UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

A SEISMIC STUDY OF YUCCA MOUNTAIN AND VICINITY, SOUTHERN NEVADA; DATA REPORT AND PRELIMINARY RESULTS

By

Lynn R. Hoffman and Walter D. Mooney

Prepared by the
U.S.GEOLOGICAL SURVEY
for the
NEVADA OPERATIONS OFFICE,
U.S.DEPARTMENT OF ENERGY
(Interagency Agreement DE-AI08-78ET44802)

OPEN-FILE REPORT 83-588

This report (map) is preliminary and has not been reviewed for conformity with U.S.Geological Survey editorial standards (and stratigraphic nomenclature). Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S.G.S.

Menlo Park, California
1984

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Lynn R. Hoffman[1] and Walter D. Mooney[2]

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1. U.S.G.S., Pasadena, CA 91125
2. U.S.G.S., Menlo Park, CA 94025

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ABSTRACT

From 1980 to 1982, the U.S. Geological Survey conducted seismic refraction studies at the Nevada Test Site to aid in an investigation of the regional crustal structure at a possible nuclear waste repository site near Yucca Mountain. Two regionally distributed deployments and one north-south deployment recorded nuclear events. First arrival times from these deployments were plotted on a location map and contoured to determine traveltime delays. The results indicate delays as large as 0.5 s in the Yucca Mountain and Crater Flat areas relative to the Jackass Flats area. A fourth east-west deployment recorded a chemical explosion and was interpreted using a two-dimensional computer raytracing technique. Delays as high as 0.7 s were observed over Crater Flat and Yucca Mountain. The crustal model derived from this profile indicates that Paleozoic rocks, which outcrop to the east at Skull Mountain and the Calico Hills, and to the west at Bare Mountain, lie at a minimum depth of 3 km beneath part of Yucca Mountain. These results confirm earlier estimates based on the modeling of detailed gravity data. A mid-crustal boundary at 15 $\pm$ 2 km beneath Yucca Mountain is evidenced by a prominent reflection recorded beyond 43 km range at 1.5 s reduced time. Other mid-crustal boundaries have been identified at 24 and 30 km and the total crustal thickness is 35 km.

INTRODUCTION

During the spring of 1980 and 1981, the U.S. Geological Survey conducted preliminary seismic refraction studies in the vicinity of Yucca Mountain, Nevada. The purpose of the study was to determine variations in the near-surface velocity structure of the upper crust which will aid in assessing the feasibility of nuclear waste storage in this area. These variations consist of changes in depth to a prevolcanic (pre-Tertiary) surface and in the thickness of near-surface lithologic units. In combination with other geophysical data, these variations can be used to derive cross sections of the uppermost crust that are important to structural, tectonic, and hydrologic analysis of the area.

Portable seismographs were deployed near Yucca Mountain and three separate nuclear events were recorded. Figure 1 shows the locations of the recording equipment and the nuclear events that were used as seismic sources. To better constrain the velocity structure of the uppermost crust and determine field parameters for a future detailed study, an east-west profile was deployed in April 1982. It extended from a shot point southeast of Beatty, Nevada, across Yucca Mountain to the Skull Mountain area of the Nevada Test Site. Figure 2 shows the recording locations and the shot point for this additional deployment. Data with clear first arrivals and a high signal to noise ratio were recorded from all four sources. P(compressional)-wave arrival times can be determined on the records to an accuracy of 0.02 s.

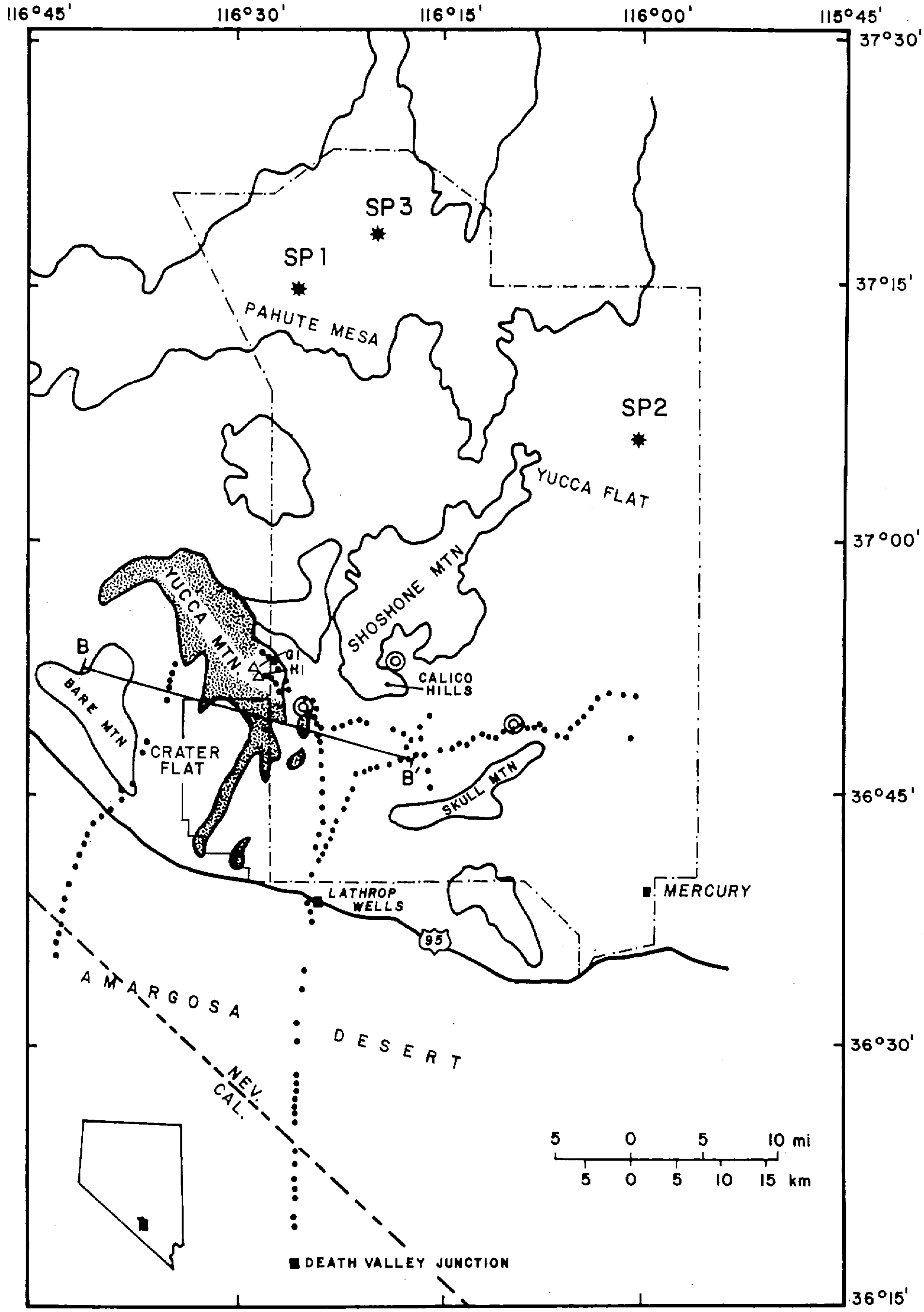


Figure 1. Recorder and shot locations for nuclear event deployments. Recorder site locations are indicated by dots, nuclear events by stars, selected drill holes by triangles, and shallow seismic refraction profiles by double circles. B-B' indicates the referenced gravity study of Snyder and Carr (1982).

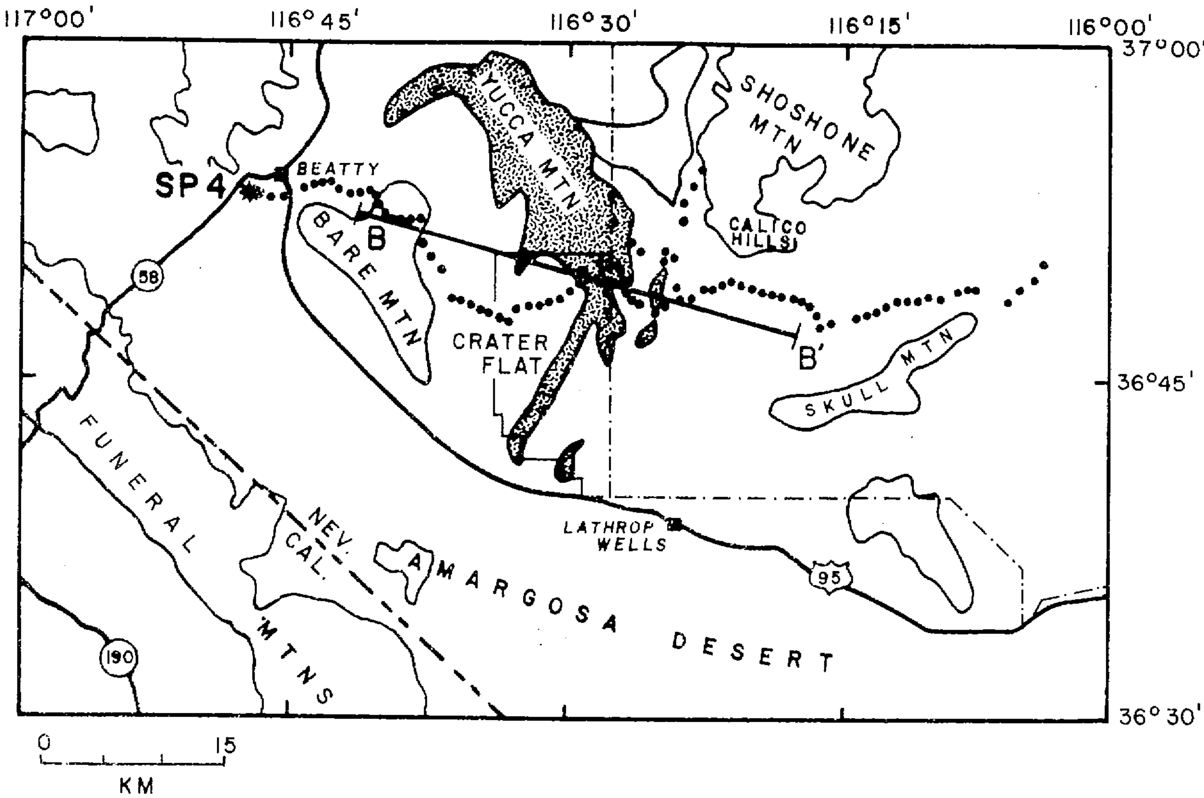


Figure 2. Shot point 4 recorder locations. SP 4 is the shot point location. Recorder site locations are indicated by dots. Line B-B' as in figure 1.

ACKNOWLEDGMENTS

This investigation was initiated by J. H. Healy; we are grateful to him for his encouragement throughout all stages. We wish to express our appreciation to S. K. Gallanthine, W. M. Kohler, W. J. Lutter, J. N. Roloff, V. D. Sutton, A. W. Walter, and S. S. Wegener for their diligent work in recording data from the nuclear events. Thanks are extended to J. M. Bonomolo, E. E. Criley, R. P. Meyer Jr., R. M. Kaderabek and G. A. Molina for their field work in connection with the fourth deployment. A. L. Boken's graphical ray tracing and R. O. Colburn's two-dimensional computer raytracing of the Beatty-Skull Mountain line is greatly appreciated. H. W. Oliver and D. B. Snyder provided valuable advice and assistance in planning the field work at the Nevada Test Site, and have suggested improvements to the text.

INSTRUMENTATION AND FIELD OPERATIONS

SEISMIC RECORDERS

One hundred portable seismic recorders, each weighing approximately 40 pounds and powered by two 6-volt rechargeable batteries, recorded the data in FM-analog form on 30-minute cassette tapes. The instruments were divided into five sets of 20 units each. Five observers were responsible for the maintenance, deployment and accurate site location for each of the 20 units in their designated set.

These seismic recorders allow much flexibility in deployment. They do not record continuously but are preprogrammed with up to ten recording times. The recording time window can vary depending on how many times the unit is to record for each thirty-minute side of tape. Instrument electronics begin warming up ten minutes prior to each recording time. Prior to the expected energy arrival time, the unit will perform a geophone release, an amplification check and a calibration sequence of 1, 10, 100 and 1,000 mv, with a 10 Hz signal. These are recorded on the cassette and can be referenced during data processing for the evaluation of performance quality of the instrument. Following the calibration sequence, the unit begins to record data. The geophone is a vertical-component velocity transducer with a natural resonance frequency of two cycles per second and a motor constant of one volt per cm/s. Three data channels are used, each with a different, pre-set amplifier gain. Maximum gain is approximately 104 db; minimum gain is 0 db. In addition, IRIG-E time signals from the internal chronometer and WWVB radio time signals are recorded (Healy and others, 1982).

DEPLOYMENT

Since nuclear events do not always occur as scheduled, it was necessary to program several large recording windows at estimated event times. These estimated times were essentially guesses based on a combination of the scheduled time of the event and experience from past recording attempts. Due to the limited amount of tape in each recorder and the lack of field mobility during times of probable nuclear events, two units were placed at each location with alternating recording times. This limited the data coverage to fifty locations, but resulted in the successful recording of the first two nuclear events. Continuous reprogramming of the equipment and added mobility in the field area made it possible to occupy 100 sites to record the third event.

A second complication resulting from the nuclear event delays was that the batteries on the recorders would run down, often causing instrument malfunctions. Where normally 100 sites are occupied with a 90% data recovery, the data return for these nuclear event recordings was less than 70%.

The shot time for the fourth deployment was selected by the seismic experiment field staff and the recorders were programmed accordingly. A 2,480-pound charge of ammonium nitrate was fired below the water table at a location southeast of Beatty, Nevada. Data recovery in this instance was 85%.

DATA REDUCTION

Following each deployment, recording units were retrieved and several preliminary data processing steps were taken. All information pertaining to the operation of the seismographs was entered on the team-shot data sheets (Appendix B). Shot information for the nuclear events was obtained through personal communication with the Nevada Test Site Control Point. The shot time for shot number four was picked from the shot record, a paper tape showing shot time and shot detonation. Recorder locations and elevations were determined from the topographic maps. Chronometer corrections were calculated in order to adjust for the clock drift at shot time. These data were entered into various computer files and used in conjunction with recorder information for digitizing. Following accuracy checks for errors in timing and site locations, the cassette tapes were digitized. Calibration settings were used to compare data channels while digitizing and performance quality of the recorder was graded (Healy and others, 1982). Trace normalized record sections were plotted using the standard reduction velocity of 6 km/s. (In trace normalized plots, all seismograms in a record section have their maximum amplitude set to an equal trace width, thus producing a uniform appearance.) Some data from shot points 1 and 2 were plotted as fan shots with the first station as zero distance and successive stations as a function of distance from that point. All lines are unreversed in that a shot was not fired from the opposite direction. Data from shot point 4 were filtered to remove some high frequency noise, and the data from some sites were omitted due to overlapping traces.

