 314	12.14
	26-AUG-77 103553 WT 84DB 00 00	215 279	13.70
	30-JAN-84 011932 WT 84DB 00 30	198 262	14.10
	11-JUN-83 120423 WT 84DB 00 30	288 352	15.24
	21-JAN-77 163817 WT 68DB 00 00	123 187	15.25
	01-SEP-77 215853 WT 84DB 00 00	239 303	15.54
	14-MAY-83 010216 WT 84DB 00 30	209 273	16.07
	11-JUN-83 114310 WT 84DB 00 30	302 366	16.40
	19-SEP-83 111406 WT 84DB 00 30	73 137	16.51
	18-AUG-77 103915 WT 84DB 00 00	176 240	16.75
	11-JUN-83 125737 WT 84DB 00 30	120 184	18.05
	17-AUG-77 085341 WT 84DB 00 00	52 118	19.90
	28-JUL-83 135852 WT 72DB 00 30	303 367	28.55
	22-SEP-77 052035 WT 96DB 00 00	241 305	30.07

Fig. 2-8. P windows for events recorded at WT (Table 2-8).



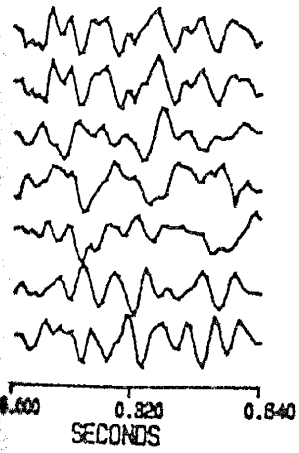
Trace	Header	Window	Dist
	28-MAY-77 173551 CC 84DB 05 00	224 288	12.89
	17-AUG-77 060323 CC 84DB 00 00	419 483	13.41
	17-AUG-77 155303 CC 84DB 00 00	300 364	14.48
	17-AUG-77 043655 CC 84DB 00 00	265 329	15.06
	17-AUG-77 153725 CC 84DB 00 00	450 514	15.72
	30-MAY-77 070055 CC 84DB 05 00	249 313	16.10
	30-MAY-77 085553 CC 84DB 05 00	411 475	17.62
	11-AUG-77 095451 CC 84DB 00 00	490 554	17.62
	18-AUG-77 103819 CC 84DB 00 00	433 497	18.20
	17-AUG-77 022025 CC 84DB 00 00	450 514	19.31
	18-AUG-77 103915 CC 84DB 00 00	430 494	19.82
	17-AUG-77 120833 CC 84DB 00 00	500 564	22.83
	17-AUG-77 141427 CC 84DB 00 00	531 595	24.80

Fig. 2-9. S windows for events recorded at CC (Table 2-9).



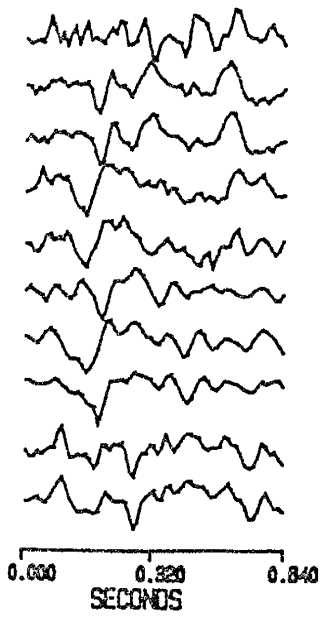
Trace	Header	Window	Dist
	15-JUN-77 054715 CM 72DB 05 30	257 321	9.02
	15-JUN-77 030921 CM 72DB 05 30	281 345	9.34
	14-JUN-77 234649 CM 72DB 05 30	391 455	9.42
	09-NOV-77 071205 CM 60DB 00 00	470 534	14.79
	09-NOV-77 102909 CM 60DB 00 00	239 303	15.11
	10-JUN-77 040451 CM 72DB 05 00	254 318	15.47
	16-JUN-77 092625 CM 72DB 05 30	522 586	24.73

Fig. 2-10. S windows for events recorded at CM (Table 2-10).



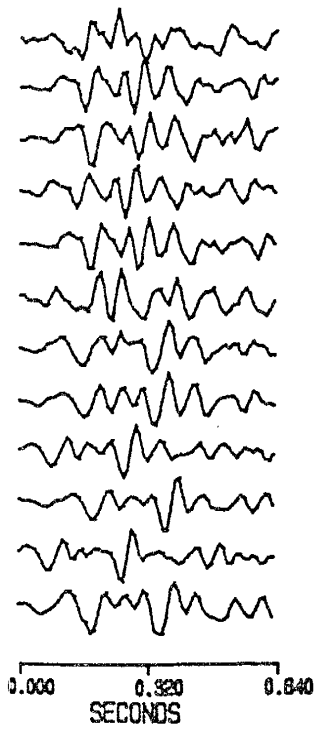
Trace	Header	Window	Dist
	12-SEP-77 185907 DM 84DB 00 00	316 380	6.63
	12-SEP-77 181539 DM 84DB 00 00	350 414	6.71
	17-SEP-77 144541 DM 84DB 00 00	408 472	9.20
	14-JUL-77 023407 DM 72DB 00 00	433 497	11.07
	14-JUL-77 113159 DM 72DB 00 00	260 324	11.12
	29-AUG-77 014231 DM 84DB 00 00	575 639	25.71
	26-AUG-77 103313 DM 84DB 00 00	580 644	26.24

Fig. 2-11. S windows for events recorded at DM (Table 2-11).



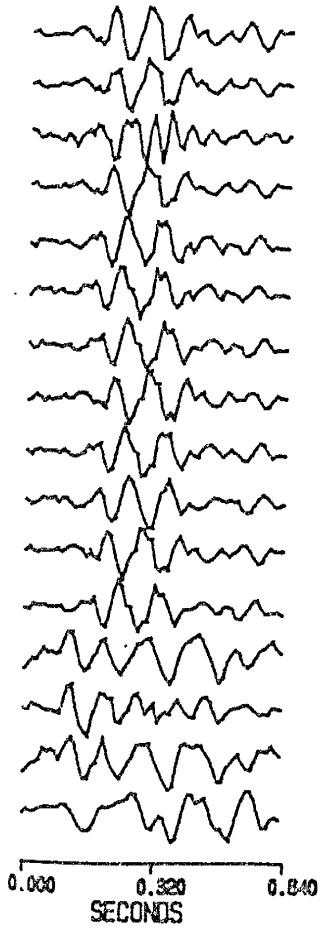
Trace	Header	Window	Dist
	25-FEB-84 190415 FM 6608 00 00	315 379	10.70
	25-OCT-77 150331 FM 6608 00 00	403 467	11.22
	25-OCT-77 125225 FM 6608 00 00	443 507	11.94
	29-OCT-77 104137 FM 6608 00 00	403 467	12.82
	08-NOV-77 030501 FM 6608 00 00	250 314	14.11
	18-NOV-77 142219 FM 6608 00 00	407 471	14.17
	09-NOV-77 070101 FM 6608 00 00	578 642	25.09
	09-NOV-77 071207 FM 6608 00 00	582 646	25.25
	12-OCT-77 212033 FM 6608 00 00	660 724	29.81
	12-OCT-77 210017 FM 6608 00 00	857 721	31.74

Fig. 2-12. S windows for events recorded at FM (Table 2-12).



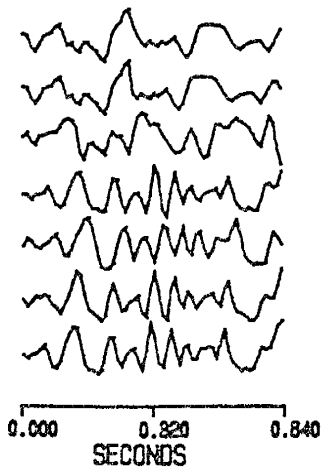
Header	Window	Dist
27-JUN-81 024403 IC 780B 00 30	360 424	6.81
17-JUN-81 203031 IC 720B 00 30	346 410	7.61
18-JUN-81 014235 IC 720B 00 30	259 323	8.01
18-JUN-81 101937 IC 720B 00 30	270 334	8.01
17-JUN-81 213851 IC 720B 00 30	370 434	8.34
05-JUL-81 112259 IC 720B 00 30	270 334	8.82
22-JUN-81 024057 IC 720B 00 30	408 472	9.14
20-JUN-81 162247 IC 720B 00 30	413 477	9.38
19-JUN-81 182847 IC 720B 00 30	263 327	9.78
22-JUN-81 024345 IC 720B 00 30	402 466	10.26
18-JUN-81 101925 IC 720B 00 30	413 477	10.34
22-JUN-81 024115 IC 720B 00 30	412 476	10.34

Fig. 2-13. S windows for events recorded at IC (Table 2-13).



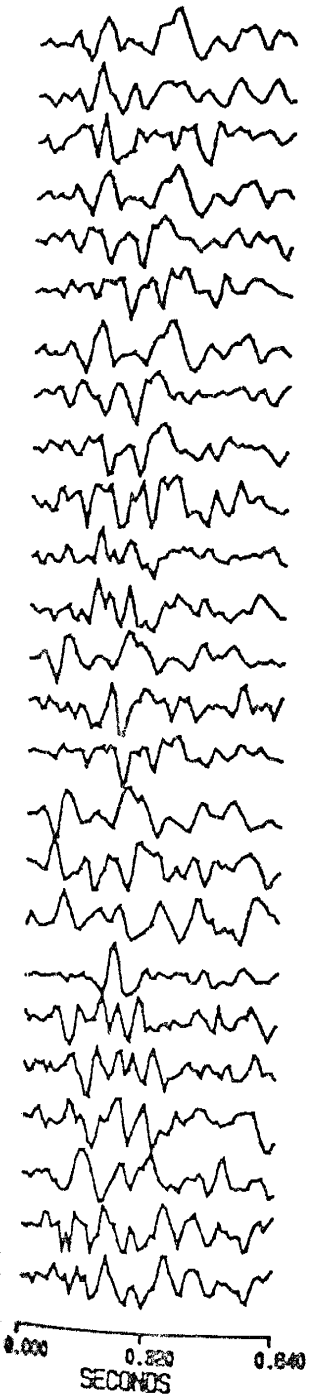
Trace	Header	Window	Dist
	02-JUN-77 065041 SC 84DB 05 00	237 301	9.38
	30-MAY-77 070757 SC 84DB 05 00	256 320	9.55
	30-MAY-77 015039 SC 84DB 05 00	229 293	9.71
	30-MAY-77 091627 SC 84DB 05 00	202 268	9.71
	30-MAY-77 070327 SC 84DB 05 00	1322 1386	9.79
	30-MAY-77 072805 SC 84DB 05 00	258 322	9.87
	30-MAY-77 080257 SC 84DB 05 00	271 335	9.95
	30-MAY-77 085553 SC 84DB 05 00	262 326	10.11
	30-MAY-77 071533 SC 84DB 05 00	417 481	10.19
	04-OCT-77 234419 SC 66DB 00 00	282 346	10.35
	30-MAY-77 071339 SC 84DB 05 00	187 251	10.43
	30-MAY-77 102733 SC 84DB 05 00	267 331	10.75
	17-JUN-81 230721 SC 72DB 00 30	457 521	10.83
	28-MAY-77 172133 SC 84DB 05 00	225 289	10.91
	17-JUN-81 203033 SC 72DB 00 30	448 510	11.31
	16-JUN-81 212729 SC 72DB 00 30	453 517	14.19

Fig. 2-14. S windows for events recorded at SC (Table 2-14).



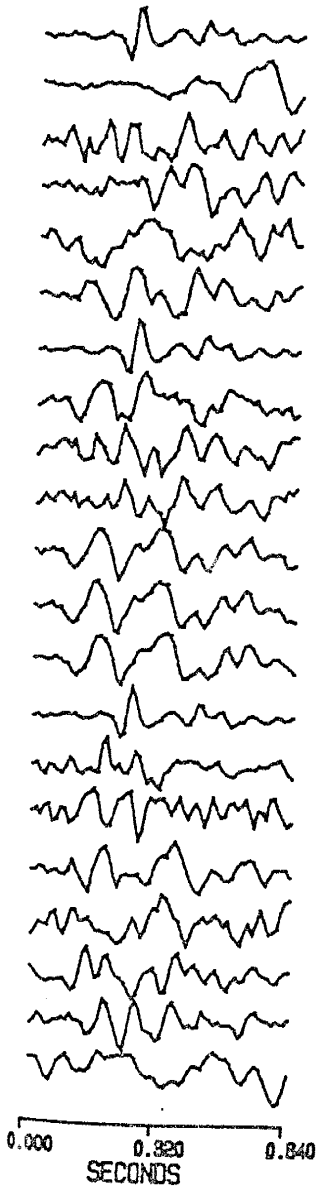
Trace	Header	Window	Dist
	29-MAR-81 065935 SNM60DB 00 30	421 485	5.45
	30-MAR-81 065934 SNM60DB 00 30	409 473	6.01
	17-JUN-81 230729 SNM72DB 00 30	458 522	10.10
	18-JUN-81 120437 SNM72DB 00 30	331 395	10.90
	22-JUN-81 024345 SNM72DB 00 30	327 391	11.22
	18-JUN-81 064955 SNM72DB 00 30	481 545	11.38
	18-JUN-81 051341 SNM72DB 00 30	324 388	12.50

Fig. 2-15. S windows for events recorded at SNM (Table 2-15).



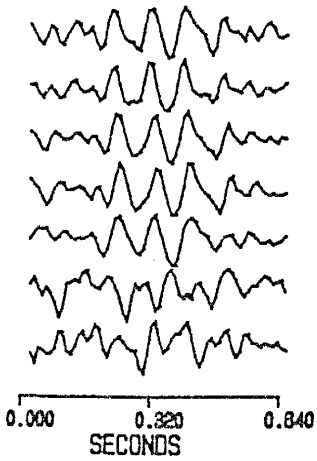
Header	Window	Dist
03-JUN-83 075808 WT 840B 00 30	362 426	7.77
20-AUG-83 053418 WT 720B 00 30	252 316	7.95
26-JUL-83 192432 WT 720B 00 30	440 504	8.41
09-JUN-83 083936 WT 840B 00 30	366 430	8.45
17-JUL-83 024240 WT 780B 00 30	431 495	8.58
14-MAY-83 144318 WT 840B 00 30	390 454	8.85
09-JUN-83 062951 WT 840B 00 30	330 394	8.98
20-JUL-83 004155 WT 720B 00 30	434 498	9.09
16-JUL-83 061207 WT 780B 00 30	430 494	9.20
14-MAY-83 010830 WT 840B 00 30	427 491	9.38
14-JUL-83 055229 WT 900B 00 30	422 486	9.78
17-JUL-83 010127 WT 780B 00 30	430 494	9.78
18-AUG-83 153511 WT 720B 00 30	445 509	10.05
24-MAY-83 225333 WT 840B 00 30	343 407	10.07
14-MAY-83 024142 WT 840B 00 30	402 466	10.71
18-AUG-83 152859 WT 720B 00 30	445 509	11.32
01-JUN-83 144239 WT 840B 00 30	312 376	12.06
04-JUL-83 145843 WT 840B 00 30	465 529	12.14
28-SEP-83 015137 WT 840B 00 30	320 384	12.37
28-JUL-77 120735 WT 780B 00 00	270 334	12.41
26-AUG-77 103553 WT 840B 00 00	244 308	13.70
30-JAN-84 011932 WT 840B 00 30	375 439	14.10
25-SEP-83 010739 WT 840B 00 30	320 384	14.66
19-AUG-77 035103 WT 840B 00 00	430 494	14.90
18-AUG-77 103853 WT 840B 00 00	260 324	15.18

Fig. 2-16. S windows for events recorded at WT (Table 2-16).



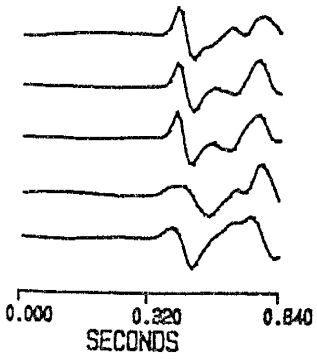
Header	Window		Dist
11-JUN-83 120423 WT 84DB 00 30	488	552	15.24
21-JAN-77 163817 WT 66DB 00 00	315	379	15.25
01-SEP-77 215853 WT 84DB 00 00	450	514	15.54
21-JAN-77 164345 WT 66DB 00 00	280	344	15.83
27-AUG-83 103024 WT 72DB 00 30	288	352	15.94
02-JUL-83 090044 WT 84DB 00 30	497	561	16.12
11-JUN-83 114310 WT 84DB 00 30	502	566	16.40
19-SEP-83 111406 WT 84DB 00 30	298	362	16.51
18-AUG-77 103915 WT 84DB 00 00	388	452	16.75
26-AUG-77 103301 WT 84DB 00 00	213	277	16.89
22-SEP-83 120740 WT 84DB 00 30	320	384	17.49
22-SEP-83 110855 WT 84DB 00 30	511	575	17.52
22-SEP-83 171232 WT 84DB 00 30	330	394	17.90
11-JUN-83 125737 WT 84DB 00 30	319	383	18.05
14-JUL-83 124242 WT 90DB 00 30	422	486	23.78
12-SEP-83 102919 WT 90DB 00 30	355	419	27.00
08-JUN-83 090558 WT 84DB 00 30	303	367	27.50
16-MAY-83 063324 WT 84DB 00 30	310	374	28.16
28-JUL-83 135852 WT 72DB 00 30	704	768	28.55
22-SEP-77 052035 WT 96DB 00 00	635	699	30.07
22-JAN-77 071309 WT 84DB 00 00	320	384	41.20

(Fig. 2-16 continued)



Trace	Header	Window		Dist
	02-JUN-77 065041 SC 84DB 05 00	858	922	29.52
	02-JUN-77 065523 SC 84DB 05 00	859	923	30.31
	02-JUN-77 114205 SC 84DB 05 00	782	846	30.79
	02-JUN-77 120709 SC 84DB 05 00	729	793	30.69
	18-OCT-77 081637 SC 72DB 00 00	870	934	28.21
	18-AUG-77 103915 WT 84DB 00 00	909	973	30.71
	01-SEP-77 215853 WT 84DB 00 00	944	1008	30.53

Fig. 2-17. SxS windows used to compute Qs (Table 2-17).



Trace	Header	Window	Dist
	23-MAY-83 170036 WT 84DB 00 30	231 295	3.80
	13-JUN-83 202728 WT 84DB 00 30	284 348	3.80
	13-JUN-83 173323 WT 84DB 00 30	288 352	3.80
	08-SEP-83 185830 WT 72DB 00 30	216 280	3.80
	29-SEP-83 175807 WT 84DB 00 30	278 342	3.80

Fig. 2-18. TERA explosion windows used to compute Qp (Table 2-18).

APPENDIX 3

PLOTS OF ANOMALOUS EVENTS

Included in this appendix are plots of the anomalous events used to identify Regions 1 through 4 in Figure 56.

Area	Figures
Region 1	3-1, 3-2
Region 2	3-3- 3-6
Region 3	3-7, 3-8
Region 4	3-9, 3-10

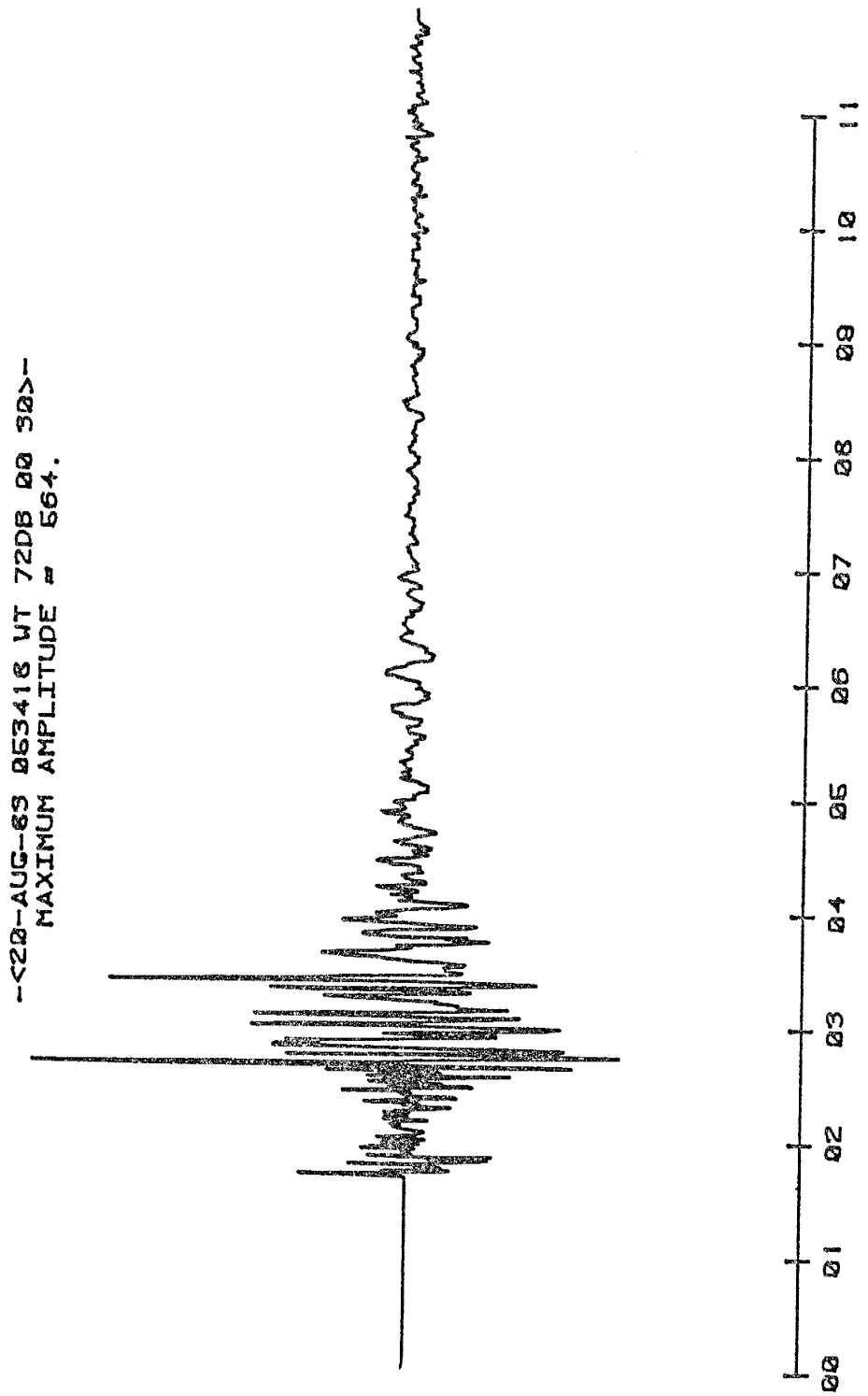


Fig. 3-1. An anomalous event from Region 1.

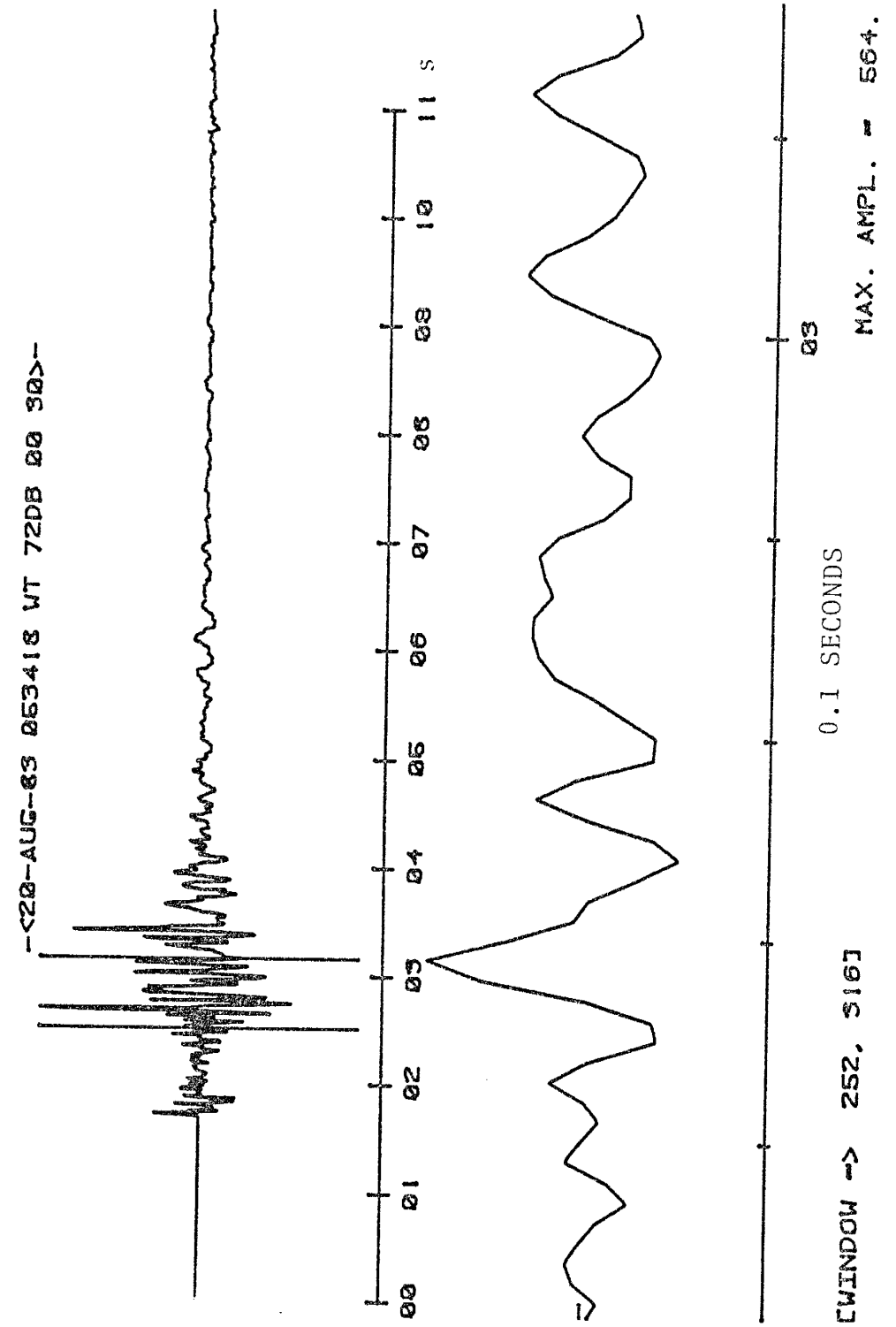


Fig. 3-2. S window for the event shown in Figure 3-1.

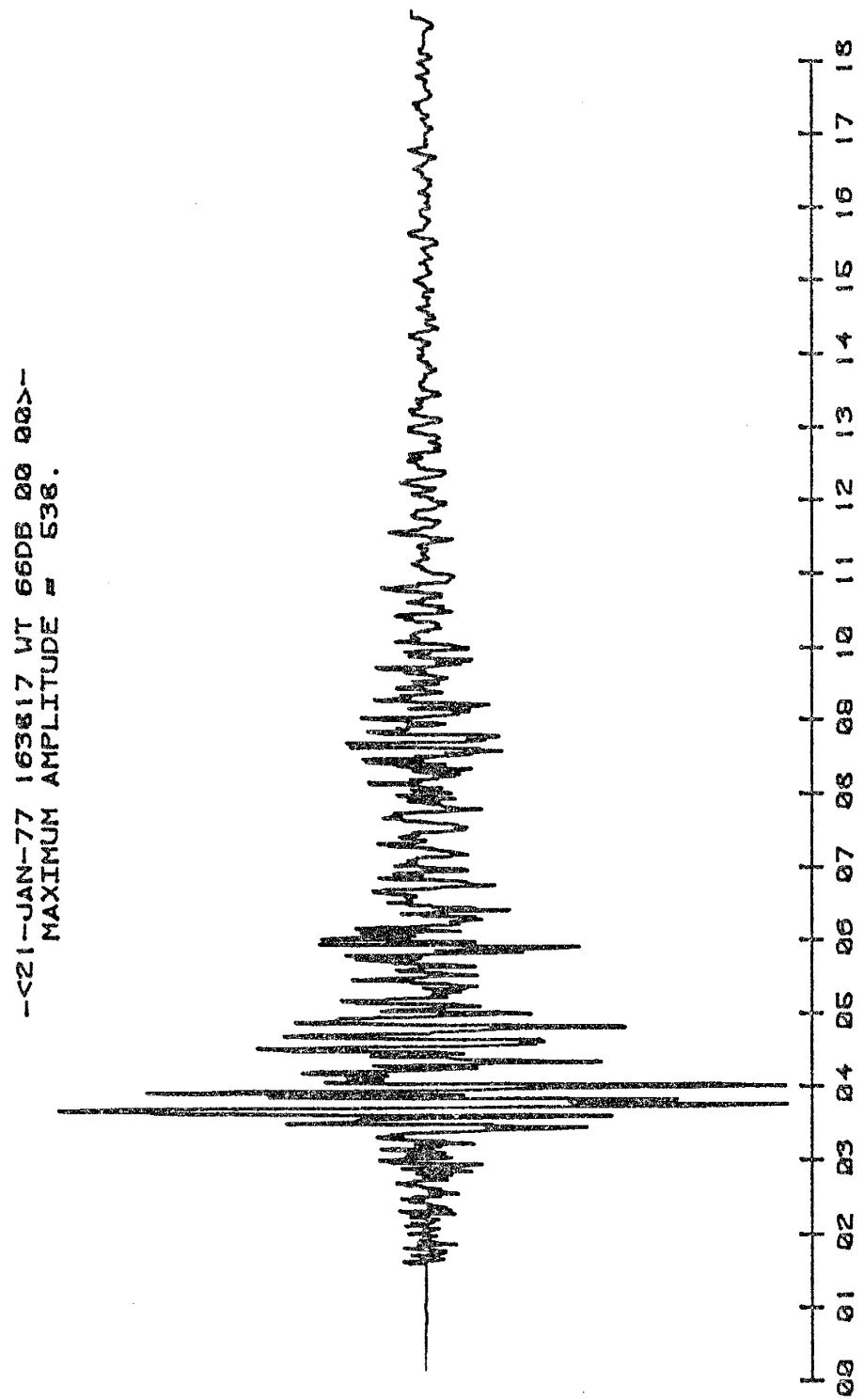


Fig. 3-3. An anomalous event from Region 2.

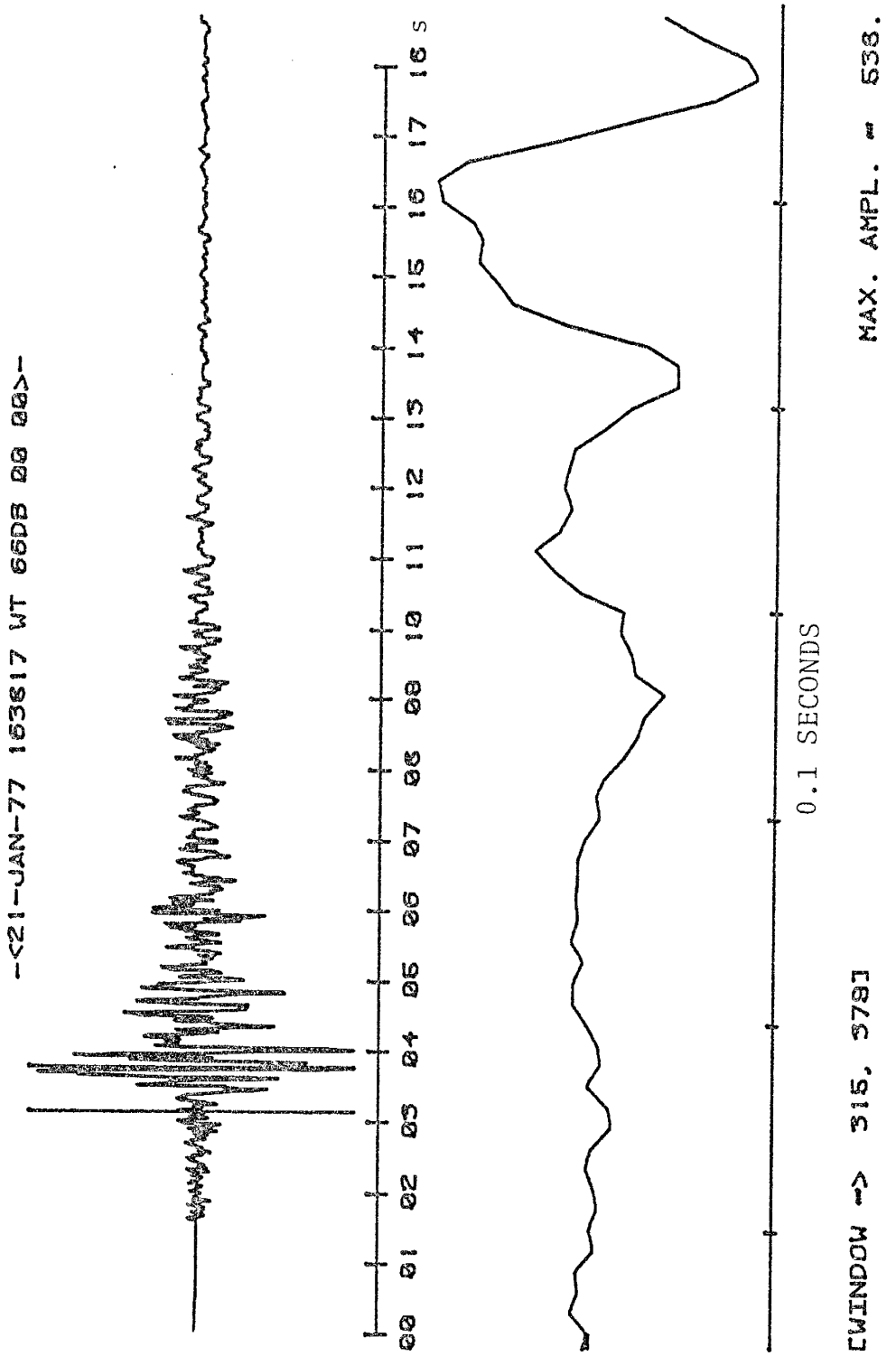


Fig. 3-4. S window for the event shown in Figure 3-3.

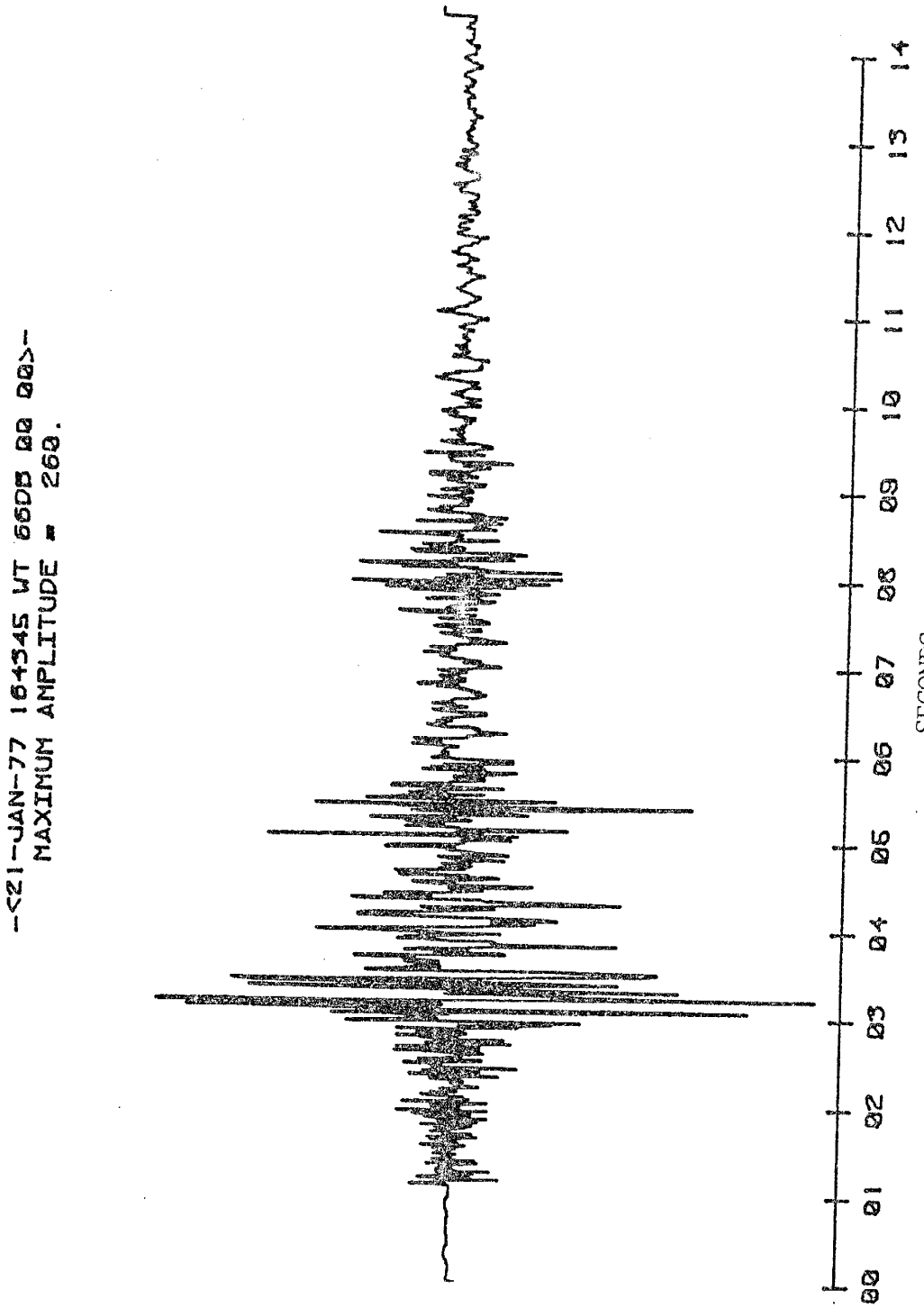


Fig. 3-5. An anomalous event from Region 2.

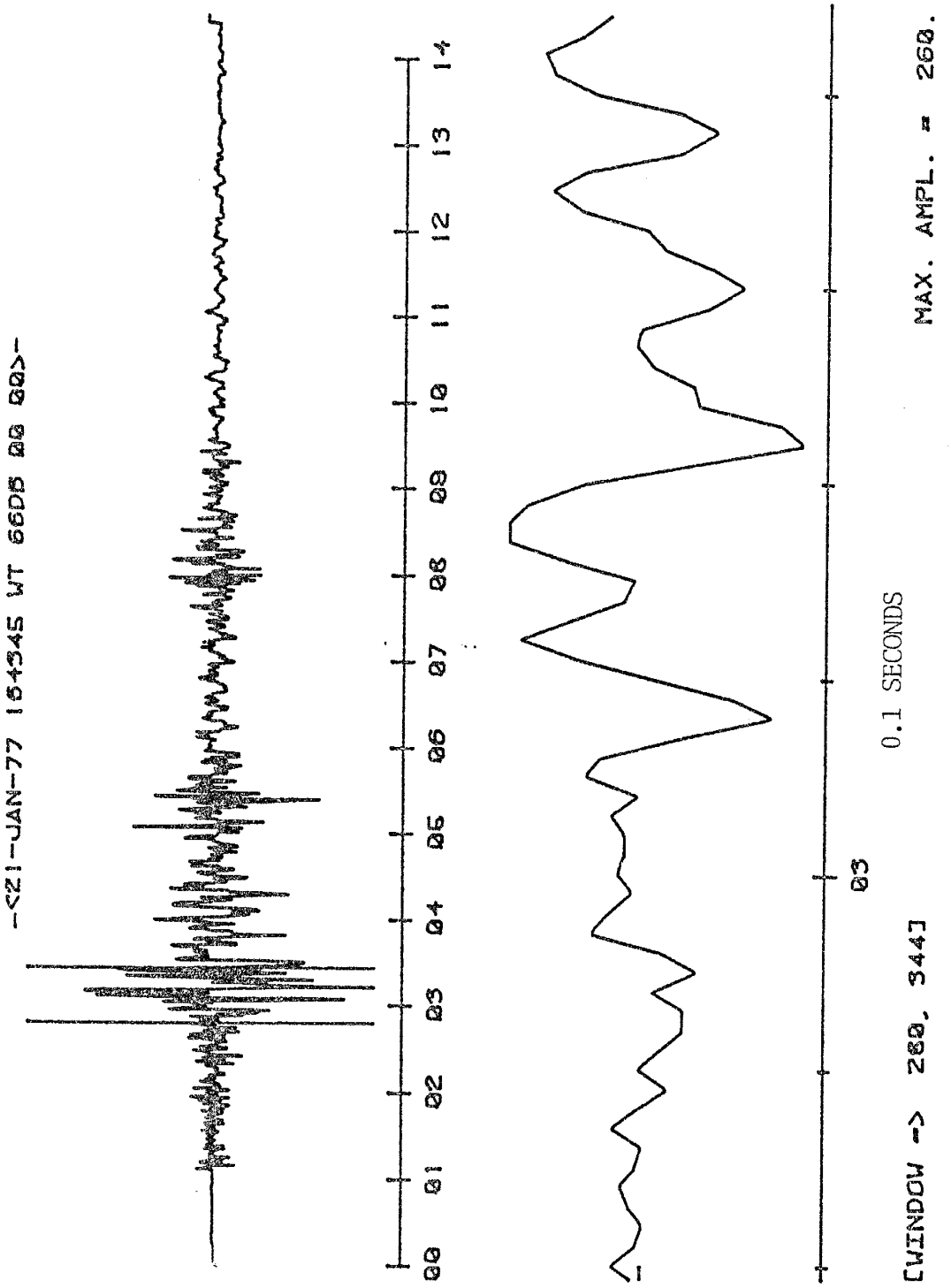


Fig. 3-6. S window for the event shown in Figure 3-5

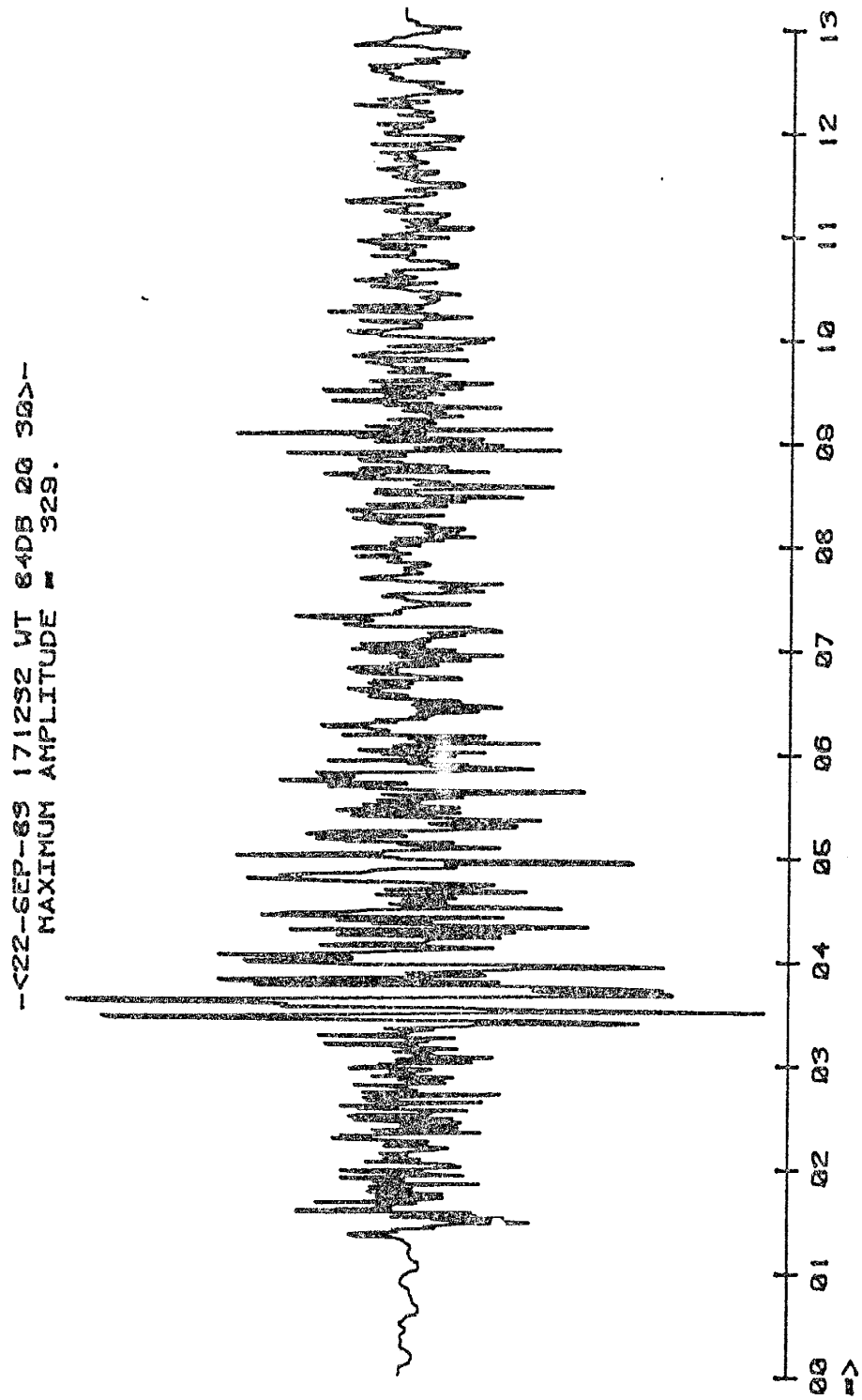


Fig. 3-7. An anomalous event from Region 3.

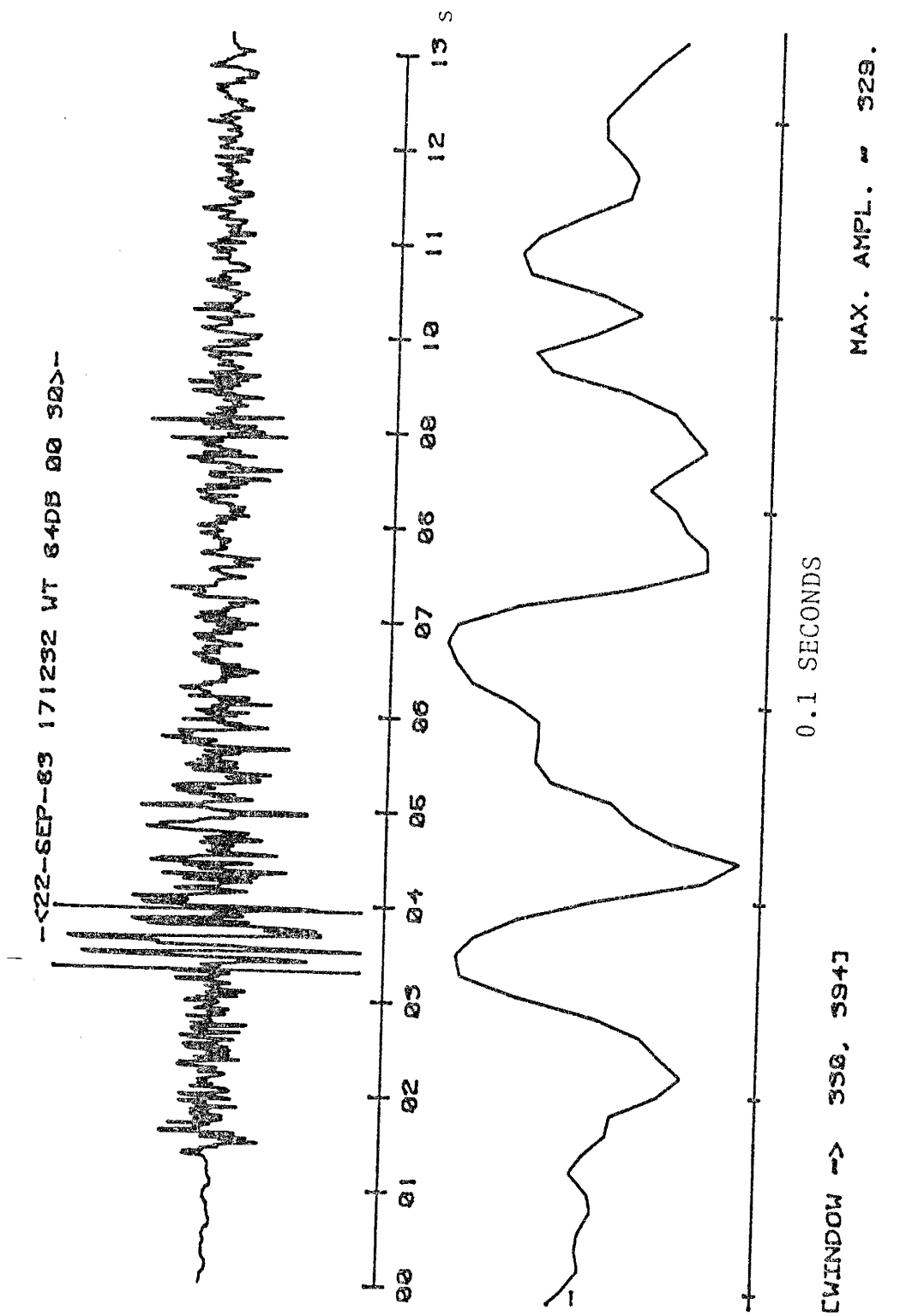


Fig. 3-8. S window for the event shown in Figure 3-7.