LOGISTICS

When this project was initiated, very few roads penetrated the Yucca Mountain area, making adequate coverage of the proposed repository site difficult. As the Yucca Mountain investigations continued more roads were constructed. By the 1982 deployment, the area could be covered fairly well and the east-west deployment line across the mountain was possible.

Due to this continuous road construction, the indicated roads on topographic maps for Yucca Mountain and vicinity are very outdated. Recorder stations could not be as easily located as in normal field operations. Many sites had to be located using a Brunton compass, which tends to reduce the accuracy in determining the location of the site. Where normally station locations are accurate to 25 feet, those along the unmapped roads have a larger error margin of 50 to 100 feet. All locations are indicated on Plate 1, which is at a scale of 1:250,000. Location numbers on this plate are also indicated on the record sections.

OBSERVATIONS

SEISMIC PROFILES

Data for the first nuclear event, shot point 1, were collected in a short north-south line and an extended east-west fan array (Figure 3). The second nuclear event, shot point 2, resulted in a northeast-southwest line of data and an east-north-east to west-southwest fan array (Figure 4). These data are of greatest value presented as delay time observations for apparent velocity analysis.

Some of the most useful data from the nuclear event recordings were obtained from the third nuclear event, shot point 3. Two lines deployed to the east and west of Yucca Mountain provide the closest data to the proposed repository (Figure 5). The distance from the source at Pahute Mesa to Yucca Mountain is approximately 50 km, and at this distance all first arrivals are basement (Pg) arrivals. The eastern profile, from Yucca Mountain to Death Valley Junction, was recorded at a distance of 48 to 110 km. Significant traveltime variations in the first-arrival curve suggest delays in near-surface rocks that amount to 0.5 s in the Yucca Mountain area. In addition, clear reflections from the mantle and midcrust indicate layering within the crust beneath Yucca Mountain. The western profile for shot point 3, from Yucca Mountain to the Amargosa Desert, was recorded in the distance range of 52 to 86 km. The data along this profile also indicate 0.5 s delays in the Yucca Mountain area and the northern data show a lower dominant frequency than those taken further south. This is due to the greater seismic attenuation at the sites above thicker sections of tuff.

First arrival times (Appendix C) for shot points 1 and 3 were plotted on a location map in order to contour the reduced traveltimes in the area of Yucca Mountain. Some recorder locations were occupied for both events which put better constraints on the traveltime correlation by enabling comparison of arrival times from the two events. The larger delay times in the vicinity of Yucca Mountain and Crater Flat are interpreted to be due to the thicker section of low velocity layers (e.g., ash-flow tuffs and Cenozoic volcanic layers) in that area . Figure 6 illustrates these delays and compares them with the Bouguer gravity anomalies (Healey and others, 1980). Traveltime delays of 1.2 s or larger generally correlate with Bouguer gravity values of -140 to -170 mgal, indicating that both the seismic and gravity data were affected by low velocity, low density volcanic material.

Data for shot point 4 (Figure 7), the chemical explosion near Beatty, Nevada, were recorded to a distance of 65 km from the shot point. Average station spacing along this profile was 1 km. The first arrivals are delayed over Crater Flat and Yucca Mountain by as much as 0.7 s relative to Bare Mountain. In addition to clear first arrivals, a prominent reflected (secondary) arrival was recorded beyond 40 km range.

NEVADA TEST SITE- SHOT POINT 1 NORMALIZED RECORD SECTIONS

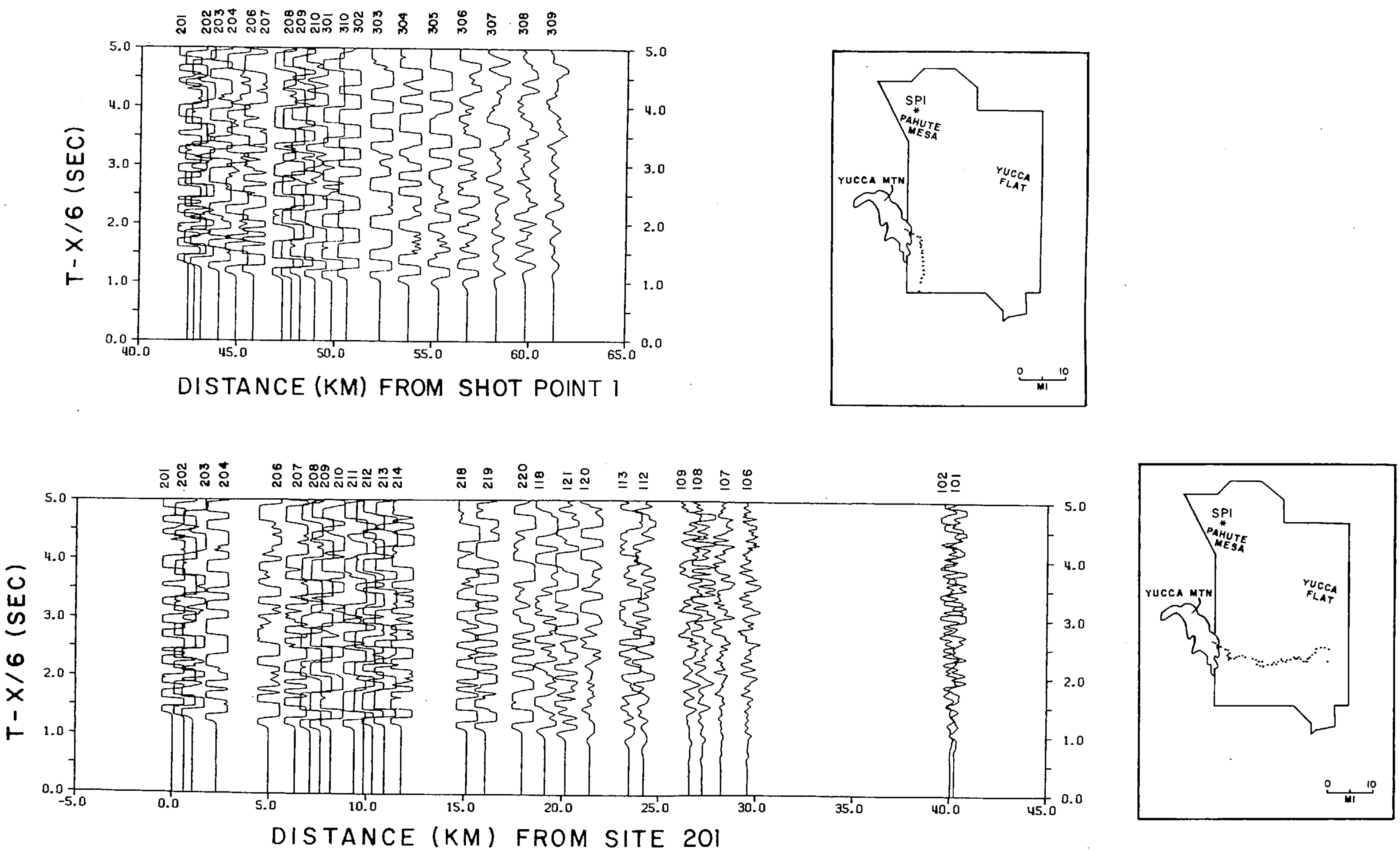


Figure 3. Nevada Test Site - Shot point 1 normalized record sections.
Top: North-south line.
Bottom: Fan plot with recorder location 201 set at zero distance and successive stations as distance from site 201.

NEVADA TEST SITE - SHOT POINT 2 NORMALIZED RECORD SECTIONS

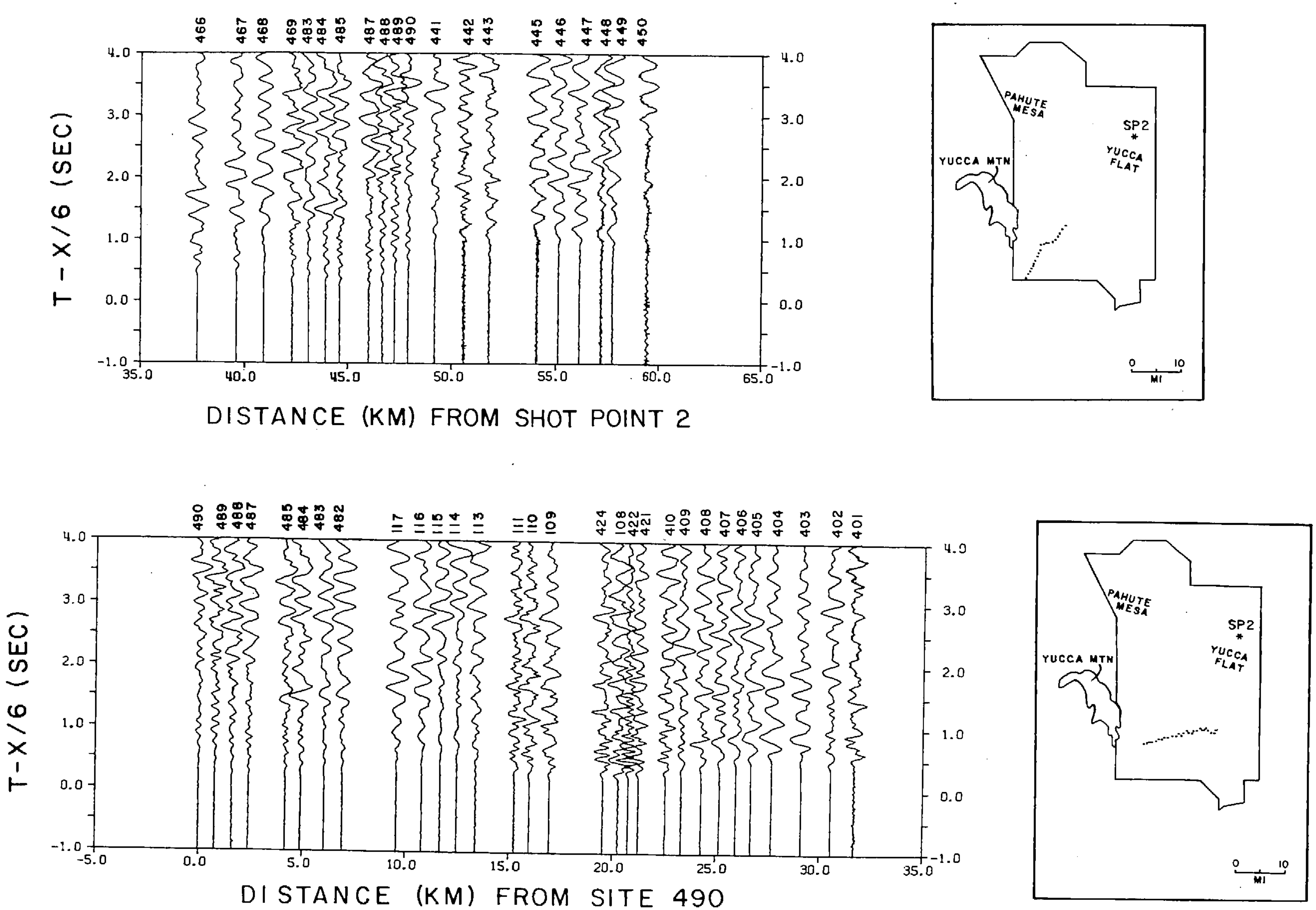


Figure 4. Nevada Test Site - Shot point 2 normalized record sections.
Top: Northeast-southwest line.
Bottom: Fan plot with recorder location 490 set at zero distance and successive stations as distance from site 490.

NEVADA TEST SITE - SHOT POINT 3 NORMALIZED RECORD SECTIONS

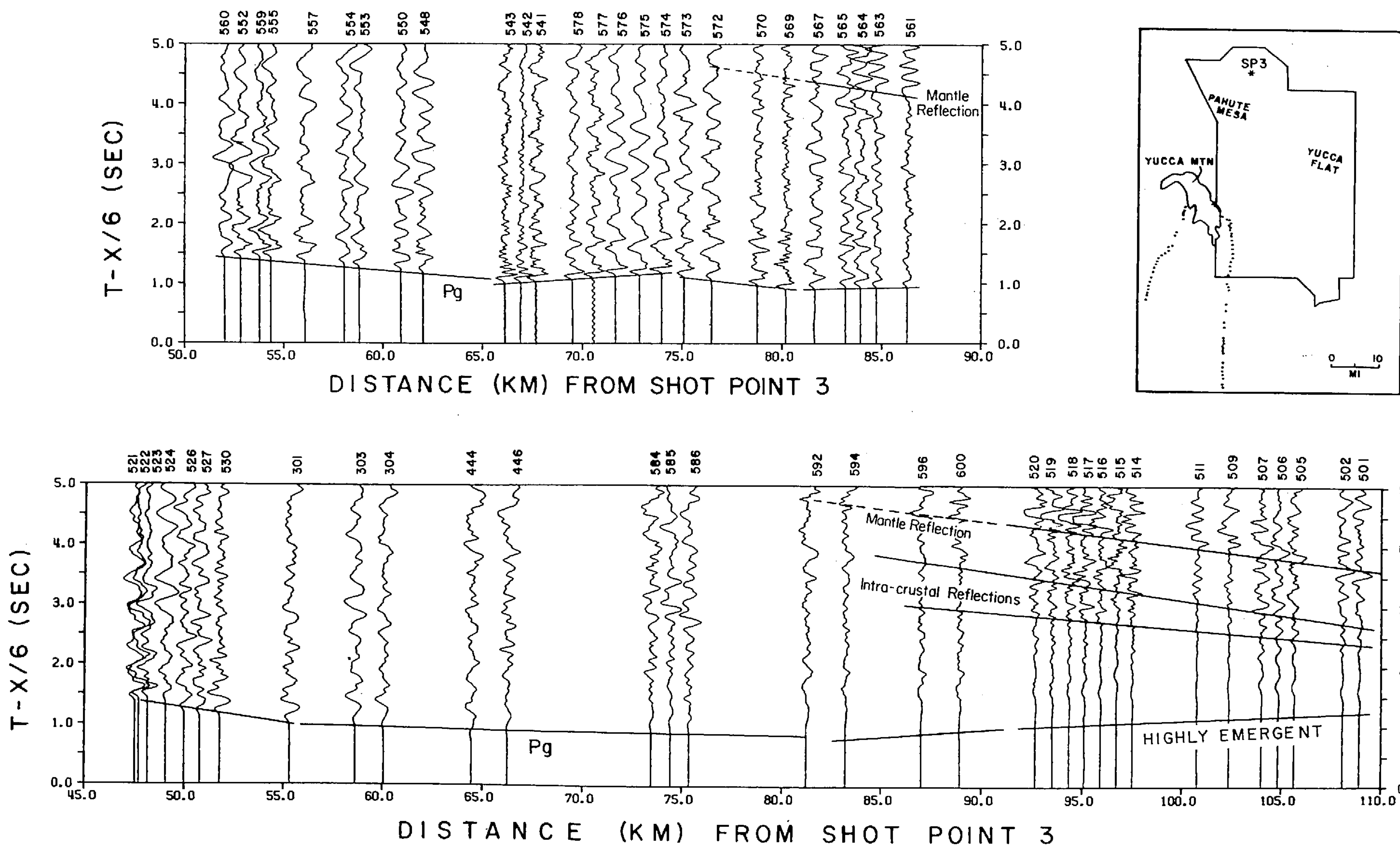


Figure 5. Nevada Test Site - Shot point 3 normalized record sections.
Top: Western line - Yucca Mountain to Amargosa Desert.
Bottom: Eastern line - Yucca Mountain to Death Valley Junction.
Expanded plots reveal emergent arrivals.

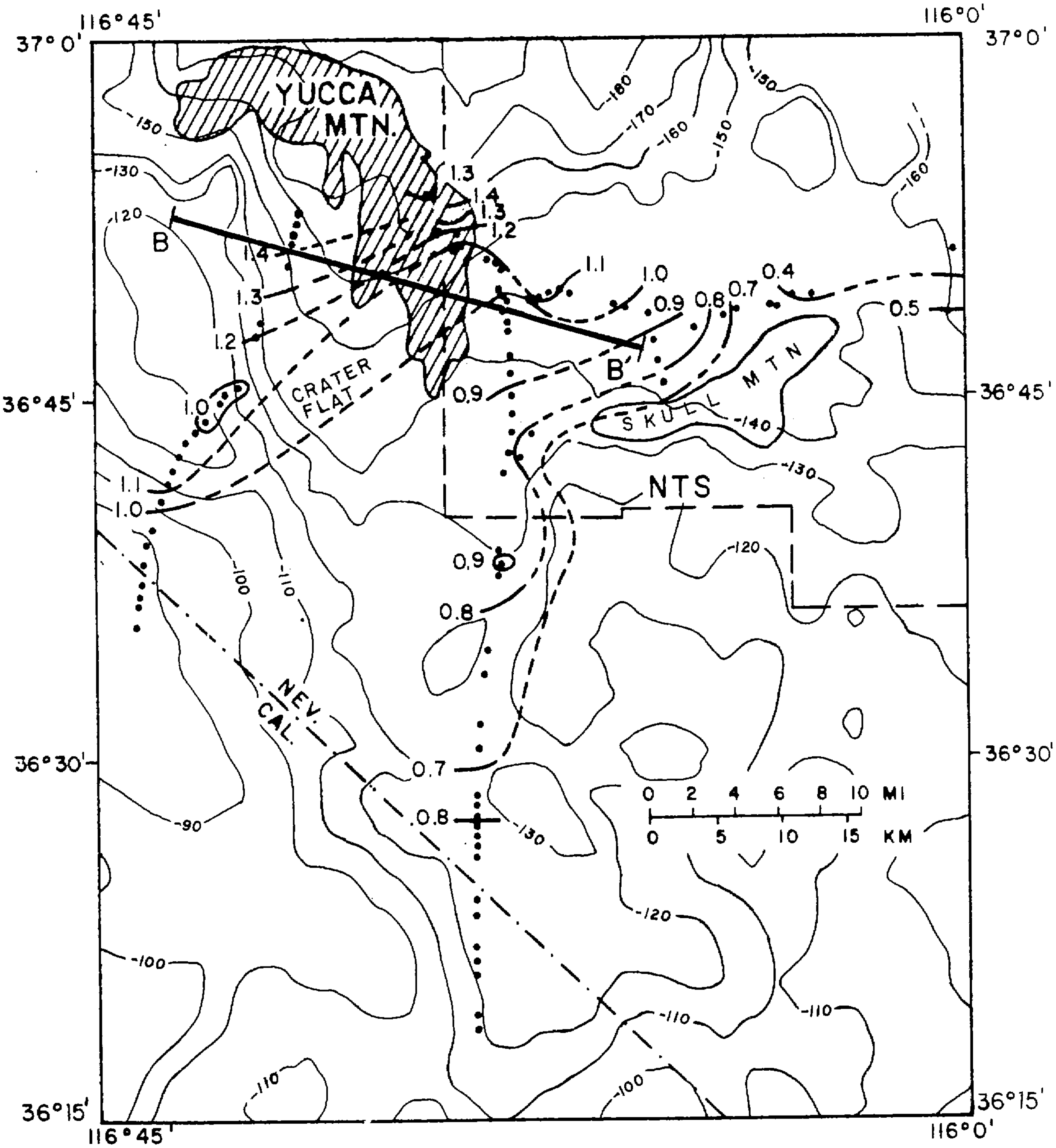


Figure 6. T-X/6 (sec) traveltimes for shot points 1 and 3 with 10 mgal Bouguer gravity contours, 2.67 reduction density (Healey and others, 1980).

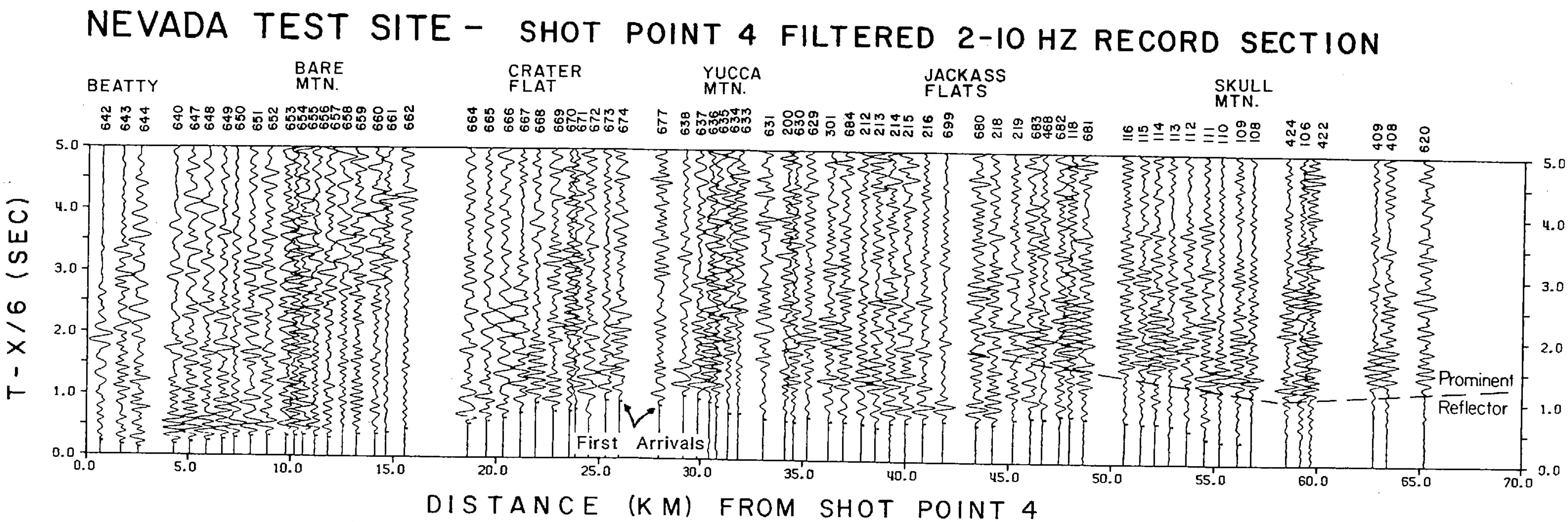


Figure 7. Nevada Test Site - Shot point 4 Filtered 2-10 Hz record section. East-west line extending from Beatty, Nevada, to the Skull Mountain area of the Nevada Test Site. Dots indicate first arrivals.

TRAVELTIME DELAYS

Since all of the P-wave arrivals are from a nearly horizontal refractor, the velocity structure between that depth and the recording stations will largely determine the relative difference in traveltime between neighboring stations. For example, considering neighboring stations at identical distances from the source, the station located on outcropping Paleozoic rocks will record significantly shorter traveltimes than one located on a thick sequence of ash-flow tuff due to the lower intrinsic velocity of the latter rocks relative to the former. These differences in traveltimes can be clearly seen in the contour map of reduced traveltimes in the study area (Figure 6).

Since the magnitude of the delay is proportional to both the depth of the horizontal refractor and the thickness of low velocity layers beneath a given station, we can estimate this thickness by combining the observed delay times with other geophysical data. We have found that the observed delay times fall into three groups:

1) 1.4 to 1.2 s, large delays over Crater Flat and Yucca Mountain
2) 1.2 to 0.8 s, moderate delays over Jackass Flats
3) 0.8 to 0.4 s, small delays over Skull and Bare Mountains

These three groups correspond to the presence of thick low velocity layers, moderately thick low velocity layers and a very thin to nonexistent low velocity layer, respectively (Figure 8).

Rock Velocities

Some knowledge of the velocities of the rocks within the study area is required in order to make use of the P-wave delay times to infer the near-surface structure. Four sources of information were used to estimate the rock velocities: local geologic studies, seismic refraction surveys, borehole measurements, and the subsurface density distribution as inferred from modeling of detailed gravity data.

The local geology (Christiansen and others, 1977; Snyder and Carr, 1982) indicates that at least three main rock types must be considered: Precambrian and Paleozoic clastic, metamorphic, and sedimentary rocks; Cenozoic ash-flow tuffs; and Cenozoic volcanics and alluvium. The velocities of these types of rocks are known to vary from about 1.0 km/s to over 6.0 km/s and this wide range of velocities is reflected in the one-second spread in the values of the bserved P-wave delay times in the study area (Figure 8). Seismic refraction surveys that have been conducted in the areaprovide important information on the velocities of individual rock types (L. W. Pankratz, 1982; figure 1). These profiles at the easternmost end of this study show velocities in the alluvium of from 1.0 to 2.2 km/s, while the ash-flow tuffs are characterized by a velocity of 2.6 to 3.2 km/s. A layer presumed to be altered argillite has a velocity of from 3.8 to 4.5 km/s and the lowest layer has a velocity of 4.4 to 5.1 km/s. The lowest layer detected is presumed to be the top of a granitic body in the profile area. The velocity in the basement refractor at

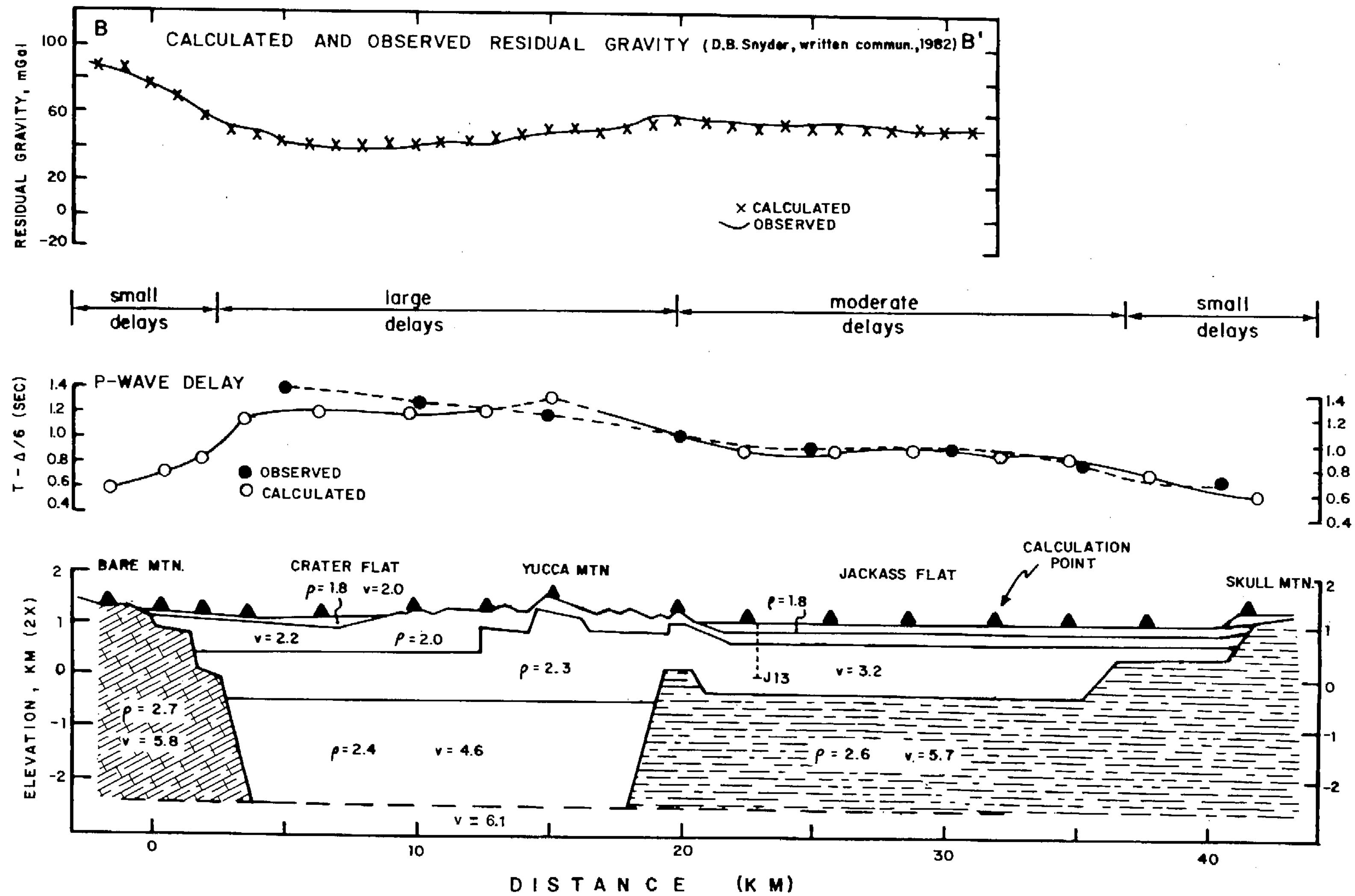


Figure 8. Crustal section modified from Snyder and Carr (1982) with layer densities and velocities (Table 1), observed and calculated traveltime delays for P-wave arrivals from nuclear sources, and calculated and observed residual gravity. Observed and calculated delay times agree well, except over Crater Flat where the observed delay is 0.2 s larger than that calculated (see text). Drill holes are projected onto the profile.

about 4 km depth is estimated to be 6.0 to 6.15 km/s based on the refraction profiles reported by Johnson (1965) and confirmed by the profiles reported here (Figures 3, 4, 5, and 7).