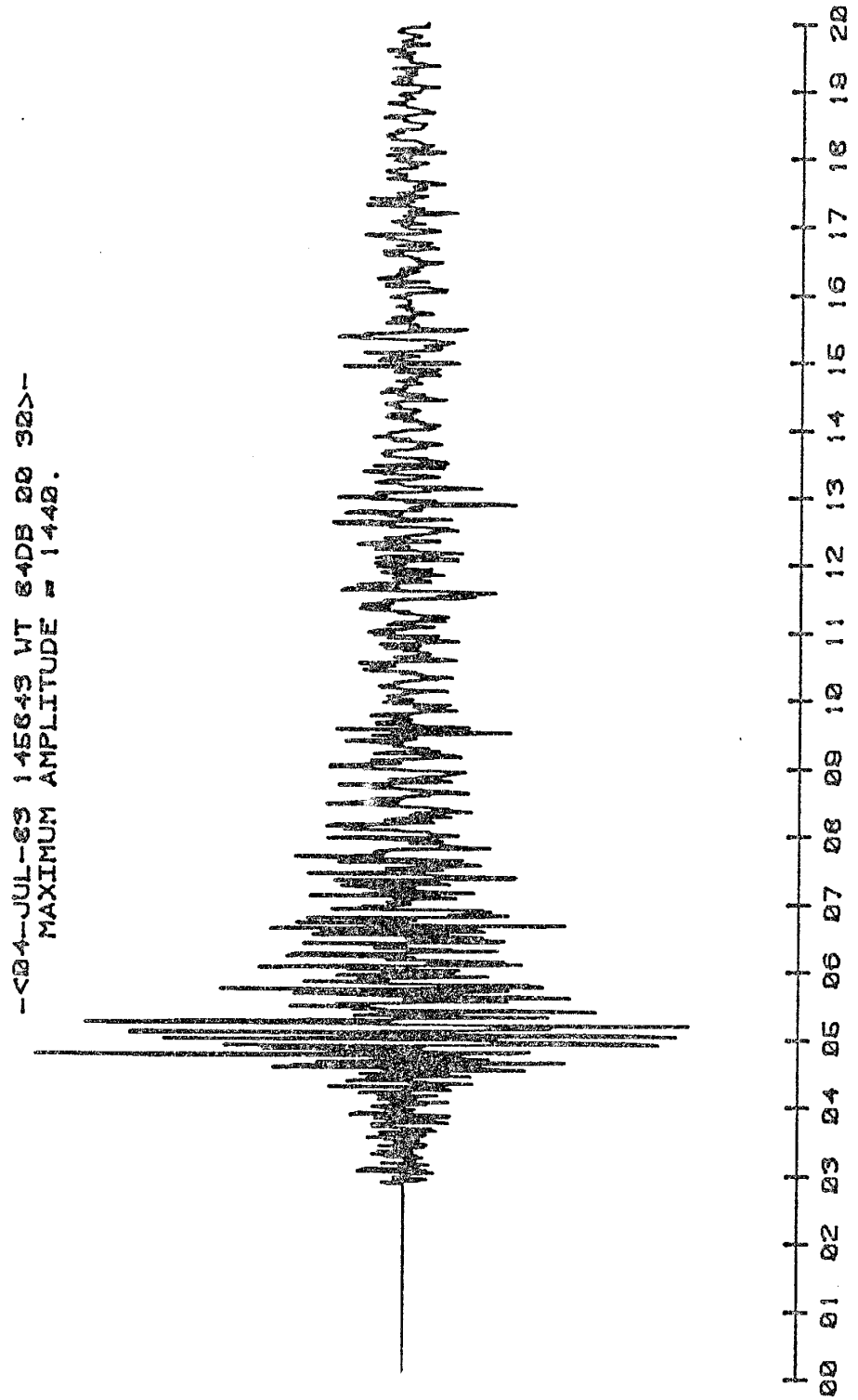


Fig. 3-9. An anomalous event from Region 4.

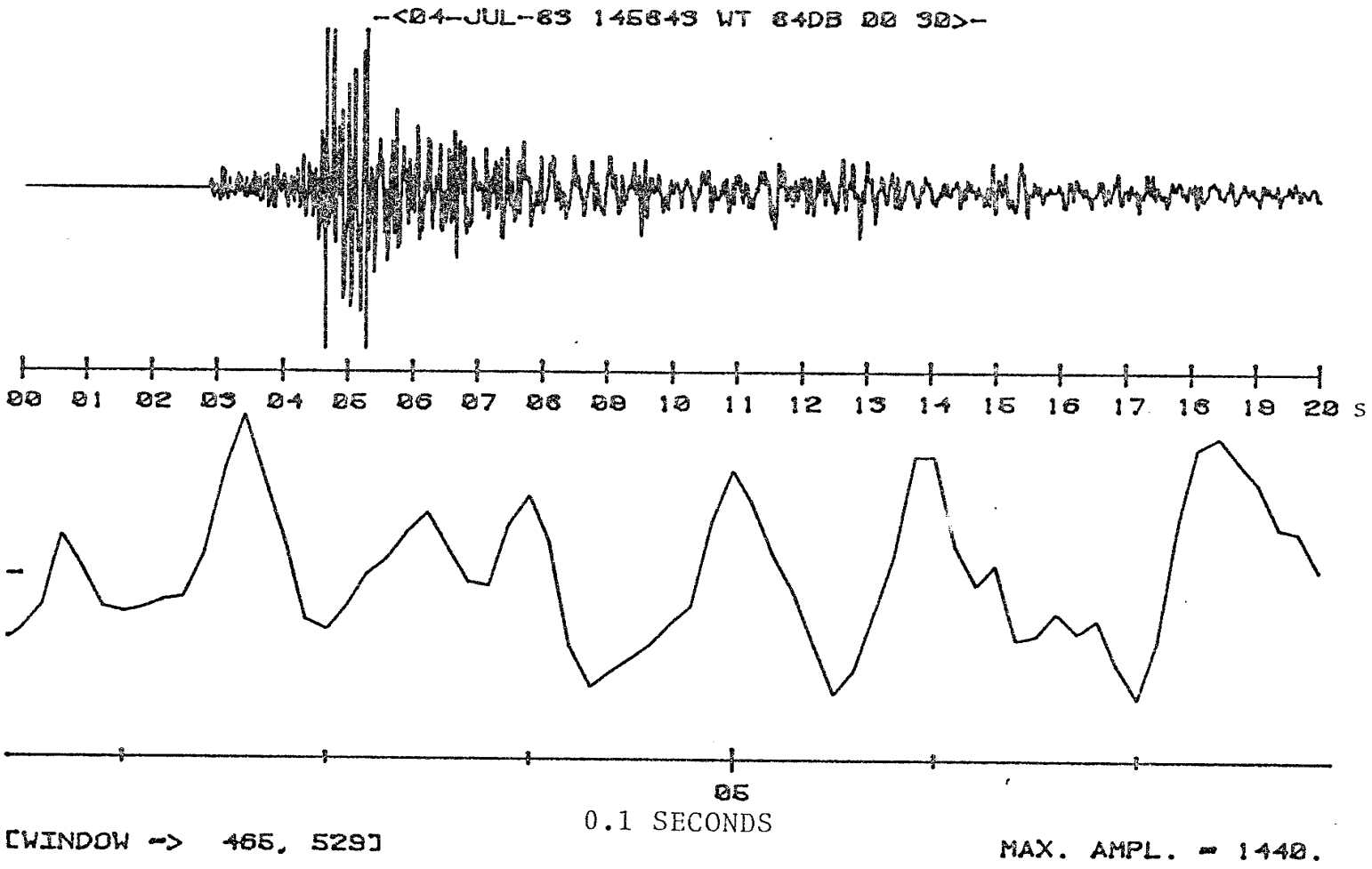


Fig. 3-10. S window for the event shown in Figure 3-9.

APPENDIX 4

PROGRAM LISTINGS AND INFORMATION

This appendix includes listings of all programs used to analyze and plot out digitally recorded seismograms and spectra. Descriptions of programs and short notes on program use are also presented in this section.

CONTENTS

Short Descriptions of Programs

Program	Page	Description
ADD	4-6	A program to update window data files (such as SLOC84.DAT) with new locations.
ADSA	4-8	A batch program that uses preset windows to do spectral analysis for a large number of events. This is a modified version of DISPAN which requires no user interaction.
BPFILT	4-10	A bandpass/rejection filter used to filter spectra undergoing homomorphic deconvolution.
CLEAN	4-12	Removes time marks and glitches from digital data.
COPY	4-16	Copies file of S windows into a new file for P windows so that only the window settings need to be changed.
CROS	4-17	Cross-correlates two time series.
CUMBAR	4-19	Cumulative bar graph plotting routine to display Q1 estimates vs. number of events for the layer over a half-space model.
DECON	4-21	Deconvolves DR100 filter response for 5 Hz low-cut and 30-Hz high-cut filters.
DISPAN	4-22	Digital Spectral Analysis-- main program for displaying digital time series, choosing windows, and computing spectra.

ADD.FOR

```
C
C  ADD-- ADD AND REVISE LOCATIONS IN WINDOW LIST FILES
C
C       IT IS OFTEN NECESSARY TO UPDATE OR ADD LOCATIONS
C       TO WINDOW LIST FILES SUCH AS SWIN84.DAT. THE
C       NEW LOCATIONS ARE IN A FILE SUCH AS PRMQKS.DAT
C       WHICH IS AUTOMATICALLY OUTPUT FROM A HYPO71 RUN.
C       THIS PROGRAM REPLACES THE OLD LOCATIONS WITH THE
C       NEW LOCATIONS AND WRITES THE WINDOW LIST FILE
C       BACK OUT AS REV.DAT, SO THE ORIGINAL IS NOT
C       DESTROYED.
C
C       INPUT FILES==> VFNIN-- ORIGINAL WINDOW LIST FILE
C                      VFLOC-- LIST OF NEW LOCATIONS
C                               (HYPO71 OUTPUT)
C
C       OUTPUT FILES=> REV.DAT-- REVISED WINDOW LIST FILE
C
C       SYMBOLS USED:
C
C              DY              DAY
C              CMP2            DIGITAL HEADER INFORMATION
C              HR              HOUR
C              MIN             MINUTES
C              SS              SECONDS
C              STA             STATION
C              LONA            LONGITUDE OF EVENT
C              LAA             LATITUDE OF EVENT
C              SLAT            STATION LATITUDE
C              SLON            STATION LONGITUDE
C              X,Y             LONG. AND LATITUDE IN
C                              MINUTES
C              VEL             VELOCITY OF WAVE
C              NUMWIN          # OF WINDOWS
C              WMIN,WMAX       WINDOW SETTINGS
C              WINAN           WINDOW SHAPE
C              SMP             S-P INTERVAL (SEC)
C              FIL1            LOW CUT FILTER
C              FIL2            HIGH CUT FILTER
C              DIST            EVENT DISTANCE
C              ERH             ERROR IN EPICENTER (KM)
C              ERZ             ERROR IN DEPTH (KM)
C              Q               QUALITY OF SOLUTION
C
      REAL VFNIN*8,VFLOC*8,CMP1*8,CMP2*8,CMP3*8,CMP4*8
      REAL LAA,LONA,LTMIN,LNMIN,MAG,CMPVAR*8(3)
      INTEGER HR1,HR2,SS1,SS2,WMIN,WMAX,DY1,DY2

      WRITE(5,2000)
 2000 FORMAT(' ENTER WINDOW INPUT FILE NAME:  '$)
      READ(5,2001) VFNIN
 2001 FORMAT(A10)
      WRITE(5,2002)
 2002 FORMAT(' ENTER LOCATIONS INPUT FILE NAME:  '$)
      READ(5,2001) VFLOC

      OPEN(UNIT=1,DEVICE='DSK',FILE=VFNIN)
      OPEN(UNIT=2,DEVICE='DSK',FILE=VFLOC)
      OPEN(UNIT=3,DEVICE='DSK',FILE='REV.DAT',
     +ACCESS='APPEND')
C
C  READ IN WINDOW SPECS FROM VFNIN
C
 50   READ(1,1000,END=899) CMPVAR

      BACKSPACE 1
      READ(1,1001) DY1,CMP2,HR1,MIN1,SS1,STA,CMP3
      READ(1,1003) NUMWIN
      READ(1,1005) WMIN,WMAX,WINAN
      READ(1,1007) VEL,SMP,FIL1,FIL2,DIST,H,ERH,ERZ
 1000 FORMAT(3A10)
 1001 FORMAT(I2,A8,3I2,1X,A3,A10)
 1003 FORMAT(I3)
 1005 FORMAT(2(I4,1X),F2.0)
 1007 FORMAT(8F8.2,2F9.4,2X,A2)

      REWIND 2
C 75  READ(2,1010,END=50) MO2,DY2,KYR,HR2,MIN2,SS2,LAA,
C    +LONA,Z,ST,QDIR,QREF
C1010 FORMAT(3I2,1X,3I2,5X,F7.4,1X,F8.4,1X,F7.2,3X,A2,
C    +3(3X,F7.2))
 75   READ(2,1010,END=50) KYR,MO2,DY2,HR2,MIN2,SEC,LAT,
     +LTMIN,LONG,LNMIN,Z,MAG,ERH,ERZ,Q
1010  FORMAT(1X,3I2,1X,2I2,F6.2,1X,I2,1X,F5.2,1X,I3,1X,
     +F5.2,2X,F5.2,2X,F5.2,17X,2F5.1,1X,A1)
C
C  CHECK TO SEE IF EVENT IN LOCATION LIST
C
      IF(HR1 .EQ. HR2 .AND. MIN1 .EQ. MIN2 .AND. DY1
     +.EQ. DY2) GO TO 100
      GO TO 75
 100  CONTINUE
      VEL=3.4
      LAA=LAT+LTMIN/60.
      LONA=LONG+LNMIN/60.
C
C  COMPUTE DISTANCE
C
      IF(STA .EQ. 'WT ') SLAT=34.0722
      IF(STA .EQ. 'WT ') SLON=106.9459

      IF(STA .EQ. 'WT*') SLAT=34.0722
      IF(STA .EQ. 'WT*') SLON=106.9459

      IF(STA .EQ. 'SNM') SLAT=34.0702
      IF(STA .EQ. 'SNM') SLON=106.9435

      IF(STA .EQ. 'SC ') SLAT=34.0100
      IF(STA .EQ. 'SC ') SLON=107.0894

      IF(STA .EQ. 'CC ') SLAT=34.1442
      IF(STA .EQ. 'CC ') SLON=106.9819

      IF(STA .EQ. 'CM ') SLAT=33.9501
      IF(STA .EQ. 'CM ') SLON=106.9576

      IF(STA .EQ. 'DM ') SLAT=34.1075
      IF(STA .EQ. 'DM ') SLON=106.8079

      IF(STA .EQ. 'FM ') SLAT=34.0829
      IF(STA .EQ. 'FM ') SLON=106.8047

      IF(STA .EQ. 'IC ') SLAT=33.9870
      IF(STA .EQ. 'IC ') SLON=106.9967

      IF(STA .EQ. 'CAR') SLAT=33.9525
      IF(STA .EQ. 'CAR') SLON=106.7345

      X=ABS(SLON-LONA)*60.*1.539798
```

```
      Y=ABS(SLAT-LAA)*60.*1.648673

      DIST=SQRT(X**2+Y**2+Z**2)
C
C  IF EVENT FOUND, WRITE OUT WINDOWS AND LOCATIONS TO DISK
C  FILE REV.FOR
C
      WRITE(3,1000) CMPVAR
      WRITE(3,1003) NUMWIN
      WRITE(3,1005) WMIN,WMAX,WINAN
      WRITE(3,1007) VEL,SMP,FIL1,FIL2,DIST,Z,ERH,ERZ,LAA,
     +LONA,Q
      GO TO 50

899   CLOSE(UNIT=1)
      CLOSE(UNIT=2)
      CLOSE(UNIT=3)
      STOP
      END
```

ADSA.FOR

```
C
C       PROGRAM ADSA-- AUTOMATIC DIGITAL SPECTRAL ANALYSIS
C
C       ADAPTED FROM PROGRAM DISPAN BY PJC (1/83)
C
C       THIS PROGRAM DOES THE SAME THING AS DISPAN BUT FOR
C       A WHOLE FILE OF SPECIFIED EVENTS.  IT DISPENSES WITH
C       PLOTTING EACH EVENT AND READS IN EACH EVENT FROM A
C       DATA FILE, DOES THE FFT, AND OUTPUTS THE SPECTRA
C       (AND WINDOW TRACE IF DESIRED). FOR FULL DOCUMENTATION
C       INCLUDING LISTS OF SYMBOLS, SEE DISPAN.FOR.
C
C       THIS PROGRAM IS PRESENTLY SET UP TO RUN ON BATCH-- SUBMIT
C       ADSA.CTL
C
C       INPUT FILES:    VFNIN1      DIGITAL DATA VALUES
C                       VFNIN2      LIST OF WINDOWS FOR ANALYSIS
C
C       OUTPUT FILES:   SPEC        SPECTRA OF DESIRED EVENTS
C                       CROS        WINDOW TIME TRACES
C
C
C       ADDITIONAL SYMBOLS USED IN ADSA:
C
C               VFNIN1          DATA FILE NAME FOR DIGITALLY
C                               RECORDED EVENTS
C               VFNIN2          WINDOW LIST DATA FILE NAME
C               ANS             OPTION TO OUTPUT WINDOW TRACES
C                               TO CROS.DAT
C               AMPL            SPECIFY IF WINDOW IS DIRECT OR
C                               REFLECTED WAVE
C
C
      INTEGER ANSWER,IBEGIN,IEND,IER,IVAR,NUMWIN,IX(2000)
      INTEGER WIDWIN(50),WINDOW(50,2),IWK(3200),NY(2000)
      COMPLEX XC(2048)

      REAL CMPVAR*8(3),WMAX,WMIN,X(2048),XNUM,PTRLOC,VFNIN1*8
      REAL EMAX,EVENT*8(2),FREQ(2048),MAX,AS(2048),VFNIN2*8
      REAL XYMV(6),YVALUE(2048),XI(2048),WK(3200)

      OPEN(UNIT=1,DEVICE='DSK',FILE='ADSA.DAT',ACCESS='SEQIN')

      READ(1,1001) WAVE
      WRITE(5,2000)
 2000 FORMAT(' DESIGNATE EVENT INPUT DATA FILE:  '$)
      READ(1,2001) VFNIN1
 2001 FORMAT(A10)
      WRITE(5,2002)
 2002 FORMAT(' DESIGNATE WINDOW INPUT DATA FILE:  '$)
      READ(1,2001) VFNIN2

C
C  OPEN DATA FILES
C
      OPEN(UNIT=20,DEVICE='DSK',ACCESS='SEQIN',FILE=VFNIN1)
      OPEN(UNIT=21,DEVICE='DSK',ACCESS='APPEND',FILE='CROS.DAT')
      OPEN(UNIT=23,DEVICE='DSK',ACCESS='SEQIN',FILE=VFNIN2)

      WRITE(5,1000)
 1000 FORMAT(' DO YOU WANT WINDOWS OUTPUT TO CROS.DAT?  '$)
      READ(1,1001) ANS
 1001 FORMAT(A1)
      WRITE(5,1016)
 1016 FORMAT(' REFLECTED OR DIRECT PHASES?  '$)
      READ(1,1001) ANSPH

C
C  READ IN EVENT FROM VFNIN2
C
 20   READ(23,40,END=288) EVENT
C     WRITE(5,40) EVENT
 40   FORMAT(2A10)
      REWIND 20
C
C  SEARCH THROUGH VFNIN1 FOR DESIRED EVENT
C
 60   READ(20,70,END=100) CMPVAR
 70   FORMAT(3A10)

C
C  CHECK HEADER
C
      IF(EVENT(1).EQ.CMPVAR(1).AND.EVENT(2).EQ.CMPVAR(2)) GO TO 140
            GO TO 60
 100  WRITE(5,110)
 110  FORMAT('+','?EVENT NOT FOUND?')
      WRITE(5,113) EVENT
 113  FORMAT(1X,3A10)
      CLOSE(UNIT=20)
      STOP '*** NO EVENTS PROCESSED ***'
C
C  READ IN DIGITAL AMPLITUDE VALUES
C
 140  CONTINUE
      DO 170 I=1,1991,10
            READ(20,150) (YVALUE(J),J=I,I+9)
      DO 111 J=I,I+9
 111  NY(J)=YVALUE(J)
C     WRITE(21,141) (NY(J),J=I,I+9)
 141  FORMAT(10I5)
 150        FORMAT(10F5.0)
            IF(YVALUE(I).EQ.99999) GO TO 160
                  GO TO 170
 160        XNUM=I-1
            GO TO 180
 170  CONTINUE


      XNUM=2000
 180  MAX=0
      DO 210 K=1,XNUM
 210  IF(ABS(YVALUE(K)).GT.MAX) MAX=ABS(YVALUE(K))


      READ(23,510) NUMWIN
 510  FORMAT(I3)
      DO 530 J=1,NUMWIN
            READ(23,520) WINDOW(J,1),WINDOW(J,2),WINAN
            READ(23,525) VEL,SMP,FIL1,FIL2,DIST,H,ERH,ERZ,XLAT,XLON
 525        FORMAT(8F8.2,2F9.4)
 520  FORMAT(I4,1X,I4,1X,F2.0)
      IF(WAVE .EQ. 'P') VEL=5.85
      IF(WAVE .EQ. 'S') VEL=3.41
      IF(WAVE .EQ. 'P') WINDOW(J,2)=WINDOW(J,1)+32
      IF(WAVE .EQ. 'P') WINDOW(J,1)=WINDOW(J,1)-32
      IF(WAVE .EQ. 'S') WINDOW(J,2)=WINDOW(J,1)+64
```

```
  530     WIDWIN(J)=WINDOW(J,2)-WINDOW(J,1)
C
C  COMPUTE TOTAL DISTANCE TRAVELED (IF REFLECTED PHASE)
C
        Z=19.2
        IF(ANSPH .EQ. 'R') DIST=SQRT(DIST**2-4.*Z*H+4.*Z**2)
        IF(DIST .EQ. 0.) DIST=SMP*1.37*5.85
C
C  USE FFT ROUTINE TO GENERATE COMPLEX SPECTRA
C
        DO 1140 J=1,NUMWIN
        IF(ANS .EQ. 'Y') WRITE(21,21) CMPVAR,WINDOW(J,1),WINDOW(J,2),DIST
  21    FORMAT(3A10,2I6,F7.2)
              DO 655 K=1,2000
  655         X(K)=0.0
              IBEGIN=(2000-(WIDWIN(J)+1))/2+1
        XMEAN=0.
              DO 660 K=1,WIDWIN(J)
              NPOINT=K+WINDOW(J,1)
              IF(NPOINT .GT. 0) X(K)=YVALUE(NPOINT)
              IF(NPOINT .LE. 0) X(K)=0.
              IX(K)=INT(X(K))
        XMEAN=XMEAN+X(K)
  660   CONTINUE
C
C  OUTPUT WINDOW VALUES TO CROS.DAT (IF DESIRED)
C
        IF(ANS .EQ. 'N') GO TO 700
        DO 663 I=1,WIDWIN(J),10
        WRITE(21,141) (IX(K),K=I,I+9)
  663   CONTINUE
        WRITE(21,702)
  702   FORMAT(50('9'))
C       GO TO 20
  700   XMEAN=XMEAN/FLOAT(WIDWIN(J))
        TN=.01
        WN=WINDOW(J,2)-WINDOW(J,1)
        N=INT(WN)
        N2=N/2
C
C  CHOOSE DATA WINDOW SHAPE
C
        IF(WINAN .EQ. 1.) GO TO 654
        CALL WSHAP(WINAN,X,WIDWIN(J))
  654   CALL FFTRC(X,N,XC,IWK,WK)
        FR=.5/TN
C
C  FORM AMPLITUDE SPECTRA BY TAKING MAGNITUDE OF XC AND
C  DIVIDING BY NUMBER OF SAMPLE POINTS IN WINDOW
C
C  ALSO CALCULATE FREQUENCY VALUES
C
        DO 659 II=1,500
  659   FREQ(II)=0.
        DO 661 II=1,N/2+1
        AS(II)=SQRT(REAL(XC(II))**2+AIMAG(XC(II))**2)
        FREQ(II)=FR*FLOAT(II-1)/FLOAT(N/2)
        IF(FREQ(II) .NE. 0.) AS(II)=AS(II)*2./WN
        IF(FREQ(II) .EQ. 0.) AS(II)=AS(II)/WN
        IF(WINAN .EQ. 2.) AS(II)=AS(II)/.935
  661   CONTINUE
              IBEGIN=WINDOW(J,1)
              IEND=WINDOW(J,2)
              IVAR=WIDWIN(J)
              OPEN(UNIT=24,DEVICE='DSK',ACCESS='APPEND',
     1FILE='SPEC.DAT')
              WRITE(24,670) CMPVAR,IBEGIN,IEND,IVAR,XMEAN,XYNV(2),
     1N2,FIL1,FIL2,DIST,VEL,H,ERH,ERZ,XLAT,XLON,SMP
  670         FORMAT(3A10/I4,2(1X,I4)/F7.2,1X,F15.4,1X,I4,7F7.2,3F9.4)
              DO 672 K=1,N2+1
              WRITE(24,674) K,FREQ(K),AS(K)
  672         FORMAT(I4,1X,F5.2,1X,F15.4)
  674         WRITE(24,676)
              FORMAT(10('99999'))
  676         CLOSE(UNIT=24)
C             WRITE(3,680) CMPVAR,IBEGIN,IEND,IVAR,XMEAN
  680         FORMAT('1'//' ',30X,72('-')/' ',30X,'|',70X,'|'/' ',30X,
     1'|  EVENT BEING PROCESSED:  ',3A10,14X,'|'/' ',30X,'|',70X,'|'/
     1' '30X,'|  CURRENT WINDOW:  START = ',I4,7X,'STOP = ',I4,7X,
     1'WIDTH = ',I4,'  |'/' ',30X,'|',70X,'|'/' ',30X,'|  MEAN OF SER
     1IES = ',F7.2,6X,'VARIANCE OF SERIES = ',15X,'  |'/' ',30X,
     1'|',70X,'|'/' ',30X,'|  NUMBER OF LAGS USED IN PROCESSING WINDO
     1W = ',4X,21X,'|'/' ',30X,'|',70X,'|'/' ',30X,72('-')//)
              IVAR=N2/160+1
C
C  PRINT OUT VALUES OF POWER SPECTRA
C
              DO 980 K=1,IVAR
C                  WRITE(3,970)
  970             FORMAT(//' ',3('FREQUENCY:',4X,'POWER SPECTRU
     1M:',4X),'FREQUENCY:',4X,'POWER SPECTRUM:'/' ',3(10('-'),4X,
     115('-'),4X),10('-'),4X,15('-')/)
                  DO 980 K1=1,40
                        K2=K1+40
                        K3=K1+80
                        K4=K1+120
C980              WRITE(3,990) FREQ(K1),AS(K1),FREQ(K2),AS(K2),FREQ(K3),
C     1AS(K3),FREQ(K4),AS(K4)
  980         CONTINUE
  990         FORMAT(' ',2X,F5.2,7X,F15.4,3(6X,F5.2,7X,F15.4))
 1140   CONTINUE
C
C  RUN EVENT THROUGH BANDPASS FILTER
C
C       WRITE(5,1113)
 1113   FORMAT(' DO YOU WANT THE EVENT FILTERED?  '$)
C       READ(5,1114) ANSF
 1114   FORMAT(A1)
C       IF(ANSF .EQ. 'N') GO TO 994
C       CALL FILTER(CMPVAR,YVALUE,XNUM)
        GO TO 20


  288   CLOSE(UNIT=20)
        CLOSE(UNIT=21)
        CLOSE(UNIT=23)
        STOP

        END
```

BPFILT.FOR

```
      SUBROUTINE BPFILT(DATA,FREQ,NP)
C
C  BPFILT-- DIGITAL BANDPASS/REJECTION FILTER ROUTINE
C           TO FILTER SPECTRA TO REMOVE RIPPLE FROM
C           REVERBERATIONS.
C
C           THIS PROGRAM IS ADAPTED FROM FILTER.FOR--
C           IT IS SUGGESTED THAT FOR FILTERING SEISMO-
C           GRAMS FILTER.FOR OR DISPAN BE USED.
C
C        SYMBOLS USED:
C
C                 NP       NUMBER OF DIGITAL POINTS
C                 DT       DELTA T DIGITIZING INTERVAL
C                 FU       UPPER TIME LIMIT OF FILTER
C                 FL       LOWER TIME LIMIT OF FILTER
C                 AMP      FREQUENCY DOMAIN AMPLITUDE
C                          OF FILTER
C                 NF       NUMBER OF POINTS IN FILTER/2-1
C                 ISIGN    +1 FOR BANDPASS,
C                          -1 FOR BAND REJECTION
C
C                 TO SEE RESPONSE OF THIS FILTER, USE
C                 FILTER.FOR WITH A FLAT INPUT SPECTRUM.
C                 ROLLOFF FOR THIS FILTER IS ABOUT 14 DB/HZ.
C
      INTEGER IWK(7000),IFILT(2010)
      DIMENSION DATA(2048), FILTER(2048), WORK(7000)
      COMMON /LABEL/CMPVAR,FU,FL,FLAG
      REAL CMPVAR*8(3),EVENT*8(2)
      COMPLEX FILT(2048)
  100 DT=1.56
      WRITE(5,1000)
 1000 FORMAT(' INPUT MINIMUM AND MAXIMUM TIME FOR FILTER')
      READ(5,*) FL,FU
      AMP=1.
      NF=75
      WRITE(5,1001)
 1001 FORMAT(' BANDPASS (1) OR BAND REJECTION (-1)? '$)
      READ(5,*) ISIGN
      NPF=2*NF+1
  101 FORMAT(16F5.1)
      FLAG=0.
C
C  GENERATE BANDPASS/REJECTION FILTER
C
      CALL SYMFIL(FILTER,NF,FU,FL,AMP,DT,ISIGN)
C     TYPE 102, (FILTER(I),I=1,NF)
C
C  CONVOLVE FILTER WITH SEISMOGRAM
C
      CALL CONVOL(DATA,NP,FILTER,NF)
C     WRITE(25,102) (DATA(I),I=1,NP)
      DO 110 I=1,NP
      IFILT(I)=INT(DATA(I))
  110 CONTINUE
C     WRITE(25,103) CMPVAR,FL,FU
  103 FORMAT(3A10,2F5.1)
      DO 120 I=1,NP,10
C     WRITE(25,104) (IFILT(J),J=I,I+9)
  104 FORMAT(10I5)
  120 CONTINUE
C     WRITE(25,105)
  105 FORMAT(10('99999'))
  102 FORMAT('0',10F10.2)
      NPF1=NPF-1
      CALL FFTRC(FILTER,NPF1,FILT,IWK,WORK)
      DO 2 I=1,NF
      A=REAL(FILT(I))
      B=AIMAG(FILT(I))
    2 FILTER(I)=SQRT(A**2+B**2)/10.
C     PRINT 102, (FILTER(I),I=1,NF)
      FLAG=1.
      RETURN
      END


      SUBROUTINE SYMFIL(FILTER,NF,FU,FL,AMP,DT,ISIGN)
C
C  SYMFIL-- GENERATES SYMMETRIC DIGITAL FILTER
C
      DIMENSION FILTER(1)
      PI=3.14159
      FN=NF
      FNN=1./(2.*DT)
      NPF=2*NF+1
      FISIGN=FLOAT(ISIGN)
      AMP=2.*AMP*FISIGN
      NN=NF+1
      NNN=NF+2
C
C  GENERATE FILTER BY SUBTRACTING SINC FUNCTIONS
C
      DO 1 K=NNN,NPF
      FK=FLOAT(K)-FLOAT(NN)
      A1=2.*PI*FU*FK*DT
      A2=2.*PI*FL*FK*DT
      A3=2.*PI*FK*DT
      FILTER(K)=AMP*(SIN(A1)/A3-SIN(A2)/A3)
      A=(1.+COS(PI*FK/FN))/2.
    1 FILTER(K)=FILTER(K)*A/10.
      DO 2 K=1,NF
      KK=NN-K
    2 FILTER(KK)=FILTER(K+NN)
      FILTER(NN)=AMP*(FU-FL-(1-ISIGN)*FNN/2)/10.
  100 CONTINUE
      RETURN
      END


      SUBROUTINE CONVOL(DATA,NP,FILTER,NF)
C
C  CONVOL-- CONVOLVE SEISMOGRAM WITH FILTER
C
      DIMENSION FILTER(1), DATA(1), A(2048)
      NPF=2*NF+1
      NN=NF+NP
C
C  SET POINTS BEFORE AND AFTER SEISMOGRAM TO ZERO
C
      DO 1 I=1,NF
      A(I)=0.
    1 A(I+NN)=0.0
C
C  REINDEX SEISMOGRAM DATA
```

BPFILT.FOR (CONTINUED)

```
C
      DO 2 I=1,NP
 2    A(NP+I)=DATA(I)
      DO 3 J=1,NP
      JJ=J-1
      SUM=0.
      DO 4 I=1,NPF
 4    SUM=SUM+(A(I+JJ)*FILTER(I))
C
C  NORMALIZE FILTER OUTPUT BY DIVIDING BY 100
C
 3    DATA(J)=SUM/10.
      RETURN
      END
```

CLEAN.FOR

```
C
C  CLEAN-- REMOVES GLITCHES AND TIME MARKS FROM DIGITAL DATA
C         FILES. THIS PROGRAM INTERPOLATES THE REMOVED POINT
C         BY REPLACING IT WITH THE AVERAGE OF TWO ADJACENT
C         POINTS. THIS PROGRAM WILL WRITE UP TO 2000 POINTS
C         OF A CLEANED EVENT. IF THE EVENT IS LONGER THAN
C         THIS IT SHOULD BE BROKEN UP INTO TWO OR MORE
C         SEPARATE EVENTS SO THAT NO DATA IS LOST.
C
C         NOTE THAT THIS PROGRAM ONLY WORKS FOR ISOLATED
C         GLITCHES. IF GLITCHES ARE SIDE-BY-SIDE THE DIGITAL
C         DATA FILE WILL NEED TO BE EDITED USING EMACS. IN
C         FACT, EMACS IS A MORE COST-EFFECTIVE TECHNIQUE TO
C         CLEAN PROGRAMS THAN THIS PROGRAM, ALTHOUGH SOME
C         GLITCHES MAY BE MISSED.
C
C         THIS PROGRAM IS ALMOST AN EXACT DUPLICATE OF DISPAN,
C         WHICH SHOULD BE REFERRED TO FOR AN EXPLANATION OF
C         PROGRAM VARIABLES AND INPUT/OUTPUT FILES.
C
C         INPUT FILE=> TAPE.DAT (FROM REFOR)
C         OUTPUT.FILE=> VFNOUT (CLEANED DIGITAL DATA)
C
      PROGRAM CLEAN

      INTEGER ANSWER,IBEGIN,IEND,ITEMP(10),IVAR,LAST,
     +LOCPTS(50),NUMPTS

      REAL ANSCAL,CMPVAR*8(4),ENUM,EMAX,EVENT*8(2),
     +EVALUE(2000),MAX,PTRLOC,VFNOUT*8,WMAX,WMIN,XNUM,
     +YVALUE(2000)

      OPEN(UNIT=20,DEVICE='DSK',ACCESS='SEQIN',FILE=
     +'TAPE.DAT')
20    CALL INITT(480)
C
C     READ IN AND SEARCH FOR PROPER EVENT
C
      WRITE(5,30)
30    FORMAT('+','DESIGNATE DESIRED DIGITAL EVENT:  ',$)
      READ(5,40) EVENT
40    FORMAT(2A10)
      REWIND 20
      WRITE(5,50)
50    FORMAT(' ',' SEARCHING TAPE: => ',$)
60    READ(20,70,END=100) CMPVAR
70    FORMAT(4A10)
      IF(EVENT(1).EQ.CMPVAR(1).AND.EVENT(2).EQ.CMPVAR(2))
     +GO TO 80
            GO TO 60
80    WRITE(5,90)
90    FORMAT('+','[OK] EVENT FOUND => TAPE: CORRECTLY
     +POSITIONED')
      GO TO 140
100   WRITE(5,110)
110   FORMAT('+','?EVENT NOT FOUND?')
      WRITE(5,120)
120   FORMAT('-','DO YOU WISH TO SELECT ANOTHER EVENT?
     +<Y OR N>:  ',$)
      READ(5,130) ANSWER
130   FORMAT(A5)
      IF(ANSWER.EQ.'Y') GO TO 20
      CLOSE(UNIT=20)
      STOP '*** NO EVENTS PROCESSED ***'
C
C     READ IN DIGITAL AMPLITUDE VALUES
C
140   DO 170 I=1,1991,10
            READ(20,150) (YVALUE(J),J=I,I+9)
150         FORMAT(10F5.0)
            IF(YVALUE(I).EQ.99999) GO TO 160
                  GO TO 170
160         XNUM=I-1
            GO TO 180
170   CONTINUE

      XNUM=2000
180   IF(YVALUE(XNUM).EQ.-2047) GO TO 190
            GO TO 200
190   XNUM=XNUM-1
      GO TO 180

200   ENUM=XNUM
      MAX=0
      DO 210 K=1,ENUM
            IF(ABS(YVALUE(K)).GT.MAX) MAX=ABS(YVALUE(K))
210   EVALUE(K)=YVALUE(K)

      EMAX=MAX
      WMIN=0
      WMAX=XNUM
      LAST=0
      CALL INITT(480)
C
C     PLOT OUT TRACE OF EVENT
C
      CALL TRACE(YVALUE,ENUM,EMAX,WMIN,WMAX,120,760)
      CALL TIMAX(ENUM,WMIN,WMAX,100.,65.)

220   CALL MOVABS(0,765)
      CALL ANMODE
C
C     WRITE HEADER INFORMATION
C
      WRITE(5,230) (CMPVAR(I),I=1,3)
230   FORMAT('+',20X,'-<',3A10,'>-',33(/))
235   WRITE(5,240)
240   FORMAT('+','=>  ',$)
C
C     SELECT CLEANING OPTION
C
      READ(5,130) ANSWER
      IF(ANSWER.EQ.'I') GO TO 241
      IF(ANSWER.EQ.'C') GO TO 282
```

```
      IF(ANSWER.EQ.'K') GO TO 20
      IF(ANSWER.EQ.'P') GO TO 360
      IF(ANSWER.EQ.'Q') GO TO 288
      IF(ANSWER.EQ.'R') GO TO 254
      IF(ANSWER.EQ.'S') GO TO 266
      IF(ANSWER.EQ.'T') GO TO 250
      IF(ANSWER.EQ.'V') GO TO 390
      IF(ANSWER.EQ.'W') GO TO 330
      IF(ANSWER.EQ.'?') GO TO 290
            GO TO 235


241   WRITE(5,242)
242   FORMAT('+','HOW MANY POINTS HAVE BEEN SELECTED FOR ',
     +'INTERPOLATION?  ',$)
      READ(5,*) NUMPTS
      CALL ERASE


      DO 248 J=LAST+1,LAST+NUMPTS
            WRITE(5,244)
244         FORMAT(' ','LOCATION OF POINT =>  ',$)
            READ(5,*) LOCPTS(J)
            IF(LOCPTS(J).NE.1.AND.LOCPTS(J).NE.ENUM)
     +GO TO 246
                  EVALUE(LOCPTS(J))=0
                  GO TO 248
C
C     INTERPOLATE POINT (LINEAR INTERP.) TO FILL POINT
C     VACATED BY TIME MARK OR GLITCH
C
246         EVALUE(LOCPTS(J))=(YVALUE(LOCPTS(J)+1)+
     +YVALUE(LOCPTS(J)
     1-1))/2
248   CONTINUE
      LAST=LAST+NUMPTS
      EMAX=0
      DO 249 K=WMIN,WMAX
249   IF(ABS(EVALUE(K)).GT.EMAX) EMAX=ABS(EVALUE(K))
      GO TO 286


250   WRITE(5,252)
252   FORMAT('+','DESIGNATE LOCATION FOR TRACE ',
     +'TERMINATION:  ',$)
      READ(5,*) ENUM
      WMIN=0
      WMAX=ENUM
      EMAX=0
      DO 253 K=1,ENUM
253   IF(ABS(EVALUE(K)).GT.EMAX) EMAX=ABS(EVALUE(K))
      GO TO 286


254   WRITE(5,256)
256   FORMAT('+','HOW MANY POINTS HAVE BEEN SELECTED FOR',
     +'  RESTORATION?  ',$)
      READ(5,*) NUMPTS
      CALL ERASE


      DO 260 J=1,NUMPTS
            WRITE(5,244)
            READ(5,*) IVAR
            DO 257 L=1,LAST
                  IF(LOCPTS(L).NE.IVAR) GO TO 257
                        IBEGIN=L
                        GO TO 258
257         CONTINUE
258         LAST=LAST-1
            IF(IBEGIN.EQ.LAST+1) GO TO 260
            DO 259 M=IBEGIN,LAST
259         LOCPTS(M)=LOCPTS(M+1)
260   EVALUE(IVAR)=YVALUE(IVAR)
      EMAX=0
      DO 262 K=WMIN,WMAX
262   IF(ABS(EVALUE(K)).GT.EMAX) EMAX=ABS(EVALUE(K))
      GO TO 286


266   WRITE(5,268)
268   FORMAT('+','DESIGNATE OUTPUT FILE NAME:  ',$)
      READ(5,270) VFNOUT
270   FORMAT(A10)
      CALL ERASE
      WRITE(5,271)
271   FORMAT(' ','SAVING FILE: => ',$)
      OPEN(UNIT=1,DEVICE='DSK',ACCESS='APPEND',FILE=VFNOUT)
C
C     WRITE OUT CLEANED TRACE
C

      WRITE(1,70) CMPVAR
      IEND=ENUM/10
      IEND=IEND*10-10
      DO 274 J=0,IEND,10
            DO 272 K=1,10
272               ITEMP(K)=EVALUE(K+J)
274         WRITE(1,276) ITEMP
276         FORMAT(10I5)
      WRITE(1,278)
278   FORMAT(10('99999'))


      CLOSE(UNIT=1)
      WRITE(5,279) CMPVAR
279   FORMAT('+','[OK] EVENT SAVED => EVENT:  ',3A10)
      WRITE(5,280)
280   FORMAT('0','ARE THERE ANY MORE EVENTS TO BE CLEANED? ',
     +'<Y OR N>: ',$)
      READ(5,130) ANSWER
      IF(ANSWER.EQ.'Y') GO TO 20
      CLOSE(UNIT=20)
      STOP  '*** THAT''S ALL FOLKS! ***'


282   ENUM=XNUM
      EMAX=MAX
      WMIN=0
      WMAX=XNUM
      LAST=0
      DO 284 K=1,ENUM
284   EVALUE(K)=YVALUE(K)
      GO TO 286


290   CALL ERASE
```

```
      WRITE(5,300)
10    FORMAT(' COMMAND ONE OF THE FOLLOWING:'//' ''C'' - COPY BACK INT
     1O GRAPHICS BUFFER ORIGINAL INPUT DATA'/' ''I'' - INTERPOLATE AD
     1JACENT POINT VALUES TO REMOVE SPIKES'/' ''K'' - KILL CURRENT DI
     1GITAL EVENT AND ENTER MODE TO SELECT ANOTHER ONE'/' ''P'' - SET
     1 REFERENCE POINTER TO DESIRED LOCATION'/' ''Q'' - QUIT ALL PROC
     1ESSING AND RETURN TO TOPS-20 COMMAND LEVEL'/' ''R'' - RESTORE S
     1ELECTED POINTS TO THEIR ORIGINAL INPUT DATA VALUES'/' ''S'' - S
     1AVE CURRENT GRAPHICS BUFFER BY OUTPUTTING TO A DATA FILE'/' ''T
     1'' - TERMINATE THE DIGITAL EVENT AT THE SELECTED LOCATION'/' ''
     1V'' - DISPLAY CURRENT VALUES OF PROGRAM CONTROL VARIABLES'/' ''
     1W'' - SET START AND STOP LOCATIONS FOR DISPLAY WINDOW OF GRAPHI
     1CS BUFFER'/' ''?'' - DISPLAY THIS LISTING OF COMMANDS'//' => '
     1,$)
10    READ(5,130) ANSWER
      IF(ANSWER.EQ.'C') GO TO 282
      IF(ANSWER.EQ.'K') GO TO 20
      IF(ANSWER.EQ.'Q') GO TO 288
      IF(ANSWER.EQ.'S') GO TO 266
      IF(ANSWER.EQ.'V') GO TO 390
      IF(ANSWER.EQ.'?') GO TO 290
      IF(ANSWER.NE.'I'.AND.ANSWER.NE.'P'.AND.ANSWER.NE.
     +'R'.AND.ANSWER.NE.'T'.AND.ANSWER.NE.'W') GO TO 320
      CALL INITT(480)
      CALL TRACE(YVALUE,ENUM,EMAX,WMIN,WMAX,440,760)
      CALL TRACE(EVALUE,ENUM,EMAX,WMIN,WMAX,60,380)
      CALL TIMAX(ENUM,WMIN,WMAX,420.,385.)
      CALL MOVABS(0,765)
      CALL ANMODE
      WRITE(5,230) CMPVAR
      IF(ANSWER.EQ.'I') GO TO 241
      IF(ANSWER.EQ.'P') GO TO 360
      IF(ANSWER.EQ.'R') GO TO 254
      IF(ANSWER.EQ.'T') GO TO 250
            GO TO 330
20    WRITE(5,240)
      GO TO 310


60    WRITE(5,370)
70    FORMAT('+','DESIGNATE LOCATION FOR POINTER:  ',$)
      READ(5,*) PTRLOC
      CALL INITT(480)
      CALL TRACE(YVALUE,ENUM,EMAX,WMIN,WMAX,440,760)
      CALL TRACE(EVALUE,ENUM,EMAX,WMIN,WMAX,60,380)
      CALL TIMAX(ENUM,WMIN,WMAX,420.,385.)
      ANSCAL=(WMAX-WMIN)*0.01
      CALL TWINDO(0,1023,440,760)
      CALL DWINDO((WMIN-ANSCAL),(WMAX+ANSCAL),-(EMAX),
     +EMAX)
      CALL MOVEA(PTRLOC,EMAX)
      CALL DRAWA(PTRLOC,-(EMAX))
      CALL MOVABS(0,765)
      CALL ANMODE
      WRITE(5,230) CMPVAR
      IVAR=PTRLOC
      WRITE(5,380) IVAR
80    FORMAT('+',56X,'[PTR LOC => ',I4,']')
      GO TO 235


90    CALL ERASE
      WRITE(5,490)
90    FORMAT('+',11X,'*** CURRENT VALUES OF PROGRAM',
     +' CONTROL VARIABLES ***'////)
      WRITE(5,400) CMPVAR
400   FORMAT(' ','EVENT BEING PROCESSED:  ',3A10)
      IVAR=XNUM
      WRITE(5,410) IVAR
410   FORMAT('0','ACTUAL NUMBER OF DATA POINTS IN EVENT:
     +',I4)
      IVAR=ENUM
      WRITE(5,420) IVAR
420   FORMAT('0','EDITED NUMBER OF DATA POINTS IN EVENT:
     +',I4)
      IVAR=MAX
      WRITE(5,430) IVAR
430   FORMAT('0','ACTUAL MAXIMUM ''Y''-DISPLACEMENT IN',
     +' EVENT IS +/- ', I4)
      IVAR=EMAX
      WRITE(5,435) IVAR
435   FORMAT('0','EDITED MAXIMUM ''Y''-DISPLACEMENT IN',
     +' CURRENT DISPLAY  WINDOW IS +/- ',I4)
      IBEGIN=WMIN
      IEND=WMAX
      WRITE(5,440) IBEGIN,IEND
440   FORMAT('0','CURRENT DISPLAY WINDOW SETTINGS:
     +WMIN = ',I4,'  WMAX = ',I4////)
      WRITE(5,450) LAST
450   FORMAT(' ','THE FOLLOWING ',I2,' POINTS HAVE BEEN',
     +' INTERPOLATED:'/)
      IF(LAST.EQ.0) GO TO 470
            WRITE(5,460) (LOCPTS(J),J=1,LAST)
460         FORMAT((' ',4(I4,8X)),I4)
470   WRITE(5,480)
480   FORMAT('0','=>  ',$)
      GO TO 310


330   WRITE(5,340)
340   FORMAT('+','DESIGNATE WINDOW START AND STOP LOCATIONS',
     +' [SEPARATED BY '','']:  ',$)
      READ(5,*) WMIN,WMAX
      EMAX=0
      DO 350 K=WMIN,WMAX
350   IF(ABS(EVALUE(K)).GT.EMAX) EMAX=ABS(EVALUE(K))

286   CALL INITT(480)
      CALL TRACE(YVALUE,ENUM,EMAX,WMIN,WMAX,440,760)
      CALL TRACE(EVALUE,ENUM,EMAX,WMIN,WMAX,60,380)
      CALL TIMAX(ENUM,WMIN,WMAX,420.,385.)
      GO TO 220


288   CALL ERASE
      CLOSE(UNIT=20)
      STOP '*** THAT''S ALL FOLKS! ***'


      END


      SUBROUTINE TRACE(YVALUE,ENUM,EMAX,WMIN,WMAX,YMIN,YMAX)


      INTEGER YMAX,YMIN
```

```
      REAL ANSCAL,EMAX,ENUM,WMAX,WMIN,YVALUE(2000)


      ANSCAL=(WMAX-WMIN)*0.01
      CALL TWINDO(0,1023,YMIN,YMAX)
      CALL DWINDO((WMIN-ANSCAL),(WMAX+ANSCAL),-(EMAX),EMAX)
      CALL MOVEA(WMIN,YVALUE(1))
      DO 10 P=2,WMAX
0     CALL DRAWA(P,YVALUE(P))


      RETURN
      END


      SUBROUTINE TIMAX(ENUM,WMIN,WMAX,LINLEV,NUMLEV)


      INTEGER IBEGIN,IEND,VALARY(2)

      REAL ANSCAL,ENUM,LINLEV,NUMLEV,WMAX,WMIN,XCOORD


      ANSCAL=(WMAX-WMIN)*0.01
      CALL TWINDO(0,1023,0,780)
      CALL DWINDO((WMIN-ANSCAL),(WMAX+ANSCAL),0.,780.)
      IBEGIN=INT((WMIN+99)/100.)*100
      IEND=INT(WMAX/100.)*100
      XCOORD=INT(ENUM/100.)*100.
      CALL MOVEA(0.,LINLEV)
      CALL DRAWA(XCOORD,LINLEV)
      DO 10 P=0,XCOORD,100
            CALL MOVEA(P,(LINLEV+10.))
10    CALL DRAWR(0.,-20.)
      IF((WMAX-WMIN).GT.500) GO TO 30
            DO 20 P=0,XCOORD,10
                  IF(AMOD(P,100.).EQ.0.) GO TO 20
                        CALL MOVEA(P,(LINLEV+5.))
                        CALL DRAWR(0.,-10.)
20          CONTINUE
30    IF(IEND.LT.IBEGIN) GO TO 60
      VALARY(1)=INT(FLOAT(IBEGIN/1000))+48
      VALARY(2)=(IBEGIN-INT(FLOAT(IBEGIN/1000))*1000)/100+47
      DO 50 P=IBEGIN,IEND,100
            VALARY(2)=VALARY(2)+1
            IF(VALARY(2).LT.58) GO TO 40
                  VALARY(1)=VALARY(1)+1
                  VALARY(2)=48
40                CALL MOVEA((P-ANSCAL),NUMLEV)
50          CALL ANSTR(2,VALARY)

60    RETURN
      END
```

COPY.FOR

```
C
C  COPY-- CONVERT S WINDOW FILES TO P WINDOW FILES
C
C       COPY ALLOWS A COMPLETELY NEW P WAVE DATA FILE
C       TO BE GENERATED FROM AN S WAVE EVENT FILE. THE
C       ONLY THING THAT IS CHANGED IS ARE THE WINDOWS AND
C       THE WAVE VELOCITY.
C
C       SYMBOLS ARE THE SAME AS FOR DISPAN.FOR
C
C       NOTE: FILE NAMES FOR UNITS 20-23 MUST BE
C             CHANGED WITH EACH RUN.
C
C
C
      REAL CMPVAR*8(2),EVENT*8(3)
      INTEGER WINDOW(10,2),WIND1,WIND2

      OPEN(UNIT=23,DEVICE='DSK',FILE='SLOC79.DAT')
      OPEN(UNIT=22,DEVICE='DSK',FILE='PLOC79.DAT')
      OPEN(UNIT=20,DEVICE='DSK',FILE='PWIN79.DAT')
C
C  READ IN EVENT FROM S WINDOW FILE
C
20    READ(23,40,END=288) EVENT

40    FORMAT(3A10)
C
C  SEARCH THROUGH P WINDOWS FOR DESIRED EVENT
C
60    READ(20,70,END=100) CMPVAR
      READ(20,510) NUMWIN
      READ(20,520) WIND1,WIND2,WINAN
      READ(20,525) VEL,SMP,FIL1,FIL2,DIST,H,ERH,ERZ,XLAT,
     +XLON
70    FORMAT(2A10)

C
C  CHECK HEADER
C
      IF(EVENT(1).EQ.CMPVAR(1).AND.EVENT(2).EQ.CMPVAR(2))
     +GO TO 140
      go to 60
100   READ(23,*)
      READ(23,*)
      READ(23,*)
      REWIND 20
      GO TO 20

140   WRITE(22,40) EVENT
      READ(23,510) NUMWIN
      WRITE(22,510) NUMWIN
510   FORMAT(I3)
      VP=5.85
      DO 530 J=1,NUMWIN
            READ(23,520) WINDOW(J,1),WINDOW(J,2),WINAN
            READ(23,525) VS,SMP,FIL1,FIL2,DIST,H,ERH,ERZ,
     +XLAT,XLON
            WRITE(22,520) WIND1,WIND2,WINAN
            WRITE(22,525) VP,SMP,FIL1,FIL2,DIST,H,ERH,ERZ,
     +XLAT,XLON
525         FORMAT(8F8.2,2F9.4)
520   FORMAT(I4,1X,I4,1X,F2.0)
530   continue
      REWIND 20
      GO TO 20
288   STOP
      END
```

CROS.FOR

```
C
C       PROGRAM CROS-- CROSS-CORRELATE SEISMOGRAMS
C
C
C       SYMBOLS USED:
C
C               CMP             EVENT RECORDING PARAMETERS
C               VFNIN           INPUT FILE NAME
C               Y1              DIGITAL AMPLITUDES (1ST EVENT)
C               Y2              DIGITAL AMPLITUDES (2ND EVENT)
C               NPTS1           LENGTH OF 1ST EVENT
C               NPTS2           LENGTH OF 2ND EVENT
C               IBEG1           WINDOW START FOR 1ST EVENT
C               IBEG2           WINDOW START FOR 2DN EVENT
C               IEND1           WINDOW END FOR 1ST EVENT
C               IEND2           WINDOW END FOR 2ND EVENT
C               NLAGS           NUMBER OF TIME SHIFTS
C               ISW,IA,IB,      FTCROS CONTROL PARAMETERS
C               IC,ID,NC
C               AC              CROSS-COVARIANCE
C               ACMAX           MAX. CROSS-CORRELATION COEFF.
C
C       INPUT FILES>>>  CROS.DAT (CONTAINS TWO EVENTS TO
C                       BE CORRELATED-- FROM DISPAN OR ADSA)
C
C       OUTPUT FILES>>  NONE
C
C       SUBROUTINES:    FTCROS          IMSL ROUTINE
C                       SECC            XCORR PLOTTER
C
C       NOTE-- THE 1ST SERIES LAGS THE 2ND I. E. IT IS
C              PROGRESSIVELY SHIFTED TOWARDS THE LEFT
C
C
C
      INTEGER ANSWER,N2,IVAR,LINE,VALARY(102),RES(2000)
      REAL CMP1*8(3),Y1(2000),Y2(2000),VFNIN*8,CMP2*8(3)
      REAL WIN*8
      DIMENSION XY(4000),NC(4),EMUSIG(4),ACV(1,1,2000),
     +AC(1,1,2000)
C
8     FORMAT(A10)
      OPEN(UNIT=1,DEVICE='DSK',ACCESS='SEQIN',FILE=
     +'CROS.DAT')
C
C     READ IN 1ST EVENT
C
      READ(1,20) CMP1
20    FORMAT(3A10)
      READ(1,21) IBEG1,IEND1
21    FORMAT(2I5)
      DO 30 I=1,1991,10
      READ(1,40) (Y1(J),J=I,I+9)
40    FORMAT(10F5.0)
      IF(Y1(I) .EQ. 99999.) GO TO 45
      GO TO 30
45    NPTS1=I-1
      GO TO 56
30    CONTINUE
C
C     READ IN 2ND EVENT
C
56    READ(1,20) CMP2
      READ(1,21) IBEG2,IEND2
      DO 50 I=1,1991,10
      READ(1,40) (Y2(J),J=I,I+9)
      IF(Y2(I) .EQ. 99999.) GO TO 55
      GO TO 50
55    NPTS2=I-1
      GO TO 57
50    CONTINUE
C
57    CONTINUE
      WRITE(5,1065)
1065  FORMAT(' ENTER MAX. LENGTH FOR TIME SERIES')
      READ(5,*) LMAX
C
C     SET UP PARAMETERS FOR CROSS-CORRELATION
C
      NC(1)=LMAX
      NC(2)=LMAX
      NC(3)=1
      WRITE(5,1071)
1071  FORMAT(' NUMBER OF LAGS?')
      READ(5,*) NLAGS
      NC(4)=NLAGS
C
      ISW=5
      IA=1
      IB=1
      IC=1
      ID=1
C
      DO 60 I=1,LMAX
      XY(I)=Y1(I)
      XY(I+LMAX)=Y2(I)
60    CONTINUE
C
C     COMPUTE CROSS-CORRELATION USING IMSL ROUTINE
C
      CALL FTCROS(XY,NC,ISW,EMUSIG,ACV,IA,IB,AC,IC,ID,IER)
      WRITE(5,1070) IER
1070  FORMAT(' ERROR PARAMETER FROM FTCROS =',I5)
      NLAG1=NLAGS+1
      WRITE(5,1100)
1100  FORMAT(' DO YOU WANT A PRINTOUT OF CROSS-',
     +' CORRELATIONS?')
      READ(5,130) ANS
130   FORMAT(A3)
      IF(ANS .EQ. 'N') GO TO 100
      WRITE(3,1200) CMP1,CMP2
1200  FORMAT(1X,'CROSS-CORRELATION DATA FOR ',3A10,
     +' X ',3A10)
      WRITE(3,1250)
1250  FORMAT(//10X,'LAG',20X,'X-CORR',/,10X,'___',20X,
     +'_____'/)
      DO 200 LAG=1,NLAGS
      WRITE(3,1300) LAG,AC(1,1,LAG)
1300  FORMAT(10X,I3,18X,F8.2)
200   CONTINUE
100   CONTINUE
      WRITE(5,1400)
1400  FORMAT(' DO YOU WANT TO COMPUTE RESIDUALS?')
      READ(5,130) ANS
      IF(ANS .EQ. 'N') GO TO 300
      ACMAX=0.
```

```
      DO 250 I=1,NLAGS
      IF(AC(1,1,I) .LE. ACMAX) GO TO 250
      ACMAX=AC(1,1,I)
      LAG=I
250   CONTINUE
      DO 275 I=LAG,LMAX
      RES(I)=Y1(I)-Y2(I-LAG+1)
275   CONTINUE
300   CONTINUE
      CALL SECC(CMP1,CMP2,AC,NLAG1,IBEG1,IBEG2,IEND1,
     +IEND2)

      STOP
      END

      SUBROUTINE SECC(CMP1,CMP2,AC,NLAG1,IBEG1,IBEG2,
     +IEND1,IEND2)

C
C     SECC-- DISPLAY OF CROSS-CORRELATION
C
C
C     SYMBOLS USED:
C
C             CMP1,CMP2       EVENT HEADERS
C             VFNIN           INPUT FILE NAME
C             IBEG1,IBEG2     BEGINNING OF WINDOW
C             IEND1,IEND2     END OF WINDOW
C             X,Y             SCREEN COORDINATES
C
      INTEGER ANSWER,N2,IVAR,LINE,VALARY(1)
      REAL CMP1*8(3),CMP2*8(3),AC(1,1,2000)
      REAL LINC,LMAX,LMIN


C
C     READ IN DATA FROM DATA FILE
C
C
C     INITIALIZE TERMINAL FOR PLOTTING
C
      CALL INITAL(23)
C
C     RESET ORIGIN TO (.5",.5")
C
      CALL PLOT(.5,.5,-3)
C
C     READ IN RANGE OF LAGS FOR PLOTTING
C
      WRITE(5,1000)
1000  FORMAT(' ENTER MIN. AND MAX. LAGS FOR PLOTTING')
      READ(5,*) LMIN, LMAX
C
C     FIND MAXIMUM CROSS-CORRELATION TO SCALE PLOT
C
150   YMAX=0
      YMIN=0.
      DO 190 J=1,NLAG1
      IF(AC(1,1,J) .LT. YMIN) YMIN=AC(1,1,J)
      IF(AC(1,1,J) .GT. YMAX) YMAX=AC(1,1,J)
190   CONTINUE
C     YMIN=YMIN-0.5
C
C     PLOT AUTOCORRELATION VALUES
C
      NPT=0.
      DO 300 I=1,NLAG1
      LAG=I-1
      IF(LAG .LT. LMIN .OR. LAG .GT. LMAX) GO TO 300
      NPT=NPT+1
      X=(LAG-LMIN)/(LMAX-LMIN)*5.
      Y=(AC(1,1,I)-YMIN)/(YMAX-YMIN)*5.
      IF(NPT .EQ. 1) CALL PLOT(X,Y,3)
      CALL PLOT(X,Y,2)
300   CONTINUE

C
C     PLOT AND LABEL AXES

C
320   CALL NEWPEN(1)
      LINC=(LMAX-LMIN)/5.
      YINC=(YMAX-YMIN)/5.
      CALL AXIS(XBASE,0.,'LAG NUMBER',-10,5.,0.,LMIN,
     +LINC,2)
      CALL AXIS(XBASE,0.,'X-CORR AMPL',11,5.,90.,YMIN,
     +YINC,2)
C
C     ADD TITLE AND PERTINENT INFORMATION FOR EACH PLOT
C
      XBASE=XBASE+2.
      CALL SYMBOL(XBASE,5.,.14,CMP1,0.,30)
      CALL SYMBOL(XBASE,4.6,.14,CMP2,0.,30)
      WIN='WINDOW=>'
      CALL SYMBOL(XBASE,4.8,0.14,WIN,0.,8)
      CALL SYMBOL(XBASE,4.4,0.14,WIN,0.,8)
      BEGIN1=FLOAT(IBEG1)
      END1=FLOAT(IEND1)
      BEGIN2=FLOAT(IBEG2)
      END2=FLOAT(IEND2)

      XBASE=XBASE+1.25

      CALL NUMBER(XBASE,4.8,.14,BEGIN1,0.,-1)
      CALL NUMBER(XBASE,4.4,.14,BEGIN2,0.,-1)
      COLON=':'
      XBASE=XBASE+.50
      CALL SYMBOL(XBASE,4.8,.14,COLON,0.,1)
      CALL SYMBOL(XBASE,4.4,.14,COLON,0.,1)
      XBASE=XBASE+.25
      CALL NUMBER(XBASE,4.8,.14,END1,0.,-1)
      CALL NUMBER(XBASE,4.4,.14,END2,0.,-1)

220   CALL RSTR(0)
      RETURN
      END
```

CUMBAR.FOR

```
C
C  CUMBAR: PLOTS Q1 VS. NUMBER OF EVENTS AS A BAR GRAPH
C
C
C      THIS PROGRAM COMPUTES THE AVERAGE VALUE FOR Q1
C  FROM THE APPARENT Q, AND AVERAGE VALUE FOR Q2, AND THE
C  DISTANCE THE WAVE TRAVELS THROUGH THE LOW VELOCITY, LOW Q
C  LAYER. THE APPARENT Q VALUES AND EVENT DISTANCES MAY BE
C  OBTAINED FROM THE OUTPUT OF MODEL.FOR: SLOPE.DAT. THE FRAC-
C  TION OF THE RAYPATH IN LOW VELOCITY, LOW Q MATERIAL MUST BE
C  ESTIMATED FROM THE STATION CORRECTIONS.
C
C      THIS PROGRAM ASSUMES THE Q AND VELOCITY STRUCTURE
C  CAN BE REPRESENTED BY A LAYER OVER A HALF-SPACE. EACH
C  Q1 VALUE IS PLOTTED ON A BAR GRAPH AND PRINTED OUT
C  IN A TABLE IN BAR.OUT. THE USER ENTERS THE BOUNDS FOR
C  GRAPHING THE DATA AND SPECIFIES THE SUMMING INTERVAL FOR
C  THE BAR GRAPH.
C
C     INPUT FILES: FILENM (SLOPE.DAT IF MODEL OUTPUT)
C     OUTPUT FILES: OUTPUT.PLT-- USE GRAFIX CMD TO VIEW
C
C  VARIABLES:
C
C           V1          LAYER VELOCITY
C           V2          HALF-SPACE VELOCITY
C           Q2          HALF-SPACE QUALITY FACTOR
C           DMIN        MINIMUM Q1 VALUE TO BE PLOTTED
C           DMAX        MAXIMUM Q1 VALUE TO BE PLOTTED
C           DINC        INCREMENT FOR SUMMING
C           EQMAX       MAXIMUM # OF QUAKES FOR VERTICAL SCALE
C           FILENM      INPUT FILE WITH APPARENT Q, DIST, DEPTH
C           SLSUM       SUM OF Q VALUES FOR EACH STATION
C           NEV         NUMBER OF EVENTS IN EACH Q1 INCREMENT
C           DIST        HYPOCENTRAL DISTANCE (FROM FILENM)
C           D           SLANT DISTANCE THROUGH NEAR SURFACE LVL
C           VAPP        APPARENT VELOCITY FOR RAYPATH
C           Q1          AVERAGE VALUE OF LVL Q
C           SSQ         SUM OF SQUARES
C           SD          STANDARD DEVIATION
C           N(I)        # OF EVENTS SUMMED IN EACH INTERVAL
C
C  READ IN Q AND DIST FROM SLOPE.DAT-- COMPUTE Q1 FOR
C  KNOWN VALUES OF Q2 AND D.
C
C
      REAL*8 FILENM,STA
      REAL MAG,LAA,LONA,N(100),SL(200),NLAST(100)
      KOUNT=0
      NEV=0
      DAT=0.50
      X0=DAT
C
C     SET LAYER VELOCITY AND HALF-SPACE Q AND VELOCITY
C
      V1=1.96
      V2=3.41
      Q2=938

      OPEN(UNIT=3,DEVICE='DSK',FILE='BAR.OUT')

      WRITE(5,2000)
 2000 FORMAT(' ENTER MIN. AND MAX. Q1 AND Q1 INCREMENT')
      READ(5,*) DMIN,DMAX,DINC
      NN=(DMAX-DMIN)/DINC
      WRITE(5,2001)
 2001 FORMAT(' MAX. NUMBER OF EARTHQUAKES FOR VERT. SCALE?')
      READ(5,*) EQMAX
      EQINC=EQMAX/5.
      WRITE(5,1000)
 1000 FORMAT(' INPUT DATA FILE?')
      READ(5,1001) FILENM
 1001 FORMAT(A10)
      OPEN(UNIT=22,DEVICE='DSK',FILE=FILENM)
      CALL INITAL(23)
C     CALL PLOT(DAT,DAT,-3)
      WRITE(3,2450) Q2,V1,V2
 2450 FORMAT(1X,'Q2 =',F7.2/,1X,'V1 =',F7.2/,' V2 =',
     +F7.2//)
      WRITE(3,2500)
 2500 FORMAT(1X,'STA',5X,'# QUAKES',7X,'D',8X,'Q1MAX',6X,
     +'SD Q1MAX'/)
      DO 50 I=1,10
   50 N(I)=0
C
C     READ STATION, Q AND DIST
C
  290 READ(22,1005,END=999) STA
      SLSUM=0.
      NEV=0
      KOUNT=0
      X=X0
      DO 291 I=1,NN
  291 N(I)=0.
C
C     LOAD SLANT DISTANCES (DISTANCE WAVE TRAVELS
C     THROUGH LOW VELOCITY LAYER)
C
      IF(STA .EQ. 'CC ') D=0.0
      IF(STA .EQ. 'CM ') D=2.3
      IF(STA .EQ. 'DM ') D=1.3
      IF(STA .EQ. 'FM ') D=1.4
      IF(STA .EQ. 'IC ') D=1.7
      IF(STA .EQ. 'SC ') D=1.8
      IF(STA .EQ. 'SNM') D=1.1
      IF(STA .EQ. 'WT ') D=0.4
 1005 FORMAT(A3)
  292 READ(22,*) Q,DIST,DEPTH,SLOPE
      IF(Q .EQ. 99999.) GO TO 360
C
C     COMPUTE APPARENT VELOCITIES
C
      R2=DIST-D
      VAPP=DIST/(D/V1+R2/V2)
C
C     COMPUTE LAYER QUALITY FACTORS
C
      Q1=D/(V1*(SLOPE-R2/(Q2*V2)))
C     WRITE(3,*) VAPP,Q1
      KOUNT=KOUNT+1
      SL(KOUNT)=Q1
      SLSUM=Q1+SLSUM
C
C     COUNT # OF EVENTS IN EACH DIST. INTERVAL
C
C     WRITE(3,*) DMIN,DMAX,DINC,NN,SLOPE
      DO 100 I=1,NN
      IF(Q1 .LE. DMIN+DINC*FLOAT(I) .AND. Q1
```

CUMBAR.FOR (CONTINUED)

```
     1 .GT. (DINC*FLOAT(I-1)+DMIN)) N(I)=N(I)+1
 100     CONTINUE
         NEV=NEV+1
         GO TO 292
 360     CONTINUE
         SLSUM=SLSUM/FLOAT(NEV)
         SSQ=0.
         DO 800 I=1,KOUNT
 800     SSQ=SSQ+(SL(I)-SLSUM)**2
         KOUNT=KOUNT-1
         SD=SQRT(SSQ/FLOAT(KOUNT))
         WRITE(3,753) STA,NEV,D,SLSUM,SD
 753     FORMAT(1X,A3,5X,I5,5X,F7.2,5X,F7.2,5X,F7.2)
C
C        PLOT BAR REPRESENTING NUMBER OF QUAKES
C
C        WRITE(3,3000)
 3000    FORMAT(1H1,10X 'Q1',10X,'NUMBER OF QUAKES'
     1,/70('-')/)
         XINC=5.0/NN
         CALL PLOT(DAT,DAT,3)
         DO 200 I=1,NN
         D=DMIN+DINC*I
         D0=DMIN+DINC*(I-1)
C        WRITE(3,3001) D0,D,N(I)
 3001    FORMAT(12X,F7.2,' -',F7.2,20X,F4.0)
         N(I)=N(I)/EQINC+DAT+NLAST(I)
         CALL PLOT(X,N(I),2)
         X=X0+FLOAT(I)*XINC
         CALL PLOT(X,N(I),2)
         DATT=DAT+NLAST(I)
         CALL PLOT(X,DATT,2)
         NLAST(I)=N(I)-DAT
C        WRITE(3,*) X,N(I)
 200     CONTINUE
         DINC1=(DMAX-DMIN)/5.
         GO TO 290
C
C        PLOT AND LABEL AXES
C
 999     CALL AXIS(DAT,DAT,'NUMBER OF EARTHQUAKES',21,5.,90.,
     +0.,EQINC,-1)
         CALL AXIS(DAT,DAT,'Q1AVE',-5,5.00,0.,DMIN,DINC1,1)
         CALL RSTR(0)
         CLOSE(UNIT=22)
         STOP
         END
```

DECON.FOR

```
C
C  DECON-- FILTER DECONVOLUTION ROUTINE-- FREQUENCY DOMAIN
C
C
C       SYMBOLS:
C
C               FREQ            FREQUENCY
C               FIL5            5 HZ FILTER AMPLITUDES
C               FIL30           30 HZ FILTER AMPLITUDES
C               NPF             # OF POINTS IN FILTER
C               FILTER          1/APPROPIATE FILTER AMPLS.
C               FILT            INTERPOLATED FILT. AMPL.
C               AMP             CORRECTED (DECONVOLVED)
C                               AMPLITUDES
C
        SUBROUTINE DECON(AMP,FIL,F,N2)

        REAL AMP(2000),F(2000),FREQ(50),FIL5(50),FIL30(50)
        REAL FILT(2000),FILTER (2000)

C
C  LOAD FILTER RESPONSE FOR FOR 5 AND 30 HZ FILTERS
C
        DATA (FREQ(I),I=1,50)/ 1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,
     +12.,13.,14.,15.,16.,17.,18.,19.,20.,21.,22.,23.,24.,25.,26.,27.,
     +28.,29.,30.,31.,32.,33.,34.,35.,36.,37.,38.,39.,40.,41.,42.,43.,
     +44.,45.,46.,47.,48.,49.,50./

        DATA (FIL5(I),I=1,50)/ .0459,.167,.291,.408,.518,.628,.750,.822,
     +.883,.911,.931,.950,.968,.981,.986,.990,.998,1.00,.998,.998,.997,
     +.993,.989,.984,.979,.973,.964,.957,.949,.937,.923,.907,.892,.876,
     +.859,.842,.824,.805,.785,.766,.746,.727,.707,.686,.666,.644,.621,
     +.600,.577,.555/

        DATA (FIL30(I),I=1,50)/ .934,.968,.984,1.,.991,.978,.956,.939,
     +.920,.903,.884,.866,.847,.828,.808,.789,.769,.749,.730,.710,.690,
     +.670,.649,.629,.609,.590,.570,.550,.530,.511,.492,.473,.454,.435,
     +.417,.399,.381,.363,.346,.329,.312,.296,.280,.265,.250,.235,.220,
     +.207,.194,.181/

        NPF=50
        N2P1=N2+1

C
C  LOAD DESIRED FILTER FUNCTION
C
        DO 100 I=1,NPF
        IF(FIL .EQ. 5.) FILTER(I)=1./FIL5(I)
        IF(FIL .EQ. 30.) FILTER(I)=1./FIL30(I)
100     CONTINUE
C
C  INTERPOLATE FILTER RESPONSE FOR APPROPIATE FREQUENCY
C
        DO 300 J=2,N2P1
        DO 150 I=1,NPF-1
        IF(F(J) .GE. FREQ(I) .AND. F(J) .LT. FREQ(I+1)) GO TO 200
150     CONTINUE
200     FILT(J)=FILTER(I)+(FILTER(I+1)-FILTER(I))*(F(J)-FREQ(I))/
     1(FREQ(I+1)-FREQ(I))
C
C  MULTIPLY FILTER RESPONSE BY SPECTRA
C
        AMP(J)=AMP(J)*FILT(J)
300     CONTINUE
        RETURN
        END
```

DISPAN.FOR

```
C
C     DISPAN-- DIGITAL SPECTRAL ANALYSIS PROGRAM
C
C     MAIN PROGRAM FOR SPECTRAL ANALYSIS OF DIGITAL
C     SEISMOGRAMS. THIS PROGRAM SHOULD BE USED WITH
C     A TEKTRONIX TERMINAL-- IT USES THE TEKTRONIX
C     PLOT10 PLOTTING PACKAGE.
C
C     DATA:  DATA FOR EACH EVENT IS READ INTO DISPAN
C            IN THE FOLLOWING FORMAT:
C
C            HEADER (3A10)
C            DIGITAL VALUES (10F5.0)
C            TAILER ('999999999999')
C
C
C            DISPAN WILL READ UP TO 2048 POINTS. IF
C            A LONGER DATA SET IS TO BE ANALYZED, IT
C            IS SUGGESTED THAT IT BE BROKEN UP INTO
C            SEPERATE EVENTS TO REDUCE COMPUTATION TIME
C            AND STORAGE.
C
C     ANALYSIS: SEVERAL ANALYSIS OPTIONS EXIST IN DISPAN.
C               A '?' RESPONSE TO THE '=>' PROMT WILL
C               DISPLAY THE OPTIONS. USUAL SEQUENCE:
C
C                 1. SELECT WINDOW-- OPTION "A"
C                 2. OUTPUT DIGITAL VAUES IN WINDOW TO
C                    CROS.DAT-- OPTION "E"
C                 3. USE FAST FOURIER TRANSFORM (FFT) TO
C                    TRANSFORM TIME SERIES IN WINDOW;
C                    CHOOSE WINDOW SHAPE-- OPTION "B"
C                 4. SPECTRAL VALUES WILL AUTOMATICALLY BE
C                    OUTPUT TO SPEC.DAT
C                 5. THE EVENT CAN ALSO BE DIGITALLY FILTERED
C                    IF THE USER DESIRES (THIS FEATURE HAS
C                    NOT BEEN RECENTLY TESTED AND IS THUS
C                    TURNED OFF TEMPORARILY)
C
C     INPUT FILE-- VFNIN (DIGITAL DATA FILE)
C     OUTPUT FILES-- CROS.DAT (CONTAINS WINDOW TRACES)
C                    SPEC.DAT (CONTANS SPECTRA)
C                    FILTER.DAT (CONTAINS FILTERED TRACES)
C
C     SUBROUTINES--
C
C            PLOT10 ROUTINES          PLOTTING PROGRAMS
C            FFTRC (IMSL)             FAST FOURIER TRANSFORM
C            WSHAP                    WINDOW SHAPE MULTIPLIER
C
C            OTHER SUBPROGRAMS ARE LISTED AT END
C
C     SYMBOLS--
C
C            VFNIN          DIGITAL DATA FILE NAME
C            EVENT          EVENT HEADER
C            CMPVAR           "     "
C            YVALUE         TIME SERIES AMPLITUDE VALUES
C            XNUM           NUMBER OF POINTS IN TIME
C                           SERIES
C            TN             SAMPLING INTERVAL IN SECONDS
C            ANSWER         USER CONTROL VARIABLE
C            NUMWIN         # OF WINDOWS TO BE ANALYZED
C            WIDWIN         WIDTH OF EACH WINDOW
C            WINDOW         WINDOW START AND STOP LOC.
C            IBEGIN,IEND      "      "    "   "    "
C            ERASE          SCREEN CLEAR COMMAND
C            NY             YVALUES IN WINDOW OUTPUT TO
C                           CROS.DAT
C            PTRLOC         POINTER LOCATION
C            ANMODE         TERMINAL IN ALPHANUMERIC
C                           MODE
C            XMEAN          MEAN OF TIME SERIES
C            IVAR           VARIANCE OF TIME SERIES
C            XYMV           STD. DEV. OF TIME SERIES
C            N2             # OR POINTS IN WINDOW/2
C            VEL            WAVE VELOCITY
C            DIST           EVENT DISTANCE
C            FIL1           LO-CUT FILTER SETTING
C            FIL2           HI-CUT FILTER SETTING
C            AS             AMPLITUDE SPECTRUM
C            FREQ           FREQUENCY (HZ)
C
C     WRITTEN BY DCB (10/80) AND REVISED BY PJC (8/82,
C     12/82,11/83)
C
C     REFERENCES: BRIGHAM, E. (1974). THE FAST FOURIER
C                   TRANSFORM.  PRENTICE-HALL.
C
C                 BATH, M. (1979). SPECTRAL ANALYSIS IN
C                   GEOPHYSICS, DEVELOPMENTS IN SOLID EARTH
C                   GEOPHYSICS, 7, ELSEVIER.
C
C                 GUTJAHR, A. (1982). NOTES FROM MATH 587,
C                   NEW MEXICO TECH.
C
      INTEGER ANSWER,IBEGIN,IEND,IER,IVAR,LAST,NUMWIN
      INTEGER WIDWIN(10),WINDOW(10,2),IWK(3200),NY(5000)
      COMPLEX XC(2048)

      REAL CMPVAR*8(3),WMIN,WMAX,X(2048),XNUM,PTRLOC
      REAL EMAX,EVENT*8(2),FREQ(2048),MAX,AS(2048),VFNOUT*8
      REAL XYMV(6),YVALUE(2048),XI(2048),WK(3200),VFNIN*8

      TN=.01

C
C  OPEN DATA FILE AND INITIALIZE TERMINAL
C
      WRITE(5,1003)
 1003 FORMAT(' DESIGNATE DATA FILE:  ',$)
      READ(5,1004) VFNIN
 1004 FORMAT(A10)

      OPEN(UNIT=20,DEVICE='DSK',ACCESS='SEQIN',FILE=VFNIN)
      OPEN(UNIT=23,DEVICE='DSK',ACCESS='APPEND',FILE=
     +'CROS.DAT')

20    CALL INITT(480)
      WRITE(5,30)
30    FORMAT('+','DESIGNATE DESIRED DIGITAL EVENT:  ',$)
      READ(5,40) EVENT
40    FORMAT(2A10)
      REWIND 20
```

```
      WRITE(5,50)
50    FORMAT(' ','SEARCHING TAPE: => ',$)
60    READ(20,70,END=100) CMPVAR
70    FORMAT(3A10)
C
C  CHECK HEADER-- SEE IF EVENT IS IN DATA FILE
C
      IF(EVENT(1).EQ.CMPVAR(1).AND.EVENT(2).EQ.CMPVAR(2))
     +GO TO 80
                GO TO 60
80    WRITE(5,90)
90    FORMAT('+','[OK] EVENT FOUND => TAPE: CORRECTLY
     +POSITIONED')
      GO TO 140
100   WRITE(5,110)
110   FORMAT('+','?EVENT NOT FOUND?')
      WRITE(5,120)
120   FORMAT('-','DO YOU WISH TO SELECT ANOTHER EVENT?
     +<Y OR N>:  ',$)
      READ(5,130) ANSWER
130   FORMAT(A5)
      IF(ANSWER.EQ.'Y') GO TO 20
      CLOSE(UNIT=20)
      STOP '*** NO EVENTS PROCESSED ***'

C
C  READ IN DIGITAL AMPLITUDE VALUES
C
21    FORMAT(3A10)
140   DO 170 I=1,1991,10
            READ(20,150) (YVALUE(J),J=I,I+9)
141   FORMAT(10F5.0)
150         FORMAT(10F5.0)
            IF(YVALUE(I).EQ.99999) GO TO 160
                  GO TO 170
160         XNUM=I-1
            GO TO 180
170   CONTINUE

      XNUM=2000
180   MAX=0
      DO 210 K=1,XNUM
210   IF(ABS(YVALUE(K)).GT.MAX) MAX=ABS(YVALUE(K))

C
C  PLOT SEISMOGRAM OF EVENT
C
      EMAX=MAX
      WMIN=0
      WMAX=XNUM
      LAST=0
      CALL INITT(480)
      CALL TRACE(YVALUE,XNUM,EMAX,WMIN,WMAX,120,760)
      CALL TIMAX(XNUM,WMIN,WMAX,100.,65.)

220   CALL MOVABS(0,765)
      CALL ANMODE
      WRITE(5,230) CMPVAR
230   FORMAT('+',20X,'-<',3A10,'>-')
      WRITE(5,231) EMAX
231   FORMAT(1X,24X,'MAXIMUM AMPLITUDE =',F6.0,32(/))
C
C  QUERY USER FOR ANALYSIS OPTION
C
235   WRITE(5,240)
240   FORMAT('+','=>  ',$)
      READ(5,130) ANSWER
      IF(ANSWER.EQ.'A') GO TO 500
      IF(ANSWER.EQ.'B') GO TO 640
      IF(ANSWER.EQ.'C') GO TO 282
      IF(ANSWER.EQ.'D') GO TO 590
      IF(ANSWER.EQ.'E') GO TO 535
      IF(ANSWER.EQ.'K') GO TO 20
      IF(ANSWER.EQ.'P') GO TO 360
      IF(ANSWER.EQ.'Q') GO TO 993
      IF(ANSWER.EQ.'V') GO TO 390
      IF(ANSWER.EQ.'W') GO TO 330
      IF(ANSWER.EQ.'?') GO TO 290
            GO TO 235

C
C  SET WINDOW SIZES
C
500   WRITE(5,510)
510   FORMAT('+','HOW MANY WINDOWS HAVE BEEN SELECTED FOR
     +ANALYSIS?  '
     1,$)
      READ(5,*) NUMWIN
      CALL ERASE
      DO 530 J=LAST+1,LAST+NUMWIN
            WRITE(5,520)
520         FORMAT(' ','DESIGNATE WINDOW START AND STOP
     +LOCATIONS [SEPARATED BY '','']:  ',$)
            READ(5,*) WINDOW(J,1),WINDOW(J,2)
530   WIDWIN(J)=WINDOW(J,2)-WINDOW(J,1)
      LAST=LAST+NUMWIN
      GO TO 390

590   WRITE(5,600)
600   FORMAT('+','HOW MANY WINDOWS HAVE BEEN SELECTED FOR
     +DELETION?  ',$)
      READ(5,*) NUMWIN
      CALL ERASE
      DO 630 J=1,NUMWIN
      WRITE(5,520)
      READ(5,*) IBEGIN,IEND
      DO 610 L=1,LAST
      IF(WINDOW(L,1).NE.IBEGIN.OR.WINDOW(L,2).NE.IEND)
     +GO TO 610
      IVAR=L
      GO TO 620
610         CONTINUE
620         LAST=LAST-1
      IF(IVAR.EQ.LAST+1) GO TO 630
      DO 630 M=IVAR,LAST
      WIDWIN(M)=WIDWIN(M+1)
      WINDOW(M,1)=WINDOW(M+1,1)
      WINDOW(M,2)=WINDOW(M+1,2)
```

```
630     CONTINUE
        GO TO 390


C
C  EXHIBIT WINDOWS SELECTED, IF DESIRED
C

535     IF(LAST.NE.0) GO TO 537
        WRITE(5,536)
536     FORMAT(' ','?NO WINDOWS HAVE BEEN SELECTED FOR
     + ANALYSIS?')
                WRITE(5,480)
                GO TO 310
537     DO 570 K=1,LAST
                WMIN=WINDOW(K,1)
                WMAX=WINDOW(K,2)
        WRITE(5,1011)
1011    FORMAT(' DO YOU WANT TO HAVE WINDOW AMPLITUDES OUTPUT
     1 TO CROS.DAT?')
        READ(5,131) ANS
131     FORMAT(A1)
        IF(ANS .EQ. 'N') GO TO 542
        MINW=INT(WMIN)
        MAXW=INT(WMAX)
C
C     PRINT OUT AMPLITUDE VALUES IN WINDOW, IF DESIRED
C

        WRITE(23,531) CMPVAR,MINW,MAXW
531     FORMAT(3A10,2I6)


                DO 538 L=WMIN,WMAX-1,10
                DO 539 J=L,L+9
539             NY(J)=INT(YVALUE(J))
                WRITE(23,541) (NY(J),J=L,L+9)
541             FORMAT(10I5)
538     CONTINUE
        WRITE(23,1012)
1012    FORMAT(50('9'))
542             EMAX=0
                DO 540 L=WMIN,WMAX
540             IF(ABS(YVALUE(L)).GT.EMAX) EMAX=ABS(YVALUE(L))
                CALL DPYCTL(YVALUE,XNUM,MAX,EMAX,WMIN,WMAX)
                ANSCAL=XNUM*0.01
                CALL TWINDO(0,1023,470,760)
                CALL DWINDO(-(ANSCAL),(XNUM+ANSCAL),-(EMAX),
     +EMAX)
                CALL MOVEA(WMIN,EMAX)
                CALL DRAWA(WMIN,-(EMAX))
                CALL MOVEA(WMAX,EMAX)
                CALL DRAWA(WMAX,-(EMAX))
                CALL MOVABS(0,765)
                CALL ANMODE
                WRITE(5,230) CMPVAR
                IBEGIN=WMIN
                IEND=WMAX
                WRITE(5,550) IBEGIN,IEND
550             FORMAT(33(/),1X,'[WINDOW => ',I4,',',I4,']',$)
                WRITE(5,551) EMAX
551             FORMAT(35X,'MAX. AMPL. =',F6.0)
570     READ(5,580) IVAR
580     FORMAT(A1)
        GO TO 390


282     EMAX=MAX
        WMIN=0
        WMAX=XNUM
        LAST=0
        CALL DPYCTL(YVALUE,XNUM,MAX,EMAX,WMIN,WMAX)
        GO TO 220


290     CALL ERASE
        WRITE(5,300)
300     FORMAT(' COMMAND ONE OF THE FOLLOWING:'//' ''A'' - SET SELECTED
     1WINDOWS FOR DIGITAL ANALYSIS'/' ''B'' - BEGIN DIGITAL SPECTRAL
     1ANALYSIS OF EVENT'/' ''C'' - COPY BACK INTO GRAPHICS BUFFER ORI
     1GINAL INPUT DATA'/' ''D'' - DELETE SELECTED WINDOWS SET FOR DIG
     1ITAL ANALYSIS'/' ''E'' - EXAMINE INDIVIDUALLY ALL WINDOWS SET F
     1OR DIGITAL ANALYSIS'/' ''K'' - KILL CURRENT DIGITAL EVENT AND E
     1NTER MODE TO SELECT ANOTHER ONE'/' ''P'' - SET REFERENCE POINTE
     1R TO DESIRED LOCATION'/' ''Q'' - QUIT ALL PROCESSING AND RETURN
     1 TO TOPS-20 COMMAND LEVEL'/' ''V'' - DISPLAY CURRENT VALUES OF
     1PROGRAM CONTROL VARIABLES'/' ''W'' - SET START AND STOP LOCATIO
     1NS FOR DISPLAY WINDOW OF GRAPHICS BUFFER'/' ''?'' - DISPLAY THI
     1S LISTING OF COMMANDS'//' =>  ',$)
310     READ(5,130) ANSWER
        IF(ANSWER.EQ.'B') GO TO 640
        IF(ANSWER.EQ.'C') GO TO 282
        IF(ANSWER.EQ.'E') GO TO 535
        IF(ANSWER.EQ.'K') GO TO 20
        IF(ANSWER.EQ.'Q') GO TO 993
        IF(ANSWER.EQ.'V') GO TO 390
        IF(ANSWER.EQ.'?') GO TO 290
        IF(ANSWER.NE.'A'.AND.ANSWER.NE.'D'.AND.ANSWER.NE.'P'
     +.AND.ANSWER.NE.'W') GO TO 320
        CALL DPYCTL(YVALUE,XNUM,MAX,EMAX,WMIN,WMAX)
        CALL MOVABS(0,765)
        CALL ANMODE
        WRITE(5,230) CMPVAR
        IF(ANSWER.EQ.'A') GO TO 500
        IF(ANSWER.EQ.'D') GO TO 590
        IF(ANSWER.EQ.'P') GO TO 360
                GO TO 330
320     WRITE(5,240)
        GO TO 310


C
C  SET POINTER LOCATION (IF DESIRED)
C

360     WRITE(5,370)
370     FORMAT('+','DESIGNATE LOCATION FOR POINTER:  ',$)
        READ(5,*) PTRLOC
        CALL DPYCTL(YVALUE,XNUM,MAX,EMAX,WMIN,WMAX)
        ANSCAL=XNUM*0.01
        CALL TWINDO(0,1023,470,760)
        CALL DWINDO(-(ANSCAL),(XNUM+ANSCAL),-(EMAX),EMAX)
        CALL MOVEA(PTRLOC,EMAX)
        CALL DRAWA(PTRLOC,-(EMAX))
        ANSCAL=(WMAX-WMIN)*0.01
        CALL TWINDO(0,1023,120,410)
        CALL DWINDO((WMIN-ANSCAL),(WMAX+ANSCAL),-(EMAX),EMAX)
        CALL MOVEA(PTRLOC,EMAX)
        CALL DRAWA(PTRLOC,-(EMAX))
        CALL MOVABS(0,765)
```