Additional information has been obtained from borehole velocity measurements made at two 1,830 m (6,000 ft)-deep holes on the eastern flank of Yucca Mountain. The velocity measurements in holes G1 and H1 (Figure 1) show velocities in the range of 3.3 to 4.2 km/s in the 400 to 1,830 m (1,300 to 6,000 ft) interval. Furthermore, it was determined that the one-way traveltime to the bottom of H1 is 0.6 s, an average velocity in the hole of 3.0 km/s (D. C. Muller, written communication, 1982).

Whereas the typical velocities of the various rock types have been determined from the foregoing seismic measurements, the distribution of rock types was estimated by modeling of the regional gravity (Ponce, 1981; Snyder and Carr, 1982). These comprehensive studies have proposed crustal structures in the study area which are unlikely to be significantly improved upon until additional deep drilling or seismic refraction work is done. In choosing rock velocities, therefore, care has been taken to use values which are reasonable for the densities shown in the gravity models.

INTERPRETATION

The upper crustal structure in the Yucca Mountain area has been inferred from both the seismic P-wave delays (Figures 3, 4, and 5) and the unreversed refraction profile from shot point 4 (Figure 7). Since the present seismic data alone is insufficient for deriving the crustal structure in this geologically complex region, we have relied heavily on existing models and have modified these to obtain new, closely related models in agreement with the seismic observations. The results provide new details on the structure in the study area, and have been used to define the need for further seismic investigations.

P-WAVE DELAY DATA

The seismic P-wave delay data from Crater Flat to Skull Mountain have been interpreted using the B-B' crustal density section of Snyder and Carr (1982; Figure 9) as a basis. Since the P-wave data reaches as far as Skull Mountain (i.e., beyond section B-B', figure 2), their model was extrapolated an additional 15 km to the east. The densities in their model were converted to velocities with close reference to the available seismic information, as shown in Table 1.

TABLE 1
DENSITY - VELOCITY RELATIONSHIP

Density (g/c^3)	Velocity (km/s)
1.8	2.0
2.0	2.2
2.3	3.2
2.4	4.6
2.6	5.7
2.7	5.8
---	6.1

The P-wave delay times associated with this velocity model were calculated by raytracing critically refracted rays through the model. A velocity of 6.1 km/s was used for the refracting medium located at a depth of 2.3 km below sea level (3.6 km below the surface; Figure 8). The comparison of observed and calculated delay times indicates that the velocity model is a reasonable one; the observed delay times clearly confirm the greater depth to the pre-volcanic rocks beneath Crater Flat and Yucca Mountain. The main discrepancy between the observed and calculated values occurs on Crater Flat where the observed delay is greater than that predicted by the model. This indicates a westward increase in either the depth of the pre-volcanic layer or in the amount of low velocity near-surface materials. We note on the contour map of Figure 6 that the maximum delay time on Crater Flat, 1.4 s, is matched by an equal delay time on Yucca Mountain at a location 5 km north of the profile line B-B'. This suggests that local variations in thickness of the low velocity tuffs is the cause of the 1.4 s delay on Crater Flat, rather than a systematic westward deepening of the pre-volcanic layer.

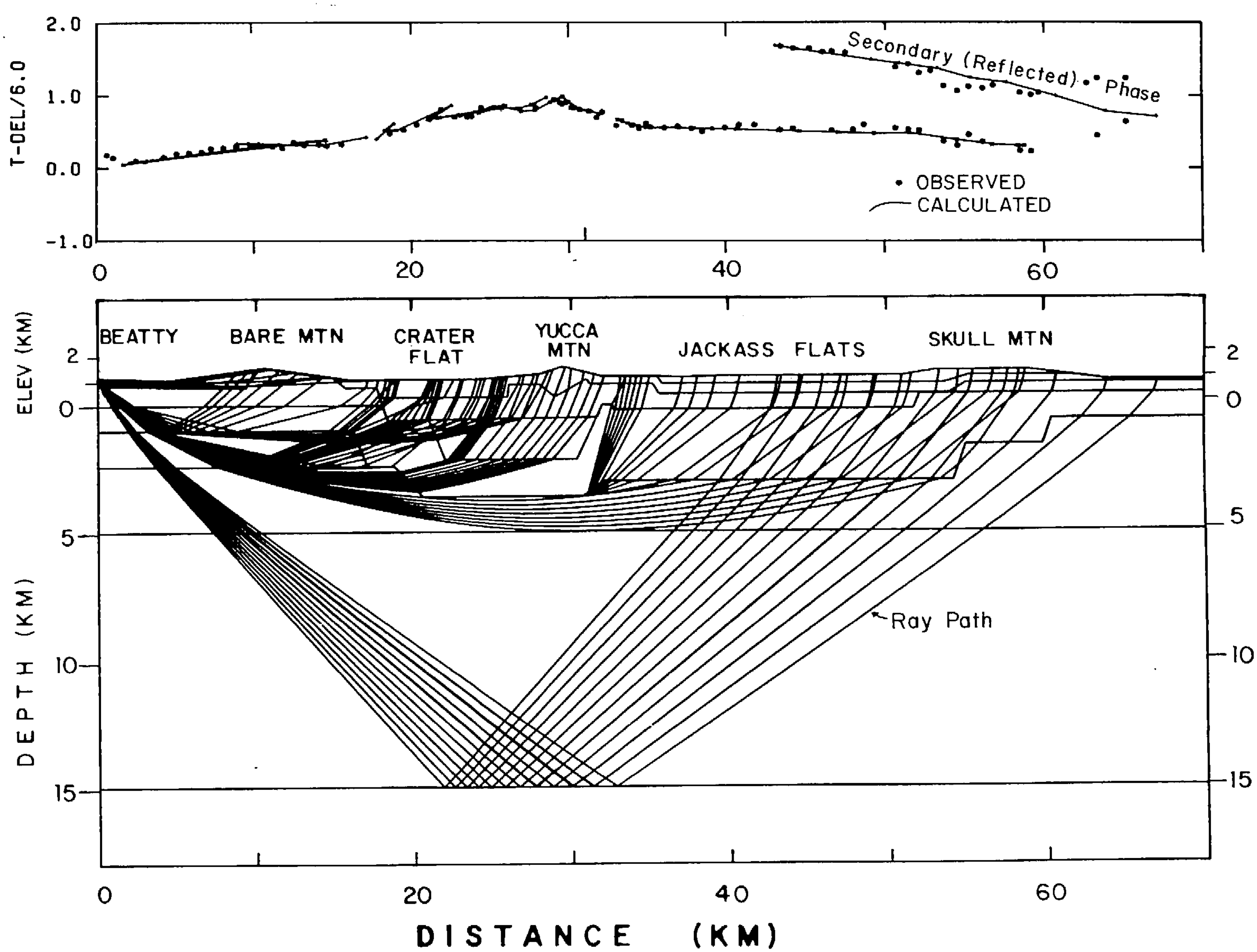


Figure 9. Crustal model, ray paths, and a comparison of observed and calculated arrival times for shot point 4 data. The calculation of ray paths through the velocity model provides the model traveltimes (solid line, top) which have been adjusted to fit the observed times (open circles). Reflected, refracted, and diffracted rays have been considered. The final model was obtained by iteratively adjusting velocities and boundary depths in the starting model derived from the crustal density section of Snyder and Carr (1982). Model parameters are given in Figure 10.

Shot Point 4 Profile

The refraction profile from shot point 4 (near Beatty) to Skull Mountain demonstrated the feasibility of recording clear refracted arrivals to a distance of 65 km in an area considered to be in a "bad data" region for seismic reflection profiling. Since the profile is unreversed, a unique model cannot be derived with the present information, despite the high signal-to-noise ratio of the data. The data does, however, give additional control on the existing density model of the upper crust obtained from the interpretation of gravity data.

The method of interpretation used for shot point 4 data was similar to that applied to the P-wave delay data; the B-B' crustal section of Snyder and Carr (1982) was converted into a velocity model and traveltimes of compressional waves were calculated through this model, in this case by two-dimensional computer raytracing. A comparison of observed and theoretical traveltimes (Figure 9) shows that the velocity model provides a close fit to the data, the error being ± 0.05 s in most places. The ray diagram shows that the arrivals to stations on Crater Flat and Yucca Mountain reach their bottoming points beneath Bare Mountain, and the arrivals to Jackass Flats bottom beneath Yucca Mountain. The diagram also makes clear that additional shot points at 20, 40, and 60 km on the distance scale would provide excellent seismic reversal coverage along the refracting and reflecting horizons. The traveltimes of the prominent secondary phase recorded on this profile (Figure 7) is fit by reflections from a boundary at a depth of 15 ± 2 km below sea level.

The velocities and layer boundaries used to compute the theoretical traveltimes in two alternative models are shown in Figure 10. In considering this diagram, it should be understood that the method of computation requires that boundaries be included wherever a change in velocity or velocity gradient is desired. Since the depth to a boundary can often be traded off against velocity at that boundary, the depth to some boundaries is non-unique, and some boundaries are included only to allow a change in the velocity gradient (e.g., the boundary at a depth of 5 km in Figure 10). To distinguish the boundaries with first order geologic importance from those that are mainly the product of the analysis method, the former boundaries are shown as heavy solid lines and the latter by light solid lines. The two heavy lines correspond to the volcanic/pre-volcanic boundary and to the major mid-crustal boundary at a depth of 15 ± 2 km. The depth estimates to pre-volcanic rocks are 3.2 km (10,500 ft) beneath eastern Crater Flat and 1.1 km (3,650 ft) beneath Jackass Flats. Whereas the gravity model of Snyder and Carr (1982) shows a single east-dipping contact between Bare Mountain and Crater Flat, located 3 km east of outcropping Paleozoic rocks on Bare Mountain, the velocity model shows a distinct 2.5 km-wide bench (down-dropped block?) at a depth of 1.6 km (5,250 ft). The apparent velocity of the pre-volcanic layer increases from about 5.7 to about 6.0 km/s or higher within the first two kilometers. The absolute velocity of the basement remains uncertain with the present unreversed seismic data. A north- south reversed profile within Crater Flat is planned in order to resolve this uncertainty and to confirm the velocity-depth structure.

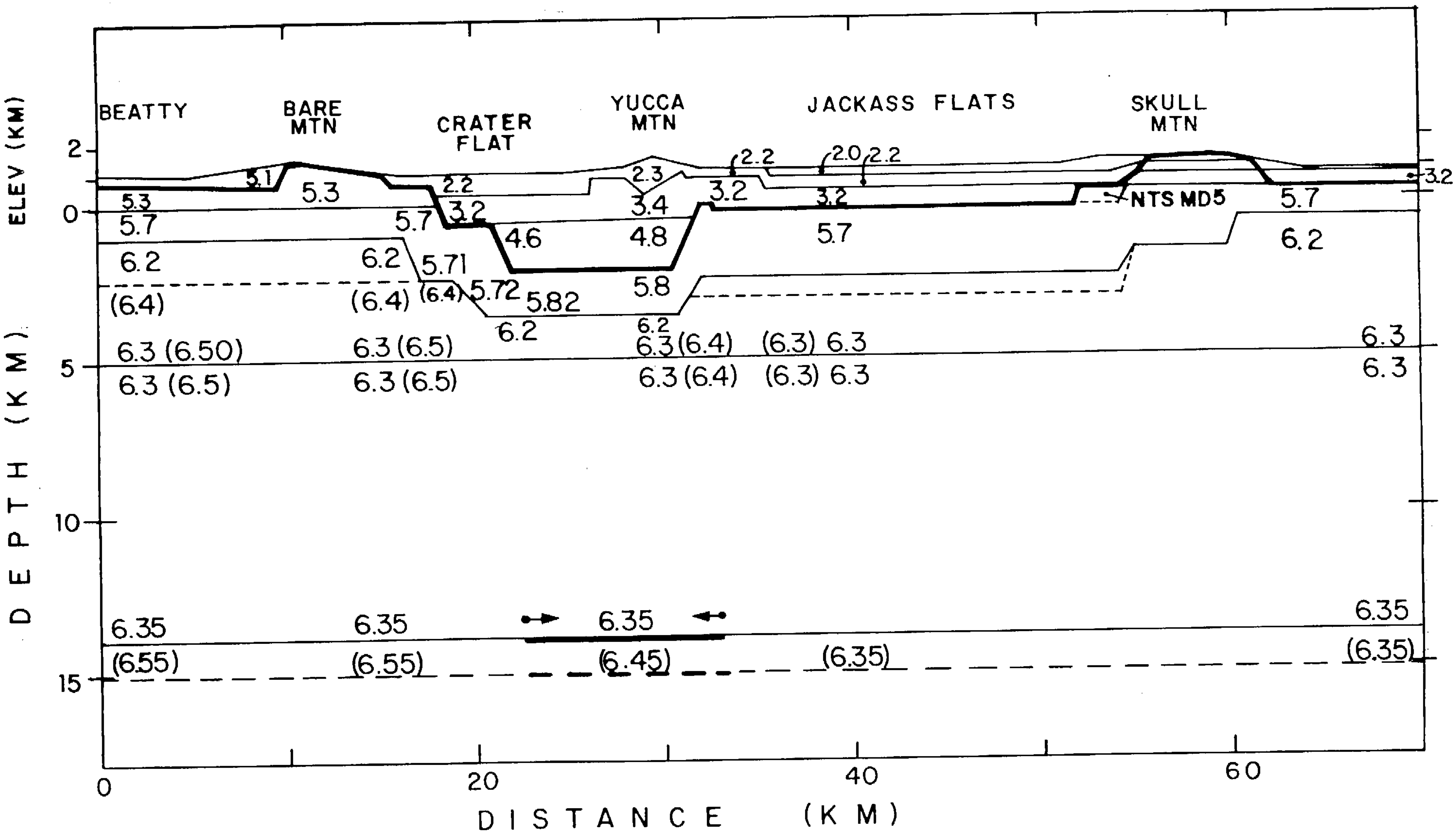
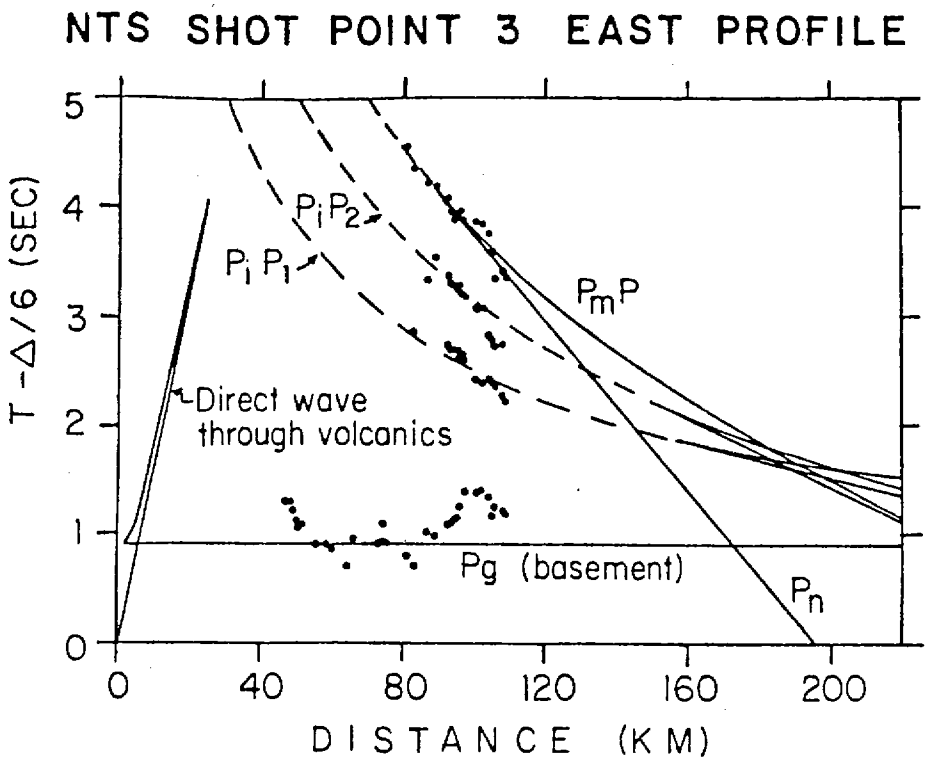