DISPAN.FOR (CONTINUED)

```
      CALL ANMODE
      WRITE(5,230) CMPVAR
      IVAR=PTRLOC
      WRITE(5,380) IVAR
380   FORMAT('+',56X,'[PTR LOC => ',I4,']')
      GO TO 235
C
C  DISPLAY PROGRAM CONTROL VARIABLES
C
390   CALL ERASE
      WRITE(5,490)
490   FORMAT('+',11X,'*** CURRENT VALUES OF PROGRAM CONTROL ',
     1'VARIABLES ***'////)
      WRITE(5,400) CMPVAR
400   FORMAT(' ','EVENT BEING PROCESSED:  ',3A10)
      IVAR=XNUM
      WRITE(5,410) IVAR
410   FORMAT('0','ACTUAL NUMBER OF DATA POINTS IN EVENT:  ',I4)
      IVAR=MAX
      WRITE(5,430) IVAR
430   FORMAT('0','ACTUAL MAXIMUM ''Y''-DISPLACEMENT IN EVENT ',
     +'IS +/- ',I4)
      IVAR=EMAX
      WRITE(5,435) IVAR
435   FORMAT('0','EDITED MAXIMUM ''Y''-DISPLACEMENT IN CURRENT ',
     +'DISPLAY WINDOW IS +/- ',I4)
      IBEGIN=WMIN
      IEND=WMAX
      WRITE(5,440) IBEGIN,IEND
440   FORMAT('0','CURRENT DISPLAY WINDOW SETTINGS:  WMIN = '
     +,I4,'  WMAX = ',I4////)
      WRITE(5,450) LAST
450   FORMAT(' ','THE FOLLOWING ',I2,' WINDOWS HAVE BEEN',
     +' SELECTED FOR ANALYSIS:')
      IF(LAST.EQ.0) GO TO 470
      WRITE(5,460)
460   FORMAT('-','START',7X,'STOP',8X,'WIDTH'/)
      WRITE(5,465) (WINDOW(J,1),WINDOW(J,2),WIDWIN(J),J=1,LAST)
465   FORMAT((' ',2(I4,8X)),I4)
470   WRITE(5,480)
480   FORMAT('0','=>  ',$)
      GO TO 310


330   WRITE(5,340)
340   FORMAT('+','DESIGNATE WINDOW START AND STOP LOCATIONS',
     +' [SEPARATED BY '','']:  ',$)
      READ(5,*) WMIN,WMAX
      EMAX=0
      DO 350 K=WMIN,WMAX
350   IF(ABS(YVALUE(K)).GT.EMAX) EMAX=ABS(YVALUE(K))
      CALL DPYCTL(YVALUE,XNUM,MAX,EMAX,WMIN,WMAX)
      ANSCAL=XNUM*0.01
      CALL TWINDO(0,1023,470,760)
      CALL DWINDO(-(ANSCAL),(XNUM+ANSCAL),-(EMAX),EMAX)
      CALL MOVEA(WMIN,EMAX)
      CALL DRAWA(WMIN,-(EMAX))
      CALL MOVEA(WMAX,EMAX)
      CALL DRAWA(WMAX,-(EMAX))
      CALL MOVABS(0,765)
      CALL ANMODE
      WRITE(5,230) CMPVAR
      IBEGIN=WMIN
      IEND=WMAX
      WRITE(5,550) IBEGIN,IEND
      GO TO 235
C
C  LOAD DIGITAL VALUES IN WINDOW FOR SPECTRAL ANALYSIS,
C  COMPUTE MEAN OF TIME SERIES
C
640   CALL ERASE
      DO 1140 J=1,LAST
            DO 655 K=1,2000
655         X(K)=0.0
            IBEGIN=(2000-(WIDWIN(J)+1))/2+1
            XMEAN=0.
            DO 660 K=1,WIDWIN(J)
            X(K)=YVALUE((K)+WINDOW(J,1))
            XMEAN=XMEAN+X(K)
660   CONTINUE
      XMEAN=XMEAN/FLOAT(WIDWIN(J))
      WN=WINDOW(J,2)-WINDOW(J,1)
      N=INT(WN)
      N2=N/2
      WRITE(5,1001)
1001  FORMAT(' ENTER MODEL VELOCITY, EVENT DISTANCE,'
     1' AND FILTER SETTINGS')
      READ(5,*) VEL,DIST,FIL1,FIL2
C
C  CHOOSE DATA WINDOW SHAPE
C
      WRITE(5,1000)
1000  FORMAT(' WINDOW: 1-RECTANGULAR, 2-TAPERED RECTANGULAR, '
     1,'3-HAMMING')
      READ(5,*) WINAN
      IF(WINAN .EQ. 1.) GO TO 654
C
C  MULTIPLY DIGITAL VALUES BY WINDOW SHAPE
C
      CALL WSHAP(WINAN,X,WIDWIN(J))
C
C  FAST FOURIER TRANSFORM DIGITAL VALUES IN WINDOW
C
654   CALL FFTRC(X,N,XC,IWK,WK)
      FR=.5/TN
C
C  FORM AMPLITUDE SPECTRA BY TAKING MAGNITUDE OF XC AND
C  DIVIDING BY NUMBER OF SAMPLE POINTS IN WINDOW
C
C  ALSO CALCULATE FREQUENCY VALUES
C
C              XC          COMPLEX SPECTRAL ESTIMATES
C              AS          AMPLITUDE SPECTRAL VALUES
C                          (MODULUS OF XC)
C              FREQ        FREQUENCY IN HZ
C              FR          FREQUENCY RANGE (1/(2*TN))
C              WN,N        # OF POINTS IN WINDOW
C
C
      DO 659 II=1,500
659   FREQ(II)=0.
      DO 661 II=1,N/2+1
      AS(II)=SQRT(REAL(XC(II))**2+AIMAG(XC(II))**2)
      FREQ(II)=FR*FLOAT(II-1)/FLOAT(N/2)
      IF(FREQ(II) .EQ. 0.) AS(II)=AS(II)/WN
      IF(FREQ(II) .NE. 0.) AS(II)=2.*AS(II)/WN
C
```

DISPAN.FOR (CONTINUED)

```
C  DIVIDE BY CORRECTION FACTOR FOR TAPERED WINDOW
C
      IF(WINAN .EQ. 2.) AS(II)=AS(II)/.935
 661  CONTINUE
            IBEGIN=WINDOW(J,1)
            IEND=WINDOW(J,2)
            IVAR=WIDWIN(J)
C
C  OUTPUT SPECTRAL ESTIMATES TO SPEC.DAT
C
            OPEN(UNIT=21,DEVICE='DSK',ACCESS='APPEND',
     1FILE='SPEC.DAT')
            WRITE(21,670) CMPVAR,IBEGIN,IEND,IVAR,XMEAN,
     1XYMV(2),N2,FIL1,FIL2,DIST,VEL
 670        FORMAT(3A10/I4,2(1X,I4)/F7.2,1X,F15.4,1X,I4,
     +4F7.2)
            DO 672 K=1,N2+1
 672        WRITE(21,674) K,FREQ(K),AS(K)
 674        FORMAT(I4,1X,F5.2,1X,F15.4)
            WRITE(21,676)
 676        FORMAT(10('99999'))
            CLOSE(UNIT=21)
      WRITE(5,679)
 679  FORMAT(' DO YOU WANT A PRINTOUT OF SPECTRAL VALUES
     +(Y OR N)?')
      READ(5,130) ANSWER
      IF(ANSWER .EQ. 'N') GO TO 1140
            WRITE(3,680) CMPVAR,IBEGIN,IEND,IVAR,XMEAN
 680        FORMAT('1'//' ',30X,72('-')/' ',30X,'|',70X,'|'/' ',30X,
     1'|  EVENT BEING PROCESSED:  ',3A10,14X,'|'/' ',30X,'|',70X,'|'/
     1' '30X,'|  CURRENT WINDOW:  START = ',I4,7X,'STOP = ',I4,7X,
     1'WIDTH = ',I4,'  |'/' ',30X,'|',70X,'|'/' ',30X,'|  MEAN OF SER
     1IES = ',F7.2,6X,'VARIANCE OF SERIES = ',15X,'  |'/' ',30X,
     1'|',70X,'|'/' ',30X,'|  NUMBER OF LAGS USED IN PROCESSING WINDO
     1W = ',4X,21X,'|'/' ',30X,'|',70X,'|'/' ',30X,72('-')//)
            IVAR=N2/160+1
C
C  PRINT OUT VALUES OF AMPLITUDE SPECTRA ON LPT IF DESIRED
C
            DO 980 K=1,IVAR
                  WRITE(3,970)
 970              FORMAT(//' ',3('FREQUENCY:',4X,'POWER SPECTRU
     1M:',4X),'FREQUENCY:',4X,'POWER SPECTRUM:'/' ',3(10('-'),4X,
     115('-'),4X),10('-'),4X,15('-')/)
                  DO 980 K1=1,40
                        K2=K1+40
                        K3=K1+80
                        K4=K1+120
 980        WRITE(3,990) FREQ(K1),AS(K1),FREQ(K2),AS(K2),FREQ(K3),
     1AS(K3),FREQ(K4),AS(K4)
 990        FORMAT(' ',2X,F5.2,7X,F15.4,3(6X,F5.2,7X,F15.4))
1140  CONTINUE
C
C  RUN EVENT THROUGH BANDPASS FILTER (IF DESIRED)
C
 993  CONTINUE
C     WRITE(5,1113)
 1113 FORMAT(' DO YOU WANT THE EVENT FILTERED?  'S)
C     READ(5,1114) ANS
 1114 FORMAT(A1)
C     IF(ANS .EQ. 'N') GO TO 994
C     CALL DIGFIL(CMPVAR,YVALUE,XNUM)
 994  WRITE(5,120)
      READ(5,130) ANSWER
      IF(ANSWER.EQ.'Y') GO TO 20

 288  CALL ERASE
      CLOSE(UNIT=20)
      CLOSE(UNIT=23)
      STOP '*** THAT''S ALL FOLKS! ***'

      END

      SUBROUTINE TRACE(YVALUE,ENUM,EMAX,WMIN,WMAX,YMIN,YMAX)

      INTEGER YMAX,YMIN

      REAL ANSCAL,EMAX,ENUM,WMAX,WMIN,YVALUE(2000)

      ANSCAL=(WMAX-WMIN)*0.01
      CALL TWINDO(0,1023,YMIN,YMAX)
      CALL DWINDO((WMIN-ANSCAL),(WMAX+ANSCAL),-(EMAX),EMAX)
      CALL MOVEA(WMIN,YVALUE(1))
      DO 10 P=2,WMAX
 10   CALL DRAWA(P,YVALUE(P))

      RETURN
      END

      SUBROUTINE TIMAX(ENUM,WMIN,WMAX,LINLEV,NUMLEV)

      INTEGER IBEGIN,IEND,VALARY(2)

      REAL ANSCAL,ENUM,LINLEV,NUMLEV,WMAX,WMIN,XCOORD

      ANSCAL=(WMAX-WMIN)*0.01
      CALL TWINDO(0,1023,0,780)
      CALL DWINDO((WMIN-ANSCAL),(WMAX+ANSCAL),0.,780.)
      IBEGIN=INT((WMIN+99)/100.)*100
      IEND=INT(WMAX/100.)*100
      XCOORD=INT(ENUM/100.)*100.
      CALL MOVEA(0.,LINLEV)
      CALL DRAWA(XCOORD,LINLEV)
      DO 10 P=0,XCOORD,100
            CALL MOVEA(P,(LINLEV+10.))
 10   CALL DRAWR(0.,-20.)
      IF((WMAX-WMIN).GT.500) GO TO 30
            DO 20 P=0,XCOORD,10
                  IF(AMOD(P,100.).EQ.0.) GO TO 20
                        CALL MOVEA(P,(LINLEV+5.))
                        CALL DRAWR(0.,-10.)
 20         CONTINUE
 30   IF(IEND.LT.IBEGIN) GO TO 60
            VALARY(1)=INT(FLOAT(IBEGIN/1000))+48
            VALARY(2)=(IBEGIN-INT(FLOAT(IBEGIN/1000))*
     +1000)/100+47
            DO 50 P=IBEGIN,IEND,100
                  VALARY(2)=VALARY(2)+1
                  IF(VALARY(2).LT.58) GO TO 40
```

```
                        VALARY(1)=VALARY(1)+1
40                      VALARY(2)=48
                  CALL MOVEA((P-ANSCAL),NUMLEV)
50          CALL ANSTR(2,VALARY)


60      RE.JRN
        END


        SUBROUTINE DPYCTL(YVALUE,XNUM,MAX,EMAX,WMIN,WMAX)


        REAL EMAX,MAX,WMAX,WMIN,XNUM,YVALUE(2000)


        CALL INITT(480)
        CALL TRACE(YVALUE,XNUM,MAX,0,XNUM,470,760)
        CALL TRACE(YVALUE,XNUM,EMAX,WMIN,WMAX,120,410)
        CALL TIMAX(XNUM,0,XNUM,450.,415.)
        CALL TIMAX(XNUM,WMIN,WMAX,100.,65.)


        RETURN
        END


        SUBROUTINE DIGFIL(CMPVAR,YVALUE,XNUM)


        INTEGER IEND,ITEMP(10)

        REAL A1,A2,A3,CMPVAR*8(3),FILTER(101),FL,FU,FVALUE(2000),
       1MAX,PI,RVAR(2100),SCALER,YVALUE(2000),XNUM,T,W


        PI=3.14159
        CALL ERASE
        WRITE(5,1001)
1001    FORMAT(' ENTER LOWER AND UPPER BOUNDS OF BANDPASS
     +FILTER:  '$)
        READ(5,*) FL,FU
                DO 10 J=52,101
                        T=J-51
                        A1=0.02*PI*T*FU
                        A2=0.02*PI*T*FL
                        A3=0.02*PI*T
C
C       LOAD SINC FUNCTION
C
                        FILTER(J)=2.0*((SIN(A1)-SIN(A2))/A3)
C
C       SMOOTH SINC FUNCTION USING COSINE BELL
C
                        W=(1.0+COS(PI*T/50.0))/2.0
10              FILTER(J)=FILTER(J)*W
20              DO 20 J=1,50
                FILTER(51-J)=FILTER(51+J)
                FILTER(51)=2.0*(FU-FL)
                DO 30 J=1,50
                        RVAR(J)=0.0
30              RVAR(XNUM+50+J)=0.0
                DO 40 J=1,XNUM
40              RVAR(50+J)=YVALUE(J)
                DO 50 J=1,XNUM
                        ITEMP(1)=J-1
                        FVALUE(J)=0.0
                        DO 50 K=1,101
50              FVALUE(J)=FVALUE(J)+(RVAR(K+ITEMP(1))*FILTER(K))
                MAX=0
                DO 52 J=1,XNUM
                FVALUE(J)=FVALUE(J)/100.
52              IF(ABS(FVALUE(J)).GT.MAX) MAX=ABS(FVALUE(J))
                IF(MAX.LE.9999) GO TO 58
                        SCALER=9999/MAX
                        DO 54 J=1,XNUM
54                      FVALUE(J)=FVALUE(J)*SCALER
58              OPEN(UNIT=22,DEVICE='DSK',ACCESS='APPEND',
     +FILE='FILTER.DAT')
                ITEMP(1)=FL
                ITEMP(2)=FU
                WRITE(22,60) CMPVAR,ITEMP(1),ITEMP(2)
50              FORMAT(3A10,2(1X,I2))
                IEND=XNUM-10
                DO 80 J=0,IEND,10
                        DO 70 K=1,10
70                      ITEMP(K)=FVALUE(K+J)
80              WRITE(22,90) ITEMP
90              FORMAT(10I5)
100     WRITE(22,110)
110     FORMAT(10('99999'))
        CLOSE(UNIT=22)


        RETURN
        END
```

DTREND.FOR

```
C
C       PROGRAM DTREND-- DETREND DATA FOR CEPSTRUM ANALYSIS
C
C       LOG SPECTRA MUST BE DETRENDED BEFORE THE FOURIER TRANSFORM
C       IS TAKEN TO FORM THE CEPSTRUM. THIS PROGRAM READS IN
C       DATA IN DISPAN OUTPUT FORMAT FROM VFNIN AND DETRENDS
C       IT, I.E. REMOVES THE LEAST SQUARES LINE FROM THE LOG
C       SPECTRUM. THE DETRENDED SPECTRUM IS THEN OUTPUT IN
C       DISPAN INPUT FORMAT SO THAT IT CAN AGAIN PASS THROUGH
C       THE FFT. THE OUTPUT FILE IS DTREND.DAT.
C
C       FOR COMPLETE EXPLANATION SEE DOCUMENTATION FOR SECEP.FOR
C
C
C       SYMBOLS USED:
C
C               CMPVAR          EVENT RECORDING PARAMETERS
C               VFNIN           INPUT FILE NAME
C               IBEGIN          BEGINNING OF WINDOW
C               IEND            END OF WINDOW
C               IVAR            VARIANCE OF TIME SERIES
C               XYMV1           MEAN OF TIME SERIES
C               XYMV2           ST. DEV. OF TIME SERIES
C               N2              NUMBER OF SAMPLES IN WINDOW/2
C               FREQ            FREQUENCY
C               AS              AMPLITUDE SPECTRA VALUES
C
      INTEGER ANSWER,IBEGIN,IEND,N2,IVAR,LINE,VALARY(102)
      INTEGER IAMP(500)
      REAL CMPVAR*8(3),FREQ(2000),AS(4000),VFNIN*8,XYMV1,
     1XYMV2,YMAX,WIN*8,SDY(2000),EVENT*8(3)
      DIMENSION XY(100,3),IV(3),PAR(3),STAT(6),VCV(6),ITER(2)
      COMMON /STAT/ANS,ABAR,FBAR,CORR,SDYBAR,SDSL,SDY

      PI=3.14159

      TYPE 5
5     FORMAT('-','DESIGNATE AMPLITUDE SPECTRA INPUT FILE NAME:  '$)
      READ(5,8) VFNIN
8     FORMAT(A10)
      OPEN(UNIT=1,DEVICE='DSK',ACCESS='SEQIN',FILE=VFNIN)
C
C     READ IN EVENT PARAMETERS AND SPECTRAL VALUES
C
      TYPE 6
6     FORMAT(' WHICH EVENT DO YOU WANT TO DETREND?  '$)
      READ(5,9) EVENT
9     FORMAT(3A10)

10    READ(1,20,END=220) CMPVAR,IBEGIN,IEND,IVAR,XYMV1,XYMV2,N2,
     1FIL1,FIL2,DIST,VS
20    FORMAT(3A10/I4,2(1X,I4)/F7.4,1X,F15.4,1X,I4,4F7.2)
C
C     READ AMPLITUDES AND FREQUENCIES FROM DISK
C
      N2P1=N2+1
      DO 30 J=1,N2P1
30    READ(1,40) FREQ(J),AS(J)
40    FORMAT(5X,F5.2,1X,E15.4)
      READ(1,50) LINE

50    FORMAT(A5)
      IF(EVENT(1).EQ.CMPVAR(1).AND.EVENT(2).EQ.CMPVAR(2)) GO TO 55
      GO TO 10

220   STOP '*** EVENT NOT FOUND ***'
55    DO 190 J=2,N2P1
      AS(J)=AS(J)/(2.*PI*FREQ(J))
190   CONTINUE
      IF(FIL1 .EQ. 0.) GO TO 195
      CALL DECON(AS,FIL1,FREQ,N2)
195   IF(FIL2 .EQ. 0.) GO TO 196
      CALL DECON(AS,FIL2,FREQ,N2)
3010  FORMAT(A1)

C
C     FIND LEAST SQUARE SOLUTION FOR FIT OF LOGE AMPLITUDES
C
196   DO 90 J=1,N2P1
      AS(J)=ALOG(AS(J))
C     WRITE(5,920) AS(J)
920   FORMAT(F7.2)
90    CONTINUE
C
C     SPECIFY FREQUENCY RANGE FOR FIT
C
      WRITE(5,1015)
1015  FORMAT(' ENTER MIN. AND MAX. FREQ. FOR LEAST SQUARES FIT')
      READ(5,*) FMIN,FMAX
C
C     DO LINEAR REGRESSION TO FIND Q
C
      CALL LINRG(FREQ,AS,FMIN,FMAX,N2P1,SLOPE,A0)
C
C     DETREND SPECTRUM AND OUTPUT TO DISK
C
C     WRITE(5,*) SLOPE,A0
      DO 300 J=1,N2P1
      AS(J)=AS(J)-SLOPE*FREQ(J)-A0
      AS(J)=AS(J)*100.
300   CONTINUE

      OPEN(UNIT=2,DEVICE='DSK',FILE='DTREND.DAT',ACCESS='SEQOUT')

310   WRITE(2,311) CMPVAR,IBEGIN,IEND
311   FORMAT(3A10,2I6)

C
C     WRITE AMPLITUDES TO DISK
C

      DO 329 I=1,N2P1
      IAMP(I)=INT(AS(I))
329   CONTINUE
      DO 330 I=1,N2P1,10
      WRITE(2,331) (IAMP(J),J=I,I+9)
330   CONTINUE
331   FORMAT(10I5)
      WRITE(2,333)
333   FORMAT(50('9'))

      STOP
      END
```

EPIPLT.FOR

```
C*************************************************************
C* EPICENTER PLOTTING PROGRAM.  THIS PROGRAM PLOTS Q VALUES OR *
C* ERRORS IN Q VALUES AT EPICENTERS. IT WAS ADAPTED FROM A     *
C* PROGRAM USED TO PLOT EPICENTERS FOR THE ENTIRE STATE OF NEW *
C* MEXICO.  EPICENTERS FOR LOCAL MICROEARTHQUAKES ARE PLOTTED  *
C* USING GRPLIB LIBRARY SUBROUTINES.                           *
C*                                                             *
C*       SYMBOLS USED:                                         *
C*                                                             *
C*              NUM             NUMBER OF STATIONS IN PLOT     *
C*              ST              STATION NAME                   *
C*              AI,AJ           STATION LATITUDE AND LONGITUDE *
C*              X,Y             SCREEN COORDINATES             *
C*              ICHECK          EVENT MAGN. SELECTION OPTION   *
C*              AMMAX           MAXIMUM MAGNITUDE TO BE PLOTTED*
C*              AMMIN           MINIMUM MAGNITUDE TO BE PLOTTED*
C*              AMAG            EVENT MAGNITUDES               *
C*              YORN            EVENT PLOTTING OPTION          *
C*              LAA,LONA        EVENT LATITUDE AND LONGITUDE   *
C*              PTY,PTX         SCREEN COORDS. OF EVENT        *
C*              Q               EVENT QUALITY FACTOR           *
C*              QMAX,QMIN       2 S.D. RANGE FOR Q             *
C*              QDEV            AVERAGE ERROR IN Q             *
C*              CORR            SPECTRAL FIT CORR. COEFF.      *
C*              DIST            EVENT DISTANCE                 *
C*              DEPTH           EVENT DEPTH                    *
C*              SX,SY           SCALE LENGTH                   *
C*                                                             *
C*       INPUT FILE-- QAPP.DAT-- A LIST OF SELECTED EVENTS     *
C*                    OUTPUT BY MODEL.FOR                      *
C*                                                             *
C*       OUTPUT FILE-- OUTPUT.PLT-- PLOT OUTPUT FILE-- TYPE    *
C*                     "GRAFIX" TO RUN                         *
C*************************************************************
      IMPLICIT REAL*8(L)
      DOUBLE PRECISION ORGT,FILENM,MONTH1,MONTH2,SOC
      INTEGER DAY,YEAR

       WRITE(5,10)
       FORMAT(1X,'DATA FILENAME?')
       READ(5,20)FILENM
       FORMAT(1A10)
       OPEN(UNIT=22,FILE=FILENM)

      CALL INITAL(1)
      CALL PLOT(4.0,0.4,-3)

C Plot the location of Socorro on the map.

      SOC='SOCORRO'
      X=106.9
      Y=34.06
      CALL TRNFM1(X,Y)
      X=(X+45.)/20.
      Y=(Y+50.)/20.
      CALL SYMBOL(X,Y,0.10,1,0.0,-1)
      CALL SYMBOL(X+.08,Y,0.10,SOC,0.0,7)

      WRITE(5,80)
      FORMAT(1X,'DO YOU WANT ANY STATIONS TO APPEAR ON THE MAP?')
      WRITE(5,90)
      FORMAT(1X,'(Y OR N)')
      READ(5,100)ICHECK

100   FORMAT(A1)
      IF(ICHECK.EQ.'N'.OR.ICHECK.EQ.'n')GO TO 170
      IF(ICHECK.EQ.'y'.OR.ICHECK.EQ.'Y')GO TO 110
      GO TO 70

110   WRITE(5,120)
120   FORMAT(1X,'HOW MANY STATIONS?   (I2 FORMAT)')
      READ(5,130)NUM
130   FORMAT(I2)
      WRITE(5,140)
140   FORMAT(1X,'TYPE IN THE STATION NAMES IN A4 FORMAT.')
      write(5,141)
141   format(' Be sure to use UPPERCASE LETTERS for the station names')

      DO 160 I=1,NUM
      READ(5,150)ST
150   FORMAT(A4)

C  Get coordinates for each of the stations specified.

      CALL GETCOD (ST,AI,AJ)
      X=AJ
      Y=AI
      CALL TRNFM1(X,Y)
      Y=(Y+50.0)/20.0
      X=(X+45.0)/20.0

C  Plot a triangle and a station label at each station location.

      CALL SYMBOL(X,Y,0.07,2,0.0,-1)
      Y=Y+.1
      CALL SYMBOL(X,Y,.05,ST,0.0,3)
160   CONTINUE


170   WRITE(5,180)
180   FORMAT(1X,'DO YOU WANT ALL EVENTS TO BE PLOTTED OR')
      WRITE(5,190)
190   FORMAT(1X,'ONLY THOSE WITH SELECTED MAGNITUDES?')
      WRITE(5,200)
200   FORMAT(1X,'(1=ALL EVENTS, 2=SELECTED MAGNITUDES)')
      READ(5,210)ICHECK
210   FORMAT(I1)
      IF(ICHECK.EQ.1.OR.ICHECK.EQ.2)GO TO 220
      GO TO 170
220   N=0
      IF(ICHECK.EQ.1)GO TO 290
      WRITE(5,230)
230   FORMAT(1X,'WHAT IS THE MAXIMUM MAGNITUDE DESIRED?')
      WRITE(5,240)
240   FORMAT(1X,'(F5.2 FORMAT)')
      READ(5,250)AMMAX
250   FORMAT(F5.2)
      WRITE(5,260)
260   FORMAT(1X,'WHAT IS THE MINIMUM MAGNITUDE DESIRED?')
      WRITE(5,270)
270   FORMAT(1X,'(F5.2 FORMAT)')
      READ(5,250)AMMIN

C   This is for the benefit of the SCALE2 subroutine.
290     IF(ICHECK.EQ.1) AMMAX=6.0
        IF(ICHECK.EQ.1) AMMIN=-3.0

        WRITE(5,810)
```

EPIPLT.FOR (CONTINUED)

```
810     FORMAT(1X,'DO YOU WANT TO SEE A LIST OF ALL THE EVENTS PLOTTED?')
        WRITE(5,811)
811     FORMAT(' (Y OR N)')
        READ(5,100) YORN
        IF(YORN.EQ.'N'.OR.YORN.EQ.'n') GO TO 909
        WRITE(5,812)
812     FORMAT(' TYPE 5 IF YOU WANT THE LIST TO GO TO THE TERMINAL,')
        WRITE(5,813)
813     FORMAT(' TYPE 3 IF YOU WANT THE LIST TO GO TO THE LINE PRINTER')
        READ(5,210) NUNIT

c   Give the user a choice about the size of the x's plotted for the quakes

909     WRITE(5,910)
910     FORMAT(' DO YOU WANT ALL OF THE Xs THE SAME SIZE? (Y OR N)')
        READ(5,100) YXN

C  Read latitude and longitude coordinates for each event from model output

7       READ(22,300,END=899) NUM,C1,C2,STA,C3,C4,IBEGIN,IEND,Q,QMAX,
     +QMIN,CORR,DIST,DEPTH,LAA,LONA
        GO TO 9

300     FORMAT(I4,3X,A10,A7,A3,A9,A1,4X,I4,1X,I4,6F10.2,2F10.4)

9       IF(ICHECK.EQ.1)GO TO 330
        IF(AMAG.LE.AMMIN)GO TO 7
        IF(AMAG.GT.AMMAX)GO TO 7

330     KOUNTR=KOUNTR+1

c   Get the dates of the first and last events.

        EYEAR=YEAR
        JMON=MON
        EDAY=DAY
        IF(KOUNTR.NE.1) GO TO 850
        IMON=MON
        ADAY=DAY
        AYEAR=YEAR

850     PTY=LAA
        PTX=LONA

C  Transform degrees to kilometers.

        CALL TRNFM1(PTX,PTY)

c   Set the window to the Socorro area and the scale to fit on the plotter
c   Add 50 km to the latitude, 45 km to the longitude, scale=20 km per inch.

        PTY=(PTY+50.0)/20.0
        PTX=(PTX+45.0)/20.0
        YPLOT=PTY
        XPLOT=PTX

c   Scale the size of the x to the magnitude (if all are to be the same,
c   skip this part).

        F=0.70
        IF(YXN.EQ.'Y'.OR.YXN.EQ.'y') go to 736

        IF(-0.5.LE.AMAG.AND.AMAG.LT.0.0)F=0.3
        IF(0.0.LE.AMAG.AND.AMAG.LT.0.50)F=0.6
        IF(0.5.LE.AMAG.AND.AMAG.LT.1.00)F=0.9
        IF(1.0.LE.AMAG.AND.AMAG.LT.1.50)F=1.2
        IF(1.5.LE.AMAG.AND.AMAG.LT.2.00)F=1.5
        IF(2.0.LE.AMAG.AND.AMAG.LT.2.50)F=1.8
        IF(2.5.LE.AMAG.AND.AMAG.LT.3.00)F=2.1
        IF(3.0.LE.AMAG.AND.AMAG.LT.3.50)F=2.4
        IF(3.5.LE.AMAG.AND.AMAG.LT.4.50)F=2.7

C  Plot a number at the location of the earthquake corresponding to
C  model.for printouts

736     F=F*0.14
        XPLOT=XPLOT-.05
        YPLOT=YPLOT-.05
        XKOUNT=FLOAT(KOUNTR)
        QDEV=(QMAX-QMIN)/2.
C       CALL NUMBER(XPLOT,YPLOT,.04,Q,0.,-1)
C       WRITE(3,*) XPLOT,YPLOT,Q,QMAX,QMIN
C       CALL NUMBER(XPLOT,YPLOT,.05,XKOUNT,0.,-1)
        CALL SYMBOL(XPLOT,YPLOT,F,4,0.0,-1)

        IF(YORN.NE.'Y'.and.YORN.NE.'y') GO TO 7
        WRITE(NUNIT,29)MON,DAY,YEAR,LAA,LONA,AMAG
29      FORMAT(2X,3I2,12X,F5.2,1X,F6.2,5X,F5.2)

        GO TO 7

c   Indicate on the plot the dates of the first and last events.

899     CALL DATE(IMON,MONTH1)
        CALL DATE(JMON,MONTH2)
        AYEAR=AYEAR+1900
        EYEAR=EYEAR+1900
        CALL PLOT(-1.9,0.5,-3)
        GO TO 901
        CALL SYMBOL(0.0,4.7,0.1,'THE FIRST EVENT IS ON',0.0,21)
        CALL SYMBOL(0.1,4.5,0.1,MONTH1,0.0,9)
        CALL NUMBER(0.9,4.5,0.1,ADAY,0.0,-1)
        CALL SYMBOL(1.05,4.5,0.1,',',0.0,1)
        CALL NUMBER(1.25,4.5,0.1,AYEAR,0.0,-1)
        CALL SYMBOL(0.0,4.1,0.1,'THE  LAST EVENT IS ON',0.0,21)
        CALL SYMBOL(0.1,3.9,0.1,MONTH2,0.0,9)
        CALL NUMBER(0.9,3.9,0.1,EDAY,0.0,-1)
        CALL SYMBOL(1.05,3.9,0.1,',',0.0,1)
        CALL NUMBER(1.25,3.9,0.1,EYEAR,0.0,-1)
901     continue

c   Indicate on the plot how many events were plotted.

        ROUNTR=KOUNTR
        CALL NUMBER(0.0,3.5,0.1,ROUNTR,0.0,-1)
        CALL SYMBOL(0.4,3.5,0.1,'EVENTS WERE PLOTTED',0.0,19)

c   Put a kilometer scale bar on the plot.

        SX=0.3
        SY=3.0
        CALL PLOT(SX,SY,3)
        DO 600 I=0,4
           CALL PLOT(SX,SY,2)
           CALL PLOT(SX,SY+.025,3)
           CALL PLOT(SX,SY-.025,2)
           AKM=I*5.
```

```
            CALL NUMBER(SX-.04,SY-.15,.07,AKM,0.0,-1)
            CALL PLOT(SX,SY,3)
            SX=SX+.25
600         CONTINUE
        CALL SYMBOL(SX-.14,SY-.15,.07,'KM',0.0,2)
        CALL PLOT(1.9,-0.5,-3)

C  Plot crosses at .1 degree marks for a reference scale.
        CALL PLOTX

c  Plot the magnitude scale if necessary.
        IF(YXN.EQ.'N'.OR.YXN.EQ.'n') CALL SCALE2(ammax,ammin)

        CLOSE(UNIT=22)
        CALL RSTR(1)
        STOP
         END
C   ***********************************
C   ***********************************
        SUBROUTINE TRNFM1(X,Y)
c   Changes degree coordinates to distance in kilometers from the center
c   of New Mexico.

        YY=Y
        Y=(Y-34.1)*((Y-34.1)/2.*.018+110.922)
        X=(106.943-X)*COS(3.1415927/360.*(34.1+YY))*111.4399
10      RETURN
         END
C   ***********************************************
C   ***********************************************
        SUBROUTINE GETCOD (STATIO,AI,AJ)

c   Gets coordinates for the stations specified from the file STA.DAT.

        OPEN(UNIT=24,FILE='STA.DAT',ACCESS='SEQIN',DEVICE='DSK')

10      READ(24,20,END=30) ST,AI,AJ
20      FORMAT(A4,F7.4,1X,F8.4)
        IF(ST.EQ.STATIO)RETURN
        GO TO 10
30      write(5,100) statio
100     format(' Station "',a4,'"  not on station list')
        TYPE 200
200     FORMAT(' TRY ENTERING THE STATION NAME AGAIN')
        READ(5,101) STATIO
101     FORMAT(A4)
        GO TO 10
        RETURN
        END
C    ****************************
C    ****************************
        SUBROUTINE SCALE2(amax,amin)

C   Plots a legend for the scaled x's.  AMAX and AMIN determine which
c   magnitudes are represented in the legend (depending on what
c   range was selected by the user).

        DIMENSION B(9,2)
        CALL PLOT(0.,0.,3)
        CALL PLOT(3.80,2.00,0)
        CALL PLOT(-1.7,0.0,-3)
        B(1,1)=-0.50
        B(1,2)=-0.01
        B(2,1)=-0.00
        B(2,2)=0.49
        B(3,1)=0.50
        B(3,2)=0.99
        B(4,1)=1.00
        B(4,2)=1.49
        B(5,1)=1.50
        B(5,2)=1.99
        B(6,1)=2.00
        B(6,2)=2.49
        B(7,1)=2.50
        B(7,2)=2.99
        B(8,1)=3.00
        B(8,2)=3.49
        B(9,1)=3.50
        B(9,2)=4.49
        if(b(1,2).LE.AMIN) go to 8
        F=0.14*0.3
        CALL SYMBOL(0.,0.,F,4,0.0,-1)
        CALL NUMBER(0.43,-0.05,0.1,B(1,1),0.0,2)
        CALL SYMBOL(0.9,-0.05,0.1,'-',0.0,1)
        CALL NUMBER(1.03,-0.05,0.1,B(1,2),0.0,2)
        CALL PLOT(0.0,0.0,3)
8       F=0.14*0.6
        DO 10 J=2,9
        if(b(j,2).le.amin) go to 9
        if(b(j,1).ge.amax) return
        A=J-1.0
        Y=(A*0.35)
        CALL SYMBOL(0.,Y,F,4,0.0,-1)
        Y=Y-0.05
        CALL NUMBER(0.5,Y,0.1,B(J,1),0.0,2)
        CALL SYMBOL(0.9,Y,0.1,'-',0.0,1)
        CALL NUMBER(1.1,Y,0.1,B(J,2),0.0,2)
9       F=F+3*.014
10      CONTINUE
        RETURN
        END


        SUBROUTINE DATE(INMON,OUTMON)

c   Changes months designated by numbers to names.

        DOUBLE PRECISION OUTMON
        IF(INMON.EQ.1) OUTMON='  JANUARY'
        IF(INMON.EQ.2) OUTMON=' FEBRUARY'
        IF(INMON.EQ.3) OUTMON='     MARCH'
        IF(INMON.EQ.4) OUTMON='     APRIL'
        IF(INMON.EQ.5) OUTMON='       MAY'
        IF(INMON.EQ.6) OUTMON='      JUNE'
        IF(INMON.EQ.7) OUTMON='      JULY'
        IF(INMON.EQ.8) OUTMON='    AUGUST'
        IF(INMON.EQ.9) OUTMON='SEPTEMBER'
        IF(INMON.EQ.10)OUTMON='  OCTOBER'
        IF(INMON.EQ.11)OUTMON=' NOVEMBER'
        IF(INMON.EQ.12)OUTMON=' DECEMBER'

        RETURN
        END

        SUBROUTINE PLOTX
c   Plots a reference scale on the outside of the plot, with or without
c   grid points on the inside of the plot.
```

EPIPLT.FOR (CONTINUED)

```
      WRITE(5,1)
1     FORMAT(' DO YOU WANT THE GRID ON THE INSIDE OF THE PLOT?')
      WRITE(5,2)
2     FORMAT('   (Y OR N)')
      READ(5,3) YORN
3     FORMAT(A1)
      IF(YORN.EQ.'N'.OR.YORN.EQ.'n') ndec=1
      FLA=33.7
      FLO=107.3
      ELA=34.6
      ELO=106.4
      ALA=33.7
      ALO=107.3
      DLO=ALO
      DLA=ALA

      CALL TRNFM1(DLO,DLA)
      FX=(DLO+45.)/20.
      FY=(DLA+50.)/20.
      CALL TRNFM1(ELO,ELA)
      EX=(ELO+45.)/20.
      EY=(ELA+50.)/20.

      DO 100 I=1,10
         DLA=FLA
         DLO=ALO
         CALL TRNFM1(DLO,DLA)
         PX=(DLO+45.)/20.
         CALL SYMBOL(PX,FY,.1,3,0.,-1)

         AMOD=MOD(I,2)
         IF(AMOD.EQ.0.0.AND.NDEC.EQ.1) GO TO 500
         CALL NUMBER(PX-0.2,FY-0.2,0.1,ALO,0.,1)

500      CALL SYMBOL(PX,EY,0.1,3,0.,-1)
         ALO=ALO-0.1
100   CONTINUE

      ALA=FLA
      DO 200 I=1,10
         DLO=FLO
         DLA=ALA
         CALL TRNFM1(DLO,DLA)
         PY=(DLA+50.)/20.
         CALL SYMBOL(FX,PY,0.1,3,0.,-1)

         IF((MOD(I,2)).EQ.0.0.AND.NDEC.EQ.1) GO TO 600

         CALL NUMBER(FX-0.5,PY-0.05,0.1,ALA,0.,1)
600      CALL SYMBOL(EX,PY,.1,3,0.,-1)
         ALA=ALA+0.1
200   CONTINUE

      IF(YORN.NE.'Y'.AND.YORN.NE.'y') return

      CALL NEWPEN(2)
      ALO=107.2

      DO 300 I=1,8
         ALA=33.8
         DO 400 J=1,8
            DLA=ALA
            DLO=ALO
            CALL TRNFM1(DLO,DLA)
            PX=(DLO+45.)/20.
            PY=(DLA+50.)/20.
            CALL SYMBOL(PX,PY,0.05,3,0.,-1)
            ALA=ALA+0.1
400      CONTINUE
         ALO=ALO-0.1
300   CONTINUE
      CALL NEWPEN(1)
      RETURN
      END
```

EPI2.FOR

```
C     ****************************************************************
C     EPI2-- PLOTS DEVIATION OF OBSERVED Q FROM AVERAGE LAYER OVER A
C           HALF-SPACE MODEL FOR LOCAL EARTHQUAKES. Q RESIDUALS ARE
C           PLOTTED AT THE EPICENTER OF EACH EVENT. THESE RESIDUALS
C           CAN THEN BE CONTOURED BY HAND AND LATERAL INHOMOGENIETIES
C           IDENTIFIED.
C
C     SYMBOLS USED:   LVL          LOW VELOCITY LAYER
C                     D            DISTANCE TRAVELED THROUGH LVL
C                     Q1           LVL QUALITY FACTOR (FROM MODEL)
C                     Q2           HALF-SPACE QUALITY FACTOR (MODEL)
C                     VAPP         APPARENT VELOCITY OF RAY
C                     Q1MAX        MAX. LVL QUALITY FACTOR (MODEL)
C                     Q1MIN        MIN. LVL QUALITY FACTOR (MODEL)
C                     Q2MAX        MAX. HALF-SPACE QUAL.FAC. (MODEL)
C                     Q2MIN        MIN. HALF-SPACE QUAL. FAC.(MODEL)
C                     QDEV         ERROR IN EACH Q ESTIMATE (1 S.D.)
C                     QMDEV        ERROR IN MODEL Q ESTIMATES (1 S.D.)
C                     QRES         OBSERVED Q - MODEL Q
C                     QRDEV        ERROR IN QRES (2 S.D.)
C                     V1           LVL VELOCITY
C                     V2           HALF-SPACE VELOCITY
C                     ICHECK       QUERY ANSWER
C                     MUM          # OF STATIONS ON PLOT
C                     ST           STATION NAMES
C                     AI,AJ        STATION COORDS.
C                     AMMAX        MAXIMUM MAGNITUDE DESIRED
C                     AMMIN        MINIMUM MAGNITUDE DESIRED
C                     AMAG         MAGNITUDE OF EVENT
C                     LAA,LONA     LAT. AND LONG. OF EVENT
C                     XPLOT        LONG. SCREEN COORDS.
C                     YPLOT        LAT. SCREEN COORDS.
C                     QAVE         MODEL QUALITY FACTOR
C                     Q            OBSERVED QUALITY FACTOR
C                     QRES         RESIDUAL Q
C                     DIST         EVENT DISTANCE
C                     C            VARIANCE-COVARIANCE MATRIX
C                                  FOR LEAST-SQUARES MODEL
C                     X0           COORDS. FOR MODEL UNCERTAINTY
C
C          INPUT FILES-- QAPP.DAT (SELECTED EVENTS FROM MODEL.FOR
C                        OUTPUT)
C
C          OUTPUT FILES-- OUTPUT.PLT (PLOT OF EPICENTERS AND
C                         SOCORRO AREA. TYPE GRAFIX TO RUN)
C
C     THIS PROGRAM IS PRESENTLY SET UP TO RUN OFF OF MODEL.FOR OUTPUT
C     FOR STATION WT.
C     ****************************************************************
      IMPLICIT REAL*8(L)
      REAL C(2,2),X0(2),TEMP(2)
      DOUBLE PRECISION ORGT,FILENM,MONTH1,MONTH2,SOC
      INTEGER DAY,YEAR
C
C  Set Average Model Parameters
C
      PI=3.14159
      D=.4
      Q1=10
      Q2=535
      V1=1.96
      V2=3.41
C
C  SET DEPTH RANGE
C
      DMIN=9.
      DMAX=10.
C
C  STORE VARIANCE-COVARIANCE MATRIX FROM
C  BIVARIATE REGRESSION
C
      C(1,1)=4.955
      C(1,2)=-0.1987
      C(2,1)=C(1,2)
      C(2,2)=0.09564
C
C  STORE SUM OF RESIDUAL SQUARES
C
      SSR=1.689E-05

      WRITE(5,10)
10    FORMAT(1X,'DATA FILENAME?')
      READ(5,20)FILENM
20    FORMAT(1A10)
      OPEN(UNIT=22,FILE=FILENM)

      CALL INITAL(1)
      CALL PLOT(4.0,0.4,-3)

C     Plot the location of Socorro on the map.

C     SOC='SOCORRO'
C     X=106.9
C     Y=34.06
C     CALL TRNFM1(X,Y)
C     X=(X+45.)/20.
C     Y=(Y+50.)/20.
C     CALL SYMBOL(X,Y,0.10,1,0.0,-1)
C     CALL SYMBOL(X+.08,Y,0.10,SOC,0.0,7)

70    WRITE(5,80)
80    FORMAT(1X,'DO YOU WANT ANY STATIONS TO APPEAR ON THE MAP?')
      WRITE(5,90)
90    FORMAT(1X,'(Y OR N)')
      READ(5,100)ICHECK
100   FORMAT(A1)
      IF(ICHECK.EQ.'N'.OR.ICHECK.EQ.'n')GO TO 170
      IF(ICHECK.EQ.'y'.OR.ICHECK.EQ.'Y')GO TO 110
      GO TO 70

110   WRITE(5,120)
120   FORMAT(1X,'HOW MANY STATIONS?   (I2 FORMAT)')
      READ(5,130)MUM
130   FORMAT(I2)
      WRITE(5,140)
140   FORMAT(1X,'TYPE IN THE STATION NAMES IN A4 FORMAT.')
      write(5,141)
141   format(' Be sure to use UPPERCASE LETTERS for the station names')
      DO 160 I=1,MUM
      READ(5,150)ST
150   FORMAT(A4)

C  Get coordinates for each of the stations specified.
```

```
      CALL GETCOD (ST,AI,AJ)
      X=AJ
      Y=AI
      CALL TRNFM1(X,Y)
      Y=(Y+50.0)/20.0
      X=(X+45.0)/20.0

C  Plot a triangle and a station label at each station location.

      CALL SYMBOL(X,Y,0.035,2,0.0,-1)
      Y=Y+.05
      CALL SYMBOL(X,Y,.025,ST,0.0,3)
160   CONTINUE


170   WRITE(5,180)
180   FORMAT(1X,'DO YOU WANT ALL EVENTS TO BE PLOTTED OR')
      WRITE(5,190)
190   FORMAT(1X,'ONLY THOSE WITH SELECTED MAGNITUDES?')
      WRITE(5,200)
200   FORMAT(1X,'(1=ALL EVENTS, 2=SELECTED MAGNITUDES)')
      READ(5,210)ICHECK
210   FORMAT(I1)
      IF(ICHECK.EQ.1.OR.ICHECK.EQ.2)GO TO 220
      GO TO 170
220   N=0
      IF(ICHECK.EQ.1)GO TO 290
      WRITE(5,230)
230   FORMAT(1X,'WHAT IS THE MAXIMUM MAGNITUDE DESIRED?')
      WRITE(5,240)
240   FORMAT(1X,'(F5.2 FORMAT)')
      READ(5,250)AMMAX
250   FORMAT(F5.2)
      WRITE(5,260)
260   FORMAT(1X,'WHAT IS THE MINIMUM MAGNITUDE DESIRED?')
      WRITE(5,270)
270   FORMAT(1X,'(F5.2 FORMAT)')
      READ(5,250)AMMIN

c   This is for the benefit of the SCALE2 subroutine.
290   IF(ICHECK.EQ.1) AMMAX=6.0
      IF(ICHECK.EQ.1) AMMIN=-3.0

      WRITE(5,810)
810   FORMAT(1X,'DO YOU WANT TO SEE A LIST OF ALL THE EVENTS PLOTTED?')
      WRITE(5,811)
811   FORMAT(' (Y OR N)')
      READ(5,100) YORN
      IF(YORN.EQ.'N'.OR.YORN.EQ.'n') GO TO 909
      WRITE(5,812)
812   FORMAT(' TYPE 5 IF YOU WANT THE LIST TO GO TO THE TERMINAL,')
      WRITE(5,813)
813   FORMAT(' TYPE 3 IF YOU WANT THE LIST TO GO TO THE LINE PRINTER')
      READ(5,210) NUNIT

c   Give the user a choice about the size of the x's plotted for the quakes

909   WRITE(5,910)
910   FORMAT(' DO YOU WANT ALL OF THE Xs THE SAME SIZE? (Y OR N)')
      READ(5,100) YXN

C  Read latitude and longitude coordinates for each event from model output

7     READ(22,300,END=899) NUM,C1,C2,STA,C3,C4,IBEGIN,IEND,Q,QMAX,
     +QMIN,CORR,DIST,DEPTH,LAA,LONA
      GO TO 9

300   FORMAT(I4,3X,A10,A7,A3,A9,A1,4X,I4,1X,I4,6F10.2,2F10.4)

9     IF(ICHECK.EQ.1)GO TO 330
      IF(AMAG.LE.AMMIN)GO TO 7
      IF(AMAG.GT.AMMAX)GO TO 7

330   KOUNTR=KOUNTR+1

c   Get the dates of the first and last events.

      EYEAR=YEAR
      JMON=MON
      EDAY=DAY
      IF(KOUNTR.NE.1) GO TO 850
      IMON=MON
      ADAY=DAY
      AYEAR=YEAR

850   PTY=LAA
      PTX=LONA

C  Transform degrees to kilometers.

      CALL TRNFM1(PTX,PTY)

c   Set the window to the Socorro area and the scale to fit on the plotter
c   Add 50 km to the latitude, 45 km to the longitude, scale=20 km per inch.

      PTY=(PTY+50.0)/20.0
      PTX=(PTX+45.0)/20.0
      YPLOT=PTY
      XPLOT=PTX

c   Scale the size of the x to the magnitude (if all are to be the same,
c   skip this part).

      F=0.70
      IF(YXN.EQ.'Y'.OR.YXN.EQ.'y') go to 736

      IF(-0.5.LE.AMAG.AND.AMAG.LT.0.0)F=0.3
      IF(0.0.LE.AMAG.AND.AMAG.LT.0.50)F=0.6
      IF(0.5.LE.AMAG.AND.AMAG.LT.1.00)F=0.9
      IF(1.0.LE.AMAG.AND.AMAG.LT.1.50)F=1.2
      IF(1.5.LE.AMAG.AND.AMAG.LT.2.00)F=1.5
      IF(2.0.LE.AMAG.AND.AMAG.LT.2.50)F=1.8
      IF(2.5.LE.AMAG.AND.AMAG.LT.3.00)F=2.1
      IF(3.0.LE.AMAG.AND.AMAG.LT.3.50)F=2.4
      IF(3.5.LE.AMAG.AND.AMAG.LT.4.50)F=2.7

C  Plot a number at the location of the earthquake corresponding to
C  model.for printouts

736   F=F*0.14
      XPLOT=XPLOT-.05
      YPLOT=YPLOT-.05
      XKOUNT=FLOAT(KOUNTR)
      DMD=DIST-D
      VAPP=DIST/(D/V1+DMD/V2)
      QAVE=DIST/(VAPP*(D/(Q1*V1)+DMD/(Q2*V2)))
C
```

```
C  Compute Q residuals
C
      QRES=Q-QAVE

C
C  Compute variance for model Q at each hypocenter
C
      X0(1)=D/V1
      X0(2)=(DIST-D)/V2
      DO 1100 J=1,2
      SUM=0.
      DO 1090 K=1,2
1090  SUM=X0(K)*C(K,J)+SUM
1100  TEMP(J)=SUM
      YVAR=0.
      DO 1110 J=1,2
1110  YVAR=TEMP(J)*X0(J)+YVAR
      YVAR=YVAR*SSR

      Y=(X0(1)*(1/Q1)+X0(2)*(1/Q2))*PI
      VVAR=0.06**2
      RVAR=1.5**2
      TERM1=(1./(Y*VAPP))**2 * RVAR
      TERM2=(DIST/(Y**2*VAPP))**2 * YVAR
      TERM3=(DIST/(Y*VAPP**2))**2 * VVAR
      QMVAR= (TERM1 + TERM2 + TERM3)*PI

C
C  Compute average variance for each spectral estimate
C
      QVAR=((QMAX-QMIN)/4.)**2

C
C  Compute errors in Q residuals (2 s.d.)
C
      QRDEV=2.*SQRT(QVAR+QMVAR)
C     write(5,*) DIST,Y,TERM1,TERM2,TERM3,QVAR,QMVAR,QRDEV
C      WRITE(5,*) DEPTH
C     IF(DEPTH .GT. DMAX .OR. DEPTH .LE. DMIN) GO TO 28
      CALL NUMBER(XPLOT,YPLOT,.015,QRES,0.,-1)
      WRITE(5,*) QRES
 28   CONTINUE

C     WRITE(3,*) XPLOT,YPLOT,Q,QMAX,QMIN
C     CALL NUMBER(XPLOT,YPLOT,.05,XKOUNT,0.,-1)
c     CALL SYMBOL(XPLOT,YPLOT,F,4,0.0,-1)

      IF(YORN.NE.'Y'.and.YORN.NE.'y') GO TO 7
      WRITE(NUNIT,29)MON,DAY,YEAR,LAA,LONA,AMAG
29    FORMAT(2X,3I2,12X,F5.2,1X,F6.2,5X,F5.2)

      GO TO 7

c  Indicate on the plot the dates of the first and last events.

899   CALL DATE(IMON,MONTH1)
      CALL DATE(JMON,MONTH2)
      AYEAR=AYEAR+1900
      EYEAR=EYEAR+1900
      CALL PLOT(-1.9,0.5,-3)
      GO TO 901
      CALL SYMBOL(0.0,4.7,0.1,'THE FIRST EVENT IS ON',0.0,21)
      CALL SYMBOL(0.1,4.5,0.1,MONTH1,0.0,9)
      CALL NUMBER(0.9,4.5,0.1,ADAY,0.0,-1)
      CALL SYMBOL(1.05,4.5,0.1,',',0.0,1)
      CALL NUMBER(1.25,4.5,0.1,AYEAR,0.0,-1)
      CALL SYMBOL(0.0,4.1,0.1,'THE  LAST EVENT IS ON',0.0,21)
      CALL SYMBOL(0.1,3.9,0.1,MONTH2,0.0,9)
      CALL NUMBER(0.9,3.9,0.1,EDAY,0.0,-1)
      CALL SYMBOL(1.05,3.9,0.1,',',0.0,1)
      CALL NUMBER(1.25,3.9,0.1,EYEAR,0.0,-1)
901   continue

c  Indicate on the plot how many events were plotted.

      ROUNTR=KOUNTR
      CALL NUMBER(0.0,3.5,0.1,ROUNTR,0.0,-1)
      CALL SYMBOL(0.4,3.5,0.1,'EVENTS WERE PLOTTED',0.0,19)

c  Put a kilometer scale bar on the plot.

      SX=0.3
      SY=3.0
      CALL PLOT(SX,SY,3)
      DO 600 I=0,4
         CALL PLOT(SX,SY,2)
         CALL PLOT(SX,SY+.025,3)
         CALL PLOT(SX,SY-.025,2)
         AKM=I*5.
         CALL NUMBER(SX-.04,SY-.15,.07,AKM,0.0,-1)
         CALL PLOT(SX,SY,3)
         SX=SX+.25
600      CONTINUE
      CALL SYMBOL(SX-.14,SY-.15,.07,'KM',0.0,2)
      CALL PLOT(1.9,-0.5,-3)

C  Plot crosses at .1 degree marks for a reference scale.
      CALL PLOTX

c  Plot the magnitude scale if necessary.
      IF(YXN.EQ.'N'.OR.YXN.EQ.'n') CALL SCALE2(ammax,ammin)

      CLOSE(UNIT=22)
      CALL RSTR(1)
      STOP
       END
C  *********************************
C  *********************************
      SUBROUTINE TRNFM1(X,Y)
c  Changes degree coordinates to distance in kilometers from the center
c  of New Mexico.

      YY=Y
      Y=(Y-34.1)*((Y-34.1)/2.*.018+110.922)
      X=(106.943-X)*COS(3.1415927/360.*(34.1+YY))*111.4399
10    RETURN
      END
C  *****************************************
C  *****************************************
      SUBROUTINE GETCOD (STATIO,AI,AJ)

c  Gets coordinates for the stations specified from the file STA.DAT.

      OPEN(UNIT=24,FILE='STA.DAT',ACCESS='SEQIN',DEVICE='DSK')

10    READ(24,20,END=30) ST,AI,AJ
20    FORMAT(A4,F7.4,1X,F8.4)
```

EPI2.FOR (CONTINUED)

```
      SUBROUTINE DATE(INMON,OUTMON)

c   Changes months designated by numbers to names.

      DOUBLE PRECISION OUTMON
      IF(INMON.EQ.1) OUTMON=' JANUARY'
      IF(INMON.EQ.2) OUTMON=' FEBRUARY'
      IF(INMON.EQ.3) OUTMON='    MARCH'
      IF(INMON.EQ.4) OUTMON='    APRIL'
      IF(INMON.EQ.5) OUTMON='      MAY'
      IF(INMON.EQ.6) OUTMON='     JUNE'
      IF(INMON.EQ.7) OUTMON='     JULY'
      IF(INMON.EQ.8) OUTMON='   AUGUST'
      IF(INMON.EQ.9) OUTMON='SEPTEMBER'
      IF(INMON.EQ.10)OUTMON=' OCTOBER'
      IF(INMON.EQ.11)OUTMON=' NOVEMBER'
      IF(INMON.EQ.12)OUTMON=' DECEMBER'

      RETURN
      END

      SUBROUTINE PLOTX
c   Plots a reference scale on the outside of the plot, with or without
c   grid points on the inside of the plot.

      WRITE(5,1)
1     FORMAT(' DO YOU WANT THE GRID ON THE INSIDE OF THE PLOT?')
      WRITE(5,2)
2     FORMAT('  (Y OR N)')
      READ(5,3) YORN
3     FORMAT(A1)
      IF(YORN.EQ.'N'.OR.YORN.EQ.'n') ndec=1
      FLA=33.7
      FLO=107.3
      ELA=34.6
      ELO=106.4
      ALA=33.7
      ALO=107.3
      DLO=ALO
      DLA=ALA

      CALL TRNFM1(DLO,DLA)
      FX=(DLO+45.)/20.
      FY=(DLA+50.)/20.
      CALL TRNFM1(ELO,ELA)
      EX=(ELO+45.)/20.
      EY=(ELA+50.)/20.

      DO 100 I=1,10
         DLA=FLA
         DLO=ALO
         CALL TRNFM1(DLO,DLA)
         PX=(DLO+45.)/20.
         CALL SYMBOL(PX,FY,.1,3,0.,-1)

         AMOD=MOD(I,2)
         IF(AMOD.EQ.0.0.AND.NDEC.EQ.1) GO TO 500
         CALL NUMBER(PX-0.2,FY-0.2,0.1,ALO,0.,1)

500      CALL SYMBOL(PX,EY,0.1,3,0.,-1)
         ALO=ALO-0.1
100   CONTINUE
      IF(ST.EQ.STATIO)RETURN
      GO TO 10
30    write(5,100) statio
100   format(' Station "',a4,'"  not on station list')
      TYPE 200
200   FORMAT(' TRY ENTERING THE STATION NAME AGAIN')
      READ(5,101) STATIO
101   FORMAT(A4)
      GO TO 10
      RETURN
      END
C     ****************************
C     ****************************
      SUBROUTINE SCALE2(amax,amin)

C   Plots a legend for the scaled x's.  AMAX and AMIN determine which
c   magnitudes are represented in the legend (depending on what
c   range was selected by the user).

      DIMENSION B(9,2)
      CALL PLOT(0.,0.,3)
      CALL PLOT(3.60,2.00,0)
      CALL PLOT(-1.7,0.0,-3)
      B(1,1)=-0.50
      B(1,2)=-0.01
      B(2,1)=-0.00
      B(2,2)=0.49
      B(3,1)=0.50
      B(3,2)=0.99
      B(4,1)=1.00
      B(4,2)=1.49
      B(5,1)=1.50
      B(5,2)=1.99
      B(6,1)=2.00
      B(6,2)=2.49
      B(7,1)=2.50
      B(7,2)=2.99
      B(8,1)=3.00
      B(8,2)=3.49
      B(9,1)=3.50
      B(9,2)=4.49
      if(b(1,2).LE.AMIN) go to 8
      F=0.14*0.3
      CALL SYMBOL(0.,0.,F,4,0.0,-1)
      CALL NUMBER(0.43,-0.05,0.1,B(1,1),0.0,2)
      CALL SYMBOL(0.9,-0.05,0.1,'-',0.0,1)
      CALL NUMBER(1.03,-0.05,0.1,B(1,2),0.0,2)
      CALL PLOT(0.0,0.0,3)
8     F=0.14*0.6
      DO 10 J=2,9
      if(b(j,2).le.amin) go to 9
      if(b(j,1).ge.amax) return
      A=J-1.0
      Y=(A*0.35)
      CALL SYMBOL(0.,Y,F,4,0.0,-1)
      Y=Y-0.05
      CALL NUMBER(0.5,Y,0.1,B(J,1),0.0,2)
      CALL SYMBOL(0.9,Y,0.1,'-',0.0,1)
      CALL NUMBER(1.1,Y,0.1,B(J,2),0.0,2)
9     F=F+3*.014
10    CONTINUE
      RETURN
      END
```

FRAC.FOR

```
C
C  FRAC-- COMPUTE FRACTION OF RAYPATH IN ANOMALOUSLY LOW Q MATERIAL
C
C         THIS PROGRAM USES THE LAYER OVER A HALF-SPACE MODEL WITH
C         WITH A SMALL FRACTION OF THE RAYPATH PASSING THROUGH
C         ANOMALOUSLY LOW Q MATERIAL.
C
C         SYMBOLS USED:
C
C               Q1              LOW VELOCITY LAYER (LVL) QUAL..FACTOR
C               Q2              HALF-SPACE QUAL. FACTOR
C               QA              QUAL. FACTOR FOR ANOMALOUS REGION
C               V1              LVL VELOCITY
C               V2              HALF-SPACE VELOCITY
C               VA              VELOCITY OF ANOMALOUS REGION
C               D               DISTANCE TRAVELED THROUGH LVL
C               QMIN            LOWEST OBSERVED Q VALUE
C               QMAX            HIGHEST OBSERVED Q VALUE
C               QINC            Q INCREMENT
C               R               EVENT DISTANCE
C               RA,RAA          DISTANCE TRAVELED OR PERCENTAGE
C                               OF ANOMALOUS MATERIAL
C               NCOL            NUMBER OF COLUMNS IN TABLE
C
C        OUTPUT-- THIS PROGRAM PRINTS OUT A TABLE WITH EVENT
C                 DISTANCE ALONG THE VERTICAL AXIS AND APPARENT
C                 Q ALONG THE HORIZONTAL AXIS. THIS TABLE IS
C                 OUTPUT TO FRAC.OUT.

      REAL RAA(20)
      OPEN(UNIT=5,DEVICE='DSK',FILE='FRAC.OUT')

      Q1=10.
      Q2=535.
      QA=.1

      V1=1.96
      V2=3.41
      VA=3.41

      D=0.40

      QMIN=50.
      QMAX=150.
      QINC=10.
      NCOL=INT((QMAX-QMIN)/QINC)

      I=0
C
C  LOOP OVER APPARENT Q VALUES
C
      DO 50 Q=QMIN,QMAX,QINC
      I=I+1
 50   RAA(I)=Q
      WRITE(5,1010) (RAA(I),I=1,NCOL)
1010  FORMAT(9X,10F7.2/)

C
C  LOOP OVER EVENT DISTANCES
C
      DO 100 R=7.,25.,1.

      RMD=R-D
      I=0
      DO 200 Q=QMIN,QMAX,QINC
      I=I+1
C
C  COMPUTE DISTANCE TRAVELED THROUGH ANOMALOUS REGION
C
      RANUM=D/(Q*V1)+RMD/(Q*V2)-D/(V1*Q1)-RMD/(V2*Q2)
      RADEN=1./(VA*QA)-1./(V2*Q2)-1./(Q*VA)+1./(Q*V2)
      RA=RANUM/RADEN
C
C  COMPUTE PERCENTAGE OF RAYPATH IN ANOMALOUS MATERIAL
C  IF DESIRED
C
C     RA=RA/R*100.
      RAA(I)=RA*1000.

200   CONTINUE
      WRITE(5,1000) R, (RAA(I),I=1,NCOL)
1000  FORMAT(2X,F5.1,2X,15F7.0)
100   CONTINUE

      CLOSE(UNIT=5)
      STOP
      END
```

HANSM.FOR

```
      SUBROUTINE HANSM(Y,N2P1)
C
CC    SMOOTH SPECTRAL/CEPSTRAL ESTIMATES USING HANNING FILTER
CC
CC
CC          N2P1            NUMBER OF POINTS IN SPECTRUM/CEPSTRUM
CC          Y               AMPLITUDE OF POINTS
C
      REAL Y(2000)
      N2=N2P1-1
      Y(1)=.5*Y(1)+.5*Y(2)
      DO 100 I=2,N2
      Y(I)=.25*Y(I-1)+.5*Y(I)+.25*Y(I+1)
100   CONTINUE
      Y(N2P1)=.5*Y(N2)+.5*Y(N2P1)
      RETURN
      END
```

LINRG.FOR

```
      SUBROUTINE LINRG(X,Y,XMIN,XMAX,NUM,SLOPE,B)
C
C     DO LINEAR REGRESSION TO FIND BEST FIT LINE TO A SET OF DATA
C
C     REFERENCE: VOLK (MARCH,1956), CHEMICAL ENGINEERING, P. 166-190.
C
C     SYMBOLS USED:
C
C          X              INDEPENDENT VARIABLE
C          Y              DEPENDENT VARIABLE
C          XMIN           MINIMUM X FOR FITTING
C          XMAX           MAXIMUM X FOR FITTING
C          XSUM           SUM OF X VALUES
C          YSUM           SUM OF Y VALUES
C          X2SUM          SUM OF SQUARES OF X VALUES
C          Y2SUM          SUM OF SQUARES OF Y VALUES
C          XYSUM          SUM OF PRODUCTS OF X AND Y VALUES
C          XBAR           1ST MOMENT OF X VALUES
C          YBAR           1ST MOMENT OF Y VALUES
C          NUM            NUMBER OF POINTS IN DATA SET
C
      REAL X(2000),Y(2000),SDY(2000)
      INTEGER DF
      COMMON/STAT/ANS,YBAR,XBAR,CORR,SDYBAR,SDSL,SDY
C
C     INITIALIZE SUMS
C
      XSUM=0.
      YSUM=0.
      X2SUM=0.
      Y2SUM=0.
      XYSUM=0.
      N=0.
C
C     COMPUTE SUMS BY LOOPING OVER DESIRED X VALUES
C
      DO 100 I=1,NUM
      IF(X(I) .LT. XMIN .OR. X(I) .GT. XMAX) GO TO 100
      XSUM=XSUM+X(I)
      YSUM=YSUM+Y(I)
      N=N+1
  100 CONTINUE
C
C     COMPUTE 1ST MOMENTS
C
      XBAR=XSUM/FLOAT(N)
      YBAR=YSUM/FLOAT(N)
C
C     REINITIALIZE AND REDEFINE SUMS FOR ESTIMATING SLOPE, INTERCEPT,
C     CORRELATION, AND ERRORS IN SLOPE, MOMENT, AND EACH POINT ON LINE
C
C          SLOPE          SLOPE OF LEAST SQUARES LINE
C          B              Y INTERCEPT OF LEAST SQUARES LINE
C          CORR           CORRELATION COEFFICIENT
C          S2Y            RESIDUAL VARIANCE
C          SDSL           STD. DEV. OF SLOPE
C          SDY            STD. DEV. OF EACH POINT
C          SDYBAR         STD. DEV. OF Y MOMENT
C          DF             DEGREES OF FREEDOM (N-2)
C
      XYSUM=0.
      X2SUM=0.
      Y2SUM=0.
      DO 300 I=1,NUM
      IF(X(I) .LT. XMIN .OR. X(I) .GT. XMAX) GO TO 300
      XYSUM=(X(I)-XBAR)*(Y(I)-YBAR)+XYSUM
      X2SUM=(X(I)-XBAR)**2+X2SUM
      Y2SUM=(Y(I)-YBAR)**2+Y2SUM
  300 CONTINUE
      DF=N-2
      SLOPE=XYSUM/X2SUM
      B=YBAR-SLOPE*XBAR
      CORR=XYSUM/SQRT(X2SUM*Y2SUM)
      S2Y=(Y2SUM-SLOPE*XYSUM)/FLOAT(DF)
      SDYBAR=SQRT(S2Y/FLOAT(N))
      SDSL=SQRT(S2Y/X2SUM)
C
C     COMPUTE HYPERBOLAS THAT ENCLOSE LSQ LINES
C
      N=100
      I=0
      XINC=(XMAX-XMIN)/100.
      DO 400 XX=XMIN,XMAX,XINC
      I=I+1
      SDY(I)=SQRT(S2Y*(1./FLOAT(N) + (XX-XBAR)**2/X2SUM))
  400 CONTINUE
C     WRITE(5,*) B,SLOPE,CORR,SDSL,SDYBAR
      RETURN
      END
```

LSTEST.FOR

```
C
C  LSTEST-- TEST LEAST SQUARES FITTING ROUTINE
C
C
C  SET MODEL PARAMETERS
C
      V1=1.96
      V2=3.41
      Q1=50.
      Q2=1000.
      R1=.40
C
C  OUTPUT TEST DATA TO SLOPE.DAT (TO BE READ IN BY MODEL.FOR)
C
      OPEN(UNIT=22,DEVICE='DSK',FILE='SLOPE.DAT',ACCESS='SEQOUT')

      DO 100 R=1.,45.,1.
      R2=R-R1
      VAPP=R/(R1/V1 + R2/V2)
      QAPP=R/(VAPP*(R1/(V1*Q1)+R2/(V2*Q2)))
      SLOPE=R/(VAPP*QAPP)
C
C  WRITE OUT APPARENT Q, DIST, DEPTH, AND SPECTRAL SLOPE FOR
C  EACH DISTANCE
C
      WRITE(22,*) QAPP,R,Z,SLOPE
100   CONTINUE

      STOP
      END
```

MODEL.FOR

```
C
C       PROGRAM MODEL-- DIST VS. APPARENT Q (SLOPE) PLOTTING ROUTINE
C
C       MODEL PLOTS Q VALUES OR SPECTRAL SLOPE AS A FUNCTION OF
C       EVENT DISTANCE OR DEPTH. THE POINTS CAN BE PLOTTED WITH OR
C       WITHOUT ERROR BARS. THEY CAN BE FIT WITH A STRAIGHT LINE
C       AND A USER-SUPPLIED CRUSTAL MODEL CAN BE SUMPERIMPOSED.
C       ALSO, PRINTOUTS ARE AVAILABLE OF ALL EVENTS PLOTTED.
C
C       INPUT FILES-- VFNIN (SPECTRAL ESTIMATES FOR EACH WINDOW
C                     E.G. SSPEC.DAT)
C
C       OUTPUT FILES:
C
C                QAPP-- LIST OF EVENTS MEETING ERROR CRITERIA FOR
C                       USE IN EPICENTER PLOTTING ROUTINES (EPI2 AND
C                       EPIPLT) AND IN SELECTING TRACES FOR DISPLAY
C                       (QTRAC).
C                SLOPE- OUTPUT SPECTRAL SLOPES FOR EVENTS MEETING ERROR
C                       CRITERIA. FOR USE IN CUMBAR.FOR AND MULT.FOR.
C                MOD--- PRINTOUT OF EVENTS MEETING ERROR CRITERIA.
C                       DISPLAY WITH TEKORD.FOR.
C
C       QAPP AND MOD.OUT CAN BE REORDERED USING TEKORD TO PLACE EVENTS
C       IN ORDER OF INCREASING HYPOCENTRAL DISTANCE
C
C       SUBROUTINES--
C
C               GRFLIB          PLOTTING ROUTINES
C               DECON           FILTER DECONVOLUTION ROUTINES
C               QERR            COMPUTES STD.DEV. OF Q ESTIMATES
C               LINRG           LINEAR REGRESSION ROUTINE (USED
C                               TWICE-- ONCE TO COMPUTE Q FROM
C                               SPECTRA AND ONCE TO FIT LINE Q/
C                               SLOPE VS. DIST/DEPTH)
C               GRAF            PLOTTING ROUTINE
C               TICX,TICY       PLACES TIC MARKS ON ERROR BARS
C
C
C      SYMBOLS USED:
C
C        EVENT DATA--
C
C               CMPVAR          EVENT RECORDING PARAMETERS
C               VFNIN           INPUT FILE NAME
C               IBEGIN          BEGINNING OF WINDOW
C               IEND            END OF WINDOW
C               IVAR            VARIANCE OF TIME SERIES
C               XYMV1           MEAN OF TIME SERIES
C               XYMV2           ST. DEV. OF TIME SERIES
C               N2              NUMBER OF SAMPLES IN WINDOW/2
C               FREQ            FREQUENCY
C               AS              AMPLITUDE SPECTRA VALUES
C               FIL1,FIL2       LO,HI-CUT FILTER SETTINGS
C               DIST            DISTANCE TO EVENT
C               VEL             WAVE VELOCITY
C               DEPTH,DP        DEPTH OF EVENT
C               ERH,ERZ         HYPO71 ERROR ESTIMATES FOR EPICENTER, DEPTH
C               STA,STN         STATION
C               T(STANAME)      STATION CORRECTION
C               NUM             NUMBER OF EVENTS PLOTTED
C
C       LINEAR REGRESSION--
C
C               ABAR            1ST MOMENT OF Q/SLOPE VALUES
C               FBAR            1ST MOMENT OF OF DISTANCES
C               CORR            CORRELATION COEFFICIENT
C               SLOPE           SLOPE OF LSQ LINE
C               SDYBAR          STD. DEV. OF 1ST MOMENT
C               SDSL            STD. DEV. OF SLOPE OF LSQ LINE
C               SDY             STD. DEV. OF POINTS FOR HYPERBOLIC
C                               ENVELOPE (2 SIGMA SLOPE ENVELOPE)
C               FMIN, FMAX      RANGE OF FREQUENCY FOR Q DETERMINATION
C
C
C       TOLERANCE LEVELS AND STD. DEV.--
C
C               ERR             MAXIMUM TOLERABLE ERROR IN Q ESTIMATES
C               CORMIN          MINIMUM TOLERABLE CORRELATION COEFFICIENT
C               QPEAK           Q ESTIMATE FROM PEAK FREQUENCY
C               QMIN,QMAX       Q -/+ 2 * SIGMAQ
C
      INTEGER ANSWER,IBEGIN,IEND,N2,IVAR,VALARY(102),LINE1
      REAL FREQ(2000),AS(4000),VFNIN*8,XYMV1,X(2000),Y(2000),
     1XYMV2,YMAX,WIN*8,SDY(2000),DP(2000),CIX(500),CIY(500)
      REAL ASP(2000),STN(500),I1,I2,I20,LAT(500),LON(500)
      REAL*8 C1,C2,C3,C4,XANS,YANS
      DIMENSION XY(100,3),IV(3),PAR(3),STAT(6),VCV(6),ITER(2)
      COMMON /STAT/STANS,ABAR,FBAR,CORR,SDYBAR,SDSL,SDY,CORMIN
      COMMON /PARAM/VEL,X,Y,NUM,STA,ERR,DP,CIX,CIY,XANS,YANS,STN
      COMMON /COORD/LAT,LON,NUMS

      DATA TWT,TSC,TCC,TFM,TDM,TCH /-0.11,0.15,-0.15,0.00,-0.01,0.13/

      PI=3.14159
      NUM=0
      DSUM=0.
      QSUM=0.
      OPEN(UNIT=2,DEVICE='DSK',ACCESS='SEQIN',FILE='MODEL.DAT')
      TYPE 5
    5 FORMAT('-','DESIGNATE AMPLITUDE SPECTRA INPUT FILE NAME:  '$)
      READ(2,8) VFNIN
    8 FORMAT(A10)
      OPEN(UNIT=1,DEVICE='DSK',ACCESS='SEQIN',FILE=VFNIN)
      OPEN(UNIT=23,DEVICE='DSK',FILE='QAPP.DAT',ACCESS='APPEND')
      OPEN(UNIT=22,DEVICE='DSK',FILE='SLOPE.DAT',ACCESS='APPEND')
      OPEN(UNIT=25,DEVICE='DSK',FILE='MOD.OUT',ACCESS='APPEND')
C
C     SPECIFY FREQUENCY RANGE FOR FIT
C
      WRITE(5,1015)
 1015 FORMAT(' ENTER MIN. AND MAX. FREQ. FOR LEAST SQUARES FIT')
      READ(2,*) FMIN,FMAX
      IF(FMIN .EQ. 0.) FMIN=.001

      WRITE(5,1019)
 1019 FORMAT(' ENTER ALLOWABLE ERROR IN Q ESTIMATES:  '$)
      READ(2,*) ERR
C     ERR=ERR/100.

      WRITE(5,1021)
 1021 FORMAT(' ENTER MINIMUM ACCEPTABLE CORRELATION COEFFICIENT:  '$)
      READ(2,*) CORMIN
      WRITE(5,1016)
 1016 FORMAT(' ENTER STATION FOR PLOT')
```

```
      READ(2,1017) STANS,STANS1
 1017 FORMAT(2A3)
      WRITE(22,1017) STANS
C
C     CHOOSE AXES
C
      WRITE(5,1030)
 1030 FORMAT(' X- AND Y- AXES (2A5 FORMAT, CHOOSE FROM DIST , DEPTH
     + FOR X; Q, SLOPE FOR Y)?  '$)
      READ(2,1032) XANS,YANS
 1032 FORMAT(2A5)
      WRITE(5,1039)
 1039 FORMAT(' DO YOU WANT EVENTS OUTPUT TO DATA FILE QAPP.DAT?  '$)
      READ(2,1017) OUTANS
      WRITE(5,1002)
 1002 FORMAT(' DO YOU WANT PRINTOUTS?')
      READ(2,1017) PNT
      IF(PNT .EQ. 'N') GO TO 10
C     ERR=ERR*100.
      WRITE(25,1005) ERR
C     ERR=ERR/100.
 1005 FORMAT(' MAXIMUM ERROR IN Q ESTIMATES =',F7.1)
      WRITE(25,1009) CORMIN
 1009 FORMAT(' MINIMUM ACCEPTABLE CORRELATION COEFFICIENT =',F7.2,///)

      WRITE(25,1001)
 1001 FORMAT(19X,'EVENT',19X,'WINDOW',8X,'Q',7X,'QMAX',6X,'QMIN',
     17X,'CORR',6X,'DIST',5X,'DEPTH',5X,'LAT',6X,'LONG'/)

C
C     READ EVENT HEADER FROM OUTPUT FILE
C
10    READ(1,20,END=220) C1,C2,STA,C3,C4
C
C     IF S WAVE, CHANGE SYMBOL
C
      IF(C1 .EQ. 'SSSSSSSSS') NUMS=NUM
      IF(C1 .EQ. 'SSSSSSSSS') GO TO 10
      READ(1,21) IBEGIN,IEND,IVAR,XYMV1,
     1XYMV2,N2,PIL1,PIL2,DIST,VEL,DEPTH,ERH,ERZ,XLAT,XLON,SMP
C     WRITE(5,*) C1,FMAX,FMIN,FIL,DIST,VS
20    FORMAT(A10,A7,A3,A9,A1)
21    FORMAT(I4,2(1X,I4)/F7.4,1X,F15.4,1X,I4,7F7.2,3P9.4)

C
C     READ AMPLITUDES AND FREQUENCIES FROM DISK
C
      N2P1=N2+1
      DO 30 J=1,N2P1
30    READ(1,40) FREQ(J),AS(J)
40    FORMAT(5X,F5.2,1X,E15.4)
      READ(1,50) LINE1
50    FORMAT(A5)
C     WRITE(5,51) STA,ANS
 51   FORMAT(1X,2A10)
      IF(STA .NE. STANS .AND. STA .NE. STANS1) GO TO 10
C     WRITE(5,*) SMP
C     IF(DEPTH .GT. 10. .OR. DEPTH .LE. 9.) GO TO 10
C     IF(DIST .LT. 15. .OR. DIST .GT. 19.) GO TO 10
C     IF(ERH .GT. 1.50 .OR. ERZ .GT. 1.50) GO TO 10
C     IF(DEPTH .GT. 7.00) GO TO 52
C     DEL=SQRT(DIST**2-DEPTH**2)
C     DEPTH=8.5
C     DIST=SQRT(DEPTH**2+DEL**2)

C 52  CONTINUE

C
C     LOOK AT ONE GEOGRAPHICAL REGION
C
C     IF(XLAT .GT. 34.3 .OR. XLAT .LT. 34.1) GO TO 10
C     IF(XLON .GT. 107.00 .OR. XLON .LT. 106.80) GO TO 10
C     IF(XLAT .GT. 33.98 .AND. XLAT .LT. 34.12) GO TO 10
C     IF(XLON .LT. 107.20 .AND. XLON .GT. 106.90) GO TO 10

C
C     REMOVE AMPLIFIER SPECTRUM
C
      DO 190 J=2,N2P1
      AS(J)=AS(J)/(2.*PI*FREQ(J))
 190  CONTINUE

C
C     DECONVOLVE FILTER SPECTRUM
C
      IF(FIL1 .EQ. 0.) GO TO 195
      CALL DECON(AS,FIL1,FREQ,N2)
 195  IF(FIL2 .EQ. 0.) GO TO 196
      CALL DECON(AS,FIL2,FREQ,N2)
 196  CONTINUE

C
C     FIND PEAK FREQUENCY AND DEDUCE Q
C
      AMAX=0.
      DO 200 I=1,N2P1
      ASP(I)=AS(I)*2.*PI*FREQ(I)
      IF(ASP(I) .LT. AMAX) GO TO 200
      AMAX=ASP(I)
      FPEAK=FREQ(I)
 200  CONTINUE

C
C     FIND LOGE AMPLITUDES
C
      DO 90 J=2,N2P1
      AS(J)=ALOG(AS(J))
C     WRITE(5,920) AS(J)
 920  FORMAT(F7.2)
 90   CONTINUE

C
C     DO LINEAR REGRESSION TO FIND Q
C
      CALL LINRG(FREQ,AS,FMIN,FMAX,N2P1,SLOPE,A0)
C
C     LOAD STATION CORRECTION
C
 313  IF(STA .EQ. 'WT ') TSTA=TWT
      IF(STA .EQ. 'WT*') TSTA=TWT
      IF(STA .EQ. 'SC ') TSTA=TSC
      IF(STA .EQ. 'CC ') TSTA=TCC
      IF(STA .EQ. 'FM ') TSTA=TFM
      IF(STA .EQ. 'DM ') TSTA=TDM
      IF(STA .EQ. 'CM ') TSTA=TCM
C
C     MODIFY S-P DISTANCES WITH STATION CORRECTION
C
      IF(DEPTH .EQ. 0.) DIST=DIST-5.81*TSTA
```

MODEL.FOR (CONTINUED)

```
      IF(DEPTH .EQ. 0.) DEPTH=8.5
      CORR=ABS(CORR)
      IF(CORR .LT. CORMIN) GO TO 10
C
C     COMPUTE TRAVEL TIME FOR RAY
C
      TT=DIST/VEL+TSTA*5.81/VEL
C
C     COMPUTE AVERAGE VELOCITY FOR RAY
C
      VAPP=DIST/TT
C
C     COMPUTE APPARENT Q FOR EACH EVENT
C
      Q=ABS(PI*TT/SLOPE)
C
C     COMPUTE ERRORS IN Q ESTIMATES
C
      CALL QERR(DIST,DEPTH,SLOPE,SDSL,VAPP,SDQ,ERH,ERZ,SDR)
C
C     COMPUTE 2 S.D. BOUNDS FOR Q ESTIMATES
C
      QMAX=Q+2.*ABS(SDQ)
      QMIN=Q-2.*ABS(SDQ)
C
C     COMPUTE APPARENT Q FROM PEAK FREQUENCY (IF DESIRED)
C
C     QPEAK=FPEAK*PI*DIST/VEL
      IF((Q-QMIN).GT.ERR.OR. (QMAX-Q).GT.ERR) GO TO 10
C
C     LOAD POINTS FOR PLOTTING
C
      NUM=NUM+1
C     WRITE(5,*) DIST
      IF(XANS .EQ. 'DIST ') X(NUM)=DIST
      IF(XANS .EQ. 'DEPTH') X(NUM)=DEPTH
      IF(YANS .EQ. 'Q    ') Y(NUM)=Q
      IF(YANS .EQ. 'SLOPE') Y(NUM)=ABS(SLOPE)
C     WRITE(5,*) SLOPE
      IF(XANS .EQ. 'DIST ') CIX(NUM)=SDR
      IF(XANS .EQ. 'DEPTH') CIX(NUM)=ERZ
      IF(YANS .EQ. 'Q    ') CIY(NUM)=2.*SDQ
      IF(YANS .EQ. 'SLOPE') CIY(NUM)=SDSL*2.
      DP(NUM)=DEPTH
      LAT(NUM)=XLAT
      LON(NUM)=XLON
      STN(NUM)=STA
      DSUM=DIST+DSUM
      QSUM=Q+QSUM
      SLOUT=-SLOPE/PI
      write(22,*) Q,DIST,DEPTH,SLOUT
C     WRITE(22,*) NUM,SLOPE,SDSL
      IF(PNT .EQ. 'N') GO TO 205
C
C     WRITE OUT TABLE OF SELECTED EVENTS
C
      WRITE(25,1000) NUM,C1,C2,STA,C3,C4,IBEGIN,
     1IEND,Q,QMAX,QMIN,CORR,DIST,DEPTH,XLAT,XLON
1000  FORMAT(I4,3X,A10,A7,A3,A9,A1,4X,I4,':',
     1I4,6F10.2,2F10.4)
205   IF(OUTANS .EQ. 'N') GO TO 10
C
C     LIST SELECTED EVENTS ON DISK FOR USE IN
C     MAP PLOTTING OR SELECTING WINDOWS FOR PANELS
C
      WRITE(23,1000) NUM,C1,C2,STA,C3,C4,IBEGIN,
     1IEND,Q,QMAX,QMIN,CORR,DIST,DEPTH,XLAT,XLON
      GO TO 10
220   CONTINUE
      WRITE(22,3025)
3025  FORMAT('99999,99999,99999,99999')
C     DAVE=DSUM/FLOAT(NUM)
C     QAVE=QSUM/FLOAT(NUM)
C     WRITE(5,3002) DAVE,QAVE
3002  FORMAT(//' AVE. DIST. =',F7.2,4X,' AVE. Q =',F7.2)
C
C     PLOT APPARENT Q VS. DISTANCE FOR DESIRED STATION
C
      CALL GRAF
      CLOSE(UNIT=1)
      CLOSE(UNIT=2)
      CLOSE(UNIT=23)
      CLOSE(UNIT=25)
      STOP
      END

      SUBROUTINE GRAF
C
C     GRAF-- DATA PLOTTING ROUTINE
C
C     WILL PLOT APPARENT Q VS. DISTANCE OR DEPTH OR SPECTRAL SLOPE
C     VS. DISTANCE OR DEPTH FOR EACH EVENT SATISFYING ERROR CRITERIA.
C
C     SYMBOLS USED:
C
C             DP              DEPTH
C             XMIN,XMAX       MIN. AND MAX. DISTANCE FOR PLOTTING (KM)
C             YMIN,YMAX       MIN. AND MAX. Q/SLOPE FOR PLOTTING
C
      INTEGER ANSWER,IBEGIN,IEND,N2,IVAR,LINE,VALARY(102)
      REAL XAXIS*8,X(2000),Y(2000),VFNIN*8,XX(500),YY(500),
     1XYMV2,YMAX,WIN*8,SDY(2000),YAXIS*8,CIX(500),CIY(500)
      REAL MERR(2),DP(2000),CIY1(500),CIY2(500),XANS,YANS
      REAL STN(500),I1,I2,I20,LAT(500),LON(500)
      COMMON /STAT/STANS,YBAR,XBAR,CORR,SDYBAR,SDSL,SDY,CORMIN
      COMMON /PARAM/V,X,Y,NUM,STA,ERR,DP,CIX,CIY,XANS,YANS,STN
      COMMON /COORD/LAT,LON,NUMS
      NN=0
      NPLOT=0
      ISYM=2
      PI=3.14159
      CALL INITAL(23)
      CALL PLOT(.5,.5,-3)
C     GO TO 345
C
```

```
C       READ IN RANGE OF ABCISSA FOR PLOTTING
C
        WRITE(5,1000)
 1000   FORMAT(' ENTER MIN. AND MAX. DISTANCE FOR PLOTTING')
        READ(2,*) XMIN,XMAX
        WRITE(5,1021)
 1021   FORMAT(' ENTER MIN. AND MAX. Q OR SLOPE FOR PLOT')
        READ(2,*) YMIN,YMAX
        WRITE(5,1011)
 1011   FORMAT(' DO YOU WANT LSQ LINE FOR COMPARISON?  '$)
        READ(2,1012) ANS
 1012   FORMAT(A1)
        WRITE(5,1023)
 1023   FORMAT(' DO YOU WANT POINTS COLOR-CODED?  '$)
        READ(2,1014) COLANS
        WRITE(5,1030)
 1030   FORMAT(' DO YOU WANT ERROR BARS ON POINTS?  '$)
        READ(2,1012) ERANS

C
C       FIND MAXIMUM SPECTRAL AMPLITUDE TO SCALE PLOT
C
C150    YMAX=0
C       YMIN=0.
C       DO 190 J=1,NUM+1
C       IF(X(J) .LT. XMIN .OR. X(J) .GT. XMAX) GO TO 190
C       IF(Y(J) .LT. YMIN) YMIN=Y(J)
C       IF(Y(J) .GT. YMAX) YMAX=Y(J)
C190    CONTINUE
C       YMAX=YMAX+1.
C
C       PLOT SPECTRAL VALUES
C
        NPT=0.
        DO 300 I=1,NUM
        IF(X(I) .LT. XMIN .OR. X(I) .GT. XMAX) GO TO 300
        NPT=NPT+1
        XPT=(X(I)-XMIN)/(XMAX-XMIN)*5.
        YPT=(Y(I)-YMIN)/(YMAX-YMIN)*5.
        IF(NPT .EQ. 1) CALL PLOT(XPT,YPT,3)
        XI=I
C
C       COLOR CODE AZIMUTH (IF DESIRED)
C

        IF(COLANS .EQ. 'N') GO TO 193
C       IF(DP(I) .EQ. 0.) GO TO 193
C       IF(DP(I) .LE. 5.) ICOL=3
C       IF(DP(I) .GT. 5. .AND. DP(I) .LE. 7.) ICOL=8
C       IF(DP(I) .GT. 7. .AND. DP(I) .LE. 9.) ICOL=4
C       IF(DP(I) .GT. 9. .AND. DP(I) .LE. 11.) ICOL=5
C       IF(DP(I) .GT. 11.) ICOL=2

C       IF(XLAT .GT. SLAT .AND. XLON .LT. SLON) ICOL=3
C       IF(XLAT .LT. SLAT .AND. XLON .LT. SLON) ICOL=8
C       IF(XLAT .LT. SLAT .AND. XLON .GT. SLON) ICOL=4
C       IF(XLAT .GT. SLAT .AND. XLON .GT. SLON) ICOL=5

C       IF(STN(I) .EQ. 'WT ' .OR. 'WT*') ICOL=2
C       IF(STN(I) .EQ. 'SC ') ICOL=3
C       IF(STN(I) .EQ. 'CC ') ICOL=4
C       IF(STN(I) .EQ. 'CM ') ICOL=5
C       IF(STN(I) .EQ. 'DM ') ICOL=6
C       IF(STN(I) .EQ. 'FM ') ICOL=7
C       IF(STN(I) .EQ. 'IC ') ICOL=8

        XLAT=LAT(I)
        XLON=LON(I)

C EAST OF SOCORRO-- BLUE
        IF(XLAT .GT. 34.0 .AND. XLAT .LT. 34.2 .AND.
     +XLON .GT. 106.6 .AND. XLON .LT. 106.9) ICOL=2

C SOCORRO PEAK AREA-- RED
        IF(XLAT .GT. 34.0 .AND. XLAT .LT. 34.1 .AND.
     +XLON .GT. 106.9 .AND. XLON .LT. 107.02) ICOL=3

C LA JENCIA BASIN-- MAGENTA
        IF(XLAT .GT. 33.98 .AND. XLAT .LT. 34.1 .AND.
     +XLON .LT. 107.15 .AND. XLON .GT. 107.02) ICOL=4

C S. MAGDELANA MTNS-- GREEN
        IF(XLAT .GT. 33.9 .AND. XLAT .LT. 33.98 .AND.
     +XLON .GT. 107.00 .AND. XLON .LT. 107.15) ICOL=5

C SOUTH CENTRAL-- CYAN
        IF(XLAT .LT. 34.0 .AND. XLON .GT. 106.9 .AND.
     +XLON .LT. 107.0) ICOL=6

C MID-RIFT NORTH-- YELLOW
        IF(XLAT .GT. 34.1 .AND. XLON .LT. 107.00 .AND.
     +XLON .GT. 106.80) ICOL=7

C CARTHAGE, JORNADA-- BROWN
        IF(XLAT .LT. 33.9 .AND. XLON .LT. 106.9) ICOL=8

        ICOL=1
        CALL NEWPEN(ICOL)

 193    XXX=XPT-.035
        YYY=YPT-.035

C       CALL NUMBER(XXX,YYY,.07,XI,0.,-1)
        IF(I .EQ. (NUMS+1)) ISYM=1
        IF(NUMS .EQ. 0) ISYM=2
        CALL SYMBOL(XPT,YPT,.10,ISYM,0.,-1)

        IF(ERANS .EQ. 'N') GO TO 300
C
C       PLOT OUT ERROR BARS FOR SPECTRAL ESTIMATES IF DESIRED
C
        YYY=YPT
        CALL PLOT(XPT,YYY,3)
        YPT1=YPT+CIY(I)/(YMAX-YMIN)*5.
        YPT2=YPT-CIY(I)/(YMAX-YMIN)*5.

        CALL PLOT(XPT,YPT1,2)
        CALL TICX(XPT,YPT1)

        YYY=YPT
        CALL PLOT(XPT,YYY,3)
        CALL PLOT(XPT,YPT2,2)
        CALL TICX(XPT,YPT2)

        XXX=XPT
        CALL PLOT(XXX,YPT,3)
        XPT1=XPT+CIX(I)/(XMAX-XMIN)*5.
        XPT2=XPT-CIX(I)/(XMAX-XMIN)*5.
```

```
      CALL PLOT(XPT1,YPT,2)
      CALL TICY(XPT1,YPT)

      XXX=XPT
      CALL PLOT(XXX,YPT,3)
      CALL PLOT(XPT2,YPT,2)
      CALL TICY(XPT2,YPT)


C     CALL SYMBOL(XPT,YPT,.14,4,0.,-1)
 300  CONTINUE
      IF(ANS .EQ. 'N') GO TO 315

      DO 305 I=1,100
 305  SDY(I)=0.
      CALL LINRG(X,Y,XMIN,XMAX,NUM,SLOPE,A0)

C
C     PLOT LEAST SQUARES LINE THROUGH DATA
C
C     OPEN(UNIT=25,DEVICE='DSK',FILE='EVENTS1.DAT',ACCESS='APPEND')
C     WRITE(25,*) SLOPE, A0
C     CLOSE(UNIT=25)

      CALL NEWPEN(2)
      N=0

      X0=0.
      Y0=(A0-YMIN)/(YMAX-YMIN)*5.
      X1=5.
      Y1=(A0+SLOPE*XMAX-YMIN)/(YMAX-YMIN)*5.

      CALL PLOT(X0,Y0,3)
      CALL PLOT(X1,Y1,2)
      GO TO 315
C
C     BYPASS PLOTTING OF 2 SIGMA LINES AND HYPERBOLIC ENVELOPES
C
      XINC=(XMAX-XMIN)/100.
      DO 310 F=XMIN,XMAX,XINC
      N=N+1
      AMP=A0+SLOPE*F
      XPT=(F-XMIN)/(XMAX-XMIN)*5.
      YPT=(AMP-YMIN)/(YMAX-YMIN)*5.
      IF(F .EQ. XMIN) CALL PLOT(XPT,YPT,3)
      IPEN=2
      IND=(-1)**(N+1)
      IF(IND .LT. 0) IPEN=2
      CALL PLOT(XPT,YPT,IPEN)
 310  CONTINUE

C
C     PLOT UPPER CONFIDENCE RANGE FOR LSQ LINE (IF DESIRED)
C

      CALL NEWPEN(5)
      N=0

      DO 313 F=XMIN,XMAX,XINC
      N=N+1
      AMP=A0+SLOPE*F
      XPT=(F-XMIN)/(XMAX-XMIN)*5.
      YPT=(AMP+2.*SDY(N)-YMIN)/(YMAX-YMIN)*5.
      IPEN=2
      IF(F .EQ. XMIN) CALL PLOT(XPT,YPT,3)
      CALL PLOT(XPT,YPT,IPEN)
 313  CONTINUE
C
C     PLOT LOWER CONFIDENCE RANGE FOR LSQ LINE (IF DESIRED)
C
      N=0
      DO 314 F=XMIN,XMAX,XINC
      N=N+1
      AMP=A0+SLOPE*F
      XPT=(F-XMIN)/(XMAX-XMIN)*5.
      YPT=(AMP-2.*SDY(N)-YMIN)/(YMAX-YMIN)*5.
      IPEN=2
      IF(F .EQ. XMIN) CALL PLOT(XPT,YPT,3)
      CALL PLOT(XPT,YPT,IPEN)
 314  CONTINUE
 315  CONTINUE
      WRITE(5,1013)
 1013 FORMAT(' DO YOU WANT MODEL PLOTTED?')
      READ(2,1014) MODANS
1014  FORMAT(A1)
      IF(MODANS .EQ. 'N') GO TO 320
C
C     MODEL CRUSTAL Q AND VELOCITY STRUCTURE TO
C     PRODUCE Q/SLOPE VS. DIST/DEPTH CURVE
C
C
C
C     SYMBOLS USED:
C
C             R,DMIN,DMAX     HYPOCENTRAL DISTANCE
C             RMD             DISTANCE TRAVELED IN  LOWER LAYER
C             Q1              Q OF UPPER LAYER
C             Q2              Q OF LOWER LAYER
C             QAVE            APPARENT Q
C             V1              VELOCITY OF UPPER LAYER
C             V2              VELOCITY OF LOWER LAYER
C

C
C     ENTER MODEL PARAMETERS FROM DISK (QMOD.DAT)


      OPEN(UNIT=21,DEVICE='DSK',FILE='QMOD.DAT',ACCESS='SEQIN')
345   READ(21,1001,END=320) DMIN,DMAX,DINC
      READ(21,1001) V1,V2
      READ(21,1001) D,Z
      READ(21,1001) Q1,Q2
1001  FORMAT(3F8.2)

C
C     COMPUTE APPARENT VS. DISTANCE CURVE
C

C
C  RAYTRACE THROUGH NEAR-SURFACE LAYER
C
C
      WRITE(5,999) V1,V2,D,Z,Q1,Q2
999   FORMAT(1H1,5X,'RAYTRAC RESULTS:'//,5X,'V1 =',F7.2,
     +3X,'V2 =',F7.2,3X,'D =',F7.2,3X,'Z =',F7.2,3X,' Q1 =',
     +F7.2,' Q2 =',F7.2//)
      I=0
      DO 50 R=DMIN,DMAX,DINC
```

```
C       DO 5  DEL=DMIN,DMAX,DINC
        I=I+1
C
C  COMPUTE STARTING ANGLE OF INCIDENCE
C
        I20=ATAN(DEL/Z)*57.3
C
C  LOOP OVER POSSIBLE INCIDENT ANGLES TO MATCH DELTAS (DEL AND DELX)
C
C       DO 100 I2=I20,89.,0.01
C       X2=(Z-D)*SIND(I2)/COSD(I2)
C       I1=ASIN(V1*SIND(I2)/V2)*57.3
C       X1=D*SIND(I1)/COSD(I1)
C       DELX=X1+X2
C
C  IF DEL AND DELX AGREE TO WITHIN 0.1, PRINT QAVE
C
C       IF(ABS(DELX-DEL) .LT. 0.1) GO TO 200
C 100   CONTINUE
C 200   R1=X1/SIND(I1)
C       R2=X2/SIND(I2)
C       R=R1+R2
        RMD=R-D
        DEN=D/(V1*Q1)+RMD/(V2*Q2)
        VAPP=R/(D/V1+RMD/V2)
        QAVE=R/(VAPP*DEN)
        IF(R .GT. 8.5) RR=SQRT(R**2-8.5**2)
        IF(R .LE. 8.5) RR=0
c       WRITE(5,*) RR,QAVE
        XX(I)=R
C       YY(I)=3.14159*R/(VAPP*QAVE)
        YY(I)=QAVE
   50   CONTINUE

C
C       SCALE PLOT
C
        DO 350 K=1,I
        XPT=(XX(K)-XMIN)/(XMAX-XMIN)*5.
        YPT=(YY(K)-YMIN)/(YMAX-YMIN)*5.
        IF(K .EQ. 1.) CALL PLOT(XPT,YPT,3)
        CALL PLOT(XPT,YPT,2)
 350    CONTINUE
        GO TO 345
C
C       PLOT AND LABEL AXES
C
 320    CALL NEWPEN(1)
        ERRAO=2.*SDY(1)
        ERRSL=2.*SDSL
        XINC=(XMAX-XMIN)/5.
        YINC=(YMAX-YMIN)/5.
        CALL AXIS(0.,0.,'DISTANCE (KM)',-13,5.,0.,XMIN,XINC,2)
        CALL AXIS(0.,0.,'APPARENT Q',10,5.,90.,YMIN,YINC,2)
C
C       ADD TITLE AND PERTINENT INFORMATION FOR EACH PLOT
C
        XBASE=0.
        XBASE=XBASE+3.
        CALL SYMBOL(XBASE,5.,.14,STANS,0.,3)
        CALL SYMBOL(XBASE,4.8,0.14,'MAX. ERROR IN Q ='
     +,0.,17)
        CALL SYMBOL(XBASE,4.6,0.14,'MIN. CORR. COEFF. =',
     +0.,19)
        XBASE=XBASE+1.90
        CALL NUMBER(XBASE,4.8,.14,ERR,0.,-1)
        XBASE=XBASE+.25
        CALL NUMBER(XBASE,4.6,.14,CORMIN,0.,2)
        CALL SYMBOL(3.1,4.45,.14,2,0.,-1)
        CALL SYMBOL(3.3,4.4,.14,'- Qp',0.,4)
        CALL SYMBOL(3.1,4.25,.14,1,0.,-1)
        CALL SYMBOL(3.3,4.2,.14,'- Qs',0.,4)

220     CALL RSTR(0)
        RETURN
        END

        SUBROUTINE TICX(X,Y)
        X1=X-.0625
        X2=X+.0625
        CALL PLOT(X1,Y,3)
        CALL PLOT(X2,Y,2)
        RETURN
        END

        SUBROUTINE TICY(X,Y)
        Y1=Y-.0625
        Y2=Y+.0625
        CALL PLOT(X,Y1,3)
        CALL PLOT(X,Y2,2)
        RETURN
        END
```