Figure 10. Crustal velocity model derived from shot point 4 data. Average layer velocities are indicated in km/s. Solid lines are layer boundaries, and dashed lines are alternative boundary depths calculated for the average layer velocities in parentheses. The heavy solid line above a depth of 5 km is the volcanic/pre-volcanic boundary. The mid-crustal boundary below 15 km is indicated by a heavy line where the depth is controlled by the seismic data (c.f., Figure 9). The depth to pre-volcanic rocks (velocity greater than 5.0 km/s) is 3.2 km (10,500 ft) beneath eastern Crater Flat.



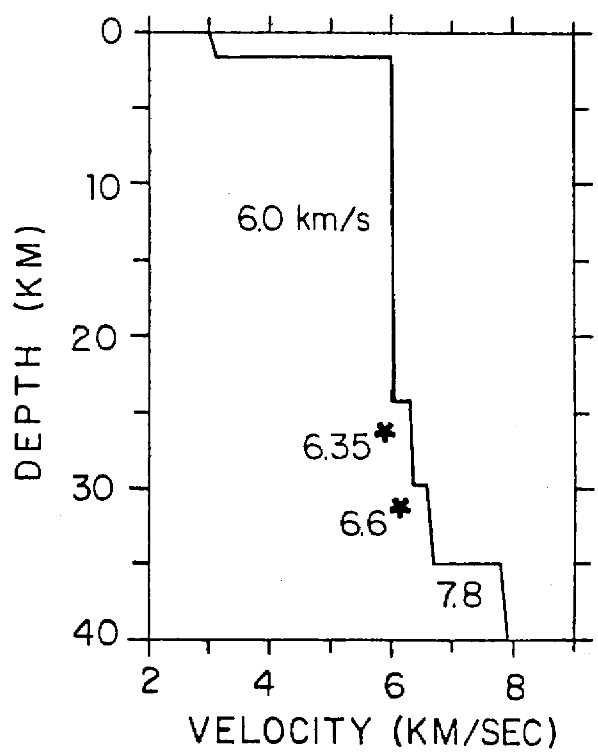


Figure 11. Traveltime curve and crustal velocity model for southern Nevada

Top: Observed (solid dots) and calculated (solid lines) traveltimes for shot point 3 profile from Yucca Mountain to Death Valley Junction (Figure 5). Definitions: Pg is the "seismic basement" refractor; PiP_1 is the first intracrustal reflector (24 km); PiP_2 is the second intracrustal reflector (30 km); PmP is the mantle reflector.

Bottom: Interpreted compressional-wave velocity structure of the crust. Velocity boundaries in the upper crust may not have been detected since the minimum source-recorder range was 47 km. Asterisks indicate estimated velocities.

SHOT POINT 3 EAST PROFILE

Further evidence for the deep crustal structure beneath the study area is provided by the clear secondary arrivals observed on the easternmost profile from shot point 3 (Figure 5). This profile recorded a crust-mantle and two intra-crustal reflections.

In view of the lack of reversal on this profile, the crustal model derived from it was constrained by the other seismic profiles in the area. An average velocity of 3.0 km/s has been used for the near-surface layer, and of 6.0 km/s for the basement (Pg) refractor. The first arrivals along this proifle show considerable scatter (Figure 11), but an average line through these points gives a depth to basement of 1.5 km. The first intracrustal reflection is most clearly observed at a reduced time of 2.6 s and a range of 93 to 97 km (Figure 5). These arrivals can be fit by a pre-critical reflection from a boundary at 24 km depth where the velocity increases from 6.0 to 6.35 km/s (Figure 11). The second reflection occurs at a reduced time of 3.15 to 3.55 s and a range of 86 to 97 km. These arrivals have been fit by a second pre-critical reflection from a boundary at 30 km depth where the velocity increases from 6.35 to 6.6 km/s. Finally, the mantle reflections between 3.4 and 4.5 s and 81 to 109 km have been fit with a reflection from the crust-mantle boundary at a depth of 35 km. A mantle velocity of 7.8 km/s has been used based on the work of Johnson (1965). This structure is illustrated in the velocity-depth plot of Figure 11.

SUMMARY

Seismic refraction data from nuclear and chemical explosions have been used to calculate the crustal velocity structure in the vicinity of Yucca Mountain, southern Nevada. A contour map of P-wave delay times and an unreversed refraction profile have been used in conjunction with gravity models to estimate the configuration of pre-volcanic surface between outcrops at Bare Mountain and Skull Mountain. The models have been constrained by geologic and geophysical information, including geologic mapping, shallow seismic refraction surveys, borehole measurements and the subsurface density distribution as inferred from modeling detailed gravity data. The greatest depth to basement (somewhat more than 3 km) is beneath eastern Crater Flat-western Yucca Mountain, where a graben-like structure exists in the deeper rocks.

The total crustal thickness has been calculated from an unreversed profile from a nuclear shot at Pahute Mesa. The crust is 35 km thick and contains intracrustal boundaries at 24 and 30 km; an additional boundary at 15 km depth has been identified on the east-west profile across Yucca Mountain.

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APPENDIX A

Seismic Recorder Locations

Appendix A is a listing of all recorder sites that were used for this experiment. "Location Number" is the reference number for the site which is used on all maps and record sections. Other information in this appendix is the latitude, longitude, and elevation in feet of each recorder location.

SEISMIC RECORDER LOCATIONS

LOCATION NUMBER	LATITUDE (DEG,MIN,SEC)	LONGITUDE (DEG,MIN,SEC)	ELEV
1	37 14 54.3	116 25 20.6	6273
2	37 6 6.7	116 0 14.6	4385
3	37 18 12.2	116 19 32.1	6960
4	36 53 20.7	116 47 19.2	3680
101	36 48 21.0	116 0 42.6	3210
102	36 50 55.5	116 0 29.7	3355
103	36 50 54.9	116 2 20.8	3460
104	36 50 11.3	116 3 40.7	3620
105	36 48 30.3	116 6 5.2	3925
106	36 49 4.2	116 7 50.2	4170
107	36 49 7.3	116 8 45.0	4280
108	36 48 42.2	116 9 32.4	4303
109	36 48 41.1	116 10 0.2	4270
110	36 48 31.0	116 10 38.3	4200
111	36 48 29.6	116 11 7.7	4150
112	36 48 31.1	116 11 43.2	4110
113	36 48 15.6	116 12 20.9	4010
114	36 48 0.3	116 12 53.6	3910
115	36 47 52.1	116 13 23.8	3845
116	36 47 44.9	116 13 58.9	3750
117	36 47 34.5	116 14 46.5	3650
118	36 47 18.6	116 15 56.4	3514
119	36 46 19.8	116 15 42.3	3500
120	36 45 28.4	116 15 29.0	3495
121	36 46 26.8	116 15 44.2	3500
201	36 51 59.2	116 27 26.4	4320
202	36 51 47.5	116 27 5.9	4200
203	36 51 36.1	116 26 55.1	4130
204	36 51 5.0	116 26 24.0	3940
205	36 50 38.3	116 25 44.0	3750
206	36 50 36.7	116 24 35.8	3540
207	36 50 9.5	116 23 50.8	3432
208	36 49 21.1	116 23 59.4	3340
209	36 49 6.3	116 23 47.8	3297
210	36 48 51.2	116 23 33.4	3550
211	36 48 47.4	116 22 56.6	3340
212	36 48 55.2	116 22 26.9	3390
213	36 49 3.5	116 21 56.6	3445
214	36 49 11.8	116 21 25.7	3510
215	36 49 20.2	116 20 53.0	3580
216	36 49 12.2	116 20 19.5	3578
217	36 48 54.5	116 18 54.2	3535
218	36 48 45.1	116 18 6.8	3575
219	36 48 37.7	116 17 28.0	3600
220	36 48 23.7	116 16 13.2	3620
301	36 48 28.0	116 23 42.0	3310
302	36 47 33.9	116 23 32.2	3240
303	36 46 38.5	116 23 25.6	3180
304	36 45 51.6	116 23 24.9	3128
305	36 45 2.1	116 23 22.5	3070

SEISMIC RECORDER LOCATIONS

LOCATION NUMBER	LATITUDE (DEG,MIN,SEC)	LONGITUDE (DEG,MIN,SEC)	ELEV
306	36 44 13.8	116 23 19.2	3010
307	36 43 24.1	116 23 23.0	2950
308	36 42 36.0	116 23 34.4	2890
309	36 41 47.4	116 23 47.0	2840
310	36 47 58.4	116 23 33.2	3270
400	36 52 0.4	116 27 29.0	4340
401	36 50 55.5	116 0 29.7	3340
402	36 50 56.8	116 1 17.7	3400
403	36 50 56.3	116 2 17.9	3460
404	36 50 36.2	116 3 10.4	3560
405	36 50 9.8	116 3 42.6	3620
406	36 49 43.5	116 4 4.3	3680
407	36 49 19.8	116 4 30.0	3740
408	36 48 59.9	116 5 0.7	3800
409	36 48 31.1	116 5 33.3	3860
410	36 48 30.3	116 6 5.2	3920
421	36 48 57.7	116 7 7.2	4080
422	36 49 6.3	116 7 30.4	4120
424	36 48 59.5	116 8 19.3	4210
441	36 45 29.4	116 21 14.5	3150
442	36 44 46.9	116 21 37.2	3060
443	36 44 8.8	116 21 57.4	3020
444	36 43 24.2	116 22 23.8	2960
445	36 42 58.4	116 22 36.5	2930
446	36 42 28.0	116 22 54.1	2890
447	36 41 57.6	116 23 11.7	2860
448	36 41 25.2	116 23 29.4	2820
449	36 41 8.9	116 23 39.4	2810
450	36 40 17.2	116 24 7.1	2750
466	36 49 41.9	116 15 24.5	3820
467	36 48 52.6	116 16 10.1	3690
468	36 48 15.0	116 16 35.4	3590
469	36 47 44.4	116 17 19.5	3500
481	36 47 18.3	116 15 56.8	3514
482	36 47 13.2	116 16 30.7	3480
483	36 47 5.4	116 17 4.5	3422
484	36 46 57.5	116 17 49.4	3390
485	36 46 46.3	116 18 16.4	3340
486	36 46 32.8	116 18 50.2	3290
487	36 46 31.6	116 19 26.0	3255
488	36 46 26.3	116 19 57.8	3210
489	36 46 21.3	116 20 29.8	3210
490	36 46 15.8	116 21 1.6	3153
501	36 19 35.3	116 25 18.9	2200
502	36 20 3.2	116 25 19.3	2200
503	36 20 29.8	116 25 19.1	2200
504	36 20 56.0	116 25 19.3	2200
505	36 21 22.1	116 25 18.5	2200
506	36 21 48.9	116 25 18.7	2200
507	36 22 15.8	116 25 18.4	2200

SEISMIC RECORDER LOCATIONS

LOCATION NUMBER	LATITUDE (DEG,MIN,SEC)	LONGITUDE (DEG,MIN,SEC)	ELEV
508	36 22 42.2	116 25 18.2	2200
509	36 23 8.6	116 25 18.1	2200
510	36 23 34.9	116 25 18.1	2200
511	36 24 0.9	116 25 18.1	2200
512	36 24 26.6	116 25 17.0	2200
513	36 25 20.1	116 25 16.5	2200
514	36 25 45.8	116 25 16.0	2200
515	36 26 11.8	116 25 15.9	2200
516	36 26 37.7	116 25 15.4	2200
517	36 27 4.1	116 25 15.1	2200
518	36 27 28.4	116 25 14.8	2200
519	36 27 56.4	116 25 15.1	2200
520	36 28 23.2	116 25 14.8	2200
521	36 53 21.8	116 27 46.9	5160
522	36 53 8.7	116 27 17.4	4940
523	36 52 51.4	116 27 4.1	4800
524	36 52 17.8	116 26 48.8	4500
525	36 51 54.4	116 26 31.8	4290
526	36 51 40.8	116 26 10.2	3920
527	36 51 12.8	116 25 58.9	3810
528	36 50 42.8	116 25 54.6	3790
529	36 50 37.0	116 25 7.9	3620
530	36 50 25.3	116 24 3.8	3470
541	36 44 52.0	116 38 26.8	2780
542	36 45 13.2	116 38 13.4	2840
543	36 45 28.4	116 37 33.1	2951
544	36 45 47.2	116 37 12.4	2921
545	36 53 36.9	116 34 4.5	3640
546	36 46 27.2	116 36 56.0	3800
547	36 46 54.5	116 36 46.9	2970
548	36 47 32.7	116 36 34.5	3020
549	36 53 12.6	116 34 12.1	3533
550	36 48 7.9	116 36 23.2	3079
551	36 48 36.9	116 36 13.8	3720
552	36 52 13.2	116 34 27.2	3420
553	36 49 6.3	116 35 39.5	3130
554	36 49 26.6	116 35 20.1	3195
555	36 51 25.1	116 34 42.3	3500
556	36 49 58.0	116 35 2.4	3580
557	36 50 28.4	116 34 53.7	3260
558	36 51 6.9	116 34 49.9	3300
559	36 51 43.4	116 34 39.1	3357
560	36 52 40.2	116 34 22.2	3470
561	36 35 30.6	116 42 53.3	3260
562	36 35 56.6	116 42 47.2	3000
563	36 36 22.7	116 42 45.4	2960
564	36 36 49.3	116 42 41.4	2780
565	36 37 14.2	116 42 36.4	2700
566	36 37 40.2	116 42 33.1	2680
567	36 38 5.5	116 42 29.8	2660

SEISMIC RECORDER LOCATIONS

LOCATION NUMBER	LATITUDE (DEG,MIN,SEC)	LONGITUDE (DEG,MIN,SEC)	ELEV
568	36 38 32.1	116 42 25.3	2620
569	36 38 56.2	116 42 22.5	2610
570	36 39 35.7	116 42 2.3	2590
571	36 40 10.9	116 41 47.2	2610
572	36 40 46.2	116 41 33.3	2620
573	36 41 29.0	116 41 14.9	2628
574	36 42 2.5	116 40 57.8	2640
575	36 42 36.3	116 40 40.1	2650
576	36 43 11.6	116 40 19.2	2660
577	36 43 38.6	116 39 47.7	2670
578	36 44 4.9	116 39 16.2	2680
581	36 40 14.4	116 24 7.1	2750
582	36 39 42.6	116 24 13.2	2720
583	36 39 11.6	116 24 12.7	2690
584	36 38 38.6	116 24 13.2	2660
585	36 38 6.9	116 24 3.9	2630
586	36 37 36.7	116 24 9.2	2610
587	36 37 4.9	116 24 15.0	2580
588	36 36 34.7	116 24 20.5	2560
589	36 36 4.3	116 24 25.8	2540
590	36 35 33.0	116 24 31.1	2520
591	36 35 2.8	116 24 36.9	2490
592	36 34 31.9	116 24 42.1	2470
593	36 34 1.3	116 24 47.4	2450
594	36 33 30.0	116 24 53.2	2420
595	36 32 59.6	116 24 58.2	2400
596	36 32 28.4	116 25 1.2	2380
597	36 31 58.2	116 25 4.6	2360
598	36 31 27.4	116 25 7.6	2340
599	36 30 56.0	116 25 10.6	2310
600	36 30 25.1	116 25 13.2	2300
619	36 49 32.3	116 4 12.7	3700
620	36 50 14.4	116 3 36.8	3600
621	36 50 16.3	116 24 42.1	3580
622	36 52 0.9	116 23 41.5	3640
623	36 54 23.7	116 22 31.2	3800
624	36 53 36.2	116 22 58.8	3750
625	36 52 51.4	116 23 35.2	3720
629	36 48 14.4	116 24 29.5	3300
630	36 47 58.3	116 25 4.3	3400
631	36 48 17.5	116 25 58.5	3560
632	36 48 31.9	116 26 19.8	3680
633	36 48 55.1	116 26 37.2	3780
634	36 49 29.5	116 26 46.9	3960
635	36 49 58.2	116 27 2.4	4200
636	36 50 3.1	116 27 15.5	4360
637	36 50 9.6	116 27 36.7	4620
638	36 50 16.3	116 28 5.7	4951
639	36 49 36.1	116 28 1.4	4840
640	36 48 49.0	116 27 46.7	4680

SEISMIC RECORDER LOCATIONS

LOCATION NUMBER	LATITUDE (DEG,MIN,SEC)	LONGITUDE (DEG,MIN,SEC)	ELEV
642	36 53 19.3	116 46 52.0	3380
643	36 53 4.6	116 46 13.2	3400
644	36 53 4.2	116 45 38.5	3320
646	36 53 34.2	116 44 26.5	3400
647	36 53 39.7	116 43 55.0	3520
648	36 53 44.7	116 43 23.1	3680
649	36 53 44.9	116 42 51.6	3808
650	36 53 29.2	116 42 25.9	4000
651	36 53 17.5	116 41 54.1	4200
652	36 53 17.3	116 41 21.6	4310
653	36 53 24.1	116 40 44.3	4533
654	36 53 7.6	116 40 28.3	4680
655	36 52 44.0	116 40 13.6	4966
656	36 52 19.9	116 39 54.2	4720
657	36 52 5.0	116 39 31.6	4400
658	36 52 4.2	116 39 2.6	4320
659	36 52 2.2	116 38 35.2	4160
660	36 52 3.4	116 37 57.4	4040
661	36 50 56.1	116 37 56.5	3780
662	36 50 26.5	116 37 29.9	3620
663	36 49 53.3	116 36 51.2	3460
664	36 48 37.0	116 36 15.5	3195
665	36 48 27.2	116 35 41.1	3180
666	36 48 15.9	116 35 10.6	3170
667	36 48 5.8	116 34 40.2	3170
668	36 47 55.7	116 34 12.6	3140
669	36 47 44.8	116 33 40.6	3160
670	36 47 33.1	116 33 12.6	3160
671	36 48 6.6	116 32 39.6	3260
672	36 48 15.2	116 32 6.8	3340
673	36 48 15.2	116 31 30.9	3440
674	36 48 29.2	116 30 56.1	3520
675	36 48 38.5	116 30 17.3	3600
676	36 49 0.2	116 29 46.0	3720
677	36 49 19.5	116 29 11.4	3820
678	36 49 50.8	116 29 2.7	4100
681	36 47 25.7	116 15 25.9	3565
682	36 47 54.1	116 16 6.1	3560
683	36 48 31.7	116 16 54.8	3610
686	36 48 51.3	116 18 38.4	3550
687	36 48 57.4	116 19 10.1	3550
688	36 49 3.6	116 19 41.6	3560
694	36 48 38.8	116 23 8.2	3320

APPENDIX B

Master Shot List and Team-Shot Data Sheets with Tape Grade Scale

The "Master Shot List" (page 33) is a table containing all important information pertaining to each recorded shot or nuclear event. Most of the information is self-explanatory. "Shot Point" refers to the location number for that particular shot. For this experiment, the shot point and shot number are the same. Additional information and the size of the shot are listed to the right of the data.

The "Team-Shot Data Sheets" (pages 34-43) contain all of the information related to the seismic recorders. Each set of 20 recorders is given a designated team number under which data is stored and referenced. Each "Data for One Team-Shot" contains shot number, team number, shot point, and shot time. Column headings for the table are explained below:

Loc	-	location number from the seismic recorder location file (Appendix A)
Dist (km)	-	distance in kilometers from the shot point to the recorder location
Azim	-	azimuthal projection from the shot point to the recorder location
Unit	-	I.D. number of the recording unit
Chron	-	chronometer correction for the recorder at shot time (calculated from the total clock drift)
Chan	-	channel number (1, 2, or 3) which was selected to be digitized by the computer
C1, C2, C3	-	amplifier gain setting (db) for each data recording channel
Tape Grade	-	value used to rate the performance quality of the seismic recorder (see Tape Grade Scale, following)

Additional information relevant to analysis of the data is listed to the right of the data columns.

The "Tape Grade Scale" (page 44) is a listing of all tape grade numbers used on the Team-Shot Data Sheets. Each number corresponds to a specific problem with the recording unit.

MASTER SHOT LIST

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982

SHOT NUMBER	DATE	SHOT POINT	LATITUDE	LONGITUDE	SHOT TIME	
1	APR 26, 1980	1	37 14.9057	116 25.3440	117 17 0 0.083	COLWICK - APPROX. 120 KT.
2	MAY 29, 1981	2	37 6.1111	116 0.2438	149 16 0 0.094	ALIGOTE - APPROX. 20 KT.
3	JUN 6, 1981	3	37 18.2038	116 19.5358	157 18 0 0.084	HARZER - APPROX. 120 KT.
4	APR 28, 1982	4	36 53.3450	116 47.3204	119 4 0 0.014	BEATTY - 2480 LBS.

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12 NEVADA TEST SITE, 1980-1982
SHOT NUMBER 1 TEAM 1
SHOT POINT 1
SHOT TIME: 117:17: 0: 0.083

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	120	56.368	165.0	103	0	3	44	26	62	0
2	121	54.532	164.9	32	-4	3	44	26	62	0
3	118	52.912	164.7	26	-2	3	44	26	62	0
4	220	50.865	164.6	38	0	3	44	26	62	0/ 6/30
5	219	49.985	166.5	125	3	3	44	26	62	0/ 6
6	218	49.547	167.5	130	-5	3	44	26	62	0
7	217	49.024	168.8	60	--		44	26	62	1
8	216	48.117	171.1	90	-3	3	44	26	62	0
9	215	47.753	172.0	94	2	3	44	26	62	0
10	114	53.072	159.6	15	2		44	26	62	6/17/24
11	115	53.054	160.5	17	--		44	26	62	1
12	116	52.982	161.5	24	-2	3	44	26	62	0
13	117	52.924	162.8	25	-5		44	26	62	18

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12 NEVADA TEST SITE, 1980-1982
SHOT NUMBER 1 TEAM 2
SHOT POINT 1
SHOT TIME: 117:17: 0: 0.083

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	211	48.433	175.8	62	0		44	26	62	17/18/25
2	210	48.260	176.9	97	1	3	44	26	62	0
3	301	48.962	177.1	63	0	3	44	26	62	0
4	310	49.884	176.9	118	-3	3	44	26	62	0
5	302	50.640	177.0	110	-4	3	44	26	62	0
6	303	52.354	176.9	33	0	3	44	26	62	0
7	304	53.799	177.0	52	-8	3	44	26	62	0
8	305	55.325	177.0	51	0	3	44	26	62	0
9	306	56.817	177.0	124	-7	3	44	26	62	0
10	307	58.342	177.1	104	0	3	44	26	62	0
11	308	59.809	177.5	105	4	3	44	26	62	0/ 6/30
12	309	61.294	177.8	30	1	3	44	26	62	0

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 1   TEAM 3
SHOT POINT   1
SHOT TIME: 117:17: 0: 0.083

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	101	61.214	143.4	18	0	3	44	26	62	0
2	102	57.642	140.3	1	0	3	44	26	62	0
3	103	55.961	142.5	43	3		44	26	62	17/25
4	104	55.876	144.9	40	3		44	26	62	1
5	105	56.613	149.7	76	-4		44	26	62	1
6	106	54.382	151.5	75	2	3	44	26	62	0
7	107	53.664	152.7	98	0	3	44	26	62	0/ 6/11
8	108	53.834	154.2	89	1	3	44	26	62	0
9	109	53.569	154.9	113	-2	3	44	26	62	0
10	110	53.460	155.9	112	2		44	26	62	1
11	111	53.208	156.7	143	-24		44	26	62	1
12	112	52.822	157.5	133	1	3	44	26	62	0/ 6/30
13	113	52.917	158.6	101	-2	3	44	26	62	0

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 1   TEAM 4
SHOT POINT   1
SHOT TIME: 117:17: 0: 0.083

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	214	47.904	173.0	14	0	3	44	26	62	0
2	213	48.073	174.0	19	-4	3	44	26	62	0
3	212	48.254	174.9	39	1	3	44	26	62	0
4	209	47.777	177.2	121	1	3	44	26	62	0
5	208	47.308	177.6	53	5	3	44	26	62	0
6	207	45.826	177.2	56	1	3	44	26	62	0
7	206	44.947	178.6	66	2	3	44	26	62	0
8	205	44.887	180.7	69	2		44	26	62	12/17
9	204	44.090	182.0	70	0	3	44	26	62	0
10	203	43.166	183.1	72	2	3	44	26	62	0
11	202	42.831	183.5	77	1	3	44	26	62	0
12	201	42.503	184.2	93	0	3	44	26	62	0/12

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 2   TEAM 1
SHOT POINT 2
SHOT TIME: 149:16: 0: 0.094

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	401	28.090	180.8	15	11	3	64	42	82	0
2	402	28.071	181.3	17	-2	1	64	42	82	0
3	403	28.090	183.2	24	-57	1	64	42	82	0
4	404	29.010	188.6	25	26	1	64	42	82	0
5	405	29.941	189.9	26	-3	1	64	42	82	0
6	406	30.834	190.6	32	12	1	64	42	82	0
7	407	31.674	191.5	36	-2	1	64	42	82	0
8	408	32.431	192.6	38	27	1	64	42	82	0
9	409	33.480	193.6	44	-37	1	64	42	82	0
10	410	33.699	194.9	58	-6	1	64	42	82	0

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 2   TEAM 2
SHOT POINT 2
SHOT TIME: 149:16: 0: 0.094

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	421	33.319	197.8	10	46	1	64	46	82	0
2	422	33.249	198.9	13	0	1	64	46	82	0
3	106	33.473	199.7	30	10	1	64	46	82	0
4	424	33.856	200.7	34	9	1	64	46	82	0
5	107	33.863	201.9	49	--		64	46	82	1
6	108	35.030	203.2	51	-6		64	46	82	3
7	109	35.337	204.2	52	-22	1	64	46	82	0
8	110	36.016	205.4	55	12	1	64	46	82	0
9	111	36.371	206.4	62	7	1	64	46	82	0
10	112	36.728	207.6	63	9		64	46	82	3

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 2   TEAM 3
SHOT POINT   2
SHOT TIME: 149:16: 0: 0.094

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	450	59.494	216.6	1	39	1	64	46	82	0
2	449	57.804	217.0	18	0	2	64	46	82	0
3	448	57.254	217.1	22	14	1	64	46	82	0
4	447	56.193	217.4	35	-40	1	64	46	82	0
5	446	55.182	217.6	40	14	1	64	46	82	0
6	445	54.172	217.8	43	15	1	64	46	82	0
7	444	53.354	218.1	65	-3		64	46	82	25
8	443	51.867	218.4	74	30	1	64	46	82	0
9	442	50.636	218.8	75	17	1	64	46	82	0
10	441	49.262	219.3	76	-13	1	64	46	82	0