MULT.FOR

```
C
C  MULT.FOR-- MULTIPLE LINEAR REGRESSION ROUTINE TO FIT APPARENT
C             Q VS. DISTANCE CURVES
C
C       MULT. FOR USES APPARENT Q VALUES FOR EVENTS AT DIFFERENT
C       DISTANCES TO COMPUTE THE VALUES OF Q1 AND Q2 FOR A LAYER
C       OVER A HALF-SPACE MODEL.
C
C
C       INPUT FILES: SLOPE.DAT (OUTPUT FROM MODEL.FOR)
C
C       OUTPUT FILES: QMOD.DAT (LEAST SQUARES SOLUTION-- INPUT TO MODEL)
C
C       VARIABLES:
C
C               V1              UPPER LAYER VELOCITY
C               V2              HALF-SPACE VELOCITY
C               D               SLANT DISTANCE THROUGH LVL
C               VAPP            APPARENT VELOCITY FOR RAYPATH
C               QAPP            APPARENT Q FROM MODEL.FOR
C               SLOPE           SPECTRAL SLOPE FROM MODEL.FOR
C               Q1              UPPER LAYER Q
C               Q2              HALF-SPACE Q
C               XTX             X TRANSPOSE TIMES X
C               C               VARIANCE-COVARIANCE MATRIX (XTX INVERSE)
C               XTY             X TRANSPOSE TIMES Y
C               SSR             RESIDUAL SUM OF SQUARES
C               NUM             NUMBER OF DEGREES OF FREEDOM
C
C      THIS ROUTINE USES A BILINEAR REGRESSION SCHEME WHICH ASSUMES
C      Q2>Q1 AND V2>V1. MAXIMUM AND MINIMUM Q1 AND Q2 VALUES ARE
C      COMPUTED FROM THE STANDARD DEVIATION OF THE FIT AND GIVE
C      AN INDICATION OF HOW GOOD THE FIT IS. Q1 OR Q2 VALUES < 0
C      INDICATE THESE PARAMETERS HAVE EXCEEDED INFINITY. MAXIMUM
C      AND MINIMUM Q1 AND Q2 MODELS ARE COMPUTED FOR 2 STD. DEV.
C
C      TO SEE A PLOT OF THE LEAST SQUARES MODEL AND THE MAX. AND
C      MIN. Q MODELS, USE THE OUTPUT FROM THIS ROUTINE WITH ANOTHER
C      RUN OF MODEL.CMD TO REPLOT THE DATA WITH THE LEAST
C      SQUARES APPARENT Q MODEL SUPERIMPOSED.
C
C      FOR MORE INFORMATION, SEE DRAPER AND SMITH (1966),
C      APPLIED REGRESSION ANALYSIS, P. 104-124.
C
C
C
       REAL I1,I2,I20,X(300,3),Y(300),XTX(3,3),C(3,3),WK(300)
       REAL XTY(3,1),B(3),EVAL(300),DELT(300),DEPTH(300),DIST(300)
       V1=1.96
       V2=3.41
       OPEN(UNIT=22,DEVICE='DSK',FILE='SLOPE.DAT')
       OPEN(UNIT=23,DEVICE='DSK',FILE='QMOD.DAT')
       D=.4
       READ(22,1017) STANS
 1017  FORMAT(A3)
       I=0
 10    READ(22,*) QAPP,R,Z,SLOPE
       IF(QAPP .EQ. 99999.) GO TO 99
       I=I+1
       DIST(I)=R
C
C  COMPUTE APPARENT VELOCITY AND FRACTION OF RAYPATH
C  IN EACH Q REGION
C
       RMD=R-D
       VAPP=R/(D/V1+RMD/V2)
C
C  LOAD MATRICES FOR INVERSION
C
       Y(I)=SLOPE
       X(I,1)=D/V1
       X(I,2)=RMD/V2
       GO TO 10
 99    NUM=I
C
C  DO BIVARIATE LINEAR REGRESSION
C
C
C  START BY COMPUTING XTX
C
       DO 201 I=1,2
       DO 201 J=1,2
       SUM=0.
       DO 400 K=1,NUM
 400   SUM=SUM+X(K,I)*X(K,J)
 201   XTX(I,J)=SUM
C      WRITE(5,*) XTX(1,1),XTX(1,2),XTX(2,1),XTX(2,2)
C
C  NOW INVERT XTX TO COMPUTE MATRIX OF COVARIANCES, C
C
       CALL LGINF(XTX,3,2,2,0,C,3,EVAL,WK,IER)
       WRITE(5,2000) IER
 2000  FORMAT(/' ERROR PARAMETER FOR LGINF =',I5)
C      WRITE(5,*) C(1,1),C(1,2),C(2,1),C(2,2)
C
C  COMPUTE XTY
C
       CALL VMULFM(X,Y,NUM,2,1,300,300,XTY,3,IER)
       WRITE(5,2010) IER
 2010  FORMAT(' ERROR PARAMETER FROM VMULFM =',I5)
C
C  COMPUTE SOLUTION VECTOR, B
C
       CALL VMULFF(C,XTY,2,2,1,3,3,B,3,IER)
       WRITE(5,2020) IER
 2020  FORMAT(' ERROR PARAMETER FROM VMULFF =',I5)
C
C  Q1 AND Q2 ARE RECIPROCALS OF B
C
       Q1=1./B(1)
       Q2=1./B(2)
C
C  COMPUTE RESIDUALS FOR SOLUTION AND SUM THEIR SQUARES
C
       SSR=0.
       DO 500 I=1,NUM
       R=DIST(I)
       RMD=R-D
       YNEW=D*B(1)/V1+RMD*B(2)/V2
       SSR=(Y(I)-YNEW)**2+SSR
 500   CONTINUE
C
C  DIVIDE SUM OF SQUARES BY REMAINING DEGREES OF FREEDOM
C
       SSR=SSR/(NUM-2)
C
C  COMPUTE UNCERTAINTIES IN Q1 AND Q2
C
```

```
      SDB1=SQRT(C(1,1)*SSR)
      SDB2=SQRT(C(2,2)*SSR)
      Q1MAX=1./(B(1)-2.*SDB1)
      Q1MIN=1./(B(1)+2.*SDB1)
      Q2MAX=1./(B(2)-2.*SDB2)
      Q2MIN=1./(B(2)+2.*SDB2)
      WRITE(5,2090) D
 2090 FORMAT(' D =',F7.2)
      WRITE(5,3000) Q1,Q1MAX,Q1MIN
      WRITE(5,3002) Q2,Q2MAX,Q2MIN
 3000 FORMAT(1X,' Q1 =',F8.2,5X,' MAX. Q1 =',F8.2,2X,'MIN. Q1 =',F8.2)
 3002 FORMAT(1X,' Q2 =',F8.2,5X,' MAX. Q2 =',F9.2,2X,'MIN. Q2 =',F8.2)
      WRITE(5,3003)
 3003 FORMAT(//' VARIANCE-COVARIANCE MATRIX ='//)
      WRITE(5,3004) ((C(I,J),J=1,2),I=1,2)
 3004 FORMAT(20X,2E12.4)
      WRITE(5,3005) SSR
 3005 FORMAT(/' SSR =',E12.4)
C
C  OUTPUT DATA TO PLOT MODELS
C
      DMIN=1.
      DMAX=45.
      DINC=1.
      VV1=1.96
      VV2=3.41
      ZZ=8.7
  900 CONTINUE

      D=D-ZINC
      WRITE(23,4001) DMIN,DMAX,DINC
      WRITE(23,4001) VV1,VV2
      WRITE(23,4001) D,ZZ
      WRITE(23,4001) Q1,Q2

      WRITE(23,4001) DMIN,DMAX,DINC
      WRITE(23,4001) VV1,VV2
      WRITE(23,4001) D,ZZ
      WRITE(23,4001) Q1MIN,Q2MAX

      WRITE(23,4001) DMIN,DMAX,DINC
      WRITE(23,4001) VV1,VV2
      WRITE(23,4001) D,ZZ
      WRITE(23,4001) Q1MAX,Q2MIN

 4001 FORMAT(3F8.2)
      CLOSE(UNIT=22)
      CLOSE(UNIT=23)
      STOP
      END
```

NES.FOR

```
C
C       NES-- NES CROSS-CORRELATES A PANEL OF DIGITALLY
C       RECORDED WINDOWS AND LINES THEM UP FOR COMPARISON.
C       CORRELATION COEFFICIENTS ARE OBTAINED BY CROSS-
C       CORRELATING A MASTER EVENT WITH A SERIES OF OTHER EVENTS.
C
C       INPUT FILES:  CROS.DAT-- WINDOW AMPLITUDES FOR DISPLAY
C                     MAS.DAT--  MASTER EVENT WINDOW AMPLITUDES
C
C       OUTPUT FILES: OUTPUT.PLT-- RUN WITH GRAFIX
C
C       SUBROUTINES: FTCROS (IMSL)-- A ROUTINE THAT COMPARES
C                    TWO TIME SERIES AND OUTPUTS THEIR CROSS-
C                    CORRELATION AT A NUMBER OF SHIFTS. THIS
C                    ROUTINE DOES NOT ALWAYS SHIFT THE SERIES
C                    ENOUGH TIMES TO OBTAIN THE MAXIMUM CROSS-
C                    CORRELATION, SO THAT SOME PRE-SHIFTING
C                    MAY BE NECESSARY IF SOME EVENTS ARE WAY
C                    OUT OF LINE.
C
C       SYMBOLS USED:
C
C               CMP1,CMP2               EVENT HEADERS
C               IBEGIN, IEND            WINDOW BEGINING AND END
C               AMP, AMP2, AMPL         DIGITAL AMPLITUDES
C               NPTSM                   POINTS IN MASTER EVENT
C               NPTSE                   POINTS IN OTHER EVENTS
C               AMAX                    MAXIMUM AMPLITUDE
C               AMIN                    MINIMUM AMPLITUDE
C               NLAGS                   NUMBER OF SHIFTS
C               XY                      MASTER EVENT ARRAY
C               NC                      PARAMETERS FOR FTCROS
C               NSHFT                   SHIFT NEEDED FOR LINEUP
C               CORR                    MAXIMUM CROSS-CORREALTION
C                                       COEFFICIENT
C               TMAX                    WINDOW LENGTH IN SECONDS
C               AC                      CROSS-CORRELATIONS FOR
C                                       ALL SHIFTS
C
C
C
      INTEGER ANSWER,N2,IVAR,LINE,VALARY(102),RES(2000)
      REAL CMP1*8(3),Y1(2000),Y2(2000),VFNIN*8,CMP2*8(3)
      REAL WIN*8,AMP2(2000),AMPL(2000)
      DIMENSION XY(4000),NC(4),EMUSIG(4),ACV(1,1,2000),AMP(2000)
      REAL AC(1,1,2000)

8     FORMAT(A10)
      OPEN(UNIT=1,DEVICE='DSK',ACCESS='SEQIN',FILE='CROS.DAT')
      OPEN(UNIT=23,DEVICE='DSK',ACCESS='SEQIN',FILE='MAS.DAT')
C
C     READ IN HEADER FOR MASTER EVENT
C
      READ(23,20) CMP2,IBEGIN,IEND
C
C     READ IN AMPLITUDE VALUES FOR MASTER EVENT
C
      DO 31 I=1,1991,10
      READ(23,40) (AMP2(J),J=I,I+9)
      IF(AMP2(I) .EQ. 99999.) GO TO 46
      GO TO 31
46    NPTSM1=I-1
      GO TO 57
31    CONTINUE
57    CALL INITAL(23)
      NPT=1
      WRITE(5,1000)
1000  FORMAT(' NUMBER OF EVENTS?')
      READ(5,*) NUM
C
C     READ IN HEADER FOR EACH EVENT
C
10    READ(1,20,END=220) CMP1,IBEGIN,IEND
20    FORMAT(3A10,2I6)
C
C     READ IN AMPLITUDE VALUES
C
      DO 30 I=1,1991,10
      READ(1,40) (AMP(J),J=I,I+9)
40    FORMAT(10F5.0)
      IF(AMP(I) .EQ. 99999.) GO TO 45
      GO TO 30
45    NPTSE=I-1
      GO TO 56
30    CONTINUE
56    CONTINUE
C
C     CHANGE POLARITY OF EVENT (IF NECESSARY) AND LOAD INTO XY
C
      DO 55 I=1,2000
55    XY(I)=0.
      AMAX=0.
      AMIN=0.
      NPTSM=NPTSM1


      IPTS=IBEG1-IBEGIN
C     NPTSE=IEND1-IBEG1
C     NPTSM=100+NPTSM
CC    NPTSE=100+NPTSE
C
      NPOL=1
C
C     CHANGE POLARITY ON SELECTED EVENTS
C
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '065437 SC ')
     1  NPOL=-1
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '070339 SC ')
     1  NPOL=-1
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '071715 SC ')
     1  NPOL=-1
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '072805 SC ')
     1  NPOL=-1
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '073515 SC ')
     1  NPOL=-1
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '080257 SC ')
     1  NPOL=-1
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '102733 SC ')
     1  NPOL=-1
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '065429 SC ')
     1  NPOL=-1
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '070327 SC ')
     1  NPOL=-1
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '071533 SC ')
     1  NPOL=-1
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '123511 SC ')
     1  NPOL=-1
        DO 100 I=1,NPTSE
```

```
      AMP(I)=FLOAT(NPOL)*AMP(I)
      IF(ABS(AMP(I)) .GT. AMAX) AMAX=ABS(AMP(I))
      IF(AMP(I) .LT. AMIN) AMIN=AMP(I)
      IF(AMP(I) .EQ. AMAX) IFLAG=I
      XY(I+NPTSM)=AMP(I)
100   CONTINUE
      GO TO 65
C
C     SHIFT SOME EVENTS PRIOR TO CROSS-CORRELATION
C
      IF(CMP1(1) .EQ. '30-MAY-77 ' .AND. CMP1(2) .EQ. '070327 SC ')
     1  IFLAG=IFLAG-10
      IF(CMP1(1) .EQ. '02-JUN-77 ' .AND. CMP1(2) .EQ. '065523 SC ')
     1  IFLAG=IFLAG-10
      IF(CMP1(1) .EQ. '02-JUN-77 ' .AND. CMP1(2) .EQ. '114205 SC ')
     1  IFLAG=IFLAG-10
      IF(CMP1(1) .EQ. '02-JUN-77 ' .AND. CMP1(2) .EQ. '120709 SC ')
     1  IFLAG=IFLAG-10

65    CONTINUE


      YINC=10./FLOAT(NUM)
      YMIN=10.-FLOAT(NPT)*YINC+.5
C
C     LOAD MASTER EVENT INTO XY
C
      DO 70 I=1,NPTSM
      XY(I)=AMP2(I)
70    CONTINUE

      NLAGS=NPTSM-1
      NC(1)=NPTSE
      NC(2)=NPTSM
      NC(3)=1
      NC(4)=NLAGS
C     WRITE(5,*) NPTSM,NPTSE,NLAGS

      ISW=5
      IA=1
      IB=1
      IC=1
      ID=1

      CALL FTCROS(XY,NC,ISW,EMUSIG,ACV,IA,IB,AC,IC,ID,IER)

      WRITE(5,1070) IER
1070  FORMAT(' ERROR PARAMETER FROM FTCROS =',I5)
      CORR=0.
      NSHFT=0
C
C     COMPUTE MAXIMUM CROSS-CORRELATION COEFFICIENT AND THE
C     NUMBER OF SHIFTS NECESSARY TO LINE UP THE EVENTS
C
      DO 400 I=1,NLAGS
      IF(AC(1,1,I) .GT. CORR) NSHFT=I-1
      IF(AC(1,1,I) .GT. CORR) CORR=AC(1,1,I)
400   CONTINUE

      DO 405 I=1,NPTSE+50
      AMPL(I)=AMP(I)
      AMP(I)=0.
405   CONTINUE

      DO 410 I=1,NPTSE+50
      AMP(I+50)=AMPL(I)
410   CONTINUE

      KOUNT=0
      IFLAG=-NSHFT
      IFLAG=IFLAG+15
      NPTSE=50
      WRITE(3,*) IFLAG
C
C     SCALE WINDOW AMPLITUDES FOR PLOTTING
C
      DO 300 I=IFLAG,IFLAG+NPTSE
      IF(AMP(50+I) .EQ. 99999) GO TO 700
      AMP(I+50)=(AMP(50+I)-AMIN)*YINC/(AMAX-AMIN)
      X=FLOAT(I-IFLAG)/FLOAT(NPTSE)*2.+1.
      Y=AMP(50+I)+YMIN
      KOUNT=KOUNT+1
C
C     PLOT PANEL OF WINDOWS
C
      IF(KOUNT .EQ. 1) CALL PLOT(X,Y,3)
      CALL PLOT(X,Y,2)
300   CONTINUE

C
C     PLOT AND LABEL AXES
C
      TMIN=0.
      TMAX=NPTSE*.01
      TINC=(TMAX-TMIN)/2.
      IF(NPT .GT. 1) GO TO 700
      CALL AXIS(1.,.3,'SECONDS',-7,2.,0.,TMIN,TINC,2)
C
C     ADD TITLE AND PERTINENT INFORMATION FOR EACH PLOT
C
700   Y=YMIN+YINC/2.
      CALL SYMBOL(3.5,Y,.14,CMP1,0.,16)
      CALL NUMBER(6.5,Y,.14,AMAX,0.,-1)
      CALL NUMBER(7.5,Y,.14,CORR,0.,2)
      NPT=NPT+1
      GO TO 10

220   CALL RSTR(0)
      STOP
      END
```

PWINPK.FOR

```
C
C       PWINPIK-- AUTOMATIC P WINDOW PICKING ROUTINE
C
C       THIS PROGRAM PICKS 32 OR 64-POINT P WINDOWS FROM
C       DIGITAL DATA IN 10I5 FORMAT (STANDARD TP77-1.DAT
C       FORMAT). THE BASIS FOR PICKING A P WINDOW IS A
C       SHARP INCREASE IN THE AMPLITUDE RATIO OVER A SHORT
C       TIME INTERVAL. AMPLITUDES MUST ALSO BE ABOVE THE
C       NOISE LEVEL.
C
C       USUALLY, SOME ADDITIONAL ADJUSTMENT IS NECESSARY
C       TO LINE UP WINDOWS. THIS PROGRAM IS GOOD FOR A
C       ROUGH ESTIMATE OF WINDOW BEGINNINGS AND ENDS.
C
C       SYMBOLS USED:
C
C               EVENT       DESIRED EVENT HEADER
C               CMPVAR      ALL EVENT HEADERS
C               WINDOW      WINDOW BEGINNING AND END
C               VEL         P WAVE VELOCITY
C               SM          S-P INTERVAL
C               FIL1        LOW CUT FILTER
C               FIL2        HIGH CUT FILTER
C               DIST        EVENT DISTANCE
C               Z           EVENT DEPTH
C               Y           DIGITAL AMPLITUDES
C               NSTART      STARTING DIGITAL VALUE TO BE EXAMINED
C               NSTOP       END DIGITAL VALUE
C               IBEG        WINDOW BEGINNING
C               IEND        WINDOW END
C               WLEN        WINDOW LENGTH (NOW SET AT 64)
C
C
C       INPUT FILES==> WINPIK (CONTROL FILE), VFNIN (DIGITAL DATA FILE),
C                      VFNIN1 (EVENT LIST)
C
C       OUTPUT FILES=> VFNOUT (VFNIN1 WITH NEW WINDOWS)
C
C       A LIST OF THE NEW WINDOWS IS ALSO OUTPUT TO THE LPT.
C
C       VFNIN1 CAN BE A STANDARD EVENT LIST WITH BOGUS WINDOWS (SUCH AS
C       FROM AN S WAVE LIST). THIS PROGRAM WILL OUTPUT VFNOUT WITH THE
C       NEW WINDOWS.
C
C
        REAL CMPVAR*8(3),VFNIN*8,VFNOUT*8,EVENT*8(2)
        REAL VFNIN1*8,Y(3000),NY(3000)
        INTEGER WINDOW(2000,10)

        NUM=70
        OPEN(UNIT=11,DEVICE='DSK',FILE='WINPIK.DAT',ACCESS='SEQIN')
        WRITE(5,1005)
 1005   FORMAT(' DESIGNATE DIGITAL DATA INPUT FILE NAME:  '$)
        READ(11,5) VFNIN
        WRITE(5,1006)
 1006   FORMAT(' DESIGNATE EVENT LIST DATA FILE:  '$)
        READ(11,5) VFNIN1
        WRITE(5,1007)
 1007   FORMAT(' DESIGNATE OUTPUT FILE NAME:  '$)
        READ(11,5) VFNOUT
    5   FORMAT(A10)

        OPEN(UNIT=1,DEVICE='DSK',FILE=VFNIN,ACCESS='SEQIN')
        OPEN(UNIT=2,DEVICE='DSK',FILE=VFNOUT,ACCESS='SEQOUT')
        OPEN(UNIT=23,DEVICE='DSK',FILE=VFNIN1,ACCESS='SEQIN')

        WRITE(3,1009)
 1009   FORMAT(10X,'AUTOMATIC WINDOW PICKS:'//)
C
C  READ IN EVENT FROM VFNIN1
C
20      READ(23,40,END=360) EVENT
C       WRITE(5,40) EVENT
40      FORMAT(2A10)
        REWIND 1
C
C  SEARCH THROUGH TAPE.DAT FOR DESIRED EVENT
C
60      READ(1,70,END=100) CMPVAR
70      FORMAT(3A10)

C
C  CHECK HEADER
C
        IF(EVENT(1).EQ.CMPVAR(1).AND.EVENT(2).EQ.CMPVAR(2)) GO TO 140
              GO TO 60
100     WRITE(5,110)
110     FORMAT('+','?EVENT NOT FOUND?')
        WRITE(5,113) EVENT
 113    FORMAT(1X,3A10)
        CLOSE(UNIT=1)
        STOP '*** NO EVENTS PROCESSED ***'


C
C  READ IN DIGITAL AMPLITUDE VALUES
C

 140    CONTINUE
        DO 170 I=1,1991,10
              READ(1,150) (Y(J),J=I,I+9)
        DO 111 J=I,I+9
 111    NY(J)=Y(J)
 141    FORMAT(10I5)
 150            FORMAT(10F5.0)
                IF(Y(I).EQ.99999) GO TO 160
                      GO TO 170
 160            XNUM=I-1
                GO TO 180
 170    CONTINUE

        XNUM=2000
 180    CONTINUE

        READ(23,510) NUMWIN
 510    FORMAT(I3)
        DO 530 J=1,NUMWIN
              READ(23,520) WINDOW(J,1),WINDOW(J,2),WINAN
              READ(23,525) VEL,SMP,FIL1,FIL2,DIST,Z
 525            FORMAT(6F8.2)
 520    FORMAT(I4,1X,I4,1X,F2.0)
 530    CONTINUE


C
C       FIND WINDOW BEGINNING AND END
C
```

```
        YMAX=0.
        NSTART=10
        NSTOP=1000

        DO 200 I=NSTART,NSTOP
        IF(ABS(Y(I)) .GT. 2046.) GO TO 200
        IF(Y(I-1) .EQ. 0.) Y(I-1)=1.
C
C  IF AMPLITUDE RATIO > 2 AND AMPLITUDE > 15, START WINDOW
C
        IF(ABS(Y(I)/Y(I-1)) .GE. 2. .AND. Y(I) .GT. 15.) GO TO 202
 200    CONTINUE
        GO TO 206
C
C  DROP BACK FROM AMPLITUDE CHANGE BY 10 POINTS
C
 202    IBEG=I-10
C
C  WINDOW LENGTH = 64
C
        WLEN=64
        IEND=IBEG+WLEN


C
C       PRINT OUT WINDOWS
C
206     WRITE(3,1000) CMPVAR,IBEG,IEND
 1000   FORMAT(10X,3A10,3X,2I6)
C
C       WRITE OUT WINDOWS TO DISK
C
        WRITE(2,70) CMPVAR
        NWIN=1
        WRITE(2,510) NWIN
        WINAN=2.
        WRITE(2,520) IBEG,IEND,WINAN
        WRITE(2,525) VEL,SMP,FIL1,FIL2,DIST,Z

        GO TO 20

360     CONTINUE

        CLOSE(UNIT=1)
        CLOSE(UNIT=2)

        STOP
        END
```

QERR.FOR

```
C
C  QERR-- QUALITY FACTOR ERROR ANALYSIS
C
C  QERR USES THE STANDARD PARTIAL DERIVATIVE ERROR PROPAGATION
C  FORUMLA AS GIVEN IN VOLK, MAR. 1956, CHEM. ENGINEERING, P. 189.
C
      SUBROUTINE QERR(R,Z,M,SDM,V,SDQ,ERH,ERZ,SDR)
C
C     SYMBOLS USED:
C
C             R       HYPOCENTRAL DISTANCE
C             DEL     EPICENTRAL DISTANCE
C             SDR     STD. DEV. OF DISTANCE
C             SDT     STD. DEV. TIMING ERRORS
C             M       SLOPE OF LEAST-SQUARES LINE
C             SDM     STD. DEV. OF SLOPE (FROM LIN. REG.)
C             V       VELOCITY
C             SDV     STD. DEV. OF VELOCITY (0.02 KM/S)
C             SDQ     STD. DEV. OF Q
C
      REAL M
      PI=3.14159
      DEL=0.
      IF(R .GT. Z) DEL=SQRT(R**2-Z**2)
C
C  COMPUTE STD. DEV. OF R
C
C  1) USE ERH AND ERZ IN STANDARD ERROR ANALYSIS
C
C  2) IF EVENT UNLOCATED, USE S-P FORMULA AND ASSUME DELT = .1 S
C
      SDV=0.06
      SDT=0.10
      VP=5.85
      ERH=ERH/2.
      ERZ=ERZ/2.
      SDR=SQRT(DEL**2*ERH**2+DEPTH**2*ERZ**2)/R
      IF(ERH .EQ. 0. .AND. ERZ .EQ. 0.) SDR=SQRT((R/VP)**2
     1*SDV**2+(1.37*VP)**2*SDT**2)
C     WRITE(5,*) SDR

      TERM1=SDR**2
      TERM2=(R/M*SDM)**2
      TERM3=(R/V*SDV)**2

      SDQ=PI/(M*V) * SQRT(TERM1+TERM2+TERM3)
C     WRITE(5,*) R,M,V,SDR,SDM,SDV,SDQ

      RETURN
      END
```

```
C
C       QFIT-- ESTIMATE Q THROUGH LEAST SQUARES FIT OF LOG SPECTRUM
C
C       QFIT FITS THE SPECTRUM OF A SEISMOGRAM WINDOW AS OUTPUT BY
C       DISPAN. GENERALLY, THE NATURAL LOGARITHM OF THE AMPLITUDE
C       VS. FREQUENCY IS FIT WITH A LEAST SQUARES STRAIGHT LINE.
C       THIS PROGRAM WILL ALSO FIT THE AMPLITUDE VS. FREQUENCY
C       CURVE WITH A POWER LAW IF SO DESIRED. TO SEE THE RAW OR
C       CORRECTED SPECTRUM WITHOUT LOG AMPLITUDES, RUN SERAW.FOR.
C
C       SUBROUTINES USED:
C
C               DECON-- DIVIDES SPECTRUM BY RESPONSE OF FILTERS
C                       THAT MAY HAVE BEEN APPLIED DURING RECORDING
C
C               LINRG-- LINEAR REGRESSION ROUTINE (USES /STAT/)
C
C               SELIN-- USES RESULTS OF LINRG TO COMPUTE Q AND ERRORS
C                       IN Q (2 S.D.) AND PLOTS LEAST SQUARES LINE AND
C                       SPECTRUM
C
C       SYMBOLS USED:
C
C               CMPVAR          EVENT RECORDING PARAMETERS
C               VFNIN           INPUT FILE NAME
C               IBEGIN          BEGINNING OF WINDOW
C               IEND            END OF WINDOW
C               IVAR            VARIANCE OF TIME SERIES
C               XYMV1           MEAN OF TIME SERIES
C               XYMV2           ST. DEV. OF TIME SERIES
C               N2              NUMBER OF SAMPLES IN WINDOW/2
C               FREQ            FREQUENCY
C               AS              AMPLITUDE SPECTRA VALUES
C               FIL1,FIL2       FILTER SETTINGS (FILTER CORNER FREQS)
C               DIST            EVENT DISTANCE (KM)
C               DEPTH           EVENT DEPTH (KM)
C               ERH,ERZ         EPICENTRAL, DEPTH ERRORS
C               VEL             VELOCITY (P- OR S-WAVE)
C
      INTEGER ANSWER,IBEGIN,IEND,N2,IVAR,LINE,VALARY(102)
      REAL CMPVAR*8(3),FREQ(2000),AS(4000),VFNIN*8,XYMV1,
     1XYMV2,YMAX,WIN*8,SDY(2000),EVENT*8(3)
      DIMENSION XY(100,3),IV(3),PAR(3),STAT(6),VCV(6),ITER(2)
      COMMON /STAT/ANS,ABAR,FBAR,CORR,SDYBAR,SDSL,SDY
      COMMON /PAR/DEPTH

      PI=3.14159

      TYPE 5
5     FORMAT('-','DESIGNATE AMPLITUDE SPECTRA INPUT FILE NAME:  '$)
      READ(5,8) VFNIN
8     FORMAT(A10)
      OPEN(UNIT=1,DEVICE='DSK',ACCESS='SEQIN',FILE=VFNIN)
C
C  READ IN EVENT PARAMETERS AND SPECTRAL VALUES
C
      TYPE 6
6     FORMAT(' WHICH EVENT DO YOU WANT TO SEE?  '$)
      READ(5,9) EVENT
9     FORMAT(3A10)
10    READ(1,20,END=220) CMPVAR,IBEGIN,IEND,IVAR,XYMV1,XYMV2,N2,
     1FIL1,FIL2,DIST,VEL,DEPTH,ERH,ERZ
20    FORMAT(3A10/I4,2(1X,I4)/F7.4,1X,F15.4,1X,I4,7F7.2)
C
C  READ AMPLITUDES AND FREQUENCIES FROM DISK
C
      N2P1=N2+1
      DO 30 J=1,N2P1
30    READ(1,40) FREQ(J),AS(J)
40    FORMAT(5X,F5.2,1X,E15.4)
      READ(1,50) LINE
50    FORMAT(A5)
      IF(EVENT(1).EQ.CMPVAR(1).AND.EVENT(2).EQ.CMPVAR(2)) GO TO 55
      GO TO 10
220   STOP '*** EVENT NOT FOUND ***'
C
C  CONVERT VELOCITY TO AMPLITUDE
C
55    DO 190 J=2,N2P1
      AS(J)=AS(J)/(2.*PI*FREQ(J))
190   CONTINUE
C
C  REMOVE FILTER RESPONSE FROM SPECTRUM
C
      IF(FIL1 .EQ. 0.) GO TO 195
      CALL DECON(AS,FIL1,FREQ,N2)
195   IF(FIL2 .EQ. 0.) GO TO 196
      CALL DECON(AS,FIL2,FREQ,N2)

196   WRITE(5,3000)
3000  FORMAT(' DO YOU WANT A LEAST SQUARES Q FIT?')
      READ(5,3010) ANS
3010  FORMAT(A1)
      IF(ANS .EQ. 'N') GO TO 210
C
C  COMPUTE NATURAL LOG OF AMPLITUDES (THIS STEP MUST BE DELETED
C  IF A POWER LAW FIT IS DESIRED)
C
      DO 90 J=2,N2P1
      AS(J)=ALOG(AS(J))
C     WRITE(5,920) AS(J)
920   FORMAT(F7.2)
90    CONTINUE
C
C  REMOVE PERIODICITIES RESULTING FROM REVERBERATION (INOPERATIVE)
C
C     WRITE(5,3012)
3012  FORMAT(' DO YOU WANT REVERBERATIONS REMOVED?  '$)
C     READ(5,3010) RANS
C     IF(RANS .EQ. 'N') GO TO 209
C     CALL CEP(AS,FREQ,N2)

C
C  SPECIFY FREQUENCY RANGE FOR FIT
C
209   WRITE(5,1015)
1015  FORMAT(' ENTER MIN. AND MAX. FREQ. FOR LEAST SQUARES FIT')
      READ(5,*) FMIN,FMAX
      IF(FMIN .EQ. 0.) FMIN=.001
C
C  FIT DECAY OF AMPLITUDE WITH FREQUENCY WITH A POWER LAW (THIS
C  SECTION IS SKIPPED IF A LINEAR FIT TO THE LOG SPECTRUM IS DESIRED)
C
C     DO 100 I=2,N2P1
C     XY(I-1,1)=FREQ(I)
C     XY(I-1,2)=AS(I)
```

QFIT.FOR (CONTINUED)

```
C 100   CONTINUE

C       IXY=100
C       IV(1)=N2
C       IV(2)=0
C       IV(3)=0
C       PAR(1)=0
C       PAR(2)=0
C       PAR(3)=.01
C
C  RSMITZ-- IMSL LEAST SQUARES POWER LAW FITTING ROUTINE
C
C       CALL RSMITZ(XY,IXY,IV,PAR,STAT,VCV,ITER,IER)
C       Q=-PI*DIST/(ALOG(STAT(3))*VEL)
C       AMAX=STAT(2)
C       QSD=-PI*DIST/(ALOG(SQRT(VCV(3)))*VEL)
C       ASD=SQRT(VCV(1))
C       WRITE(5,1007) IER
 1007   FORMAT(' ERROR PARAMETER FROM RSMITZ =',I5)
C       WRITE(5,2000) Q,AMAX
 2000   FORMAT(/10X,' Q =',F7.2,5X,' MAXIMUM AMPLITUDE =',F7.2)
C       WRITE(5,2010) QSD,ASD
 2010   FORMAT(/10X,' STANDARD DEVIATION IN Q =',F7.2,
     1/10X,' STANDARD DEVIATION IN MAXIMUM AMPLITUDE =',F7.2)
       ARES=0.
C       DO 200 I=1,N2
C       ARES=ABS(XY(I,2)-AMAX*XY(I,3))+ARES
C 200   CONTINUE
C       ARES=ARES/N2
C       PER=ARES/AMAX*100.
C       WRITE(5,2020) ARES,PER
C       STOP
C 2020  FORMAT(' AVERAGE RESIDUAL =',F8.4,' OR ', F7.2,' % OF
C     1 MAXIMUM AMPLITUDE')
C
C  DO LINEAR REGRESSION ON LOG SPECTRUM
C
       CALL LINRG(FREQ,AS,FMIN,FMAX,N2P1,SLOPE,A0)
C
C  PLOT SPECTRUM, BEST FIT STRAIGHT LINE, UNCERTAINTIES, CALCULATE Q
C
210    CALL SELIN(CMPVAR,FREQ,AS,VEL,DIST,SLOPE,A0,IBEGIN,IEND,
     1N2,ERH,ERZ)
       STOP
       END
```

QTRAC.FOR

```
C
C  QTRAC-- SELECT TRACES FOR DISPLAY
C
C       QTRAC LIES IN THE SEQUENCE FOR DISPLAYING EVENTS AS SHOWN BELOW.
C       MODEL MUST BE RUN BEFORE USING THIS PROGRAM
C
C       MODEL.FOR==>QAPP.DAT==>QTRAC.FOR==>QTRAC.DAT==>SEWIN.FOR
C
C       A FILE OF DIGITAL WINDOWS MUST ALSO BE AVAILABLE (GENERATED
C       FROM DISPAN OR ADSA AS FILE CROS.DAT.
C
C
C       SYMBOLS USED:
C
C               NUM       EVENT NUMBER IN QAPP.DAT
C               EVENT     EVENT HEADER
C               DIST      HYPOCENTRAL DISTANCE
C               CMPVAR    EVENT HEADER
C               IBEG      WINDOW BEGINNING
C               IEND      WINDOW END
C               YVALUE    DIGITAL AMPLITUDE VALUES
C               NY        DIGITAL AMPLITUDES TO BE DISPLAYED
C
C       INPUT FILE==> PTRAC OR STRAC.DAT (DIGITAL WINDOWS)
C                     QAPP.DAT (LIST OF EVENTS-- FROM MODEL.FOR)
C
C       OUTPUT FILE=> QTRAC-- DIGITAL WINDOWS LISTED IN QAPP.DAT
C
C
      INTEGER NY(2000)
      REAL CMPVAR*8(3),EVENT*8(3),YVALUE(2048)

      OPEN(UNIT=20,DEVICE='DSK',FILE='QAPP.DAT')
      OPEN(UNIT=21,DEVICE='DSK',FILE='TERATRAC.DAT')
      OPEN(UNIT=22,DEVICE='DSK',FILE='QTRAC.DAT')

 10   READ(20,1000,END=399) NUM,EVENT,DIST
 1000 FORMAT(I4,3X,3A10,53X,F10.7)
      REWIND 21
 20   READ(21,1001,END=100) CMPVAR,IBEG,IEND
 1001 FORMAT(3A10,2A6,F7.2)

C
C  CHECK HEADER
C
      IF(EVENT(1).EQ.CMPVAR(1).AND.EVENT(2).EQ.CMPVAR(2)) GO TO 140
            GO TO 20
100   WRITE(5,110)
110   FORMAT('+','?EVENT NOT FOUND?')
      WRITE(5,113) EVENT
 113  FORMAT(1X,3A10)
      CLOSE(UNIT=20)
      STOP '*** NO EVENTS PROCESSED ***'
C
C  READ IN DIGITAL AMPLITUDE VALUES
C
 140  CONTINUE
      DO 170 I=1,1991,10
            READ(21,150) (YVALUE(J),J=I,I+9)
      DO 111 J=I,I+9
 111  NY(J)=YVALUE(J)
 141  FORMAT(10I5)
150         FORMAT(10F5.0)
            IF(YVALUE(I).EQ.99999) GO TO 160
                  GO TO 170
160         INUM=I-1
            GO TO 160
170   CONTINUE

C
C  OUTPUT WINDOW VALUES TO QTRAC.DAT
C
 180  CONTINUE
      WRITE(22,1001) CMPVAR,IBEG,IEND,DIST
      DO 663 I=1,INUM,10
      WRITE(22,141) (NY(K),K=I,I+9)
 663  CONTINUE
      WRITE(22,702)
 702  FORMAT(50('9'))
      GO TO 10
 399  STOP
      END
```

RDTAP.FOR

```
C
C  RDTAP-- THIS PROGRAM READS TAPES WRITTEN USING THE
C          OPERATING SYSTEM (ANYTHING BESIDES DUMPER).
C          IT WAS WRITTEN BY DCB IN 1980 WHEN RECORD
C          LENGTHS WERE DIFFERENT. IN ITS CURRENT STATE,
C          RDTAP WILL READ HEADERS FROM ABOUT 11 FILES BEFORE
C          BOMBING OUT. SINCE IT READS 11 FILES FURTHER
C          INTO THE TAPE WITH EACH RUN, IT CAN BE RUN AGAIN
C          AND AGAIN UNTIL THE END OF THE TAPE IS REACHED.
C          HEADERS SCANNED WILL BE WRITTEN INTO DOCTAP.DOC.
C
C          THE COMPUTER SYSTEM CONSULTANTS DID NOT KNOW HOW
C          THIS PROGRAM COULD BE FIXED-- 7/82 (PJC).
C
      INTEGER BUFFER(132)
      OPEN(UNIT=20,DEVICE='GPRC01',ACCESS='SEQIN')
      OPEN(UNIT=21,DEVICE='DSK',FILE='DOCTAP.DOC',ACCESS='APPEND')
10    READ(20,2 ,END=40) BUFFER
20    FORMAT(132A1)
      IF(BUFFER(1) .EQ. '=') WRITE(21,20) BUFFER
      SKIP FILE 20
      GO TO 10
40    STOP
      END
```

READ.FOR

```
C-------------------------------------------------------
C   READ-- READS HEADERS OF EVENTS IN DIGITAL DATA FILES
C
C          READ IS USEFUL WHEN A LISTING OF EVENTS IN
C          A DIGITAL DATA EVENT FILE IS NEEDED BUT
C          LOOKING THROUGH THE FILE IS INPRACTICAL.
C-------------------------------------------------------

       REAL A*8(100)
       N=1
       IOUT=5
       OPEN(UNIT=22,DEVICE='DSK',FILE='TP84.DAT')
 10    READ(22,1000,END=360) (A(I),I=1,10)
       IF(N .EQ. 1) WRITE(IOUT,1001) (A(I),I=1,10)
       IF(A(1) .EQ. '99999') NUM=N+1
 1000  FORMAT(10A5)
       IF(NUM .EQ. N) WRITE(IOUT,1001) (A(I),I=1,10)
 1001  FORMAT(1X,10A5)
       N=N+1
       GO TO 10
 360   CLOSE(UNIT=22,DEVICE='DSK')
       STOP
       END
```