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 2   TEAM 4
SHOT POINT   2
SHOT TIME: 149:16: 0: 0.094

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	113	37.588	208.6	14	-8	1	64	46	82	0
2	114	38.394	209.3	19	-35	1	64	46	82	0
3	115	38.982	210.1	39	5	1	64	46	82	0
4	116	39.616	211.0	48	42	1	64	46	82	0
5	117	40.506	212.2	53	0	1	64	46	82	0
6	466	37.790	216.6	56	4	1	64	46	82	0
7	467	39.684	216.6	66	-33	1	64	46	82	0
8	468	40.989	216.3	69	10	1	64	46	82	0
9	469	42.397	216.7	70	11	1	64	46	82	0

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 2   TEAM 5
SHOT POINT   2
SHOT TIME: 149:16: 0: 0.094

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	481	41.873	213.8	3	12		64	46	82	12
2	482	42.475	214.7	12	29	1	64	46	82	0
3	483	43.152	215.4	23	33	1	64	46	82	0
4	484	44.001	216.4	28	43	1	64	46	82	0
5	485	44.676	216.8	31	15	1	64	46	82	0
6	486	45.513	217.3	45	--		64	46	82	1
7	487	46.085	218.2	73	18	1	64	46	82	0
8	488	46.702	218.8	78	-25	1	64	46	82	0
9	489	47.323	219.5	82	-5	1	64	46	82	0
10	490	47.955	220.1	83	22	1	64	46	82	0

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 3   TEAM 1
SHOT POINT   3
SHOT TIME: 157:18: 0: 0.084

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	501	108.960	184.5	15	14	3	44	26	62	0
2	502	108.102	184.6	17	-9	3	44	26	62	0
3	503	107.284	184.6	24	-83		44	26	62	17
4	504	106.479	184.6	25	15		44	26	62	17
5	505	105.672	184.7	26	-2	3	44	26	62	0
6	506	104.849	184.7	32	-22	3	44	26	62	0
7	507	104.018	184.7	36	-15	3	44	26	62	0
8	508	103.207	184.8	38	-36		44	26	62	3
9	509	102.395	184.8	44	-148	3	44	26	62	0
10	510	101.584	184.8	58	-23		44	26	62	1
11	511	100.785	184.9	60	-13	3	44	26	62	0
12	512	99.990	184.9	71	-76		44	26	62	1
13	513	98.344	185.0	85	121		44	26	62	1
14	514	97.550	185.0	90	27	3	44	26	62	0
15	515	96.752	185.1	94	8	3	44	26	62	0
16	516	95.952	185.1	103	40	3	44	26	62	0
17	517	95.141	185.1	106	-43	3	44	26	62	0
18	518	94.392	185.2	125	65	3	44	26	62	0
19	519	93.531	185.2	130	-55	3	44	26	62	0
20	520	92.707	185.3	146	-27	3	44	26	62	0

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12 NEVADA TEST SITE, 1980-1982
SHOT NUMBER 3 TEAM 2
SHOT POINT 3
SHOT TIME: 157:18: 0: 0.084

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	521	47.543	194.9	10	42	3	64	46	82	0
2	522	47.752	193.9	13	-26	3	64	46	82	0
3	523	48.192	193.4	30	8	3	64	46	82	0
4	524	49.117	192.7	34	1	3	64	46	82	0
5	525	49.730	192.0	49	0		64	46	82	3
6	526	50.034	191.3	51	-49	3	64	46	82	0
7	527	50.828	190.8	52	-82	3	64	46	82	0
8	528	51.716	190.5	55	16		64	46	82	3
9	529	51.695	189.2	62	14		64	46	82	3
10	206	51.582	188.4	63	17		64	46	82	3
11	530	51.822	187.4	64	16	3	64	46	82	0
12	207	52.265	187.0	97	26		64	46	82	17
13	209	54.191	186.7	104	6		64	46	82	17
14	301	55.347	186.4	105	19	3	64	46	82	0
15	302	56.979	186.0	110	-108		64	46	82	3
16	303	58.662	185.6	118	-32	3	64	46	82	0
17	304	60.099	185.5	124	-44	3	64	46	82	0
18	444	64.507	183.8	137	-75	3	64	46	82	0
19	446	66.286	184.3	142	49	1	64	46	82	0
20	448	68.288	184.9	145	-2		64	46	82	17

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12 NEVADA TEST SITE, 1980-1982
SHOT NUMBER 3 TEAM 3
SHOT POINT 3
SHOT TIME: 157:18: 0: 0.084

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	541	67.739	204.5	1	37	3	64	46	82	0
2	542	67.007	204.4	18	32	3	64	46	82	0
3	543	66.171	203.8	22	15	3	64	46	82	0
4	544	65.433	203.6	35	--		64	46	82	1
5	545	50.322	205.3	40	85		64	46	82	17
6	546	64.142	203.7	43	5		64	46	82	17
7	547	63.279	203.8	65	22		64	46	82	29
8	548	62.080	204.0	74	61	3	64	46	82	0
9	549	51.081	205.2	75	25		64	46	82	17
10	550	60.973	204.2	76	1	3	64	46	82	0
11	551	60.062	204.3	79	16		64	46	82	17
12	552	52.900	204.7	87	-2	3	64	46	82	0
13	553	58.888	203.9	89	28	3	64	46	82	0
14	554	58.121	203.8	98	88	3	64	46	82	0
15	555	54.404	204.4	100	58	3	64	46	82	0
16	556	57.058	203.8	101	37		64	46	82	17
17	557	56.116	203.9	112	-48	3	64	46	82	0
18	558	54.993	204.3	113	-16		64	46	82	17
19	559	53.858	204.6	133	19	3	64	46	82	0
20	560	52.093	205.0	143	-59	3	64	46	82	0

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 3   TEAM 4
SHOT POINT 3
SHOT TIME: 157:18: 0: 0.084

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	561	86.347	203.7	14	-5	1	64	52	82	0
2	562	85.552	203.8	19	56		64	46	82	1
3	563	84.795	204.0	39	9	1	64	46	82	0
4	564	84.004	204.2	48	7	1	64	46	82	0
5	565	83.250	204.3	53	8	3	64	46	82	0
6	566	82.486	204.5	56	-13		64	46	82	3
7	567	81.739	204.7	66	-6	3	58	46	82	0
8	568	80.946	204.8	69	3		64	46	82	17
9	569	80.240	205.0	70	1	1	64	46	82	0
10	570	78.831	205.1	72	9	3	64	46	82	0
11	571	77.688	205.2	77	2		64	46	82	3
12	572	76.557	205.3	93	-11	3	64	46	82	0
13	573	75.169	205.4	96	-35	3	64	46	82	0
14	574	74.055	205.4	115	1	3	64	46	82	0
15	575	72.924	205.5	119	-19	3	64	46	82	0
16				121	--		64	46	82	20
17				122	--		64	46	82	20
18	576	71.719	205.5	132	13	3	64	46	82	0
19	577	70.634	205.2	134	13	3	64	46	82	0/17
20	578	69.568	204.9	139	19	3	64	46	82	0/30

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 3   TEAM 5
SHOT POINT 3
SHOT TIME: 157:18: 0: 0.084

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	581	70.545	185.5	3	13		64	46	82	3
2	582	71.535	185.6	12	39		64	46	82	3
3	583	72.485	185.5	23	-18		64	46	82	17
4	584	73.499	185.4	28	55	1	64	46	82	0
5	585	74.451	185.2	31	31	1	64	46	82	0
6	586	75.390	185.2	45	11	1	64	46	82	0
7	587	76.379	185.3	73	47		64	46	82	17
8	588	77.318	185.3	78	-23		64	46	82	17
9	589	78.264	185.3	82	-19		64	46	82	17
10	590	79.236	185.4	83	27		64	46	82	17
11	591	80.330	185.4	88	38		64	46	82	17
12	592	81.293	185.4	92	20	1	64	46	82	0
13	593	82.247	185.5	99	-78		64	46	82	3
14	594	83.220	185.5	107	-165	1	64	46	82	0
15	595	84.167	185.5	108	44		64	46	82	17
16	596	85.134	185.5	120	7		64	46	82	3
17	597	86.071	185.5	128	29		64	46	82	1
18	598	87.026	185.5	129	41	1	64	46	82	0
19	599	87.999	185.5	131	35		64	46	82	3
20	600	88.952	185.5	136	-133	1	64	46	82	0

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 4   TEAM 1
SHOT POINT   4
SHOT TIME: 119: 4: 0: 0.014

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	409	62.722	98.2	15	1	1	24	6	42	0
2	410	61.945	98.3	17	19		24	6	42	1
3	421	60.301	97.7	24	-10		24	6	42	12
4	422	59.697	97.5	25	-12	1	24	6	42	0
5	106	59.218	97.7	26	2	2	24	6	42	0
6	424	58.526	97.9	32	2	1	24	6	42	0
7	107	57.862	97.8	36	-2		24	6	42	1
8	108	56.812	98.7	38	2	1	24	6	42	0
9	109	56.137	98.8	44	-2	2	24	6	42	0
10	110	55.254	99.3	58	-2	2	24	6	42	0
11	111	54.543	99.5	60	-3	2	24	6	42	0
12	112	53.667	99.6	71	0	2	24	6	42	0
13	113	52.831	100.3	85	9	1	24	6	42	0
14	114	52.124	100.9	90	9	2	24	6	42	0
15	115	51.439	101.4	94	4	2	24	6	42	0
16	116	50.631	101.8	103	2	2	24	6	42	0
17	117	49.545	102.4	106	-4		24	6	42	25
18	408	63.400	97.3	125	-7	1	24	6	42	0
19	619	64.459	96.3	130	7		24	6	42	12
20	620	65.211	95.1	146	-6	2	24	6	42	0

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 4   TEAM 2
SHOT POINT   4
SHOT TIME: 119: 4: 0: 0.014

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE	
1	640	30.233	106.1	10	18	2	54	18	24	0	
2	639	29.506	103.6	13	-4	1	24	6	42	0	
3	638	29.132	101.2	30	2	1	24	6	42	0	VABM
4	637	29.880	101.4	34	2	1	24	6	42	0	
5	636	30.434	101.5	49	2	1	24	6	42	0	
6	635	30.782	101.7	51	6	1	24	6	42	0	
7	634	31.349	103.1	52	2	1	24	6	42	0	
8	633	31.840	104.9	55	2	1	24	6	42	0	
9	632	32.448	105.9	62	2		24	6	42	13	
10	631	33.079	106.4	63	2	1	24	6	42	0	
11	630	34.536	106.7	64	3	1	24	6	42	0/17/30	
12	629	35.225	105.5	97	3	1	24	6	42	0	
13	625	35.275	91.5	104	3	1	24	6	42	0	
14	624	36.164	89.2	105	6	2	24	6	42	0/17/30	
15	623	36.894	87.0	110	8	1	24	6	42	0	
16	622	35.197	94.0	118	0	1	24	6	42	0	
17	621	34.094	99.6	124	-3	1	24	6	42	0	
18	528	32.190	98.7	137	0	1	24	6	42	0	
19	204	31.369	97.7	142	-13	1	24	6	42	0	UE25A-1
20	201	29.647	94.9	145	6	1	24	6	42	0	

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 4   TEAM 3
SHOT POINT   4
SHOT TIME: 119: 4: 0: 0.014

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE	
1	4	0.000	180.0	1	--		64	46	82	1	
2	642	0.676	93.7	18	1	3	64	46	82	0	BAD LOC
3	643	1.708	106.8	22	9	3	64	46	82	0	
4	644	2.544	101.5	35	-32	1	44	26	62	0	
5	645			40	--		44	26	62	1	
6	646	4.296	84.4	43	-18	1	44	26	62	0	
7	647	5.089	83.4	65	2	1	24	6	42	0	
8	648	5.894	82.8	74	-8	3	24	6	42	0	
9	649	6.669	83.6	75	11	3	24	6	42	0	
10	650	7.269	87.9	76	-18	3	24	6	42	0	
11	651	8.051	90.7	79	-5	3	24	6	42	0	
12	652	8.855	90.7	87	9	3	24	6	42	0	
13	653	9.779	89.4	89	9	3	24	6	42	0	
14	654	10.183	92.3	98	-19	1	24	6	42	0	
15	655	10.601	96.1	100	5	1	24	6	42	0	
16	656	11.180	99.6	101	15	3	24	6	42	0	
17	657	11.813	101.4	112	-10	1	24	6	42	0	
18	658	12.524	100.9	113	-5	3	24	6	42	0	
19	659	13.201	100.6	133	11	3	24	6	42	0	
20	660	14.116	99.7	143	6	1	24	6	42	0	

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 4   TEAM 4
SHOT POINT   4
SHOT TIME: 119: 4: 0: 0.014

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE	
1	661	14.634	107.7	14	20	3	24	6	42	0	
2	662	15.555	110.2	19	14	3	24	6	42	0	
3	663	16.819	112.3	39	5		24	6	42	25	
4	664	18.626	118.0	48	8	1	24	6	42	0	
5	665	19.520	117.6	53	1	1	24	6	42	0	
6	666	20.351	117.5	56	0	1	24	6	42	0	
7	667	21.164	117.3	66	-10	1	24	6	42	0	
8	668	21.914	117.2	69	4	1	24	6	42	0/30	
9	669	22.772	117.0	70	6	1	24	6	42	0	
10	670	23.556	117.1	72	7	1	24	6	42	0	
11	671	23.847	114.0	77	0	1	24	6	42	0/30	
12	672	24.491	112.6	93	7	3	24	6	42	0/11	TRUNCATED
13	673	25.312	111.8	96	-22	3	24	6	42	0	
14	674	25.962	110.3	115	3	1	24	6	42	0	
15	675	26.770	109.0	119	-9		24	6	42	25	
16	676	27.300	107.1	132	6		24	6	42	25	
17	677	27.955	105.4	134	14	1	24	6	42	0	
18	678	27.924	103.4	139	5		24	6	42	25	
19											
20											

DATA FOR ONE TEAM-SHOT

EXPERIMENT NO. 12   NEVADA TEST SITE, 1980-1982
SHOT NUMBER 4   TEAM 5
SHOT POINT 4
SHOT TIME: 119: 4: 0: 0.014

	LOC	DIST(KM)	AZIM	UNIT	CHRON	CHAN	C1	C2	C3	TAPE GRADE
1	118	47.969	103.5	3	2	1	24	6	42	0
2	681	48.654	103.0	12	1	2	24	6	42	0
3	682	47.490	102.2	23	-5	1	24	6	42	0
4	468	46.644	101.7	28	5	2	24	6	42	0
5	683	46.069	101.2	31	3	1	24	6	42	0
6	219	45.225	101.1	45	0	1	24	6	42	0
7	218	44.238	101.1	73	0	1	24	6	42	0
8	686	43.434	101.0	78	12	1	24	6	42	0
9	687	42.625	101.0	82	-2		24	6	42	1
10	688	41.823	100.9	83	5	1	24	6	42	0
11	216	40.851	100.8	88	6	1	24	6	42	0
12	215	39.989	100.7	92	3	2	24	6	42	0
13	214	39.243	101.3	99	3	1	[illegible]	6	42	0
14	213	38.545	101.9	107	-18	1	24	6	42	0
15	212	37.866	102.5	108	4	1	24	6	42	0
16	694	36.985	103.6	120	1	1	24	6	42	0
17	301	36.252	104.4	128	1	1	24	6	42	0
18	209	35.836	102.6	129	1	1	24	6	42	0
19	530	34.984	98.9	131	2	1	24	6	42	0
20	206	34.148	98.5	136	1	1	24	6	42	0

Tape Grade Scale

0 - Good
1 - Tape did not run
2 - Tape ran but no signal
3 - Skipped record time
4 - Fast forward; no signal
5 - Rewound and erased
6 - Weak signal; cannot read TCT; low record level
7 - Continuous calibration of periodic offsets
8 - Noise, sinusoidal
9 - Noise, spike
10 - Noise, WWVB cross-feed
11 - Noise, periodic ticks
12 - Noise, random
13 - Bad clock
14 - Off frequency, tape speed
15 - Calibration
16 - Incomplete record; recorder stopped
17 - Bad time code
18 - Tape speed way off; belt slipped
19 - Turned on too early
20 - In for repair; not deployed
21 - Geophone disconnected or shorted
22 - Wrong unit number
23 - Wrong gain settings
24 - Late start
25 - Bad geophone test (usually no signal)
26 - One or more channels missing
27 - Bad WWVB
28 - Unit or tape damaged/vandalized
29 - Wrong program time
30 - Digitized without calibrations
31 - Amplifier out of balance

APPENDIX C

First Arrival Times

Appendix C is a listing of the first arrival times picked from the record sections. Included are: shot point number, recorder site location, travel-time picks in both real and reduced (T-X/6) times, and distance (km) and azimuth of the recorder from the shot point.

SHOT POINT	RECORDER LOCATION	TRAVEL TIME (REAL)	TRAVEL TIME (T-X/6)	DISTANCE	AZIMUTH
1	301	9.185	1.025	48.962	177.147
1	310	9.319	1.005	49.884	176.949
1	302	9.470	1.030	50.640	176.965
1	303	9.726	1.000	52.354	176.886
1	304	9.906	0.940	53.799	176.950
1	305	10.116	0.895	55.325	176.974
1	306	10.335	0.865	56.817	176.970
1	307	10.584	0.860	58.342	177.142
1	309	11.151	0.935	61.294	177.834
1	308	10.938	0.970	59.809	177.481
1	120	10.195	0.800	56.368	164.959
1	121	9.994	0.905	54.532	164.851
1	118	9.729	0.910	52.912	164.717
1	219	9.356	1.025	49.985	166.485
1	218	9.313	1.055	49.547	167.501
1	216	9.155	1.135	48.117	171.100
1	215	9.104	1.145	47.753	172.036
1	116	9.700	0.870	52.982	161.454
1	220	9.493	1.015	50.865	164.573
1	210	9.133	1.089	48.260	176.852
1	101	10.757	0.555	61.214	143.358
1	102	10.122	0.515	57.642	140.286
1	106	9.509	0.445	54.382	151.485
1	107	9.424	0.480	53.664	152.705
1	108	9.417	0.445	53.834	154.191
1	109	9.368	0.440	53.569	154.868
1	113	9.595	0.775	52.917	158.640
1	112	9.409	0.605	52.822	157.511
1	214	9.109	1.125	47.904	173.038
1	213	9.187	1.175	48.073	173.978
1	212	9.107	1.065	48.254	174.894
1	208	8.905	1.020	47.308	177.566
1	209	9.008	1.045	47.777	177.245
1	207	8.738	1.100	45.826	177.224
1	206	8.566	1.075	44.947	178.586
1	204	8.513	1.165	44.090	182.035
1	202	8.384	1.245	42.831	183.483
1	201	8.394	1.310	42.503	184.193
1	203	8.424	1.230	43.166	183.099
2	482	7.299	0.220	42.475	214.655
2	483	7.497	0.305	43.152	215.387
2	484	7.574	0.240	44.001	216.383
2	485	7.681	0.235	44.676	216.812
2	487	7.781	0.100	46.085	218.189
2	488	7.949	0.165	46.702	218.824
2	489	8.132	0.245	47.323	219.453
2	490	8.457	0.465	47.955	220.051
2	421	5.763	0.210	33.319	197.839
2	422	5.772	0.230	33.249	198.918

SHOT POINT	RECORDER LOCATION	TRAVEL TIME (REAL)	TRAVEL TIME (T-X/6)	DISTANCE	AZIMUTH
2	106	5.764	0.185	33.473	199.678
2	424	5.878	0.235	33.856	200.740
2	109	6.074	0.185	35.337	204.202
2	110	6.188	0.185	36.016	205.369
2	111	6.302	0.240	36.371	206.374
2	401	5.182	0.500	28.090	180.758
2	402	5.038	0.360	28.071	183.185
2	403	5.112	0.430	28.090	186.199
2	404	5.325	0.490	29.010	188.617
2	405	5.460	0.470	29.941	189.893
2	406	5.579	0.440	30.834	190.618
2	407	5.669	0.390	31.674	191.504
2	408	5.575	0.170	32.431	192.604
2	409	5.875	0.295	33.480	193.621
2	410	5.827	0.210	33.699	194.913
2	448	10.387	0.845	57.254	217.095
2	447	10.245	0.880	56.193	217.354
2	446	10.082	0.885	55.182	217.582
2	113	6.680	0.415	37.588	208.557
2	114	6.809	0.410	38.394	209.280
2	115	7.052	0.555	38.982	210.057
2	116	6.943	0.340	39.616	210.985
2	117	7.111	0.360	40.506	212.182
2	466	6.708	0.410	37.790	216.554
2	467	6.989	0.375	39.684	216.559
2	468	7.121	0.290	40.989	216.299
2	469	7.296	0.230	42.397	216.735
2	441	9.028	0.818	49.262	219.266
2	442	9.286	0.846	50.636	218.822
2	443	9.384	0.739	51.867	218.441
2	445	9.968	0.939	54.172	217.820
2	449	10.488	0.854	57.804	216.995
2	450	10.798	0.882	59.494	216.601
3	522	9.364	1.405	47.752	193.922
3	561	15.341	0.950	86.347	203.703
3	521	9.289	1.365	47.543	194.893
3	524	9.511	1.325	49.117	192.684
3	523	9.432	1.400	48.192	193.392
3	526	9.509	1.170	50.034	191.334
3	527	9.581	1.110	50.828	190.834
3	530	9.747	1.110	51.822	187.441
3	301	10.194	0.970	55.347	186.406
3	303	10.707	0.930	58.662	185.645
3	304	10.936	0.920	60.099	185.492
3	446	11.828	0.780	66.286	184.320
3	444	11.526	0.775	64.507	183.773
3	563	15.082	0.950	84.795	204.018
3	564	14.951	0.950	84.004	204.183
3	565	14.825	0.950	83.250	204.320

SHOT POINT	RECORDER LOCATION	TRAVEL TIME (REAL)	TRAVEL TIME (T-X/6)	DISTANCE	AZIMUTH
3	567	14.553	0.930	81.739	204.672
3	569	14.258	0.885	80.240	205.018
3	570	14.118	0.980	78.831	205.062
3	572	13.805	1.045	76.557	205.263
3	573	13.653	1.125	75.169	205.376
3	574	13.523	1.180	74.055	205.420
3	575	13.289	1.135	72.924	205.461
3	576	13.093	1.140	71.719	205.460
3	577	12.882	1.110	70.634	205.177
3	578	12.645	1.050	69.568	204.881
3	542	12.203	1.035	67.007	204.432
3	541	12.345	1.055	67.739	204.458
3	543	12.059	1.030	66.171	203.813
3	548	11.542	1.195	62.080	204.014
3	550	11.387	1.225	60.973	204.187
3	553	11.095	1.280	58.888	204.187
3	554	11.007	1.320	58.121	204.187
3	557	10.723	1.370	56.116	203.934
3	555	10.507	1.440	54.404	204.409
3	559	10.421	1.445	53.858	204.578
3	560	10.107	1.425	52.093	204.958
3	552	10.247	1.430	52.900	204.702
3	505	18.747	1.135	105.672	184.668
3	506	18.390	0.915	104.849	184.708
3	507	18.091	0.755	104.018	184.741
3	509	17.986	0.920	102.395	184.812
3	515	17.285	1.160	96.752	185.059
3	517	16.837	0.980	95.141	185.132
3	518	16.567	0.835	94.392	185.169
3	520	16.291	0.840	92.707	185.262
3	584	13.115	0.865	73.499	185.428
3	585	13.358	0.950	74.451	185.181
3	586	13.430	0.865	75.390	185.216
3	592	14.367	0.818	81.293	185.425
3	598	15.351	0.846	87.026	185.486
3	600	15.743	0.918	88.952	185.457
3	519	16.464	0.875	93.531	185.220
3	516	16.796	0.804	95.952	185.094
3	514	17.048	0.789	97.550	185.018
3	511	17.580	0.782	100.785	184.888
3	502	18.985	0.968	108.102	184.575
3	501	19.056	0.896	108.960	184.533
3	594	14.645	0.775	83.220	185.490
4	642	0.295	0.182	0.676	93.697
4	643	0.424	0.139	1.708	106.839
4	644	0.528	0.104	2.544	101.497
4	646	0.870	0.154	4.296	84.430
4	647	1.045	0.196	5.089	83.399
4	648	1.207	0.225	5.894	82.779

SHOT POINT	RECORDER LOCATION	TRAVEL TIME (REAL)	TRAVEL TIME (T-X/6)	DISTANCE	AZIMUTH
4	649	1.358	0.246	6.669	83.571
4	650	1.486	0.275	7.269	87.944
4	651	1.631	0.289	8.051	90.705
4	652	1.779	0.304	8.855	90.679
4	653	1.955	0.325	9.779	89.385
4	654	2.015	0.318	10.183	92.280
4	655	2.085	0.318	10.601	96.125
4	656	2.203	0.339	11.180	99.645
4	657	2.222	0.254	11.813	101.401
4	658	2.455	0.368	12.524	100.858
4	659	2.525	0.325	13.201	100.560
4	660	2.656	0.304	14.116	99.720
4	661	2.771	0.332	14.634	107.739
4	662	2.989	0.396	15.555	110.200
4	664	3.608	0.504	18.626	118.008
4	665	3.800	0.546	19.520	117.610
4	666	4.002	0.611	20.351	117.492
4	667	4.209	0.682	21.164	117.298
4	668	4.499	0.846	21.914	117.203
4	669	4.542	0.746	22.772	117.045
4	670	4.644	0.718	23.556	117.055
4	671	4.728	0.754	23.847	113.955
4	672	4.942	0.861	24.491	112.617
4	673	5.129	0.911	25.312	111.845
4	674	5.209	0.882	25.962	110.251
4	677	5.499	0.839	27.955	105.422
4	638	5.816	0.961	29.132	101.249
4	639	5.843	0.925	29.506	103.569
4	201	5.866	0.925	29.647	94.859
4	637	5.905	0.925	29.880	101.372
4	640	5.907	0.868	30.233	106.081
4	636	5.947	0.875	30.434	101.544
4	635	5.963	0.832	30.782	101.702
4	633	5.996	0.689	31.840	104.900
4	528	6.154	0.789	32.190	98.696
4	631	6.110	0.596	33.079	106.412
4	630	6.324	0.568	34.536	106.725
4	530	6.434	0.604	34.984	98.891
4	209	6.719	0.746	35.836	102.642
4	212	6.907	0.596	37.866	102.481
4	213	6.963	0.539	38.545	101.871
4	214	7.080	0.539	39.243	101.275
4	215	7.240	0.575	39.989	100.685
4	204	6.139	0.911	31.369	97.663
4	634	6.135	0.911	31.349	103.140
4	621	6.293	0.611	34.094	99.595
4	206	6.352	0.661	34.148	98.513
4	622	6.541	0.675	35.197	94.007
4	629	6.503	0.632	35.225	105.549
4	625	6.504	0.625	35.275	91.466

SHOT POINT	RECORDER LOCATION	TRAVEL TIME (REAL)	TRAVEL TIME (T-X/6)	DISTANCE	AZIMUTH
4	624	6.595	0.568	36.164	89.244
4	301	6.681	0.639	36.252	104.412
4	623	6.845	0.696	36.894	86.984
4	694	6.754	0.589	36.985	103.591
4	116	8.978	0.539	50.631	101.797
4	115	9.077	0.504	51.439	101.356
4	114	9.184	0.496	52.124	100.923
4	113	9.252	0.446	52.831	100.253
4	112	9.362	0.418	53.667	99.574
4	111	9.444	0.354	54.543	99.470
4	110	9.555	0.346	55.254	99.302
4	109	9.745	0.389	56.137	98.832
4	108	10.258	0.789	56.812	98.692
4	424	10.108	0.354	58.526	97.906
4	106	10.095	0.225	59.218	97.672
4	422	10.417	0.468	59.697	97.548
4	409	11.029	0.575	62.722	98.182
4	408	11.027	0.461	63.400	97.284
4	620	11.522	0.654	65.211	95.052
4	216	7.412	0.604	40.851	100.807
4	688	7.595	0.625	41.823	100.924
4	686	7.821	0.582	43.434	101.023
4	218	7.934	0.561	44.238	101.070
4	219	8.098	0.561	45.225	101.120
4	683	8.499	0.821	46.069	101.151
4	468	8.573	0.799	46.644	101.655
4	682	8.663	0.748	47.490	102.238
4	118	8.726	0.731	47.969	103.456
4	681	8.797	0.688	48.654	102.996

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