REFOR.FOR

```
C-----------------------------------------------------------------
C   REFOR-- REFORMATS DIGITAL DATA TRANSFERRED FROM APPLE
C           ===> FOR INPUT TO DISPAN
C
C           SINCE THE DR100S USUALLY SCRAMBLE HEADERS IT
C           IS NECESSARY TO REENTER HEADER INFORMATION AT
C           THIS STAGE. THE HEADERS SHOULD BE DIRECTLY TAKEN
C           FROM THE EVENT TRANSFER SHEETS.
C
C           INPUT FILE==> EVENT.DAT (RAW TRANSFERRED DATA)
C
C           OUTPUT FILE=> TAPE.DAT (INPUT FOR CLEAN, DISPAN, ETC.)
C
C           EVENT TO BE REFORMATTED MUST BE IN
C           EVENT.DAT. DATE,TIME,GAIN,FILTER SETTINGS,
C           SEISMOMETER NUMBER SHOULD BE KNOWN. IF SOME
C           OF THIS INFORMATION IS NOT AVAILABLE, ENTER
C           BLANKS OR ?????...
C-----------------------------------------------------------------
      INTEGER NUM(10)
      REAL*8 DATE,GAIN,TIME,SEIS
      OPEN(UNIT=22,DEVICE='DSK',FILE='EVENT.DAT')
      OPEN(UNIT=23,DEVICE='DSK',FILE='TAPE.DAT',ACCESS='APPEND')
      READ(22,1000) A1,STA
 1000 FORMAT(A9,A2)
      READ(22,1001) A1,HR1,HR2,MIN,SEC
 1001 FORMAT(A8,2A1,1X,A2,1X,A2)
      WRITE(5,1005)
 1005 FORMAT(' ENTER DATE: DAY-MONTH-YEAR')
      READ(5,1007) DATE
 1007 FORMAT(A10)
      WRITE(5,1025)
 1025 FORMAT(' ENTER EVENT TIME AND STATION E.G. 012523 WT')
      READ(5,1007) TIME
      WRITE(5,1003)
 1003 FORMAT(' ENTER GAIN AND FILTER SETTINGS E.G. 72DB 00 00')
      READ(5,1004) GAIN
 1004 FORMAT(A10)
      WRITE(5,1008)
 1008 FORMAT(' ENTER SEISMOMETER NUMBER')
      READ(5,1004) SEIS
      IF(HR1 .EQ. ' ') HR1='0'
      WRITE(23,1010) DATE,TIME,GAIN,SEIS
 1010 FORMAT(A9,1X,A10,A10,1X,A10)
  50  READ(22,1020,END=360) (NUM(I),I=1,10)
 1020 FORMAT(10I1)
      WRITE(23,1030) (NUM(I),I=1,10)
 1030 FORMAT(10I5)
      GO TO 50
  360 WRITE(23,1050)
 1050 FORMAT(50('9'))
      STOP
      END
```

RES.FOR

```
C
C  RES-- RESPONSE CURVE GENERATOR-- PROGRAM USED TO COMPUTE
C        THE MINIMUM MAXIMUM AMPLITUDES THAT COULD BE
C        DIGITALLY RECORDED. THIS PROGRAM WAS USED TO
C        COMPUTE THE "DIGITAL WORST CASE" CURVE DISCUSSED
C        IN APPENDIX 1 OF PJC'S DISSERTATION.
C
C
C       SYMBOLS USED:
C
C                AMAX          RESPONSE CURVE FOR FILTER
C                FREQ          FREQUENCY (HZ)
C                AMIN          DIGITAL "WORST CASE" AMPLITUDE
C                AMP           AVERAGE AMPLITUDE
C
       REAL AMP(100),AMAX(100),AMIN(100),FREQ(100)

       DATA (AMAX(I),I=1,50)/ .0413,.121,.217,.344,.500,.570,.650,.690,
     +.780,.833,.840,.870,.890,.905,.917,.937,.952,.962,.967,.972,.976,
     +.980,.984,.988,.991,.994,.996,.998,.999,1.000,.999,.998,.995,.990,
     +.984,.976,.972,.969,.966,.963,.959,.954,.948,.941,.933,.924,.914,
     +.903,.891,.888/

       PI=3.14159

       DO 100 I=1,50
 100   FREQ(I)=FLOAT(I)
C
C  LAG BEHIND WAVE PEAK 1/2 SAMPLING INTERVAL
C
       DO 300 I=1,50
       T=1./(4.*FREQ(I))-0.005
       AMIN(I)=AMAX(I)*SIN(2.*PI*FREQ(I)*T)
       AMP(I)=(AMAX(I)+AMIN(I))/2.
 300   CONTINUE

       DO 400 I=1,50
 400   IF(AMP(I) .GT. AMPMAX) AMPMAX=AMP(I)
C
C   WRITE OUT CORRECTED AMPLITUDES (THESE CORRESPOND
C   TO THE AVERAGE OF THE DIGITAL WORST CASE AND THE
C   ANALOG AMPLITUDES.
C
       DO 500 I=1,50
C      WRITE(5,*) FREQ(I),AMP(I)
       AMP(I)=AMP(I)/AMPMAX
       WRITE(5,*) FREQ(I),AMP(I)
 500   CONTINUE

       STOP
       END
```

RIPPL.FOR

```
C
C       RIPPL-- FILTER RIPPLE FROM LOG AMPL. SPECTRUM AND
C               REFIT TO OBTAIN BETTER Q ESTIMATES
C
C       IT IS SUGGESTED THAT THE PERIOD OF THE RIPPLE BE
C       IDENTIFIED FROM QFIT PLOTS OR FROM THE CEPSTRUM.
C       THIS ROUTINE USES A RELATIVELY NARROW BANDPASS
C       DIGITAL FILTER TO REMOVE THE RIPPLE FROM THE SPECTRUM.
C
C
C       SYMBOLS USED:
C
C               CMPVAR          EVENT RECORDING PARAMETERS
C               VFNIN           INPUT FILE NAME
C               IBEGIN          BEGINNING OF WINDOW
C               IEND            END OF WINDOW
C               IVAR            VARIANCE OF TIME SERIES
C               XYMV1           MEAN OF TIME SERIES
C               XYMV2           ST. DEV. OF TIME SERIES
C               N2              NUMBER OF SAMPLES IN WINDOW/2
C               FREQ            FREQUENCY
C               AS              AMPLITUDE SPECTRA VALUES
C
C       SUBROUTINES USED:
C
C               BPFILT (BANDPASS/REJECTION FILTER ROUTINE)
C
C               LINRG (LEAST SQUARES LINE FIT TO SPECTRUM)
C
C               SELIN (PLOTS OUT LOGE SPECTRUM)
C
        INTEGER ANSWER,IBEGIN,IEND,N2,IVAR,LINE
        INTEGER IAMP(500)
        REAL CMPVAR*8(3),FREQ(2000),AS(4000),VFNIN*8,XYMV1,
       1XYMV2,YMAX,WIN*8,SDY(2000),EVENT*8(3),CMP*8(2)
        DIMENSION XY(100,3),IV(3),PAR(3),STAT(6),VCV(6),ITER(2)
        COMMON /STAT/ANS,ABAR,FBAR,CORR,SDYBAR,SDSL,SDY
C
        PI=3.14159
C
        TYPE 5
5       FORMAT('-','DESIGNATE AMPLITUDE SPECTRA INPUT FILE NAME:  '$)
        READ(5,8) VFNIN
8       FORMAT(A10)
        OPEN(UNIT=1,DEVICE='DSK',ACCESS='SEQIN',FILE=VFNIN)
        OPEN(UNIT=2,DEVICE='DSK',ACCESS='APPEND',FILE='DTREND.DAT')
        TYPE 7
7       FORMAT(' DESIGNATE DIGITAL EVENT HEADER:  '$)
        READ(5,1017) CMP
1017    FORMAT(2A10)
C
C       SPECIFY FREQUENCY RANGE FOR FIT
C
        WRITE(5,1015)
1015    FORMAT(' ENTER MIN. AND MAX. FREQ. FOR LEAST SQUARES FIT')
        READ(5,*) FMIN,FMAX
C
C       READ IN EVENT PARAMETERS AND SPECTRAL VALUES
C
10      READ(1,20,END=399) CMPVAR,IBEGIN,IEND,IVAR,XYMV1,XYMV2,N2,
     1FIL1,FIL2,DIST,VS,DEPTH,ERH,ERZ
20      FORMAT(3A10/I4,2(1X,I4)/F7.4,1X,F15.4,1X,I4,7F7.2)
C
C       READ AMPLITUDES AND FREQUENCIES FROM DISK
C
        N2P1=N2+1
        DO 30 J=1,N2P1
30      READ(1,40) FREQ(J),AS(J)
40      FORMAT(5X,F5.2,1X,E15.4)
        READ(1,50) LINE
50      FORMAT(A5)
        IF(CMPVAR(1) .EQ. CMP(1) .AND. CMPVAR(2) .EQ. CMP(2)) GO TO 55
        GO TO 10
399     STOP ' EVENT NOT FOUND'
C
C       DECONVOLVE EVENT SPECTRUM
C
55      DO 190 J=2,N2P1
        AS(J)=AS(J)/(2.*PI*FREQ(J))
190     CONTINUE
        IF(FIL1 .EQ. 0.) GO TO 195
        CALL DECON(AS,FIL1,FREQ,N2)
195     IF(FIL2 .EQ. 0.) GO TO 196
        CALL DECON(AS,FIL2,FREQ,N2)
3010    FORMAT(A1)
C
196     DO 90 J=1,N2P1
        AS(J)=ALOG(AS(J))
C       WRITE(5,920) AS(J)
920     FORMAT(F7.2)
90      CONTINUE
C
C       FIND LEAST SQUARE SOLUTION FOR FIT OF LOGE AMPLITUDES
C
        CALL LINRG(FREQ,AS,FMIN,FMAX,N2P1,SLOPE,A0)
C
C       DETREND SPECTRUM USING LSQ LINE AS AVERAGE TREND
C
C       WRITE(5,*) SLOPE,A0
        DO 300 J=1,N2P1
        AS(J)=AS(J)-SLOPE*FREQ(J)-A0
        AS(J)=AS(J)*100.
300     CONTINUE
C
C       FILTER DETRENDED SPECTRUM
C
        CALL BPFILT(AS,FREQ,N2P1)
C
C       FIT FILTERED SPECTRUM
C
C
C       PUT TREND BACK INTO SPECTRUM
C
        DO 310 J=1,N2P1
        AS(J)=AS(J)+SLOPE*FREQ(J)+A0
310     CONTINUE
C
        WRITE(5,3000)
3000    FORMAT(' DO YOU WANT A LEAST SQUARES Q FIT (FILTERED SPECTRUM)?')
        READ(5,3010) ANS
        IF(ANS .EQ. 'N') GO TO 210
C
C       SPECIFY FREQUENCY RANGE FOR NEW FIT
C
        WRITE(5,1015)
        READ(5,*) FMIN,FMAX
```

RIPPL.FOR (CONTINUED)

```
C
C       DO LINEAR REGRESSION TO FIND NEW Q
C
        CALL LINRG(FREQ,AS,FMIN,FMAX,N2P1,SLOPE,A0)
210     CALL SELIN(CMPVAR,FREQ,AS,VS,DIST,SLOPE,A0,IBEGIN,IEND,
     1N2,ERH,ERZ)
220     STOP
        END
```

SECEP.FOR

```
C
C       PROGRAM SECEP-- CEPSTRUM PLOT ROUTINE
C
C       THIS PROGRAM WILL PLOT A CEPSTRUM IN DISPAN OUTPUT FORMAT.
C       PEAKS IN THE CEPSTRUM CORRESPOND TO PERIODICITIES IN THE
C       SPECTRUM WHICH MAY BE DUE TO DELAY TIMES FOR REVERBERATIONS
C       AND THEIR INTEGRAL MULTIPLES. RANNING SMOOTHING (3-POINT
C       WEIGHTED MOVING AVERAGE) MAY BE EMPLOYED HERE TO SEE THE
C       PEAKS MORE CLEARLY. THE PROCESSING SEQUENCE NECESSARY TO
C       USE THIS PROGRAM IS AS FOLLOWS:
C
C       (TIME SERIES)>>DISPAN>>(SPECTRUM)>>DTREND>>DISPAN>>(CEPSTRUM)>>SECEP
C
C       DISPAN-- DIGITAL SPECTRAL ANALYSIS PROGRAM
C       DTREND-- DETRENDS THE LOG SPECTRUM
C
C       SYMBOLS USED:
C
C               CMPVAR          EVENT RECORDING PARAMETERS
C               VFNIN           INPUT FILE NAME
C               IBEGIN          BEGINNING OF SPECTRAL WINDOW
C               IEND            END OF SPECTRAL WINDOW
C               IVAR            VARIANCE OF CEPSTRUM
C               XYMV1           MEAN OF CEPSTRUM
C               XYMV2           ST. DEV. OF CEPSTRUM
C               N2              NUMBER OF SAMPLES IN SPECTRAL WINDOW/2
C               T               TIME
C               AS              GAMNITUDE VALUES
C               YMAX            MAX. GAMN. VALUE
C               YMIN            MIN. GAMN. VALUE
C               X,Y             SCREEN COORDINATES
C               DIST            EVENT DISTANCE
C               VS              VELOCITY
C
      INTEGER ANSWER,IBEGIN,IEND,N2,IVAR,LINE,VALARY(102)
      REAL CMPVAR*8(3),T(2000),AS(4000),VFNIN*8,XYMV1,
     1XYMV2,YMAX,WIN*8,EVENT*8(3)
C
      NPLOT=0
      PI=3.14159
C
C     READ IN DATA FROM DATA FILE
C
      TYPE 5
5     FORMAT('-','DESIGNATE INPUT FILE NAME CONTAINING CEPSTRAL ESTIMATES:
     +  '$)
      READ(5,8) VFNIN
8     FORMAT(A10)
      OPEN(UNIT=1,DEVICE='DSK',ACCESS='SEQIN',FILE=VFNIN)
C
C     INITIALIZE TERMINAL FOR PLOTTING
C
      CALL INITAL(23)
C
C     RESET ORIGIN TO (.5",.5")
C
      CALL PLOT(.5,.5,-3)
C
C     READ IN EVENT PARAMETERS AND SPECTRAL VALUES
C
      TYPE 6
6     FORMAT(' WHICH EVENT DO YOU WANT TO SEE?  '$)
      READ(5,9) EVENT
9     FORMAT(3A10)
      TYPE 7
7     FORMAT(' FREQUENCY INCREMENT?  '$)
      READ(5,*) FINC
      TMAX=1./(2.*FINC)
10    READ(1,20,END=51) CMPVAR,IBEGIN,IEND,IVAR,XYMV1,XYMV2,N2,
     1FIL1,FIL2,DIST,VS
      N2P1=N2+1
      TINC=(TMAX-TMIN)/N2
20    FORMAT(3A10/I4,2(1X,I6)/F7.4,1X,F15.4,1X,I4,4F7.2)
C
C     READ GAMNITUDE AND COMPUTE TIMES FOR EACH POINT
C
      DO 30 J=1,N2P1
      READ(1,40) T(J),AS(J)
      T(J)=TINC*(J-1)
30    CONTINUE
40    FORMAT(5X,F5.2,1X,E15.4)
      READ(1,50) LINE
50    FORMAT(A5)
      IF(EVENT(1).EQ.CMPVAR(1).AND.EVENT(2).EQ.CMPVAR(2)) GO TO 55
      GO TO 10
51    STOP '*** EVENT NOT FOUND ***'
C55   WRITE(5,1000)
1000  FORMAT(' ENTER MIN. AND MAX. TIME FOR PLOT')
C     READ(5,*) TMIN, TMAX
55    WRITE(5,2010)
2010  FORMAT(' DO YOU WANT HANNING SMOOTHING? '$)
      READ(5,2011) ANS
2011  FORMAT(A1)
      IF (ANS .EQ. 'N') GO TO 56
C     CALL HANSM(AS,N2P1)
C
C     FIND MAXIMUM SPECTRAL AMPLITUDE TO SCALE PLOT
C
56    WRITE(5,1001)
1001  FORMAT(' ENTER WINDOW BEGINNING AND END')
      READ(5,*) IBEGIN,IEND
      YMAX=0.
      YMIN=0.
      DO 190 J=1,N2P1
      IF(T(J) .LT. TMIN .OR. T(J) .GT. TMAX) GO TO 190
C     IF(AS(J) .LT. YMIN) YMIN=AS(J)
      IF(AS(J) .GT. YMAX) YMAX=AS(J)
190   CONTINUE
C
C     PLOT SPECTRAL VALUES
C
      NPT=0.
      TMIN=0.
      DO 300 I=1,N2P1
      IF(T(I) .LT. TMIN .OR. T(I) .GT. TMAX) GO TO 300
      NPT=NPT+1
      X=(T(I)-TMIN)/(TMAX-TMIN)*5.
      Y=(AS(I)-YMIN)/(YMAX-YMIN)*5.
      IF(NPT .EQ. 1) CALL PLOT(X,Y,1)
      CALL PLOT(X,Y,2)
300   CONTINUE
C
C     PLOT AND LABEL AXES
C
      WRITE(5,*) N2P1
      TINC=(TMAX-TMIN)/5.
      YINC=(YMAX-YMIN)/5.
      XBASE=NPLOT*20.
```

SECEP.FOR (CONTINUED)

```
      CALL AXIS(XBASE,0.,'QUEFRENCY (S)',-13,5.,0.,TMIN,TINC,2)
      CALL AXIS(XBASE,0.,'GAMNITUDE',9,5.,90.,YMIN,YINC,2)
C
C     PRINT TITLE
C
      XBASE=XBASE+3.
      CALL SYMBOL(XBASE,5.,.14,CMPVAR,0.,19)
      WIN='WINDOW=>'
      CALL SYMBOL(XBASE,4.8,0.14,WIN,0.,8)
C     CALL SYMBOL(XBASE,4.6,0.14,'MEAN OF SERIES = ',0.,17)
      BEGIN=FLOAT(IBEGIN)
      XEND=FLOAT(IEND)
      XBASE=XBASE+1.00
      CALL NUMBER(XBASE,4.8,.14,BEGIN,0.,-1)
      COLON=':'
      XBASE=XBASE+.50
      CALL SYMBOL(XBASE,4.8,.14,COLON,0.,1)
      XBASE=XBASE+.25
C     CALL NUMBER(XBASE,4.8,.14,XEND,0.,-1)
      CALL NUMBER(XBASE,4.6,0.14,XYMV1,0.,2)

      STOP
      END
```

SECORR.FOR

```
C
C       SECORR-- DISPLAY SELECTED WINDOWS EN MASSE AND MOVE THEM
C                AROUND FOR OPTIMUM DISPLAY
C
C       SECORR WILL DISPLAY UP TO 25 SEISMOGRAM WINDOWS
C       FOR 1 STATION AS A VERTICAL PANEL. THIS PROGRAM
C       IS IDENTICAL TO SEWIN EXCEPT THAT WINDOWS CAN
C       BE SHIFTED TO LINE UP ARRIVALS OF P AND S WAVES.
C       THE SHIFTS ARE THEN RECORDED AND CORRECTIONS ARE
C       MADE TO THE APPROPIATE WINDOW LIST FILES (SUCH
C       AS SWIN77-1.DAT).
C
C            ALL THE WINDOWS ARE NORMALIZED AND SCALED
C       TO FIT ON A PAGE. IF MORE THAN 25 WINDOWS ARE TO
C       BE DISPLAYED, SEWIN GENERATES A NEW PAGE. ON THE
C       TEKTRONIX TERMINAL THIS WILL BE INDICATED BY THE
C       BOTTOM TRACE BEING REPEATED, DURING WHICH TIME IT
C       IS RECOMMENDED A CTL/S BE TYPED TO HOLD THE PAGE SO
C       THAT A HARD COPY MAY BE MADE.
C
C       TO USE THIS PROGRAM, MUST FIRST RUN MODEL.FOR, QTRAC.FOR
C       AND HAVE QAPP.DAT AND STRAC.DAT OR PTRAC.DAT AS DATA FILES
C
C
C       ==> WHEN PLOTTING USE OFFSET = 0,-0.5, SCALE FAC. = 2,2
C
C       SYMBOLS USED:
C
C                 VFNIN         INPUT FILE NAME
C                 STANS         STATION FOR WINDOWS
C                 NUM           NUMBER OF WINDOWS
C                 CMP1          EVENT HEADERS
C                 NPTS1         NUMBER OF POINTS IN WINDOW
C                 AMAX,AMIN     MAX. AND MIN. AMPL. IN EACH WINDOW
C                 TMAX          DURATION OF EACH WINDOW (SECONDS)
C
C       THIS PROGRAM IS IDEAL FOR LINING UP WINDOWS FOR SPECTRAL
C       ANALYSIS AND FOR NOTING SUBTLE CHANGES IN WAVEFORM BETWEEN EVENTS
C
      INTEGER ANSWER,N2,IVAR,LINE,VALARY(102),RES(2000)
      REAL CMP1*8(3),Y1(2000),Y2(2000),VFNIN*8,WIN*8
      REAL*8 C1,C2,C3,C4,STA,STANS
      DIMENSION XY(4000),AMP(2000),AMP1(2000)

      WRITE(5,7)
7     FORMAT(' ENTER INPUT FILE NAME:  '$)
      READ(5,8) VFNIN
8     FORMAT(A10)
      OPEN(UNIT=1,DEVICE='DSK',ACCESS='SEQIN',FILE=VFNIN)

      WRITE(5,1001)
1001  FORMAT(' ENTER STATION DESIRED:'$)
      READ(5,1003) STANS
1003  FORMAT(A3)

C
      CALL INITAL(23)
      NPT=1
      WRITE(5,1000)
1000  FORMAT(' NUMBER OF EVENTS?')
      READ(5,*) NUM
10    READ(1,19,END=220) CMP1
19    FORMAT(3A10)
      BACKSPACE 1
      READ(1,20,END=220) C1,C2,STA,C3,IBEGIN,IEND
20    FORMAT(A10,A7,A3,A10,2I6)
      DO 30 I=1,1991,10
      READ(1,40) (AMP(J),J=I,I+9)
40    FORMAT(10F5.0)
      IF(AMP(I) .EQ. 99999.) GO TO 45
      GO TO 30
45    NPTS1=I-1
      GO TO 56
30    CONTINUE
56    CONTINUE

      IF(STA .NE. STANS) GO TO 10
      AMAX=0.
      AMIN=0.

C
C     FIND MAX AND MIN AMPLITUDE FOR EACH WINDOW
C


      DO 100 I=1,NPTS1
      IF(AMP(I) .GT. AMAX) AMAX=AMP(I)
      IF(AMP(I) .LT. AMIN) AMIN=AMP(I)
100   CONTINUE

C
C     SCALE FOR PLOTTING
C
      IF(NUM .GT. 25) NUM=25

      YINC=10./FLOAT(NUM)
      YMIN=10.-FLOAT(NPT)*YINC+.5
C
C     PLOT INDIVIDUAL SEISMOGRAMS
C
      KOUNT=0
      NPTS1=64
      ISTART=0
C
C  ADJUST CERTAIN WINDOWS TO FIND APPROPIATE CORRECTION
C  TO BE APPLIED TO WINDOW FILES
C
C  STATION DM
C
C     IF(CMP1(1) .EQ. '14-JUL-77 ') ISTART=-10
C
C  STATION SC
C
      IF(CMP1(1) .EQ. '04-OCT-77 ') ISTART=4
      IF(CMP1(1) .EQ. '16-JUN-81 ') ISTART=-11
      IF(CMP1(1) .EQ. '17-JUN-81 ') ISTART=-11
      IF(CMP1(2) .EQ. '072805 SC ') ISTART=4
      IF(CMP1(2) .EQ. '102733 SC ') ISTART=3
      IF(CMP1(2) .EQ. '070327 SC ') ISTART=2
      IF(CMP1(2) .EQ. '080257 SC ') ISTART=1
      IF(CMP1(2) .EQ. '123511 SC ') ISTART=2
      IF(CMP1(2) .EQ. '071533 SC ') ISTART=3
      IF(CMP1(2) .EQ. '234419 SC ') ISTART=2
C
C WT
C
C     IF(CMP1(2) .EQ. '103301 WT ') ISTART=10
```

```
C       IF(CMP1(2) .EQ. '144239 WT ') ISTART=7
C       IF(CMP1(2) .EQ. '051410 WT ') ISTART=3
C       IF(CMP1(2) .EQ. '192432 WT ') ISTART=20
C       IF(CMP1(2) .EQ. '061207 WT ') ISTART=5
C       IF(CMP1(2) .EQ. '010127 WT ') ISTART=5
C       IF(CMP1(2) .EQ. '135852 WT ') ISTART=6
C       IF(CMP1(2) .EQ. '055229 WT ') ISTART=6
C       IF(CMP1(2) .EQ. '124242 WT ') ISTART=6
C       IF(CMP1(2) .EQ. '024240 WT ') ISTART=5
C       IF(CMP1(2) .EQ. '004155 WT ') ISTART=5

        DO 300 I=1,NPTS1
        IF((I+ISTART) .GT. 0) AMP1(I)=AMP(I+ISTART)
        IF((I+ISTART) .LE. 0) AMP1(I)=0.
        IF(AMP(I) .EQ. 99999) GO TO 700
        AMP1(I)=(AMP1(I)-AMIN)*YINC/(AMAX-AMIN)
        X=FLOAT(I)/FLOAT(NPTS1)*2.+1.
        Y=AMP1(I)+YMIN
        KOUNT=KOUNT+1
        IF(KOUNT .EQ. 1) CALL PLOT(X,Y,3)
        CALL PLOT(X,Y,2)
  300   CONTINUE

C
C       PLOT AND LABEL AXES
C

        TMIN=0.
        TMAX=NPTS1*.01
        TINC=(TMAX-TMIN)/2.
C       CALL AXIS(XBASE,0.,'            ',10,5.,0.,LMIN,LINC,2)
        IF(NPT .GT. 1) GO TO 700
        CALL AXIS(1.,.3,'SECONDS',-7,2.,0.,TMIN,TINC,2)
C
C       ADD TITLE AND PERTINENT INFORMATION FOR EACH PLOT
C
  700   Y=YMIN+YINC/2.
        CALL SYMBOL(3.5,Y,.14,CMP1,0.,30)
        AMPN=FLOAT(MAMP)
        BEG=FLOAT(IBEGIN)
        END=FLOAT(IEND)
        CALL NUMBER(7.5,Y,.14,BEG,0.,-1)
        CALL NUMBER(8.0,Y,.14,END,0.,-1)
        IF(NPT .LT. 25) GO TO 215
C
C       PLOT OUT INVISIBLE POINTS TO ALLOW TIME
C       FOR PAGE HOLD (CTL/S). PAGE CAN THEN
C       BE COPIED ON HARD-COPY UNIT.

        DO 211 I=1,NPTS1
        X=FLOAT(I)/FLOAT(NPTS1)*2.+1.
        Y=AMP1(I)+YMIN
        IF(I .EQ. 1) CALL PLOT(X,Y,3)

        CALL PLOT(X,Y,2)
  211   CONTINUE
        CALL CLEAR(-1)
        NPT=1.

  215   NPT=NPT+1
        GO TO 10

  220   CALL RSTR(0)
        STOP
        END
```

SELIN.FOR

```
      SUBROUTINE SELIN(CMPVAR,FREQ,AS,V,R,SLOPE,A0,IBEGIN,
     1IEND,N2,ERH,ERZ)
C
C     SELIN-- LOG AMPLITUDE SPECTRA PLOT ROUTINE,
C             ALSO CALCULATES Q AND UNCERTAINTIES
C
C
C     SYMBOLS USED:
C
C             CMPVAR          EVENT RECORDING PARAMETERS
C             IBEGIN          BEGINNING OF WINDOW
C             IEND            END OF WINDOW
C             N2              NUMBER OF SAMPLES IN TIME WINDOW/2
C             FREQ,F          FREQUENCY
C             FMAX            MAXIMUM FREQUENCY
C             FMIN            MINIMUM FREQUENCY
C             AS              AMPLITUDE SPECTRA VALUES
C             YMAX            MAX. AMPL. SPECTRA VALUE
C             YMIN            MIN. AMPL. SPECTRA VALUE
C             X,Y             SCREEN COORDINATES
C
      INTEGER ANSWER,IBEGIN,IEND,N2,IVAR,LINE,VALARY(102)
      REAL CMPVAR*8(3),FREQ(2000),AS(4000),VPNIN*8,XYMV1,
     1XYMV2,YMAX,WIN*8,SDY(2000)
      COMMON /STAT/ANS,ABAR,FBAR,CORR,SDYBAR,SDSL,SDY
      COMMON /PAR/Z

      NN=0
      NPLOT=0
      PI=3.14159
C
C     INITIALIZE TERMINAL FOR PLOTTING
C
      CALL INITAL(23)
C     RESET ORIGIN TO (.5",.5")
      CALL PLOT(.5,.5,-3)
C
C     READ IN RANGE OF FREQUENCIES FOR PLOTTING
C
      WRITE(5,1000)
 1000 FORMAT(' ENTER MIN. AND MAX. FREQ. FOR PLOTTING')
      READ(5,*) FMIN, FMAX
C
C     FIND MAXIMUM SPECTRAL AMPLITUDE TO SCALE PLOT
C
  150 YMAX=0
      YMIN=0.
      DO 190 J=2,N2+1
      IF(FREQ(J) .LT. FMIN .OR. FREQ(J) .GT. FMAX)
     +GO TO 190
      IF(AS(J) .LT. YMIN) YMIN=AS(J)
      IF(AS(J) .GT. YMAX) YMAX=AS(J)
  190 CONTINUE
C
C     ADJUST RANGE OF GRAPH SO THAT DATA STAYS AWAY FROM AXES
C
      YMIN=YMIN-.5
      YMAX=YMAX+1.
C     WRITE(5,1001)
C1001 FORMAT(' ENTER MIN. AND MAX. AMPL. FOR PLOTTING')
C     READ(5,*) YMIN,YMAX
C
C     SCALE AND PLOT SPECTRAL VALUES-- CONNECT WITH LINES
C
      NPT=0.
      DO 300 I=2,N2+1
      IF(FREQ(I) .LT. FMIN .OR. FREQ(I) .GT. FMAX) GO TO 300
      NPT=NPT+1
      X=(FREQ(I)-FMIN)/(FMAX-FMIN)*5.
      Y=(AS(I)-YMIN)/(YMAX-YMIN)*5.
      IF(NPT .EQ. 1) CALL PLOT(X,Y,3)
      CALL PLOT(X,Y,2)
  300 CONTINUE
      X=(FBAR-FMIN)/(FMAX-FMIN)*5.
      Y=(ABAR-YMIN)/(YMAX-YMIN)*5.
C
C     PLOT SPECTRAL ESTIMATES IF DESIRED
C
      CALL SYMBOL(X,Y,.14,2,0.,-1)
      IF(ANS .EQ. 'N') GO TO 320
C
C     CALCULATE AND PLOT LEAST SQUARES LINE
C
C     WRITE(5,*) FMIN,FMAX
      CALL NEWPEN(2)
      N=0

      FINC=(FMAX-FMIN)/N2
      DO 310 F=FMIN,FMAX,FINC
      N=N+1
      AMP=A0+SLOPE*F
      X=(F-FMIN)/(FMAX-FMIN)*5.+FLOAT(NPLOT)*20.
      Y=(AMP-YMIN)/(YMAX-YMIN)*5.
      IF(F .EQ. FMIN) CALL PLOT(X,Y,3)
      IPEN=2
      IND=(-1)**(N+1)
      IF(IND .LT. 0) IPEN=2
      CALL PLOT(X,Y,IPEN)
  310 CONTINUE
      GO TO 312
C
C     PLOT LINES WITH 2 STD. DEV. SLOPES (IF DESIRED)
C     THESE LINES AND FOLLOWING HYPERBOLAS ARE 95% CONFIDENCE LEVEL
C
C     CALL NEWPEN(3)
      N=0
      AMAX=ABAR-(SLOPE+2.*SDSL)*FBAR

      DO 311 F=FMIN,FMAX,FINC
      N=N+1
      AMP=AMAX+(SLOPE+2.*SDSL)*F
      X=(F-FMIN)/(FMAX-FMIN)*5.
      Y=(AMP-YMIN)/(YMAX-YMIN)*5.
      IF(F .EQ. FMIN) CALL PLOT(X,Y,3)
      IPEN=2
      IND=(-1)**(N+1)
      IF(IND .LT. 0) IPEN=2
      CALL PLOT(X,Y,IPEN)
  311 CONTINUE

      N=0
      AMAX=ABAR-(SLOPE-2.*SDSL)*FBAR

      DO 312 F=FMIN,FMAX,FINC
```

```
      N=N+1
      AMP=AMAX+(SLOPE-2.*SDSL)*F
      X=(F-FMIN)/(FMAX-FMIN)*5.
      Y=(AMP-YMIN)/(YMAX-YMIN)*5.
      IF(F .EQ. FMIN) CALL PLOT(X,Y,3)
      IPEN=2
      IND=(-1)**(N+1)
      IF(IND .LT. 0) IPEN=2
      CALL PLOT(X,Y,IPEN)
  312 CONTINUE
C      go to 314
C
C     PLOT UPPER CONFIDENCE HYPERBOLA FOR LSQ LINE
C

c     CALL NEWPEN(5)
      N=0
      FINC=(FMAX-FMIN)/100.

      DO 313 F=FMIN,FMAX,FINC
      N=N+1
      AMP=A0+SLOPE*F
      X=(F-FMIN)/(FMAX-FMIN)*5.
      Y=(AMP+2.*SDY(N)-YMIN)/(YMAX-YMIN)*5.
      IPEN=2
      IND=(-1)**(N+1)
      IF(IND .LT. 0) IPEN=2
      IF(F .EQ. FMIN) CALL PLOT(X,Y,3)
      CALL PLOT(X,Y,IPEN)
C     WRITE(5,*) X,Y
  313 CONTINUE
C
C     PLOT LOWER CONFIDENCE HYPERBOLA FOR LSQ LINE
C
      N=0
      DO 314 F=FMIN,FMAX,FINC
      N=N+1
      AMP=A0+SLOPE*F
      X=(F-FMIN)/(FMAX-FMIN)*5.
      Y=(AMP-2.*SDY(N)-YMIN)/(YMAX-YMIN)*5.
      IPEN=2
      IND=(-1)**(N+1)
      IF(IND .LT. 0) IPEN=2
      IF(F .EQ. FMIN) CALL PLOT(X,Y,3)
      CALL PLOT(X,Y,IPEN)
  314 CONTINUE
C
C     COMPUTE Q AND ERROR RANGE FOR Q
C
C             Q               SEISMIC QUALITY FACTOR
C             QERR            SUBROUTINE TO CALCULATE ERROR IN Q VALUES
C             QMIN,QMAX       2 SIGMA +/- Q
C             R               EVENT DISTANCE
C             V               VELOCITY (ASSUME HALF-SPACE)
C             SLOPE           SLOPE OF LSQ LINE FIT TO LOG SPECTRUM
C             SDSL            STANDARD DEVIATION OF SLOPE
C             CORR            CORRELATION COEFFICIENT FOR LSQ LINE
C
C
C     ENTER STATION TIME CORRECTION
C
      WRITE(5,3013)
 3013 FORMAT(' ENTER STATION TIME CORRECTION:  '$)
      READ(5,*) TSTA
C
C     COMPUTE TRAVEL TIME
C
      TT=R/V+TSTA*5.85/V
C
C     COMPUTE Q
C
      Q=ABS(PI*TT/SLOPE)
C
C     COMPUTE Q STANDARD DEVIATIONS USING STANDARD ERROR ANALYSIS
C
      CALL QERR(R,Z,SLOPE,SDSL,V,SDQ,ERH,ERZ,SDR)
      QMIN=Q-2.*ABS(SDQ)
      QMAX=Q+2.*ABS(SDQ)
C     QMIN=PI*R/(V*(SLOPE+2.*SDSL))
C     QMAX=PI*R/(V*(SLOPE-2.*SDSL))

      CORR=ABS(CORR)
C
C     PLOT AND LABEL AXES
C
  320 CALL NEWPEN(1)
      FINC=(FMAX-FMIN)/5.
      YINC=(YMAX-YMIN)/5.
      XBASE=NPLOT*20.
      CALL AXIS(XBASE,0.,'FREQUENCY (HZ)',-14,5.,0.,FMIN,FINC,2)
      CALL AXIS(XBASE,0.,'LOGE AMPLITUDE',14,5.,90.,YMIN,YINC,2)
C
C     ADD TITLE AND PERTINENT INFORMATION FOR EACH PLOT
C
      XBASE=XBASE+2.
      CALL SYMBOL(XBASE,5.,.14,CMPVAR,0.,30)
      WIN='WINDOW=>'
      CALL SYMBOL(XBASE,4.8,0.14,WIN,0.,8)
      BEGIN=FLOAT(IBEGIN)
      END=FLOAT(IEND)
      XBASE=XBASE+1.00
      CALL NUMBER(XBASE,4.8,.14,BEGIN,0.,-1)
      COLON=':'
      XBASE=XBASE+.50
      CALL SYMBOL(XBASE,4.8,.14,COLON,0.,1)
      XBASE=XBASE+.25
      CALL NUMBER(XBASE,4.8,.14,END,0.,-1)
      IF(ANS .EQ. 'N') GO TO 220
      XBASE=2.
      CALL SYMBOL(XBASE,4.6,.14,'Q = ',0.,4)
      XBASE=XBASE+.5
      CALL NUMBER(XBASE,4.6,.14,Q,0.,-1)
      XBASE=XBASE+1.1
      CALL SYMBOL(XBASE,4.6,.14,'A0 =',0.,4)
      XBASE=XBASE+.5
      CALL NUMBER(XBASE,4.6,.14,A0,0.,2)
      XBASE=2.
      CALL SYMBOL(XBASE,4.4,.14,'QMIN =',0.,6)
      CALL SYMBOL(XBASE,4.2,.14,'R =',0.,3)
      XINC=XBASE+.50
      CALL NUMBER(XINC,4.2,.14,CORR,0.,2)
      XBASE=XBASE+0.75
      CALL NUMBER(XBASE,4.4,.14,QMIN,0.,-1)
      XBASE=XBASE+0.8
      CALL SYMBOL(XBASE,4.4,.14,'QMAX =',0.,6)
      XBASE=XBASE+0.75
      CALL NUMBER(XBASE,4.4,.14,QMAX,0.,-1)
  220 CALL RSTR(6)
```

SELIN.FOR (CONTINUED)

```
      RETURN
      END
```

SERAW.FOR

```
C
C       PROGRAM SERAW-- AMPLITUDE/VELOCITY SPECTRUM PLOT ROUTINE
C
C       SERAW PLOTS SPECTRAL ESTIMATES FROM DISPAN OR ADSA AS
C       A FUNCTION OF FREQUENCY. THE SPECTRUM CAN BE
C       CORRECTED FOR INSTRUMENT AND SMOOTHED IF THE USER
C       SO DESIRES.
C
C       SUBROUTINES:    PLOT            GRAFIX LIBRARY
C                       DECON           DECONVOLUTION ROUTINE
C                       SMOOTH          MVG AVERAGE FILTER
C                       SPERR           ERRORS IN SPECTRUM
C                       AXIS            GRAFIX LIBRARY
C                       INITAL            "       "
C                       RSTR              "       "
C
C
C       SYMBOLS USED:
C
C               CMPVAR          EVENT RECORDING PARAMETERS
C               VFNIN           INPUT FILE NAME
C               IBEGIN          BEGINNING OF WINDOW
C               IEND            END OF WINDOW
C               IVAR            VARIANCE OF TIME SERIES
C               XYMV1           MEAN OF TIME SERIES
C               XYMV2           ST. DEV. OF TIME SERIES
C               N2              NUMBER OF SAMPLES IN WINDOW/2
C               FREQ            FREQUENCY
C               AS              AMPLITUDE SPECTRA VALUES
C               YMAX            MAX. AMPL. SPECTRA VALUE
C               YMIN            MIN. AMPL. SPECTRA VALUE
C               X,Y             SCREEN COORDINATES
C
C       INPUT FILES==> SPEC.DAT OR FILE OF SPECTRAL ESTIMATES
C       OUTPUT FILES=> OUTPUT.PLT (TYPE "GRAFIX" TO RUN)
C
        INTEGER ANSWER,IBEGIN,IEND,N2,IVAR,LINE,VALARY(102)
        REAL CMPVAR*8(3),FREQ(2000),AS(4000),VFNIN*8,XYMV1,
       1XYMV2,YMAX,WIN*8,EVENT*8(3)

        NPLOT=0
        PI=3.14159
C
C       READ IN DATA FROM DATA FILE
C
        TYPE 5
5       FORMAT('-','DESIGNATE AMPLITUDE SPECTRA INPUT FILE NAME:  '$)
        READ(5,8) VFNIN
8       FORMAT(A10)
        OPEN(UNIT=1,DEVICE='DSK',ACCESS='SEQIN',FILE=VFNIN)
C
C       INITIALIZE TERMINAL FOR PLOTTING
C
        CALL INITAL(23)
C
C       RESET ORIGIN TO (.5",.5")
C
        CALL PLOT(.5,.5,-3)
C
C       READ IN EVENT PARAMETERS AND SPECTRAL VALUES
C
        TYPE 6
 6      FORMAT(' WHICH EVENT DO YOU WANT TO SEE?  '$)
        READ(5,9) EVENT
 9      FORMAT(3A10)
 10     READ(1,20,END=51) CMPVAR,IBEGIN,IEND,IVAR,XYMV1,XYMV2,N2,
      1FIL1,FIL2,DIST,VS
        N2P1=N2+1
 20     FORMAT(3A10/I4,2(1X,I4)/F7.4,1X,F15.4,1X,I4,4F7.2)
        DO 30 J=1,N2P1
        READ(1,40) FREQ(J),AS(J)
 30     CONTINUE
 40     FORMAT(5X,F5.2,1X,E15.4)
        READ(1,50) LINE
 50     FORMAT(A5)
        IF(EVENT(1).EQ.CMPVAR(1).AND.EVENT(2).EQ.CMPVAR(2)) GO TO 55
        GO TO 10
 51     STOP '*** EVENT NOT FOUND ***'
 55     WRITE(5,1000)
 1000   FORMAT(' ENTER MIN. AND MAX. FREQ. FOR PLOT')
        READ(5,*) FMIN, FMAX
        WRITE(5,1350)
 1350   FORMAT(' DO YOU WANT TO DIVIDE SPECTRUM BY 2*PI*FREQ? ')
        READ(5,2010) ANS
        IF(ANS .EQ. 'N') GO TO 130
        DO 127 I=2,N2P1
        AS(I)=AS(I)/(2.*PI*FREQ(I))
 127    CONTINUE
 130    WRITE(5,1070)
 1070   FORMAT(' DO YOU WANT FILTER RESPONSE REMOVED?')
        READ(5,2010) ANS
        IF(ANS .EQ. 'N') GO TO 151
        IF(FIL1 .EQ. 0.) GO TO 150
        CALL DECON(AS,FIL1,FREQ,N2)
 150    IF(FIL2 .EQ. 0.) GO TO 151
        CALL DECON(AS,FIL2,FREQ,N2)
 151    WRITE(5,1090)
 1090   FORMAT(' NUMBER OF POINTS FOR MOVING AVERAGE FILTER?')
        READ(5,*) NPF
C
C       SMOOTH SPECTRAL ESTIMATES USING MOVING AVERAGE FILTER (IF DESIRED)
C

        CALL SMOOTH(NPF,AS,N2P1)
C       DO 113 I=2,N2P1
C 113   AS(I)=AS(I)*EXP(-PI*10*FREQ(I)/(50.*3.4))*2.*PI*FREQ(I)
        DO 189 I=2,N2P1
        WRITE(3,3011) FREQ(I),AS(I)
 189    CONTINUE
 3011   FORMAT(1X,'FREQUENCY =',F7.2,3X,'AMPLITUDE =',F7.2)
C
C       FIND MAXIMUM SPECTRAL AMPLITUDE TO SCALE PLOT
C
        YMAX=0.
        YMIN=0.
        DO 190 J=2,N2P1
        IF(FREQ(J) .LT. FMIN .OR. FREQ(J) .GT. FMAX) GO TO 190
C       IF(AS(J) .LT. YMIN) YMIN=AS(J)
        IF(AS(J) .GT. YMAX) YMAX=AS(J)
190     CONTINUE
C
C       PLOT SPECTRAL VALUES
C
        NPT=0.
        DO 300 I=2,N2P1
        IF(FREQ(I) .LT. FMIN .OR. FREQ(I) .GT. FMAX) GO TO 300
        NPT=NPT+1
        X=(FREQ(I)-FMIN)/(FMAX-FMIN)*5.
```

```
      Y=(AS(I)-YMIN)/(YMAX-YMIN)*5.
      IF(NPT .EQ. 1) CALL PLOT(X,Y,1)
      CALL PLOT(X,Y,2)
C     CALL SYMBOL(X,Y,.01,1,0.,-1)
 300  CONTINUE
C
C     PLOT AND LABEL AXES
C
      FINC=(FMAX-FMIN)/5.
      YINC=(YMAX-YMIN)/5.
      XBASE=NPLOT*20.
      CALL AXIS(XBASE,0.,'FREQUENCY (HZ)',-14,5.,0.,FMIN,FINC,2)
      CALL AXIS(XBASE,0.,'AMPLITUDE',9,5.,90.,YMIN,YINC,2)
      XBASE=XBASE+3.
      CALL SYMBOL(XBASE,5.,.14,CMPVAR,0.,20)
      WIN='WINDOW=>'
      CALL SYMBOL(XBASE,4.8,0.14,WIN,0.,8)
C     CALL SYMBOL(XBASE,4.6,0.14,'MEAN OF SERIES = ',0.,17)
      BEGIN=FLOAT(IBEGIN)
      END=FLOAT(IEND)
      XBASE=XBASE+1.25
      CALL NUMBER(XBASE,4.8,.14,BEGIN,0.,-1)
      COLON=':'
      XBASE=XBASE+.50
      CALL SYMBOL(XBASE,4.8,.14,COLON,0.,1)
      XBASE=XBASE+.25
      CALL NUMBER(XBASE,4.8,.14,END,0.,-1)
C     CALL NUMBER(XBASE,4.6,0.14,XYMV1,0.,2)
      GO TO 220
C
C     SKIP COMPUTATION OF CHI-SQUARED CONFIDENCE INTERVALS
C     FOR SPECTRAL ESTIMATES
C
210   WRITE(5,2000)
 2000 FORMAT(' DO YOU WANT TO SEE CONFIDENCE INTERVALS?')
      READ(5,2010) ANS
 2010 FORMAT(A1)
      IF(ANS .EQ. 'N') GO TO 220
      DT=.01
C
C     IF CONFIDENCE INTERVALS DESIRED, COMPUTE AND PLOT ON LOG GRAPH OF SPECTRUM
C
C     CALL SPERR(N2,DT,CI1,CI2,NPF,BW)
      CI1=ALOG(CI1)
      CI2=ALOG(CI2)
      YMAX=-10.
      YMIN=10.
      NPLOT=NPLOT+1
      CALL PLOT(8.,0.,-3)
      DO 400 I=2,N2P1
C     AS(I)=ALOG(AS(I))
      IF(AS(I) .LT. YMIN) YMIN=AS(I)
      IF(AS(I) .GT. YMAX) YMAX=AS(I)
 400  CONTINUE
C
C     PLOT LOG SPECTRA
C
      NPT=0.
      DO 600 I=2,N2P1
      IF(FREQ(I) .LT. FMIN .OR. FREQ(I) .GT. FMAX) GO TO 600
      NPT=NPT+1
      X=(FREQ(I)-FMIN)/(FMAX-FMIN)*5.
      Y=(AS(I)-YMIN)/(YMAX-YMIN)*5.
      IF(NPT .EQ. 1) CALL PLOT(X,Y,3)
      CALL PLOT(X,Y,2)
 600  CONTINUE
C
C     PLOT AND LABEL AXES
C
      FINC=(FMAX-FMIN)/5.
      YINC=(YMAX-YMIN)/5.
      XBASE=0.
      CALL AXIS(XBASE,0.,'FREQUENCY (HZ)',-14,5.,0.,FMIN,FINC,2)
      CALL AXIS(XBASE,0.,'LOGE VELOCITY',13,5.,90.,YMIN,YINC,2)
C
C     LABEL PLOT WITH PERTINENT INFORMATION
C
      XBASE=3.
      CALL SYMBOL(XBASE,5.,.14,'CI=',0.,3)
      CALL SYMBOL(XBASE,4.8,.14,'BW=',0.,4)
      XBASE=XBASE+0.5
      CALL NUMBER(XBASE,5.,.14,CI1,0.,2)
      CALL NUMBER(XBASE,4.8,.14,BW,0.,3)
      XBASE=XBASE+0.75
      CALL SYMBOL(XBASE,5.,.14,',',0.,1)
      CALL SYMBOL(XBASE,4.8,.14,'HZ',0.,2)
      XBASE=XBASE+.25
      CALL NUMBER(XBASE,5.,.14,CI2,0.,2)
C
C     PLOT OUT ERROR BARS FOR SPECTRAL ESTIMATES AND BANDWIDTH
C
      CALL PLOT(1.5,1.,-3)
      CI1=CI1/(YMAX-YMIN)*5.
      CI2=CI2/(YMAX-YMIN)*5.

      CALL PLOT(0.,0.,3)
      CALL PLOT(0.,CI1,2)
      CALL TICX(0.,CI1)

      CALL PLOT(0.,0.,3)
      CALL PLOT(0.,CI2,2)
      CALL TICX(0.,CI2)

      BW=BW/(FMAX-FMIN)*2.5

      CALL PLOT(0.,0.,3)
      CALL PLOT(BW,0.,2)
      CALL TICY(BW,0.)

      BW=-BW

      CALL PLOT(0.,0.,3)
      CALL PLOT(BW,0.,2)
      CALL TICY(BW,0.)

220   CALL RSTR(0)
      STOP
      END

      SUBROUTINE TICX(X,Y)
      X1=X-.0625
      X2=X+.0625
      CALL PLOT(X1,Y,3)
      CALL PLOT(X2,Y,2)
      RETURN
      END

      SUBROUTINE TICY(X,Y)
```

SERAW.FOR (CONTINUED)

```
Y1=Y-.0625
Y2=Y+.0625
CALL PLOT(X,Y1,3)
CALL PLOT(X,Y2,2)
RETURN
END
```

SERAY.FOR

```
C     ****************************************************************
C     * RAYPATH AND EPICENTER PLOTTING PROGRAM.  THIS PROGRAM WAS    *
C     * ADAPTED FROM A PROGRAM USED TO PLOT EPICENTERS FOR THE ENTIRE*
C     * STATE OF NEW MEXICO.  EPICENTERS FOR LOCAL MICROEARTHQUAKES  *
C     * ARE PLOTTED AS WELL AS STRAIGHT LINES CONNECTING EPICENTERS  *
C     * WITH STATIONS USING GRFLIB LIBRARY SUBROUTINES. RAYPATHS     *
C     * ARE COLOR-CODED ACCORDING TO DEGREE OF ATTENUATION.          *
C     *                                                              *
C     *                                                              *
C     * SYMBOLS USED:                                               *
C     *                                                              *
C     *              FILENM          INPUT DATA FILE NAME            *
C     *              ORGT            ORIGIN TIME FOR EVENT           *
C     *              ST              STATION NAME                    *
C     *              LAA             LATITUDE OF EVENT               *
C     *              LONA            LONGITUDE OF EVENT              *
C     *              AMAG            EVENT MAGNITUDE                 *
C     *              Q               SEISMIC QUALITY FACTOR          *
C     *              QREL            RELATIVE Q (OFFSET FROM         *
C     *                              A LINEAR INCREASE IN Q          *
C     *                              WITH DISTANCE)                  *
C     *              ICOL            PEN COLOR                       *
C     *              F               PLOT SCALE FACTOR               *
C     *              SX,SY           KM LENGTH SCALES                *
C     *              ICHECK          QUERY ANSWER                    *
C     *              MUM             NUMBER OF STATIONS              *
C     *              ST              STATION NAME                    *
C     *              AI,AJ           STATION COORDINATES             *
C     *              AMMIN           MINIMUM MAGNITUDE DESIRED       *
C     *              AMMAX           MAXIMUM MAGNITUDE DESIRED       *
C     *              AMAG            MAGNITUDE OF EACH EVENT         *
C     *              LAA,LONA        LAT. AND LONG. OF EACH EVENT    *
C     *              XPLOT,YPLOT     SCREEN COORDS. OF EACH EVENT    *
C     *              DIST            EVENT DISTANCE                  *
C     *              DEPTH           EVENT DEPTH                     *
C     *                                                              *
C     *       INPUT FILE>>> QAPP.DAT-- SELECTED EVENTS FROM MODEL    *
C     *       OUTPUT FILE>> OUTPUT.PLT-- MAP FOR PLOTTER             *
C     ****************************************************************
C
C
      IMPLICIT REAL*8(L)
      DOUBLE PRECISION ORGT,FILENM,MONTH1,MONTH2,SOC
      INTEGER DAY,YEAR,HR,MIN,SS

       WRITE(5,10)
10     FORMAT(1X,'DATA FILENAME?')
       READ(5,20)FILENM
20     FORMAT(1A10)
       OPEN(UNIT=22,FILE=FILENM)

21    FORMAT(A1)

      CALL INITAL(1)
      CALL PLOT(4.0,0.4,-3)

C   Plot the location of Socorro on the map.

      SOC='SOCORRO'
      X=106.9
      Y=34.06
      CALL TRNFM1(X,Y)
      X=(X+45.)/20.
      Y=(Y+50.)/20.
c     CALL SYMBOL(X,Y,0.10,1,0.0,-1)
c     CALL SYMBOL(X+.08,Y,0.10,SOC,0.0,7)

70    WRITE(5,80)
80    FORMAT(1X,'DO YOU WANT ANY STATIONS TO APPEAR ON THE MAP?')
      WRITE(5,90)
90    FORMAT(1X,'(Y OR N)')
      READ(5,100)ICHECK
100   FORMAT(A1)
      IF(ICHECK.EQ.'N'.OR.ICHECK.EQ.'n')GO TO 170
      IF(ICHECK.EQ.'y'.OR.ICHECK.EQ.'Y')GO TO 110
      GO TO 70

110   WRITE(5,120)
120   FORMAT(1X,'HOW MANY STATIONS?   (I2 FORMAT)')
      READ(5,130)MUM
130   FORMAT(I2)
      WRITE(5,140)
140   FORMAT(1X,'TYPE IN THE STATION NAMES IN A4 FORMAT.')
      write(5,141)
141   format(' Be sure to use UPPERCASE LETTERS for the station names')

      DO 160 I=1,MUM
      READ(5,150)ST
150   FORMAT(A4)

C  Get coordinates for each of the stations specified.

      CALL GETCOD (ST,AI,AJ)
      X=AJ
      Y=AI
      CALL TRNFM1(X,Y)
      Y=(Y+50.0)/20.0
      X=(X+45.0)/20.0

C  Plot a triangle and a station label at each station location.

      CALL SYMBOL(X,Y,0.05,2,0.0,-1)
      Y=Y+.05
      CALL SYMBOL(X,Y,.05,ST,0.0,3)
160   CONTINUE


170   WRITE(5,180)
180   FORMAT(1X,'DO YOU WANT ALL EVENTS TO BE PLOTTED OR')
      WRITE(5,190)
190   FORMAT(1X,'ONLY THOSE WITH SELECTED MAGNITUDES?')
      WRITE(5,200)
200   FORMAT(1X,'(1=ALL EVENTS, 2=SELECTED MAGNITUDES)')
      READ(5,210)ICHECK
210   FORMAT(I1)
      IF(ICHECK.EQ.1.OR.ICHECK.EQ.2)GO TO 220
      GO TO 170
220   N=0
      IF(ICHECK.EQ.1)GO TO 290
      WRITE(5,230)
230   FORMAT(1X,'WHAT IS THE MAXIMUM MAGNITUDE DESIRED?')
      WRITE(5,240)
240   FORMAT(1X,'(F5.2 FORMAT)')
      READ(5,250)AMMAX
250   FORMAT(F5.2)
      WRITE(5,260)
260   FORMAT(1X,'WHAT IS THE MINIMUM MAGNITUDE DESIRED?')
      WRITE(5,270)
```

SERAY.FOR (CONTINUED)

```
270     FORMAT(1X,'(F5.2 FORMAT)')
        READ(5,250)AMMIN

c   This is for the benefit of the SCALE2 subroutine.
290     IF(ICHECK.EQ.1) AMMAX=6.0
        IF(ICHECK.EQ.1) AMMIN=-3.0

        WRITE(5,810)
810     FORMAT(1X,'DO YOU WANT TO SEE A LIST OF ALL THE EVENTS PLOTTED?')
        WRITE(5,811)
811     FORMAT(' (Y OR N)')
        READ(5,100) YORN
        IF(YORN.EQ.'N'.OR.YORN.EQ.'n') GO TO 909
        WRITE(5,812)
812     FORMAT(' TYPE 5 IF YOU WANT THE LIST TO GO TO THE TERMINAL,')
        WRITE(5,813)
813     FORMAT(' TYPE 3 IF YOU WANT THE LIST TO GO TO THE LINE PRINTER')
        READ(5,210) NUNIT

c   Give the user a choice about the size of the x's plotted for the quakes

909     WRITE(5,910)
910     FORMAT(' DO YOU WANT ALL OF THE Xs THE SAME SIZE? (Y OR N)')
        READ(5,100) YXN

C  Read latitude and longitude coordinates for each event, as well as magnitude
C
C7      IF(YXN.EQ.'Y'.OR.YXN.EQ.'y') GO TO 8
C        READ(22,300,END=899)MON,DAY,YEAR,LAA,LONA,AMAG
C       GO TO 9
 7       READ(22,300,END=899) NUM,C1,C2,ST,C3,C4,IBEGIN,
     1IEND,Q,QMAX,QMIN,CORR,DIST,DEPTH,LAA,LONA

300     FORMAT(I4,3X,A10,A7,A3,A9,A1,4X,I4,1X,I4,6F10.2,2F10.4)

        CALL GETCOD (ST,AI,AJ)
        X=AJ
        Y=AI
        CALL TRNFM1(X,Y)
        Y=(Y+50.0)/20.0
        X=(X+45.0)/20.0
        CALL PLOT(X,Y,3)

9       IF(ICHECK.EQ.1)GO TO 330
        IF(AMAG.LE.AMMIN)GO TO 7
        IF(AMAG.GT.AMMAX)GO TO 7

330     KOUNTR=KOUNTR+1

c   Get the dates of the first and last events.

        EYEAR=YEAR
        JMON=MON
        EDAY=DAY
        IF(KOUNTR.NE.1) GO TO 850
        IMON=MON
        ADAY=DAY
        AYEAR=YEAR

850     PTY=LAA
        PTX=LONA

C  Transform degrees to kilometers.

        CALL TRNFM1(PTX,PTY)

c   Set the window to the Socorro area and the scale to fit on the plotter
c   Add 50 km to the latitude, 45 km to the longitude, scale=20 km per inc

        PTY=(PTY+50.0)/20.0
        PTX=(PTX+45.0)/20.0
        YPLOT=PTY
        XPLOT=PTX

c   Scale the size of the x to the magnitude (if all are to be the same,
c   skip this part).

        F=0.70
        IF(YXN.EQ.'Y'.OR.YXN.EQ.'y') go to 736

        IF(-0.5.LE.AMAG.AND.AMAG.LT.0.0)F=0.3
        IF(0.0.LE.AMAG.AND.AMAG.LT.0.50)F=0.6
        IF(0.5.LE.AMAG.AND.AMAG.LT.1.00)F=0.9
        IF(1.0.LE.AMAG.AND.AMAG.LT.1.50)F=1.2
        IF(1.5.LE.AMAG.AND.AMAG.LT.2.00)F=1.5
        IF(2.0.LE.AMAG.AND.AMAG.LT.2.50)F=1.8
        IF(2.5.LE.AMAG.AND.AMAG.LT.3.00)F=2.1
        IF(3.0.LE.AMAG.AND.AMAG.LT.3.50)F=2.4
        IF(3.5.LE.AMAG.AND.AMAG.LT.4.50)F=2.7


c
c  Plot a line resresenting the surface projection of
c  the raypath between epicenter and station. Color
c  code according to apparent Q.
c
 736    IF(Q .EQ. -100.) GO TO 28
        QREL=Q-(Q0+SLOPE*DIST)
        IF(QREL .LT. -100.) ICOL=3
        IF(QREL .GT. -100. .AND. QREL .LT. -25.) ICOL=8
        IF(QREL .GT. -25. .AND. QREL .LT. 0.) ICOL=4
        IF(QREL .GT. 0. .AND. QREL .LT. 25.) ICOL=5
        IF(QREL .GT. 25. .AND. QREL .LT. 100.) ICOL=2
        IF(QREL .GT. 100.) ICOL=6
c       CALL NEWPEN(ICOL)
        CALL NEWPEN(1)

        CALL PLOT(XPLOT,YPLOT,2)
        CALL NEWPEN(1)

C  Plot an x at the location of the earthquake.

        F=F*0.07
        CALL SYMBOL(XPLOT,YPLOT,F,4,0.0,-1)

28      IF(YORN.NE.'Y'.and.YORN.NE.'y') GO TO 7
        WRITE(NUNIT,29)MON,DAY,YEAR,LAA,LONA,AMAG
29      FORMAT(2X,3I2,12X,F5.2,1X,F6.2,5X,F5.2)

        GO TO 7

c   Indicate on the plot the dates of the first and last events.

899     CALL DATE(IMON,MONTH1)
        CALL DATE(JMON,MONTH2)
        AYEAR=AYEAR+1900
        EYEAR=EYEAR+1900
        CALL PLOT(-1.9,0.5,-3)
```

```
      GO TO 901
      CALL SYMBOL(0.0,4.7,0.1,'THE FIRST EVENT IS ON',0.0,21)
      CALL SYMBOL(0.1,4.5,0.1,MONTH1,0.0,9)
      CALL NUMBER(0.9,4.5,0.1,ADAY,0.0,-1)
      CALL SYMBOL(1.05,4.5,0.1,',',0.0,1)
      CALL NUMBER(1.25,4.5,0.1,AYEAR,0.0,-1)
      CALL SYMBOL(0.0,4.1,0.1,'THE  LAST EVENT IS ON',0.0,21)
      CALL SYMBOL(0.1,3.9,0.1,MONTH2,0.0,9)
      CALL NUMBER(0.9,3.9,0.1,EDAY,0.0,-1)
      CALL SYMBOL(1.05,3.9,0.1,',',0.0,1)
      CALL NUMBER(1.25,3.9,0.1,EYEAR,0.0,-1)
901   CONTINUE
c   Indicate on the plot how many events were plotted.

      ROUNTR=KOUNTR
      CALL NUMBER(0.0,3.5,0.1,ROUNTR,0.0,-1)
      CALL SYMBOL(0.4,3.5,0.1,'EVENTS WERE PLOTTED',0.0,19)


c   Put a kilometer scale bar on the plot.

      SX=0.3
      SY=3.0
      CALL PLOT(SX,SY,3)
      DO 600 I=0,4
         CALL PLOT(SX,SY,2)
         CALL PLOT(SX,SY+.025,3)
         CALL PLOT(SX,SY-.025,2)
         AKM=I*5.
         CALL NUMBER(SX-.04,SY-.15,.07,AKM,0.0,-1)
         CALL PLOT(SX,SY,3)
         SX=SX+.25
600      CONTINUE
      CALL SYMBOL(SX-.14,SY-.15,.07,'KM',0.0,2)
      CALL PLOT(1.9,-0.5,-3)

C  Plot crosses at .1 degree marks for a reference scale.
      CALL PLOTX

c  Plot the magnitude scale if necessary.
      IF(YXN.EQ.'N'.OR.YXN.EQ.'n') CALL SCALE2(ammax,ammin)

      CLOSE(UNIT=22)
      CALL RSTR(1)
      STOP
       END
C     ***********************************
C     ***********************************
      SUBROUTINE TRNFM1(X,Y)
c   Changes degree coordinates to distance in kilometers from the center
c   of New Mexico.

      YY=Y
      Y=(Y-34.1)*((Y-34.1)/2.*.018+110.922)
      X=(106.943-X)*COS(3.1415927/360.*(34.1+YY))*111.4399
10    RETURN
       END
C     ***********************************************
C     ***********************************************
      SUBROUTINE GETCOD (STATIO,AI,AJ)

c   Gets coordinates for the stations specified from the file STA.DAT.

      OPEN(UNIT=24,FILE='STA.DAT',ACCESS='SEQIN',DEVICE='DSK')

10    READ(24,20,END=30) ST,AI,AJ
20    FORMAT(A4,F7.4,1X,F8.4)
      IF(ST.EQ.STATIO)RETURN
      GO TO 10
30    write(5,100) statio
100   format(' Station "',a4,'"  not on station list')
      TYPE 200
200   FORMAT(' TRY ENTERING THE STATION NAME AGAIN')
      READ(5,101) STATIO
101   FORMAT(A4)
      GO TO 10
      RETURN
      END
C     ****************************
C     ****************************
      SUBROUTINE SCALE2(amax,amin)

C   Plots a legend for the scaled x's.  AMAX and AMIN determine which
c   magnitudes are represented in the legend (depending on what
c   range was selected by the user).

      DIMENSION B(9,2)
      CALL PLOT(0.,0.,3)
      CALL PLOT(3.80,2.00,0)
      CALL PLOT(-1.7,0.0,-3)
      B(1,1)=-0.50
      B(1,2)=-0.01
      B(2,1)=-0.00
      B(2,2)=0.49
      B(3,1)=0.50
      B(3,2)=0.99
      B(4,1)=1.00
      B(4,2)=1.49
      B(5,1)=1.50
      B(5,2)=1.99
      B(6,1)=2.00
      B(6,2)=2.49
      B(7,1)=2.50
      B(7,2)=2.99
      B(8,1)=3.00
      B(8,2)=3.49
      B(9,1)=3.50
      B(9,2)=4.49
      if(b(1,2).LE.AMIN) go to 8
      F=0.14*0.3
      CALL SYMBOL(0.,0.,F,4,0.0,-1)
      CALL NUMBER(0.43,-0.05,0.1,B(1,1),0.0,2)
      CALL SYMBOL(0.9,-0.05,0.1,'-',0.0,1)
      CALL NUMBER(1.03,-0.05,0.1,B(1,2),0.0,2)
      CALL PLOT(0.0,0.0,3)
8     F=0.14*0.6
      DO 10 J=2,9
      if(b(j,2).le.amin) go to 9
      if(b(j,1).ge.amax) return
      A=J-1.0
      Y=(A*0.35)
      CALL SYMBOL(0.,Y,F,4,0.0,-1)
      Y=Y-0.05
      CALL NUMBER(0.5,Y,0.1,B(J,1),0.0,2)
      CALL SYMBOL(0.9,Y,0.1,'-',0.0,1)
      CALL NUMBER(1.1,Y,0.1,B(J,2),0.0,2)
9     F=F+3*.014
10    CONTINUE
```

```
      RETURN
      END


      SUBROUTINE DATE(INMON,OUTMON)

c     Changes months designated by numbers to names.

      DOUBLE PRECISION OUTMON
      IF(INMON.EQ.1) OUTMON='  JANUARY'
      IF(INMON.EQ.2) OUTMON=' FEBRUARY'
      IF(INMON.EQ.3) OUTMON='    MARCH'
      IF(INMON.EQ.4) OUTMON='    APRIL'
      IF(INMON.EQ.5) OUTMON='      MAY'
      IF(INMON.EQ.6) OUTMON='     JUNE'
      IF(INMON.EQ.7) OUTMON='     JULY'
      IF(INMON.EQ.8) OUTMON='   AUGUST'
      IF(INMON.EQ.9) OUTMON='SEPTEMBER'
      IF(INMON.EQ.10)OUTMON='  OCTOBER'
      IF(INMON.EQ.11)OUTMON=' NOVEMBER'
      IF(INMON.EQ.12)OUTMON=' DECEMBER'

      RETURN
      END

      SUBROUTINE PLOTX
c     Plots a reference scale on the outside of the plot, with or without
c     grid points on the inside of the plot.

      WRITE(5,1)
1     FORMAT(' DO YOU WANT THE GRID ON THE INSIDE OF THE PLOT?')
      WRITE(5,2)
2     FORMAT('  (Y OR N)')
      READ(5,3) YORN
3     FORMAT(A1)
      IF(YORN.EQ.'N'.OR.YORN.EQ.'n') ndec=1
      FLA=33.7
      FLO=107.3
      ELA=34.6
      ELO=106.4
      ALA=33.7
      ALO=107.3
      DLO=ALO
      DLA=ALA

      CALL TRNFM1(DLO,DLA)
      PX=(DLO+45.)/20.
      PY=(DLA+50.)/20.
      CALL TRNFM1(ELO,ELA)
      EX=(ELO+45.)/20.
      EY=(ELA+50.)/20.

      DO 100 I=1,10
         DLA=FLA
         DLO=ALO
         CALL TRNFM1(DLO,DLA)
         PX=(DLO+45.)/20.
         CALL SYMBOL(PX,PY,.1,3,0.,-1)

         AMOD=MOD(I,2)
         IF(AMOD.EQ.0.0.AND.NDEC.EQ.1) GO TO 500
         CALL NUMBER(PX-0.2,PY-0.2,0.1,ALO,0.,1)

500      CALL SYMBOL(PX,EY,0.1,3,0.,-1)

         ALO=ALO-0.1
100   CONTINUE

      ALA=FLA
      DO 200 I=1,10
         DLO=FLO
         DLA=ALA
         CALL TRNFM1(DLO,DLA)
         PY=(DLA+50.)/20.
         CALL SYMBOL(PX,PY,0.1,3,0.,-1)

         IF((MOD(I,2)).EQ.0.0.AND.NDEC.EQ.1) GO TO 600

         CALL NUMBER(PX-0.5,PY-0.05,0.1,ALA,0.,1)
600      CALL SYMBOL(EX,PY,.1,3,0.,-1)
         ALA=ALA+0.1
200   CONTINUE

      IF(YORN.NE.'Y'.AND.YORN.NE.'y') return

      CALL NEWPEN(2)
      ALO=107.2

      DO 300 I=1,8
         ALA=33.8
         DO 400 J=1,8
            DLA=ALA
            DLO=ALO
            CALL TRNFM1(DLO,DLA)
            PX=(DLO+45.)/20.
            PY=(DLA+50.)/20.
            CALL SYMBOL(PX,PY,0.05,3,0.,-1)
            ALA=ALA+0.1
400      CONTINUE
         ALO=ALO-0.1
300   CONTINUE
      CALL NEWPEN(1)
      RETURN
      END
```

SEWIN.FOR

```
C
C       SEWIN-- DISPLAY SELECTED WINDOWS EN MASSE
C
C       SEWIN WILL DISPLAY UP TO 25 SEISMOGRAM WINDOWS
C       FOR 1 STATION AS A VERTICAL PANEL. ALL THE WINDOWS
C       ARE NORMALIZED AND SCALED TO FIT ON A PAGE. IF
C       MORE THAN 25 WINDOWS ARE TO BE DISPLAYED, SEWIN
C       GENERATES A NEW PAGE. ON THE TEKTRONIX TERMINAL
C       THIS WILL BE INDICATED BY THE BOTTOM TRACE BEING
C       REPEATED, DURING WHICH TIME IT IS RECOMMENDED
C       A CTL/S BE TYPED TO HOLD THE PAGE SO THAT A HARD
C       COPY MAY BE MADE.
C
C       ==> WHEN PLOTTING USE OFFSET = 0,-1, SCALE FAC. = 2,2
C
C       SYMBOLS USED:
C
C                 VFNIN         INPUT FILE NAME
C                 STANS         STATION FOR WINDOWS
C                 NUM           NUMBER OF WINDOWS
C                 CMP1          EVENT HEADERS
C                 STA           EVENT STATIONS
C                 NPTS1         NUMBER OF POINTS IN EACH WINDOW
C                 IBEGIN        WINDOW BEGINNING
C                 IEND          WINDOW END
C                 DIST          EVENT DISTANCE
C                 AMAX,AMIN     MAX. AND MIN. AMPL. IN EACH WINDOW
C                 X,Y           SCREEN COORDINATES
C                 TMAX          DURATION OF EACH WINDOW (SECONDS)
C
C       THIS PROGRAM IS IDEAL FOR LINING UP WINDOWS FOR SPECTRAL
C       ANALYSIS AND FOR NOTING SUBTLE CHANGES IN WAVEFORM BETWEEN EVENTS
C
        INTEGER ANSWER,N2,IVAR,LINE,VALARY(102),RES(2000)
        REAL CMP1*8(3),Y1(2000),Y2(2000),VFNIN*8,WIN*8
        REAL*8 C1,C2,C3,C4,STA,STANS
        DIMENSION XY(4000),AMP(2000)

        WRITE(5,7)
7       FORMAT(' ENTER INPUT FILE NAME:  '$)
        READ(5,8) VFNIN
8       FORMAT(A10)
        OPEN(UNIT=1,DEVICE='DSK',ACCESS='SEQIN',FILE=VFNIN)

        WRITE(5,1001)
 1001   FORMAT(' ENTER STATION DESIRED:'$)
        READ(5,1003) STANS
 1003   FORMAT(A3)

C
        CALL INITAL(23)
        NPT=1
        WRITE(5,1000)
 1000   FORMAT(' NUMBER OF EVENTS?')
        READ(5,*) NUM
 10     READ(1,19,END=220) CMP1
 19     FORMAT(3A10)
        BACKSPACE 1
        READ(1,20,END=220) C1,C2,STA,C3,IBEGIN,IEND,DIST
20      FORMAT(A10,A7,A3,A10,2I6,F7.2)
        DO 30 I=1,1991,10
        READ(1,40) (AMP(J),J=I,I+9)
 40     FORMAT(10F5.0)
        IF(AMP(I) .EQ. 99999.) GO TO 45
        GO TO 30
 45     NPTS1=I-1
        GO TO 56
 30     CONTINUE
 56     CONTINUE

        IF(STA .NE. STANS) GO TO 10
        AMAX=0.
        AMIN=0.

C
C       FIND MAX AND MIN AMPLITUDE FOR EACH WINDOW
C


        DO 100 I=1,NPTS1
        IF(AMP(I) .GT. AMAX) AMAX=AMP(I)
        IF(AMP(I) .LT. AMIN) AMIN=AMP(I)
 100    CONTINUE

C
C       SCALE FOR PLOTTING
C
        IF(NUM .GT. 25) NUM=25

        YINC=10./FLOAT(NUM)
        YMIN=10.-FLOAT(NPT)*YINC+.5
C
C       PLOT INDIVIDUAL SEISMOGRAMS
C
        KOUNT=0
        NPTS1=64
        DO 300 I=1,NPTS1
        IF(AMP(I) .EQ. 99999) GO TO 700
        AMP(I)=(AMP(I)-AMIN)*YINC/(AMAX-AMIN)
        X=FLOAT(I)/FLOAT(NPTS1)*2.+1.
        Y=AMP(I)+YMIN
        KOUNT=KOUNT+1
        IF(KOUNT .EQ. 1) CALL PLOT(X,Y,3)
        CALL PLOT(X,Y,2)
 300    CONTINUE

C
C       PLOT AND LABEL AXES
C
        TMIN=0.
        TMAX=NPTS1*.01
        TINC=(TMAX-TMIN)/2.
C       CALL AXIS(XBASE,0.,'          ',10,5.,0.,LMIN,LINC,2)
        IF(NPT .GT. 1) GO TO 700
        CALL AXIS(1.,.3,'SECONDS',-7,2.,0.,TMIN,TINC,2)
C
C       ADD TITLE AND PERTINENT INFORMATION FOR EACH PLOT
C
700     Y=YMIN+YINC/2.
        CALL SYMBOL(3.5,Y,.14,CMP1,0.,30)
        AMPM=FLOAT(MAMP)
        BEG=FLOAT(IBEGIN)
        END=FLOAT(IEND)
        CALL NUMBER(7.0,Y,.14,BEG,0.,-1)
        CALL NUMBER(7.5,Y,.14,END,0.,-1)
        CALL NUMBER(8.5,Y,.14,DIST,0.,2)
        IF(NPT .LT. 25) GO TO 215
C
```

SEWIN.FOR (CONTINUED)

```
C       PLOT OUT INVISIBLE POINTS TO ALLOW TIME
C       FOR PAGE HOLD (CTL/S). PAGE CAN THEN
C       BE COPIED ON HARD-COPY UNIT.
C
        DO 211 I=1,NPTS1
        X=FLOAT(I)/FLOAT(NPTS1)*2.+1.
        Y=AMP(I)+YMIN
        IF(I .EQ. 1) CALL PLOT(X,Y,3)

        CALL PLOT(X,Y,2)
 211    CONTINUE
        CALL CLEAR(-1)
        NPT=1.

 215    NPT=NPT+1
        GO TO 10

 220    CALL RSTR(0)
        STOP
        END
```

SMOOTH.FOR

```
      SUBROUTINE SMOOTH(NPF,Y,N2P1)
C
C     SMOOTH SPECTRAL ESTIMATES USING MOVING AVERAGE FILTER
C
C
C           NPF             NUMBER OF POINTS TO BE AVERAGED
C           Y               AMPLITUDE OF POINTS
C
      REAL Y(2000)
      NP=(NPF-1)/2
      DO 100 I=1,N2P1
      SUM=0.
      DO 120 J=I-NP,I+NP,1
      IF(J .LT. 1 .OR. J .GT. N2P1) GO TO 120
      SUM=Y(J)+SUM
120   CONTINUE
      Y(I)=SUM/FLOAT(NPF)
100   CONTINUE
      RETURN
      END
```

SWINPK.FOR

```
C
C       SWINPIK-- AUTOMATIC S WINDOW PICKING ROUTINE
C
C       THIS PROGRAM COMPUTES S WINDOWS ON THE BASIS OF
C       A RAPID CHANGE IN AMPLITUDE OVER A SHORT TIME
C       INTERVAL. IF THE DIGITAL AMPLITUDES CHANGE BY
C       A FACTOR OF 2.5 OVER 0.1 S, A WINDOW BEGINNING
C       IS SET. THE WINDOW DURATION IS 0.64 S.
C
C       INPUT FILES: WINPIK.DAT-- CONTROL FILE
C                    VFNIN--      DIGITAL DATA FILE
C                    VFNIN1--     WINDOW LIST DATA FILE
C
C       OUTPUT FILES: VFNOUT--    NEW WINDW LIST DATA FILE
C
C       A LIST OF NEW WINDOWS IS ALSO OUTPUT ON THE LPT.
C
C
C       SYMBOLS USED:
C
C               EVENT           HEADER FOR EVENT DESIRED
C               CMPVAR          EVENT HEADERS FOR DIGITAL DATA
C               Y               DIGITAL AMPLITUDE VALUES
C               NWIN, NUMWIN    NUMBER OF WINDOWS
C               VEL             VELOCITY
C               SMP             S-P INTERVAL
C               FIL1            LOW CUT FILTER
C               FIL2            HIGH CUT FILTER
C               DIST            DISTANCE
C               Z               FOCAL DEPTH
C               NSTART          WHERE WINDOW SEARCH IS STARTED
C               NSTOP           END OF S WAVE WINDOW SEARCH
C               IBEG            WINDOW BEGINNING
C               IEND            WINDOW END
C
C

      REAL CMPVAR*8(3),VFNIN*8,VFNOUT*8,EVENT*8(2)
      REAL VFNIN1*8,Y(3000),NY(3000)
      INTEGER WINDOW(2000,10)

      NUM=70
      OPEN(UNIT=11,DEVICE='DSK',FILE='WINPIK.DAT',ACCESS='SEQIN')
      WRITE(5,1005)
1005  FORMAT(' DESIGNATE DIGITAL DATA INPUT FILE NAME:  '$)
      READ(11,5) VFNIN
      WRITE(5,1006)
1006  FORMAT(' DESIGNATE EVENT LIST DATA FILE:  '$)
      READ(11,5) VFNIN1
      WRITE(5,1007)
1007  FORMAT(' DESIGNATE OUTPUT FILE NAME:  '$)
      READ(11,5) VFNOUT
   5  FORMAT(A10)

      OPEN(UNIT=1,DEVICE='DSK',FILE=VFNIN,ACCESS='SEQIN')
      OPEN(UNIT=2,DEVICE='DSK',FILE=VFNOUT,ACCESS='SEQOUT')
      OPEN(UNIT=23,DEVICE='DSK',FILE=VFNIN1,ACCESS='SEQIN')

      WRITE(3,1009)
1009  FORMAT(10X,'AUTOMATIC WINDOW PICKS:'//)
C
C  READ IN EVENT FROM WIND.DAT
C
20    READ(23,40,END=360) EVENT
40    FORMAT(2A10)
      REWIND 1
C
C  SEARCH THROUGH TAPE.DAT FOR DESIRED EVENT
C
60    READ(1,70,END=100) CMPVAR
70    FORMAT(3A10)

C
C  CHECK HEADER
C
      IF(EVENT(1).EQ.CMPVAR(1).AND.EVENT(2).EQ.CMPVAR(2)) GO TO 140
                GO TO 60
100   WRITE(5,110)
110   FORMAT('+','?EVENT NOT FOUND?')
      WRITE(5,113) EVENT
113   FORMAT(1X,3A10)
      CLOSE(UNIT=1)
      STOP '*** NO EVENTS PROCESSED ***'


C
C  READ IN DIGITAL AMPLITUDE VALUES
C


140   CONTINUE
      DO 170 I=1,1991,10
              READ(1,150)  (Y(J),J=I,I+9)
      DO 111 J=I,I+9
111   NY(J)=Y(J)
141   FORMAT(10I5)
150           FORMAT(10F5.0)
              IF(Y(I).EQ.99999) GO TO 160
                      GO TO 170
160           XNUM=I-1
              GO TO 180
170   CONTINUE

      XNUM=2000
180   CONTINUE

      READ(23,510) NUMWIN
510   FORMAT(I3)
      DO 530 J=1,NUMWIN
              READ(23,520) WINDOW(J,1),WINDOW(J,2),WINAN
              READ(23,525) VEL,SMP,FIL1,FIL2,DIST,Z
525           FORMAT(6F8.2)
520   FORMAT(I4,1X,I4,1X,F2.0)
530   CONTINUE

      XSMP=DIST/(1.732*VEL*1.37)
      XSMP=(XSMP-.70)*100.
      NSMP=INT(XSMP)

C
C  FIND WINDOW BEGINNING AND END
C
      YMAX=0.
      II=0
      NSTART=2
      NSTOP=1000

198   DO 200 I=NSTART,NSTOP
```

SWINPK.FOR (CONTINUED)

```
        IF(ABS(Y(I)) .GT.  100. .AND. II .EQ. 0) GO TO 202
C
C  IF GLITCH, SKIP
C
        IF(ABS(Y(I)) .GT. 2046.) GO TO 200
        IF(ABS(Y(I)) .LT. 150.) GO TO 200
C
C  COMPARE AMPLITUDES 10 POINTS APART. IF RATIO > 2.5, START WINDOW
C
        IF(ABS(Y(I)) .GE. ABS(2.5*Y(I-10))) GO TO 204
 200    CONTINUE
        GO TO 206

 202    NSTART=I+NSMP
        NSTOP=NSTART+300
        II=1
        GO TO 198

 204    CONTINUE
        IF(ABS(Y(I)) .LT. YMAX) GO TO 200
        YMAX=ABS(Y(I))
C
C  DROP BACK 25 POINTS FROM AMPITUDE CHANGE TO START WINDOW
C
        IBEG=I-25
        IEND=IBEG+64
        GO TO 200

C
C       PRINT OUT WINDOWS
206     WRITE(3,1000) CMPVAR,IBEG,IEND
 1000   FORMAT(10X,3A10,3X,2I6)
C
C  WRITE OUT NEW WINDOWS TO DISK
C
        WRITE(2,70) CMPVAR
        NWIN=1
        WRITE(2,510) NWIN
        WINAN=2.
        WRITE(2,520) IBEG,IEND,WINAN
        WRITE(2,525) VEL,SMP,FIL1,FIL2,DIST,Z

        GO TO 20

 360    CONTINUE

        CLOSE(UNIT=1)
        CLOSE(UNIT=2)

        STOP
        END
```

SYN.FOR

```
C
C  SYN-- GENERATE WAVEFORMS TO TEST SPECTRAL ANALYSIS ROUTINES
C
C
C       SYMBOLS USED:
C
C               A(N)            AMPLITUDE
C               F0,F1           FREQUENCIES IN WAVEFORM
C               N               POINT COUNTER
C               T               TIME
C
C       THE WAVEFORM GENERATED IT OUTPUT TO A FILE CALLED TAPE.DAT
C       IN 10I5 FORMAT. THIS FORMAT IS READ BY DISPAN AND ADSA.
C

        INTEGER A(1100)
        PI=3.14159
C
C  SET FREQUENCIES TO BE INCLUDED IN WAVEFORM
C
        F0=12.
        F1=1.
        OPEN(UNIT=23,DEVICE='DSK',FILE='TAPE.DAT')
        WRITE(23,1002)
 1002   FORMAT('WHITE NOISE ')
        N=0
C
C  LOOP OVER TIMES (0.01 SAMPLING INTERVAL)
C
        DO 100 T=.01,2.50,.01
        N=N+1
C
C  GENERATE COSINE WAVEFORM
C
        A(N)=0.
        IF(N .EQ. 125) A(N)=100.
        A(N)=25.*COS(2.*PI*F0*T/1.00)
C       A(N)=25.*COS(2.*PI*F0*T/1.00)+100.*COS(2.*PI*F1*T/1.00)
 100    CONTINUE
        DO 150 I=0,N-10,10
 150    WRITE(23,1000) (A(I+J),J=1,10)
        WRITE(5,*) N
        WRITE(23,1003)
 1003   FORMAT(70('9'))
 1000   FORMAT(10I5)
        CLOSE(UNIT=23,DEVICE='DSK')
        STOP
        END
```

TEK.FOR

```
C
C  TEK-- DISPLAY WIDE TABLES IN HALVES ON TEKTRONIX TERMINAL. THEY
C        CAN THEN BE PASTED TOGETHER. THIS PROGRAM IS SPECIALIZED
C        TO HANDLE TABLES OF Q VALUES ALONG WITH THE DISTANCES,
C        DEPTHS, ETC., THAT ARE NORMALLY OUTPUT TO THE LPT FROM
C        MODEL.FOR. THIS PROGRAM WILL REARRANGE THE EVENTS IN ORDER
C        OF NEAREST TO FAREST, AND ALSO ORDER THE QAPP.DAT FILE WHICH
C        CAN BE USED TO CONTROL THE WINDOW PANELS.
C
C        INPUT FILES: MOD.OUT-- EVENT LISTINGS IN TABLE FORM
C                     QAPP.DAT- DATA FILE OF EVENT LISTINGS FOR MAPS
C
C        OUTPUT FILES: QAPP.DAT-REORDERED EVENT LISTINGS
C
C              SYMBOLS USED:
C
C                       LHS             LEFT HAND SIDE OF TABLE
C                       RHS             RIGHT HAND SIDE OF TABLE
C                       LTEMP           TEMPORARY ARRAY FOR ORDERING
C                       RTEMP             "     "   "     "
C                       IFLAG           SWITCH USED IN COMPARING
C                                       TABLE LINES
C
      REAL*8 LHS(100,8),RHS(100,7),LTEMP(8),RTEMP(7)
C
C  LOAD TEXT INTO ARRAYS
C
      OPEN(UNIT=25,DEVICE='DSK',FILE='MOD.OUT')
      DO 5 I=1,7
      READ(25,1002) (LHS(I,J),J=1,7), (RHS(I,J),J=1,7)
C     WRITE(5,1002) (LHS(I,J),J=1,7), (RHS(I,J),J=1,7)
 5    CONTINUE
      I=8
 10   READ(25,1000,END=99) (LHS(I,J),J=1,8), (RHS(I,J),J=1,7)
C     WRITE(5,1000) (LHS(I,J),J=1,8), (RHS(I,J),J=1,7)
C     WRITE(5,1000) LHS(I,1)
C     WRITE(5,*) RHS(I,3),RHS(I,4)
 1000 FORMAT(A4,A6,6A10,2A10,F10.2,2A10,2A5)
 1001 FORMAT(A1)
 1002 FORMAT(7A10,5A10,2A5)

      I=I+1
      GO TO 10
 99   CONTINUE
C     go to 91

C
C  ORDER EVENTS ACCORDING TO DISTANCE
C
 400  IFLAG=0
      DO 500 J=8,I-2
      IF(RHS(J,3) .LE. RHS(J+1,3)) GO TO 500
      IFLAG=1
      DO 525 K=2,8
      LTEMP(K)=LHS(J,K)
      LHS(J,K)=LHS(J+1,K)
      LHS(J+1,K)=LTEMP(K)
 525  CONTINUE

      DO 526 K=1,7
      RTEMP(K)=RHS(J,K)
      RHS(J,K)=RHS(J+1,K)
      RHS(J+1,K)=RTEMP(K)
 526  CONTINUE

 500  CONTINUE
      IF (IFLAG .EQ. 1) GO TO 400
 91   READ(5,1001) ANS
C
C  WRITE LEFT HAND SIDE
C
      DO 105 J=1,7
 105  WRITE(5,1009) (LHS(J,K),K=1,7)
 1009 FORMAT(1X,7A10,5A10,2A5)
      DO 100 J=8,I-1
      WRITE(5,1010) (LHS(J,K),K=1,8)
 1010 FORMAT(1X,A4,A6,6A10)
 100  CONTINUE
      READ(5,1001) ANS
C
C  WRITE RIGHT HAND SIDE
C
      DO 205 J=1,7
 205  WRITE(5,1004) (RHS(J,K),K=1,7)
 1004 FORMAT(1X,5A10,2A5)
      DO 200 J=8,I-1
      WRITE(5,1003) (RHS(J,K),K=1,7)
 1003 FORMAT(1X,2A10,F10.2,2A10,2A5)
 200  CONTINUE
      OPEN(UNIT=21,DEVICE='DSK',FILE='QAPP.DAT')
      DO 700 J=8,I-1
      WRITE(21,1000) (LHS(J,K),K=1,8),(RHS(J,K),K=1,7)
 700  CONTINUE

      CLOSE(UNIT=21)
      CLOSE(UNIT=25)
      STOP
      END
```

WSHAP.FOR

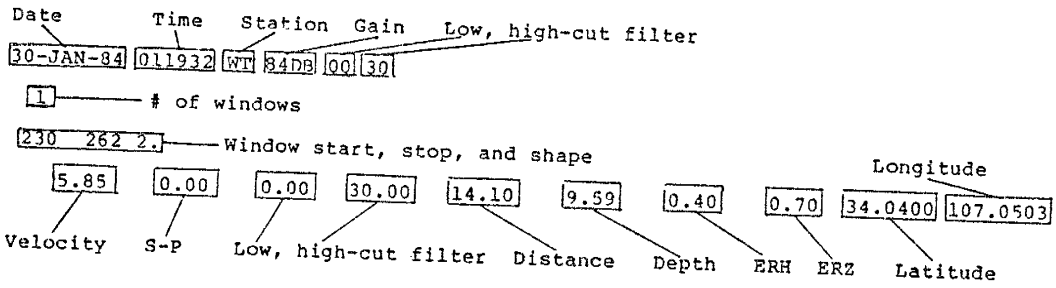
```
C
C  WSHAP-- TAPERS DIGITAL DATA FOR SPECIFIC WINDOW FORMS
C
C
C       ANS=2: COSI I-TAPERED RECTANGULAR WINDOW
C       ANS=3: HAMMING WINDOW
C
        SUBROUTINE WSHAP(ANS,X,WIDTH)
        INTEGER WIDTH
        REAL X(2000)
        PI=3.14159
        IF(ANS .GT. 3.) GO TO 250
        IF(ANS .NE. 2.) GO TO 150
        DO 100 I=1,WIDTH
        FRAC=FLOAT(I-1)/FLOAT(WIDTH)
        IF(FRAC.LE.0.1.OR.FRAC.GE.0.9) X(I)=(1.-COS(PI*10.*FRAC))/
     12.*X(I)
 100    CONTINUE
        GO TO 250
 150    DO 200 I=1,WIDTH
        FRAC=FLOAT(I-35)/FLOAT(WIDTH)
        X(I)=(.46+0.54*COS(PI*FRAC))*X(I)
 200    CONTINUE
 250    RETURN
        END
```

Instructions for Spectral Analysis

Spectral analysis of a digital time series is easily accomplished by running DISPAN. This program can take an event from one of the TP*.DAT digital data files and, with a choice of window, perform a Fourier transform and output the spectral estimates to SPEC.DAT. The window trace can also be output to CROS.DAT. The following sequence is used to generate and view spectra:

```
**********
* TP*.DAT *          (digital time series)
**********
     V
     V
     V
**************
* RUN DISPAN *       (select and transform window)
**************
     V
     V
     V
************
* SPEC.DAT *        (contains spectrum)
************
     V
     V
     V
**************
* RUN SERAW *       (examine uncorrected spectrum)
**************
     V
     V
     V
************
* RUN QFIT *        (obtain Q from spectrum)
************
```

To save time, another routine was written which will mpute spectra for several events. The main program here ADSA (Automatic Digital Spectral Analysis). ADSA is iden- cal to DISPAN except that it takes no input from the user d produces no plots. Windows are specified in a window list le as presented below. The following is a window specifica- on from PLOC84.DAT for one event:



In general, when 10 or more events are being analyzed by ADSA, it makes sense to run this program on batch. This is easily done by submitting ADSA.CTL. The general sequence for processing events using ADSA is presented below:

```
           ***********
           * TP*.DAT *          (digital time series)
           ***********
                 V
                 V
           *************
           * S*WIN.DAT *       (list of windows)
           *************
                 V
                 V
           ************
           * RUN ADSA *        (spectral analysis)
           ************
                 V
                 V
           ************
V<<<<<< * SPEC.DAT *           (contains spectra)
V          ************
V
V
V          *************
V>>>>>> * RUN SERAW *          (plots any uncorrected spectrum)
V          *************
V
V
V          ************
V>>>>>>>* RUN QFIT *           (fits a line to any corrected
V          ************        spectrum)
V
V
V          *************
 >>>>>>>* RUN MODEL *          (fits multiple spectra and
           *************       plots Q vs. distance)
```

Instructions for Cepstral Analysis

Cepstral analysis in this study may be divided into two parts:

1) Generating the cepstrum.

2) Filtering the spectrum to remove the ripple (effect of reverberations). This is called homomorphic deconvolution.

(2) may be accomplished simply by running RIPPLE.FOR. (1) requires several steps as shown below: