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GRAVITY AND SEISMIC EXPLORATION IN YUCCA VALLEY, NEVADA TEST SITE -- JANUARY - APRIL, 1959

By W. H. Diment, D. L. Healey, and J. C. Roller

Trace Elements Investigations Report 545

UNITED STATES DEPARTMENT OF THE INTERIOR

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This report is preliminary and has not been edited for conformity with Geological Survey format and nomenclature.

*This report concerns work done on behalf of Albuquerque Operations Office, U. S. Atomic Energy Commission.

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ABSTRACT

The thickness of the alluvial and tuffaceous deposits that overlie bedrock in Yucca Valley has been inferred from gravity and seismic measurements. Preliminary interpretations indicate that these deposits are thickest in a narrow north-trending trough in the eastern part of the valley. The gravity data delineate a buried north-trending ridge of bedrock that extends from Mine Mountain almost to Quartzite Ridge. Seismic refraction measurements confirm the existence of the bedrock ridge and indicate that the bedrock is as close as 100 feet to the surface. The buried bedrock high is important because it may alter concepts of the movement of groundwater within the valley.

A single seismic-refraction profile was located near the area of thickest alluvium and tuff to determine the feasibility of using refraction techniques for determining the depth to bedrock where it is covered with several thousand feet of alluvium and tuff. The results are encouraging but not enough data were acquired to give a reliable depth estimate.

Seismic-refraction measurements were used successfully to determine the thickness of alluvium in narrow valleys partly filled with alluvium. This work was in the northwestern part of Yucca Valley and was done to choose drilling sites for studies of ground-water movement.

INTRODUCTION

This progress report describes a part of a continuing geophysical program being conducted by the U. S. Geological Survey on behalf of the Albuquerque Operations Office, U. S. Atomic Energy Commission. In order to permit early use of the results, progress reports are being prepared as the information becomes available. Therefore, it is necessary to recognize that interpretations may change as additional information becomes available and as interpretations are refined.

The report covers information obtained from January through April 1959 and supplements the work of V. R. Wilmarth and others (1959, written communication). Their work is the most recent summary of geologic, hydrologic, and geophysical information on Yucca Valley, and contains background information for this report.

The general objective of the geophysical studies at the Nevada Test Site is to define the type and configuration of the various rock units below the surface in areas of interest. To date particular attention has been given to Yucca Valley (fig. 1) where knowledge of the configuration of the bedrock surface below the alluvium and tuff is important in problems of ground-water movement and supply.

The specific objectives of this progress report are: (1) To present a gravity map of Yucca Valley and to give a preliminary interpretation of the gravity data in terms of the configuration of the bedrock surface below the alluvium of Yucca Valley. (2) To present the results of a seismic-refraction survey which supplements the gravity interpretation of the depth to bedrock. (3) To present the results of seismic-refraction survey which gives the depth to bedrock in shallow stream channels filled with alluvium. (4) To present miscellaneous information, such as driller's logs for shot holes, that may be of value to other participants.

The efforts of the following Survey personnel are acknowledged: F. E. Currey made most of the gravity determinations and surveyed many of the station locations. D. G. Murrey drilled the shot holes for the seismic work and assisted in the gravity investigations. E. K. Bare and C. H. Miller did the gravity terrain corrections. C. H. Miller, W. A. Bradley, and E. D. Seals assisted in the seismic field work.

ROCK TYPES AND ROCK PROPERTIES

A three-fold grouping of rock units into alluvium, volcanic rocks, and bedrock, may establish the necessary background for the interpretations contained in this report. It must be recognized that there are considerable variations within the groups and the properties of the groups overlap to some extent.

Alluvium

Unconsolidated rock fragments comprise most of the surface of Yucca Valley. The dominant sizes of the fragments range from boulders near the edges of the valley to fine sands and clay in Yucca Playa. Below the surface the distribution of the layers of sand, gravel caliche, and the like is complex. The degree of cementation of the rock fragments varies but it is assumed that most of the alluvium is not cemented (V. R. Wilmarth and others, 1959, written communication, p. 20).

The thickness of the alluvium is known from drilling to be 1,530 feet thick at well 3 and 950 feet thick at well 7. It is at least 500 feet thick in the Jangle area and in area 3.

Density

The only density measurements made on alluvial samples in Yucca Valley are those of A. M. Piper (1952, written communication) who measured the density of 21 samples taken from depths of 0.5 to 16 feet in the Jangle area (table 1). The average density of the alluvium

Table 1.--Density of alluvium and similar materials

Material	Average density (gm/cm^3)	Range in density (gm/cm^3)	Remarks
Alluvium [1]	1.46	1.30 - 1.81	0.5 - 2 ft., Jangle area, 7 samples
Alluvium [1]	1.65	1.30 - 1.81	2 - 16 ft., Jangle area, 14 samples
Caliche [1]	2.02	-----	15 - 25 ft., Jangle area
Sand (dry) [2]	1.6	1.4 - 1.8	
Gravel (dry) [2]	1.8	1.4 - 2.2	
Glacial drift (dry) [2]	1.8	1.4 - 2.2	
Glacial drift (dry) [2]	1.8	-----	
Gravel (dry) [3]	1.89		Pleistocene gravel
Gravel (dry) [3]	---	1.36 - 2.19	Pleistocene terrace gravel
Gravel (dry) [3]	1.75		

1. A. M. Piper (1952, written communication).
2 Jakosky (1950).
3 Birch and others (1942).

between 0.5 and 2 feet is 1.5 gm/cm^3 and the average density between 2 and 16 feet is 1.7 gm/cm^3. The density of the caliche (fragments cemented with calcium carbonate) is 2.0 gm/cm^3.

Most of the alluvium is above the water table (about 1,500 feet below the surface in the center of the valley) and since there is no evidence of perched water, it is probably safe when making calculations to consider the alluvium to be dry at depths of 1,500 feet and less. The density varies with the degree of cementation but the extent of cementation is not well known. Available information (V. R. Wilmarth and others, 1959, written communication), suggests that most of the alluvium is poorly cemented. The density probably increases slightly with depth because of compaction and because there has been more time for cementation of the deeper materials. On the basis of this reasoning the density of thick sections of alluvium, 1,000 feet in thickness, is estimated to be 1.8 gm/cm^3 plus 0.2 gm/cm^3 or minus 0.1 gm/cm^3.

More work should be done to determine the density of alluvium, especially at depths greater than 100 feet.

Velocity

The available information on the velocity of dilatational waves through the alluvium in Yucca Valley is summarized in figure 2. The data were obtained in several parts of the valley in materials ranging from loose boulders and gravels to fine sands and clay; hence, the velocities show considerable variation.

The velocity measurements discussed above were determined by measuring the time required for energy to travel from an explosion in a drill hole or on the surface to detectors on the surface. A different type of velocity determination is shown in figure 3, where the time required to travel between receivers separated by 3 feet was

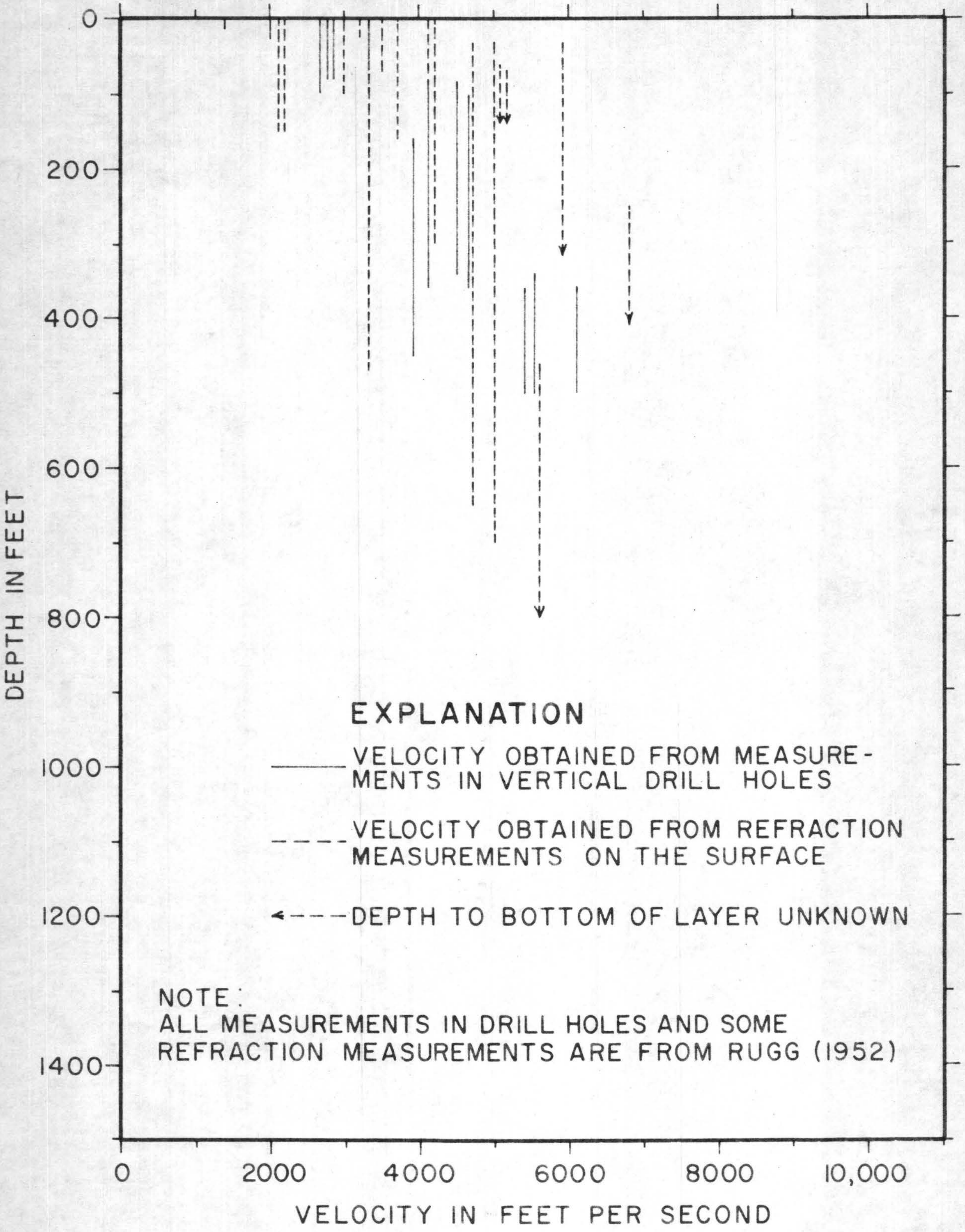

FIGURE 2 : VELOCITY OF DILATATIONAL WAVES THROUGH ALLUVIUM IN YUCCA VALLEY

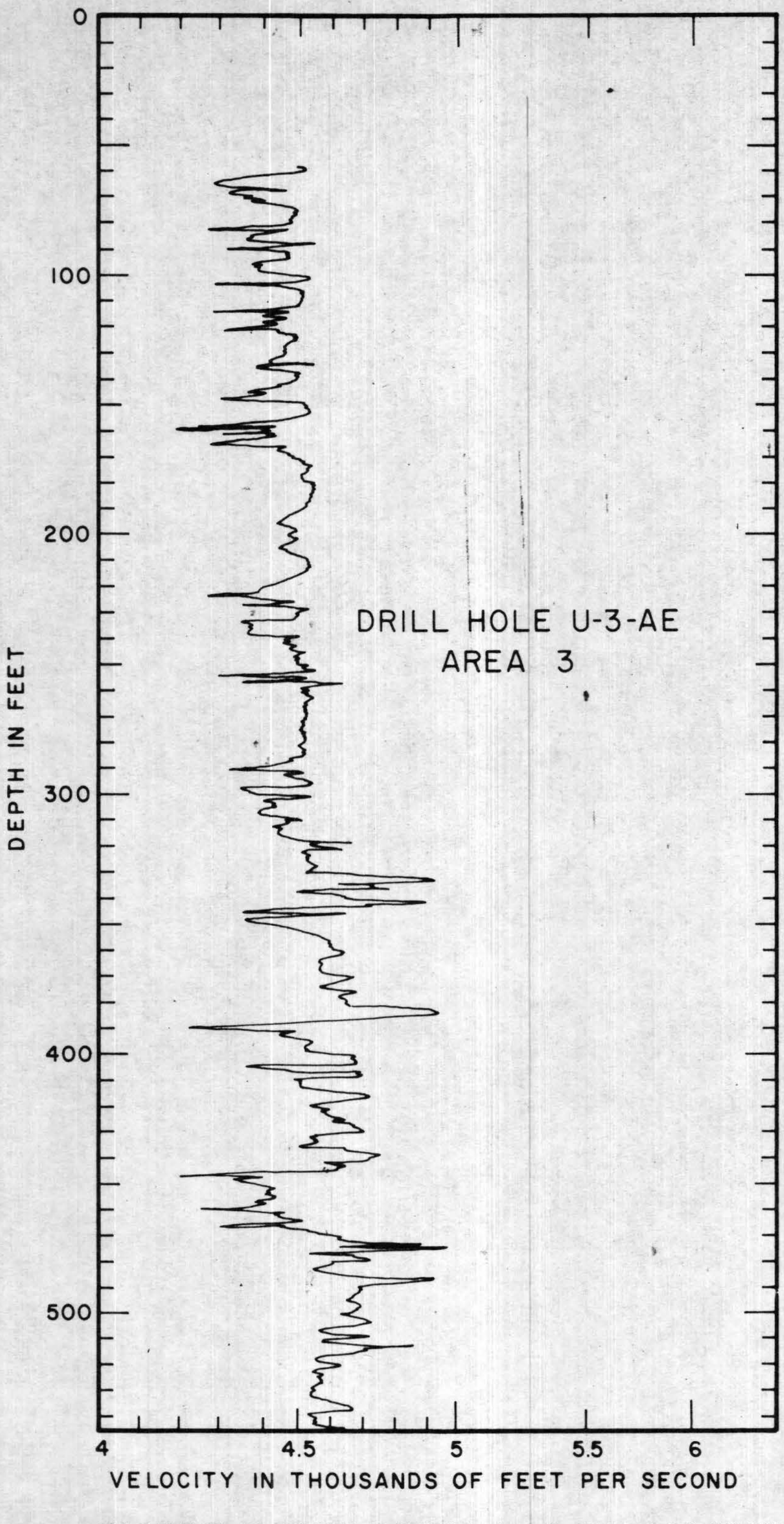

FIGURE 3 : VELOCITY LOG IN ALLUVIUM

measured continuously as the assembly was lowered in the drill hole. This log cannot be interpreted yet because of lack of some details of the method. The principal uncertainty is that the hole was filled with mud which might have had a velocity greater than that of the alluvium.

The velocities range from about 2,000 f.p.s. near the surface to roughly 5,000 f.p.s. at 500 feet. Below this depth there is no reliable velocity data. In order to make reliable determinations at depth more control must be obtained either by measurements in deep drill holes or with surface refraction measurements.

Velocities as high as about 13,000 f.p.s. between the surface and 500 feet have been mentioned (A. M. Piper, 1952, written communication) and have been attributed to caliche zones. Undoubtedly velocities in these cemented zones are higher than in the uncemented or poorly cemented zones, but examination of the available data shows no such high velocities. Perhaps the caliche layers are too thin or discontinuous to transmit sufficient energy to be recorded in the frequency range used.

Volcanic rocks

Volcanic rocks are known to overlie the bedrock near the edge of Yucca Valley and in the two deep drill holes (wells 3 and 7) in the central part of the valley (fig. 1). The contact between the alluvium and the underlying volcanic rocks is 950 feet below the surface in well 7 and 1,530 feet below the surface in well 3. Well 7 penetrated 1,325 feet of tuff and well 3 penetrated 300 feet of tuff. Both wells were bottomed in tuff so the thickness of this rock is not known at either place.

The volcanic rocks penetrated by wells 7 and 3 are similar to those of the Oak Spring formation, which is 2,000 feet thick in Rainier Mesa near the U12b and U12e tunnel systems. Thus the volcanic tuffs may be 2,000 feet thick in the deeper part of Yucca Valley and possibly even thicker because the whole volcanic sequence may not be represented in Rainier Mesa.

The volcanic rocks in area 12 are highly felsic in composition and include welded tuff, bedded devitrified ash, and tuffaceous sandstone. Basalt(?) has been identified in the drill cuttings from well 7 (V. R. Wilmarth and others, 1959, written communication), and from a shallow drill hole near Whiterock Spring. If massive basalt is present in the volcanic section it could have a marked effect on the interpretation of the geophysical results because its density, velocity, and magnetic susceptibility are high.

Density

The density of the volcanic section in Rainier Mesa is well known (table 2). The average density of the units ranges from 1.77 to 2.34 gm/cm^3 and the average density of the whole section is 1.94 gm/cm^3. These densities are for rocks saturated with water. The assumption of saturation is probably valid for the deeper zones below the valley because most of the tuffs are below the water table.

Table 2.--Density of volcanic rocks

Material	Member	Bulk density (wet) σ (gm/cm³)	Thickness T (feet)	Remarks
Tuff	Tos_1 *	1.94	30	All samples from
	Tos_2	1.94	120	
	Tos_3	1.89	240	drill holes 2 and
	Tos_4	1.88	180	
	Tos_5	1.77	215	3, UCRL site,
	Tos_6	2.21	65	
	Tos_7	1.85	765	Rainier Mesa
	Tos_8	2.32	285	
Totals			1,900	

Average density = 1.94 gm/cm^3 (weighted for thickness of units)
* Assumed same as Tos_2
All measurements are from Keller (1959)

Velocity

Two continuous velocity logs (fig. 4) obtained from drill holes in Rainier Mesa show that the velocity through the tuff varies from a few thousand feet per second to as much as 14,000 f.p.s. The velocity in the welded tuff capping the mesa is as much as 12,000 f.p.s. although it drops to about 3,000 f.p.s. near the surface because of many open joints.

Bedrock

Density

Density measurements for granite and dolomite obtained near the edges of the valley are reported in table 3 along with values from the literature on other materials which might comprise the bedrock beneath the valley. The range in density of the bedrock is probably between 2.55 and 2.85 gm/cm^3. The lower density limit is approximately that of

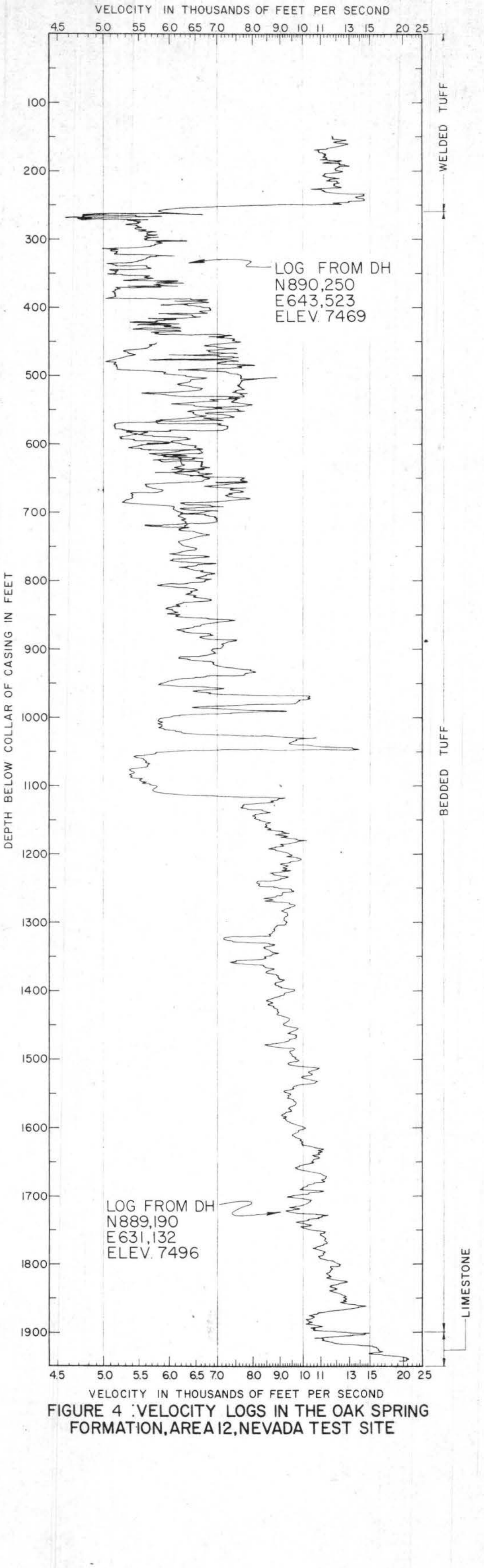

FIGURE 4 : VELOCITY LOGS IN THE OAK SPRING FORMATION, AREA 12, NEVADA TEST SITE

Table 3.--Density of bedrock

Rock type	Average density (gm/cm^3)	Range in density (gm/cm^3)	Remarks
Granodiorite [1]	2.67	2.66 - 2.68	N. Yucca Valley, 6 samples
Granite [2]	2.67	2.52 - 2.81	
Granodiorite [2]	2.72	2.67 - 2.79	
Syenite [2]	2.76	2.63 - 2.90	
Dolomite (dense) [3]	2.84	2.83 - 2.85	NW Yucca Valley, 6 samples
Marble (dense) [2]		2.66 - 2.86	
Limestone (porous) [2]	1.91		
Limestone (dense) [2]	2.63		
Calcite [2]	2.72		Crystal density
Quartzite [4]		2.5 - 2.6	
Quartz [2]	2.65		Crystal density

1 G. A. Izett (1959, personal communication).
2 Birch and others (1942).
3 C. H. Roach (1959, personal communication).
4 Jakosky (1950).

quartzite. Some of the bedrock sandstones and shales may have densities lower than 2.55 gm/cm^3 but the fraction of those materials is probably small. The upper density limit is that obtained for dolomite in area 12. Certain rock types such as massive basalts and schists have densities higher than 2.85 gm/cm^3 but their existence in large masses in the shallow bedrock is doubtful.

It is important to recognize that density contrasts within the bedrock can give significant gravity anomalies. For an example 2,000 feet of dolomite (2.85 gm/cm^3) horizontally juxtaposed against quartzite (2.60 gm/cm^3) would cause an anomaly of 6.5 milligals, which is roughly 20 percent of the Bouguer anomaly relief in the area.

Velocity

The velocity of dilatational waves through the various types of bedrock which probably underlie the alluvium and tuff in Yucca Valley are given in table 4. The velocity through the bedrock might be as low as 10,000 f.p.s. where the bedrock is at shallow depths, or if the bedrock is deeply weathered the velocity might even be lower. Therefore, considerable care must be taken when differentiating the bedrock from the tuff which has velocities as high as 14,000 f.p.s. where deeply buried.

METHODS

Standard geophysical methods were used in the gravity and seismic refraction surveys. Details of field procedure and interpretation of data can be found in Nettleton (1940), Heiland (1946), Jakosky (1950), and Dix (1952).

Gravity methods

The gravity stations in Yucca Valley were established on benchmarks, at points where elevations could be obtained from the three 7 1/2 minute quadrangle maps, and on points surveyed by transit crews of Holmes and Narver, Inc., and a plane-table crew of the Geological Survey. All points are considered to be accurate to within a foot except those established by plane-table surveying, which are accurate to within three feet. An error of 3 feet in elevation results in an error of about 0.2 milligal in the Bouguer anomaly, which is well below the tolerable error for most interpretations.

Table 4.--Velocity of dilatational waves through various types of bedrock

Rock type	Depth (feet)	Velocity (f.p.s.)	Remarks
Dolomite	surface	12,000	NW Yucca Valley, surface refraction
Dolomite*	-----	16,400 - 20,200	
Limestone	1,950	20,000+	Rainier Mesa, continuous velocity log
Limestone*	surface	17,400	Cambro-Ordovician, Arbuckle formation
Limestone*	surface	16,700	Ordovician, Viola formation
	3,950	20,000	
Limestone*	surface	14,000	Devonian, Hunton formation
	4,700	17,500	
Limestone*	surface	12,500	Mississippian, Mayer formation
	4,900	17,000	
Limestone*	surface	15,000	Pennsylvanian, Belle City formation
	3,000	15,500	
Shale and sandstone	2,000 - 3,000	13,400	Devonian
Shale and sandstone	2,000 - 3,000	11,200	Pennsylvanian
Shale and sandstone	2,000 - 3,000	10,900	Permian
Quartzite*	-----	20,000	
Granite*	surface	15,000	Tishomingo granite
	30	17,000	
	?	18,000	
Granite*	surface	17,200	Yosemite, California
	6,600	18,000	

* Values from Birch and others (1942).

The observed gravity of 979,604.7 milligals at McCarran Field, Las Vegas, Nevada (Woollard, 1958), was used as a reference for the survey.

Standard latitude, elevation, and terrain corrections were made. A combined free-air and Bouguer elevation factor of 0.06 milligals per foot was used, which corresponds to a density of 2.67 gm/cm^3. Terrain corrections, through Zone L of the Hammer Chart (Hammer, 1939) have been added to the data. The terrain effect near the center of the valley is small (0.1 to 0.4 milligal), but increases towards the mountains. Gravity stations on top of the hills that surround Yucca Valley have terrain corrections of as much as 15 milligals. Differences in Bouguer anomalies in the area surveyed are considered to be accurate to within 0.3 milligal, except stations located on hill tops where uncertainty in the terrain corrections may be as large as 1 milligal.

Seismic-refraction methods

Seismic-refraction measurements were made by detonating dynamite charges in drill holes and measuring the time required for the first waves to travel from the explosion to each of 12 equally-spaced seismometers aligned linearly with the shotpoint. The details (table 5) of detector spacing, charge size, and the like varied with the problem and with the maximum depth of interest.

The measurements were made with standard reflection-refraction equipment having a frequency range of about 5 to 500 cps.

The frequency band pass used was usually 5 to 215 cps; however, the upper limit was lowered at times to reduce background noise. Seismometers with a natural frequency of 2 cps were used on profiles 4, 6, and 8, and seismometers with a natural frequency of 40 cps were used for the remainder of the work. Automatic gain control was not used because the first arrivals were of primary interest. The shot time was transmitted by telephone for the short shot-seismometer distances and by FM radio for the longer distances.

The basic equipment for the survey included a truck-mounted rotary drill, two water trucks, and an instrument truck containing the recording unit.

Table 5.--Seismic-refraction measurements in Yucca Valley

Problem	Location and profile numbers	Depth range of interest (feet)	Distance to nearest seismometer (feet)	Seismometer spacing (feet)	Charge size (pounds)	Depth of shot below surface (feet)
Thickness of alluvium in valleys partly filled with alluvium (water test-site location)	Northwestern Yucca Valley (1,2,3,5,7)	0 - 300	50 or 100	25, 50, and 100	2.5 - 15	3 - 30
Thickness of alluvium over bedrock high	West-central Yucca Valley (4 and 8)	0 - 700+	100 - 4,000	100	5 - 50	4 - 30
Thickness of alluvium and tuff over bedrock in the part of Yucca Valley where the bedrock is deepest (experimental)	Yucca Playa	0 - 4,000	225, 2,640, 5,280 and 6,920	571 (150 meters)	50 and 100	60 and 100

Elevation and position for each shot point and each detector were determined by plane-table surveying.

Shot-hole drilling

The shot holes were drilled with a truck-mounted rotary drill rated at a maximum depth of 1,500 feet. Roller rock bits were used for all of the drilling, with the exception of the holes on Yucca Playa, which were drilled with finger bits. All bits were 4-3/4 inches in diameter. The driller's logs are given in the appendix.

Drilling was rapid in the fine sand and clay of Yucca Playa. Six holes with a total footage of 355 feet were drilled in approximately six hours, including moving time. These holes were drilled with a finger bit using air circulation. They stood up well, with the exception of the bottom 10 feet of shot hole 18 which was in a dry gravel that readily caved. The bit used in drilling the 6 holes showed some wear, but could have been used for several more holes.

Drilling in boulders and gravel was extremely tedious. Holes 15 feet deep (the length of the Kelly) could be drilled in the gravel and boulders using air circulation, but they usually collapsed when the Kelly was pulled up to add drill pipe. Heavy drilling mud (bentonite from Wyoming) helped present caving somewhat, but many holes still caved. Usually it was necessary to run the bit up and down the hole four or five times before all of the loose material was washed to the surface. No attempt was made to drill holes deeper than 30 feet in the gravel. Shot holes in the gravel usually collapsed after the first charge was fired.

Two holes were drilled without difficulty to depths of 30 and 15 feet into the dolomite, using air circulation. The drilling rate was approximately 20 feet per hour. Drilling in the dolomite will require approximately one drill bit per 100 feet of hole.

One hole 4 feet deep was drilled into the quartzite in 1-1/2 hours. One rock bit was practically worn out in drilling the hole. Diamond coring would probably be more economical for drilling in the quartzite.

INTERPRETATION

Major subsurface features in Yucca Valley

In interpreting the complete Bouguer anomaly map (fig. 1) the following should be kept in mind:

1) The absolute values of the complete Bouguer anomaly have no local significance. Any arbitrary gravity datum would suffice for the interpretations which follow.

2) The gravity data were reduced using a density of 2.67 gm/cm^3 which is close to the density of the bedrock. The density of the alluvium and tuff are much less (approximately 1.9 gm/cm^3). Therefore, differences in the Bouguer anomalies reflect differences in the thickness of these light rocks. To a first approximation, the differences in the anomalies are proportional to the combined thickness of alluvium and tuff.

3) Although the anomalies are mainly caused by the density contrast between the unit of alluvium and tuff and the bedrock, density contrasts among various types of bedrock undoubtedly result in significant anomalies. At this stage of the analysis these

anomalies must be largely ignored because the distribution and depths of the various bedrock types are not well known beneath the valley.

The main trough

The Bouguer anomalies are low in Yucca Valley and high in the bedrock hills surrounding the valley. The most pronounced gravity feature in the valley is the north-trending gravity low which extends the entire length of the valley. The axis of this low is near, but mainly east of, the Yucca fault. The tuff-alluvium deposits are thickest near this axis.

An interpretation of a gravity profile (A-A', fig. 1) indicates that the bedrock is as deep as 4,000+ feet if a density contrast of 0.5 gm/cm^3 is assumed and as deep as 2,000 feet for a density contrast of 1.0 gm/cm^3 (fig. 5). It is very unlikely that the density contrast lies outside this range and it is probable that the density contrast is close to 0.8 gm/cm^3, hence, the maximum thickness is probably 3,000 feet along this profile. The gravity data do not define Yucca fault; therefore, no attempt was made to infer fault displacement along profile A-A'. Just the surface indication of Yucca fault is shown.

Similar profiles could be drawn farther south but their interpretation would be less certain because the depth to the buried bedrock ridges bordering the main trough on the west is not known from seismic measurements. Furthermore, density contrasts within the bedrock distort the anomalies in the southwest part of the valley.

An experimental seismic-refraction profile (no. 6, fig. 1) was located near the south end of Yucca Valley, where the bedrock is near a maximum depth and where shot-hole drilling is easy. The purpose of

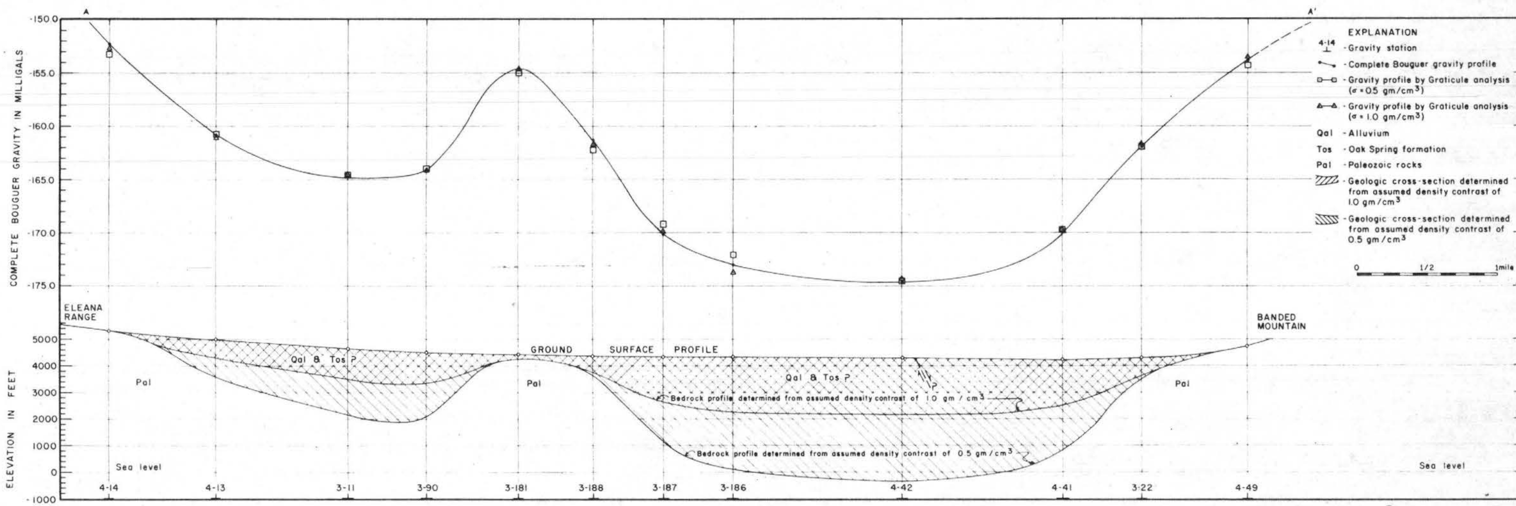

FIGURE 5 :GENERALIZED GEOLOGIC CROSS SECTION ALONG LINE A-A' DETERMINED BY TWO-DIMENSIONAL GRATICULE ANALYSIS ASSUMING DENSITY CONTRASTS OF 1.0 gm/cm^3 & 0.5 gm/cm^3

this profile was to determine whether it is possible to find the depth to bedrock under three or four thousand feet of alluvium and beds of tuff. Owing to the limited time available no effort was made to map the subsurface in detail. Measurements were taken along only one profile to determine if it was possible to obtain usable data at the great distances required between the shotpoint and seismometers. Standard techniques and instrumentation were used (table 5) but the necessity for a very low background noise level required shooting in the quiet hours of the night. The time-distance curves (fig. 6) indicate four distinct layers of successively increasing velocity with depth. The velocities obtained were 3,000, 5,650, 8,800, and 18,500 f.p.s. By using the critical distances (X_{1c}, X_{2c}, X_{3c}) and assuming that the beds are horizontal and that the velocities do not vary laterally, the depths to the contacts were computed.

Layer No.	Velocity (ft/sec)	Depth (feet)
1	3,300	0 - 470
2	5,650	470 - 1,950
3	8,850	1,950 - 4,300
4	18,500	4,300 - ?

These depths are approximations because of the assumptions made. It would be necessary to use continuous profiling and reverse shooting to obtain accurate depths. The conclusion can be made that refraction techniques can be used to map the bedrock surface at depths to 4,000 feet, but the work will be slow and expensive because it is necessary to wait for quiet periods and because explosive charges of 100 pounds or more will be required.

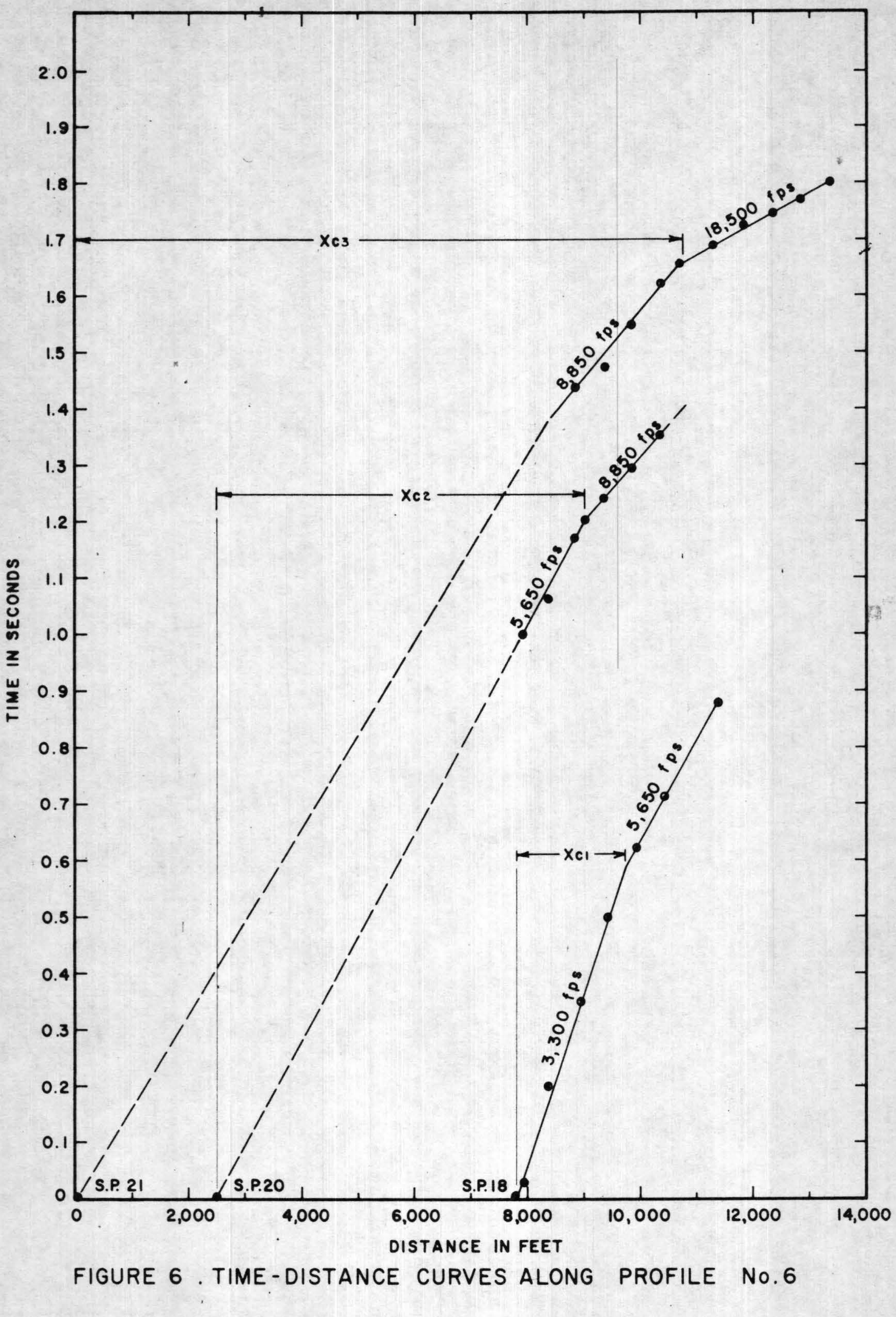

FIGURE 6 . TIME-DISTANCE CURVES ALONG PROFILE No. 6

Subsurface bedrock highs bordering main trough on the west

A pronounced north-trending gravity high, or series of gravity highs, borders the main trough on the west. This high separates the main trough from a smaller trough which is adjacent to the bedrock outcrops forming the western edge of Yucca Valley. The gravity high is interpreted as being caused by a subsurface bedrock ridge. This interpretation has been substantiated by two seismic-refraction profiles. The existence of the bedrock ridge was neither known nor suspected before the geophysical work.

The northernmost of the gravity highs was selected as a test area where gravity and seismic-refraction measurements could be combined to map the depth to bedrock (profiles 4 and 8, fig. 1). The seismic-refraction method was used to determine depths to bedrock at these points to control depth calculations from the gravity data and a generalized cross section was made by delay-time analysis (Pakiser and Black, 1957) along this profile (fig. 7).

Seismic measurements along profile 4 indicate a depth of 260 feet at the shallowest point. From this information it was estimated that the depth to bedrock at the maximum point of the gravity anomaly, about 1 mile north of profile 4, would be approximately 100 feet. This estimate was later verified by seismic-refraction measurements along the trend of the high (profile 8, fig. 8).

By use of the seismic depth control and the gravity data, the density contrast between the alluvium and the bedrock was computed to be roughly 1 gm/cm^3. This value is compatible with that derived from measurements on samples.

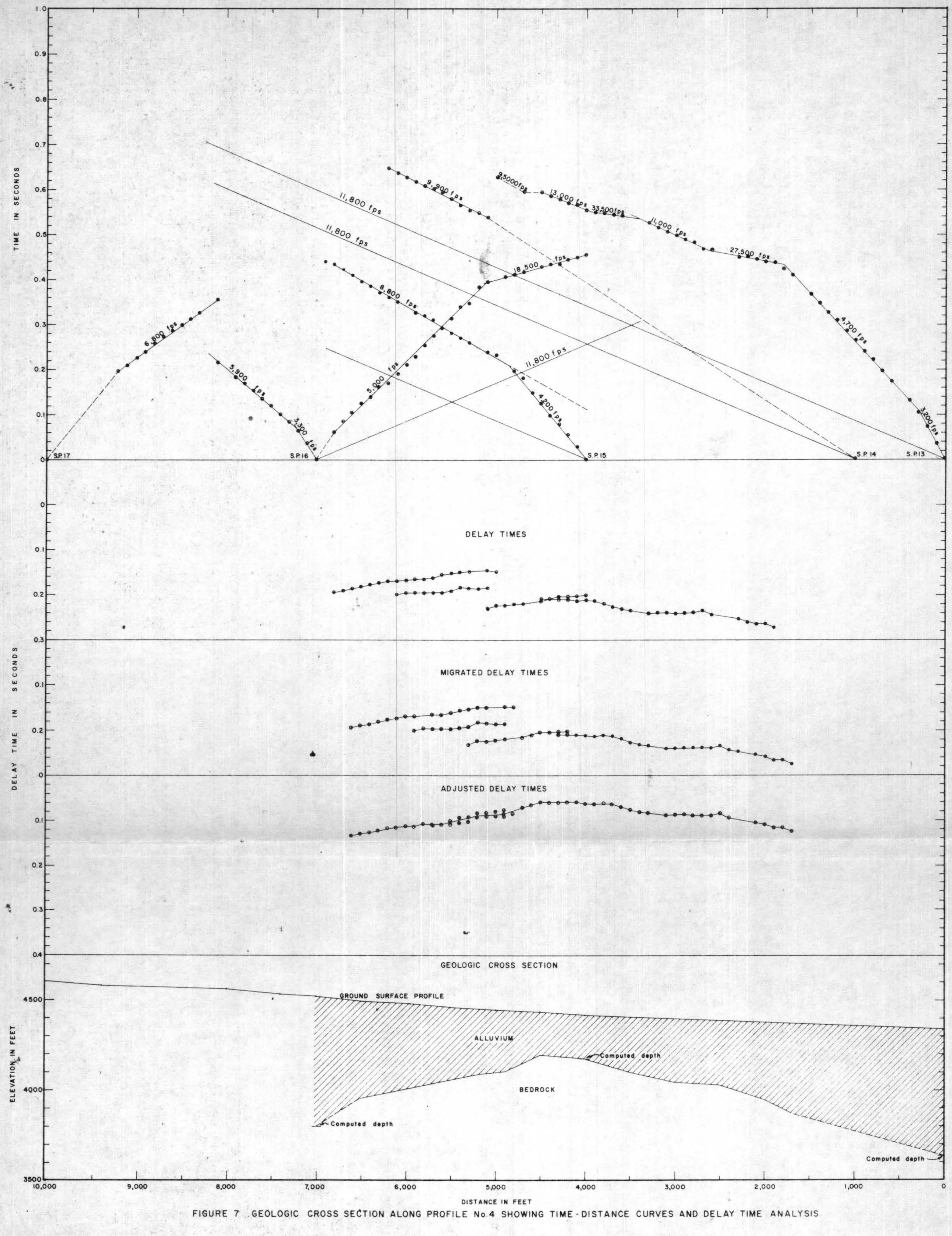

FIGURE 7 . GEOLOGIC CROSS SECTION ALONG PROFILE No.4 SHOWING TIME-DISTANCE CURVES AND DELAY TIME ANALYSIS

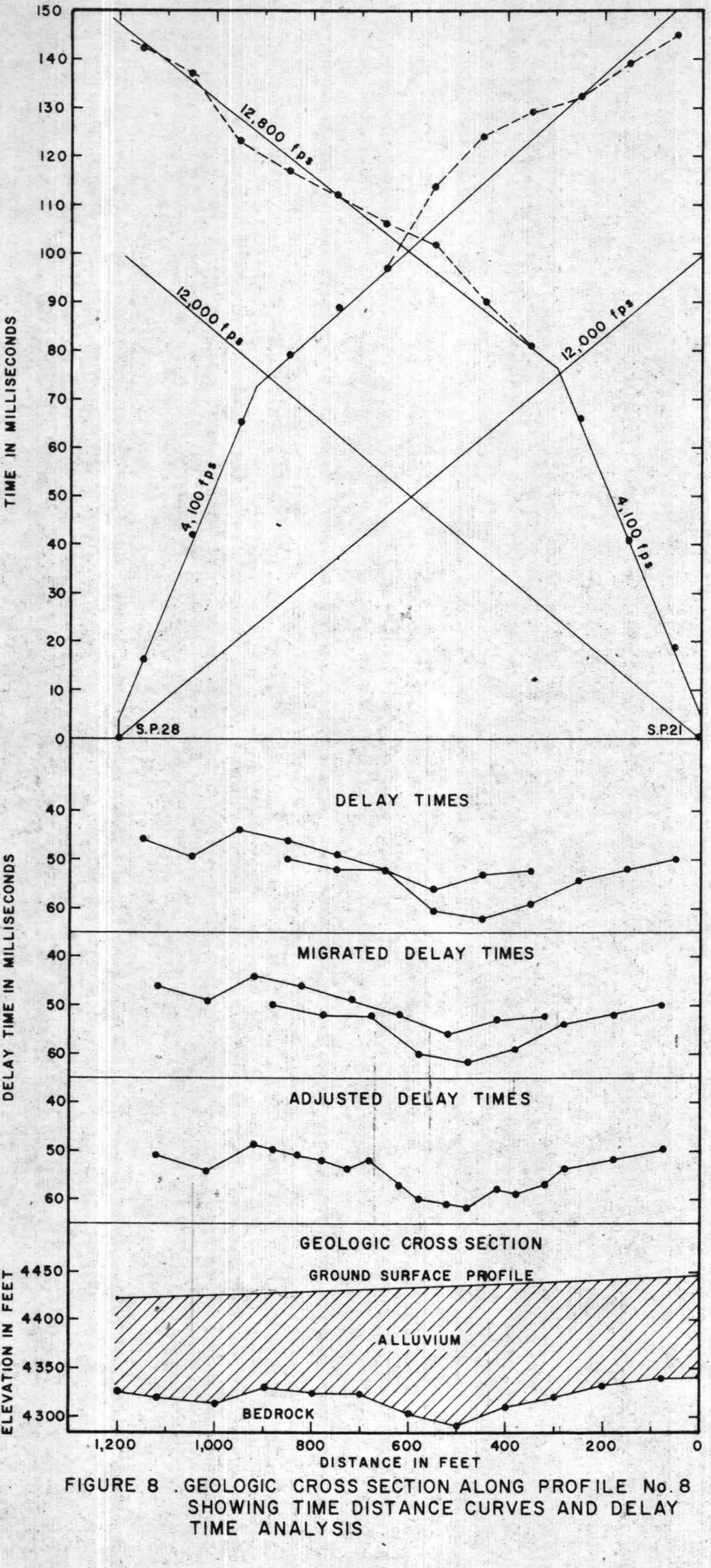

FIGURE 8 . GEOLOGIC CROSS SECTION ALONG PROFILE No. 8 SHOWING TIME DISTANCE CURVES AND DELAY TIME ANALYSIS

A generalized geologic cross section along B-B' (see fig. 1) was computed by using a two-dimensional graticule analysis (Dobrin, 1952) based on a density contrast of 1.0 gm/cm^3 and three seismic depths (fig. 9). Good agreement was obtained between the seismic and gravity data except at a location 600 feet west of gravity station 3-90. Seismic measurements indicate that the bedrock is 760 feet deep at this point, whereas the gravity data for a density contrast of 1.0 gm/cm^3 require a depth of 1,200 feet to Paleozoic rocks. Perhaps this structural low is filled with tuff from the Tertiary Oak Spring formation. The seismic data may have been obtained from a dipping surface at the top of a welded tuff member and this velocity misinterpreted as that of Paleozoic rocks. It is also possible that the gravity anomaly is partly caused by density contrasts within the bedrock.

At station 4-8, where the generalized geologic cross section (fig. 9) indicates a gravity low, the assumed 1.0 gm/cm^3 contrast between the Paleozoic basement rocks and the alluvium is probably not correct. Increased compaction and cementation of the alluvial fill with depth and the likely presence of welded tuff of the Oak Spring formation in the deeper part of the valley might reduce the average density contrast to as little as 0.5 gm/cm^3. Therefore, the 2,000 feet depth at the right side of figure 9 is considered a minimum. The true depth may be as much as 4,000 feet.

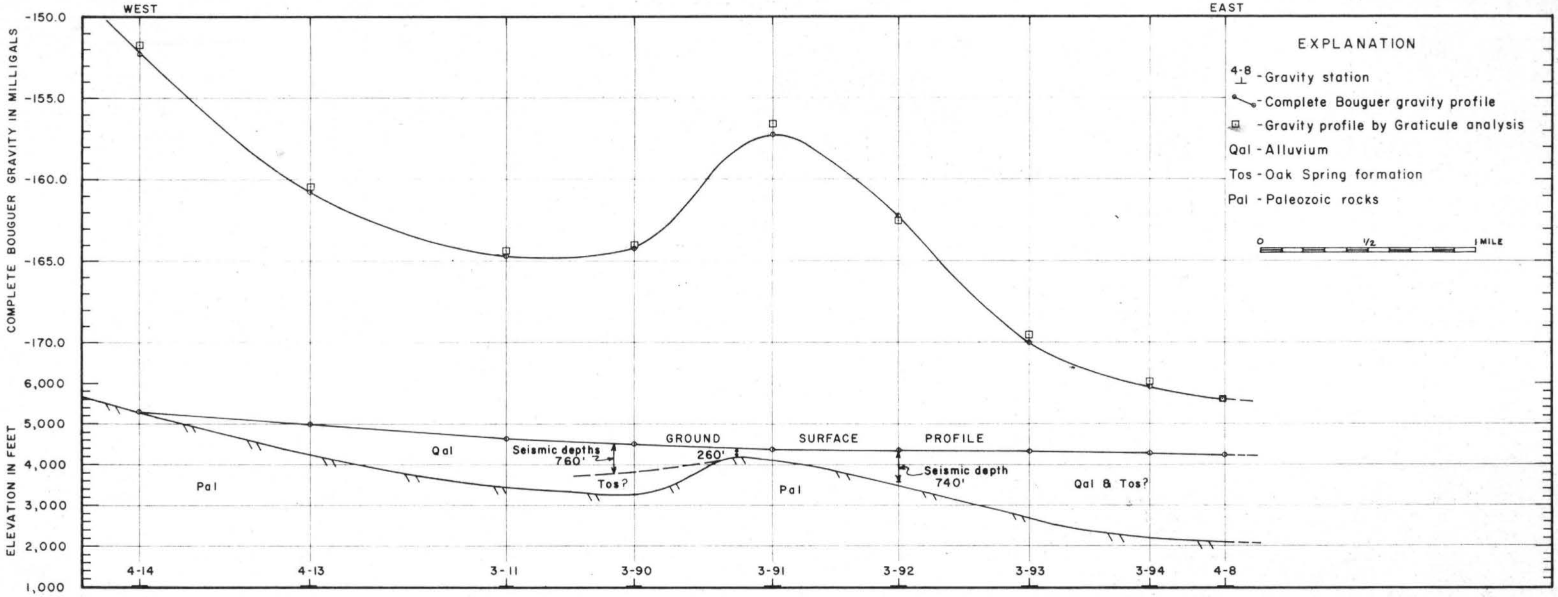

FIGURE 9 . GENERALIZED GEOLOGIC CROSS SECTION ALONG B-B' DETERMINED BY TWO DIMENSIONAL GRATICULE ANALYSIS AND BASED ON REFRACTION SEISMIC DEPTHS

Thickness of alluvium in dry stream channels

A water supply is desired in northwestern Yucca Valley. It is possible that significant quantities of water flow through the alluvium in channels cut into bedrock. The alluvium ranges from a few tens to a few hundreds of feet in thickness. Usually, along any given cross section of a valley partly filled with alluvium the best place to drill a well is the point where the bedrock is deepest. Five refraction profiles (1, 2, 3, 5, and 7, fig. 1) were made to choose drilling sites. The results of the drilling and water testing will be given in a separate report.

Seismic-refraction measurements were made, using geophones spaced 50 and 100 feet apart and spread lengths ranging from 550 to 1,100 feet. Charges of 2-1/2 to 5 lbs of dynamite in shot holes ranging from 4 to 30 feet deep were fired at both ends of the spreads. Time-distance graphs were plotted from the seismograms, and geologic cross sections were made using the delay-time analysis method (Barthelmes, 1946 and Pakiser and Black, 1957).

The time-distance curves, delay-time analysis curves, and the geologic cross section along profile 1 are shown in figure 10. Velocity in alluvium of 2,200 f.p.s. was obtained in the center of the valley from shot point 2. A velocity of 12,000 f.p.s. was assumed for bedrock (dolomite); this velocity made the reverse delay times from the shot points 1 and 2 parallel.

The depth to bedrock is referred to both ends of the spread, because shot holes 1 and 3 were both drilled into dolomite and the depths there are known. The deepest alluvium is 750 feet south of shot point 1 where the depth to bedrock is 110 feet.

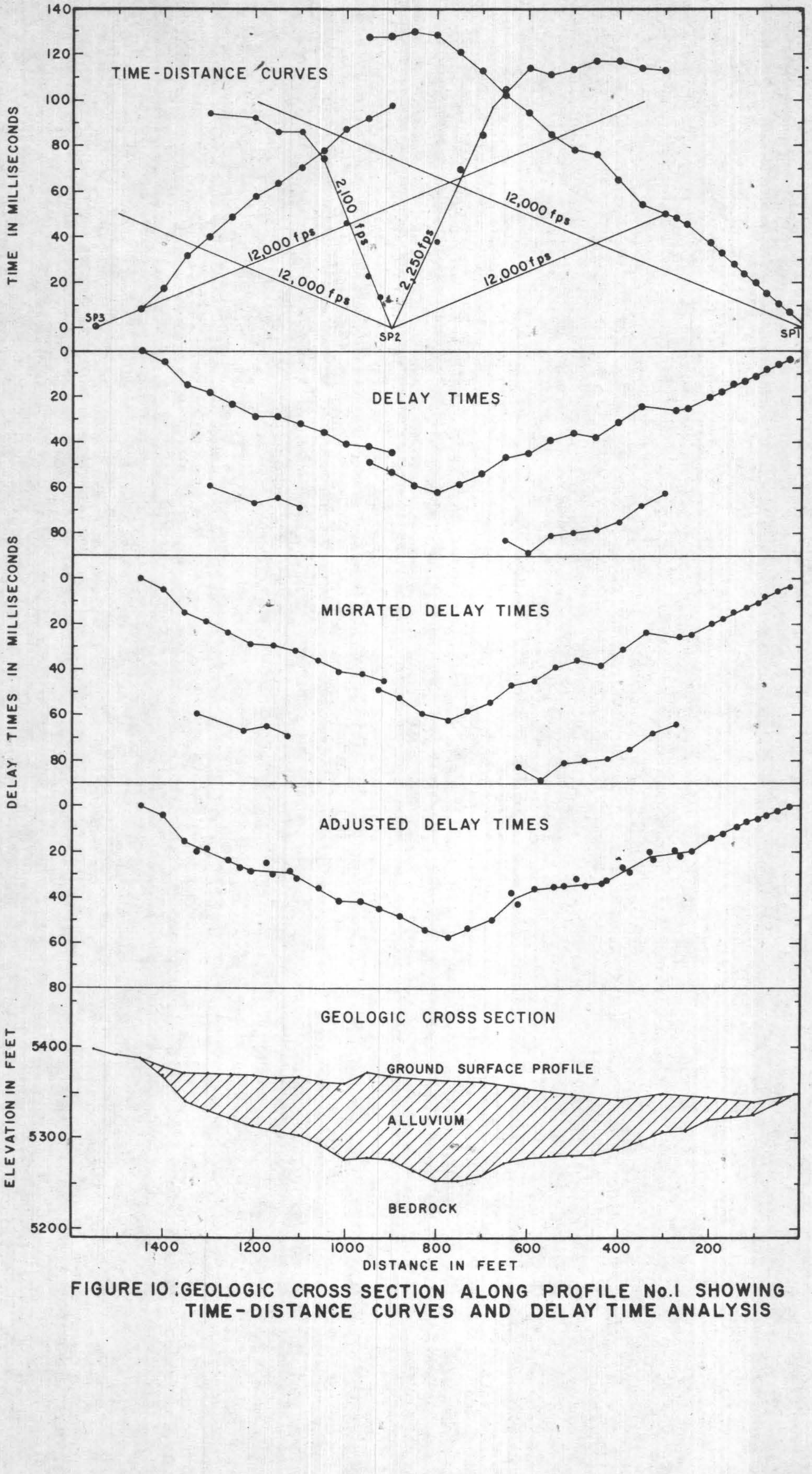

FIGURE 10: GEOLOGIC CROSS SECTION ALONG PROFILE No.1 SHOWING TIME-DISTANCE CURVES AND DELAY TIME ANALYSIS

The time-distance curves, delay times, and the geologic cross section along profile 2 are shown in figure 11. Quartzite is exposed at shot point 4 and approximately 50 feet west of shot 7. The alluvium has an average velocity of 3,200 f.p.s. which was used in computing the depth to bedrock. A velocity of 10,000 f.p.s. was used for the quartzite because it gave parallel delay times for the reverse shots from shot point 4 and shot point 7. The deepest alluvium along this profile is 800 feet northeast of shot point 7. The depth was computed to be 160 feet. Depth to bedrock has been found to be 169 feet by drilling at this location.

The seismic data obtained along profile 3 are not presented in this progress report, because additional field work will be needed to complete this profile.

The north end of profile 5 (fig. 12) could not be shot because it was near a power line and a highway. A velocity in alluvium of 2,200 f.p.s. and a velocity in bedrock of 9,000 f.p.s. were used in calculating depths along this profile. The 2,200 f.p.s. velocity was measured on profile 1, which is approximately 1 mile east of profile 5. Bedrock is exposed 50 feet south of shot point 23 and approximately 1,300 feet north of shot point 23. A drill hole 650 feet north of shot point 23 reached bedrock at 43 feet. The 9,000 f.p.s. bedrock velocity tied the delay times to these three control depths. The deepest alluvium is 250 feet north of shot point 23.

Profile 7 (fig. 13) crosses a fault approximately 300 feet west of shot point 24. It appears that the bedrock was downthrown to the west, and the valley filled with tuff of unknown thickness and extent. The velocity of 8,600 f.p.s. used to compute the depths is probably that

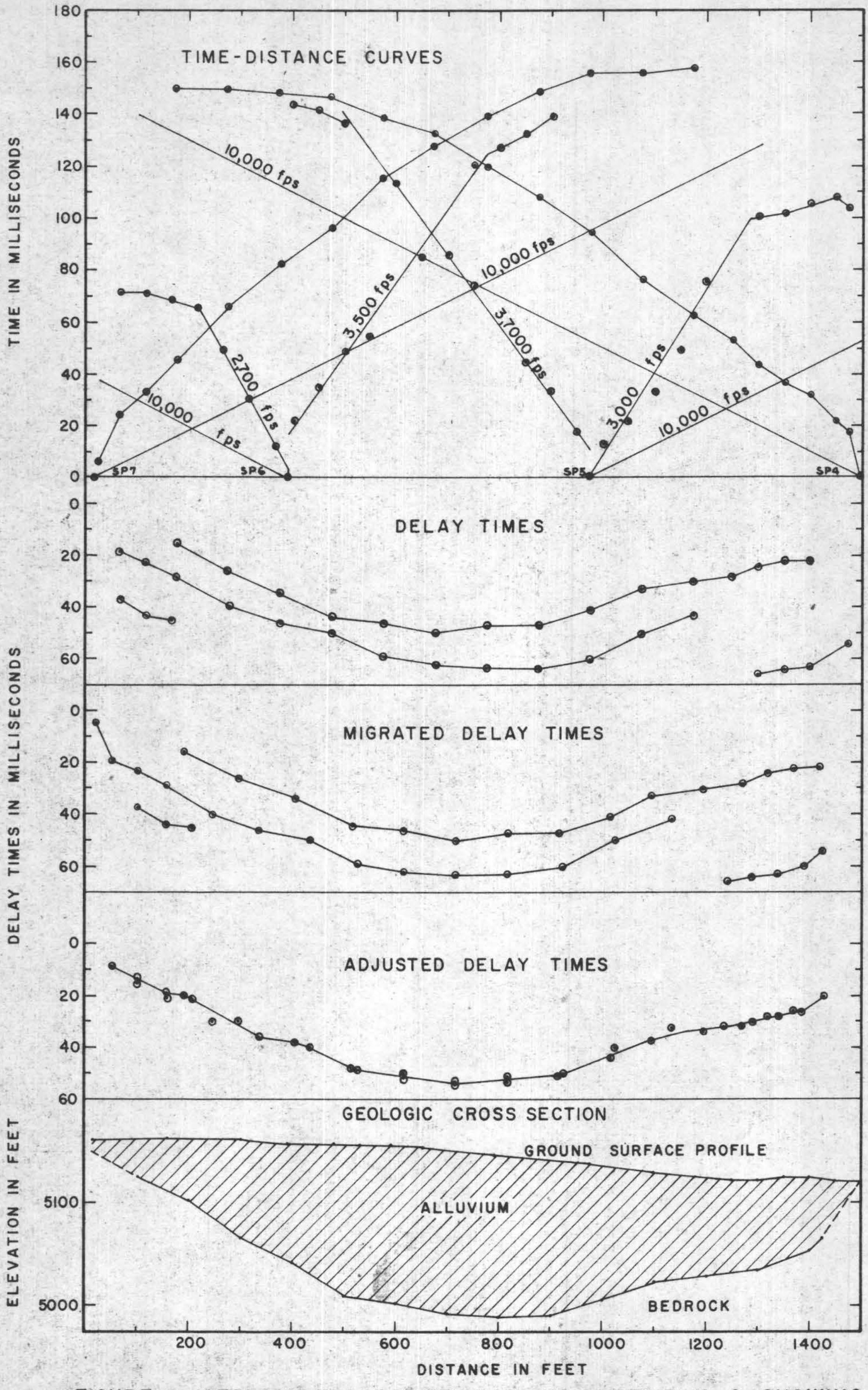

FIGURE 11 :GEOLOGIC CROSS SECTION ALONG PROFILE No.2 SHOWING TIME-DISTANCE CURVES AND DELAY TIME ANALYSIS

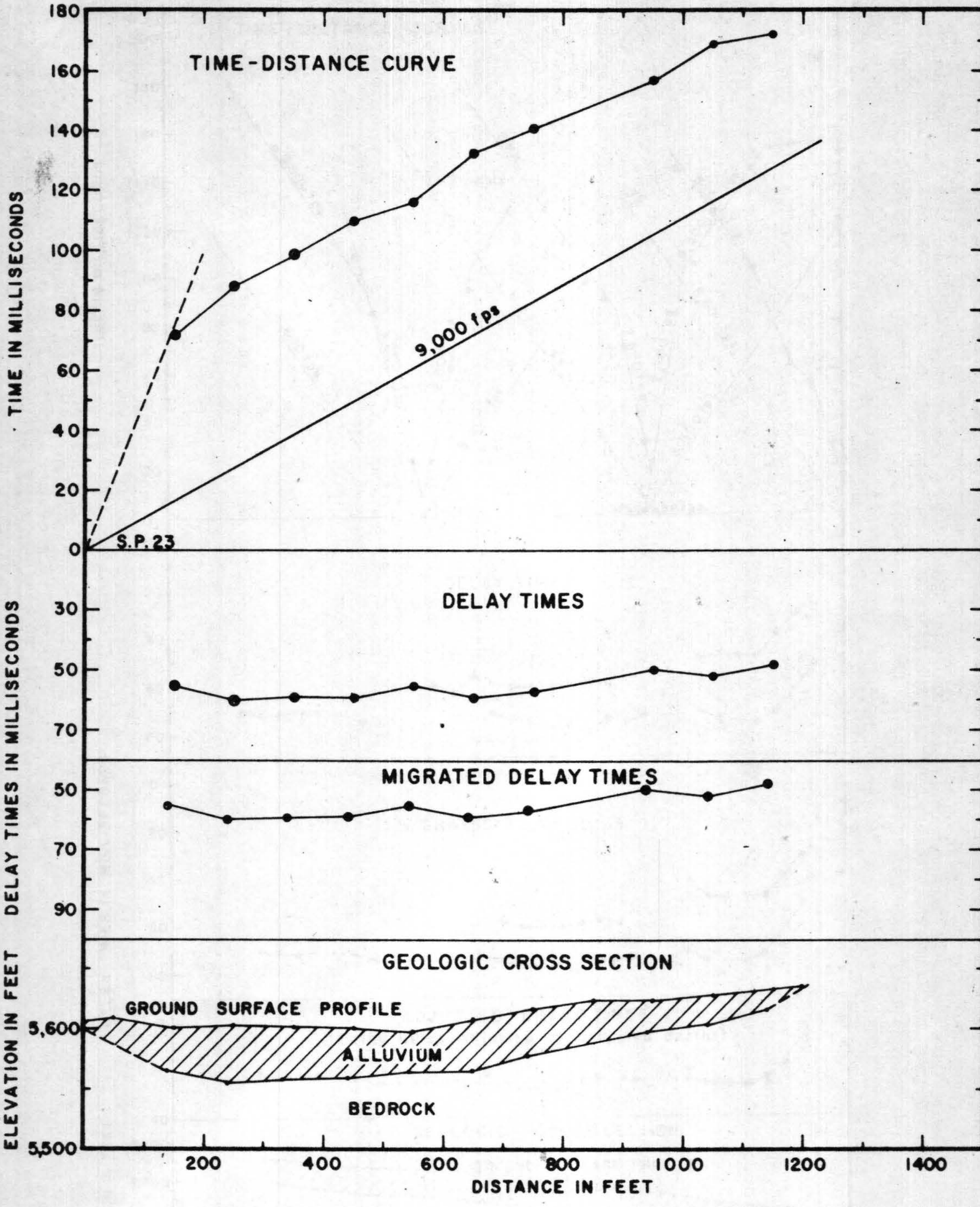

FIGURE 12 : GEOLOGIC CROSS SECTION ALONG PROFILE No.5 SHOWING TIME-DISTANCE CURVES AND DELAY TIME ANALYSIS

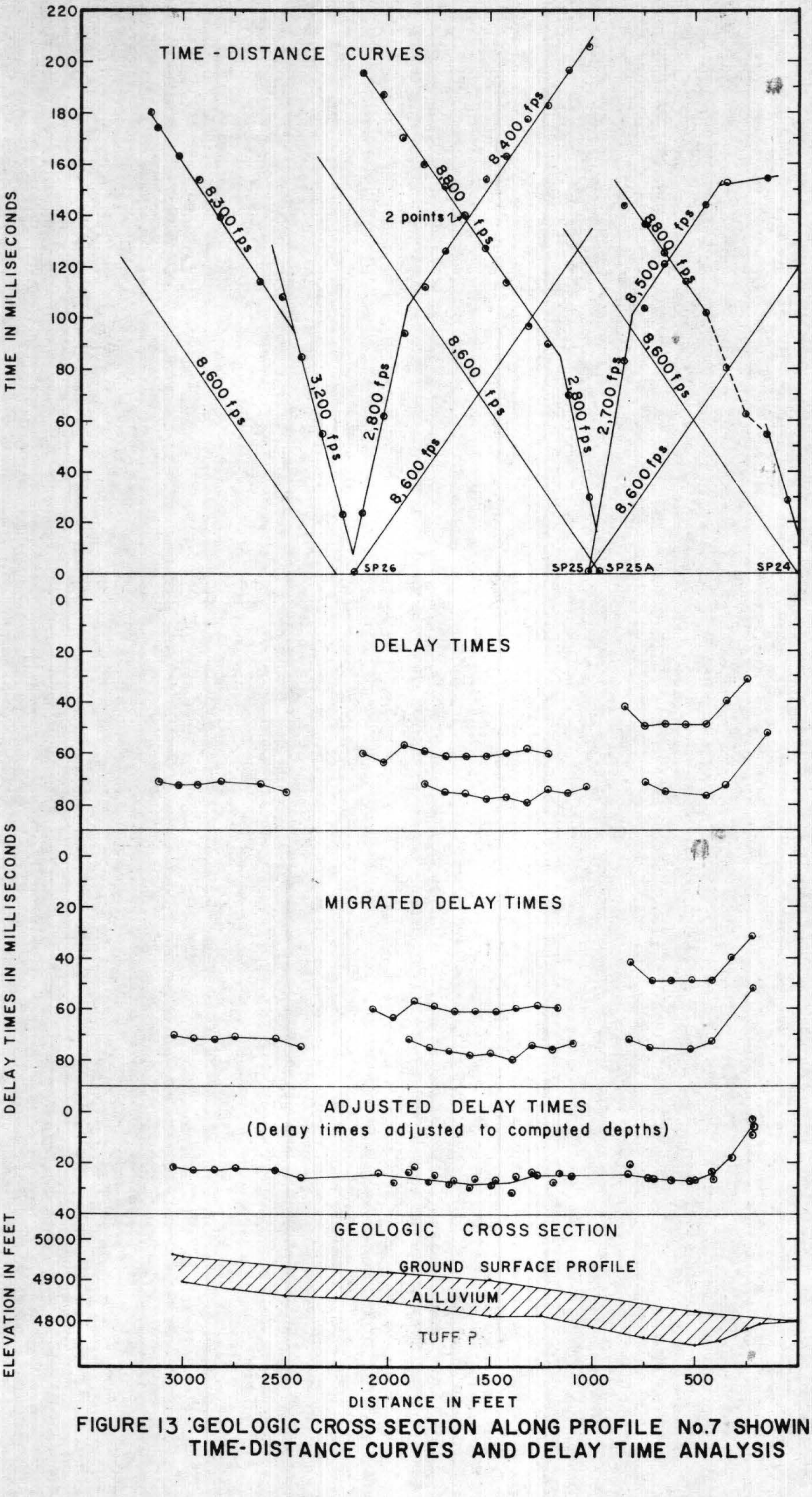

FIGURE 13 :GEOLOGIC CROSS SECTION ALONG PROFILE No.7 SHOWING TIME-DISTANCE CURVES AND DELAY TIME ANALYSIS

tuff, because it is too low for dolomite or quartzite; therefore, the rock underlying alluvium is probably tuff rather than bedrock. The thickness of the alluvium is nearly constant along this profile; however, because of the slope of the valley the lowest point is near the east side, probably at the fault which is suggested by the time distance curves. It would be difficult to determine the most favorable place to drill for water along this traverse, because the water may not be flowing through the alluvium, but in the deepest tuff. It would also flow in the bedrock along fractures associated with the faulting.

SUMMARY

The gravity survey of Yucca Valley has proved to be effective in delineating the configuration of the bedrock surface below alluvium and volcanic tuff. Gravity and seismic data delineated a buried bed-rock ridge which extends from Mine Mountain almost to Quartzite Ridge. This ridge has special significance because it may influence movement of groundwater.

Results from an experimental refraction profile, involving shot-seismometer spacings as great as 2.5 miles, indicate that the configuration of the bedrock can be mapped at depth of 4,000 feet, and possibly deeper.

The seismic-refraction method proved to be successful in determining the depth to bedrock in stream channels partly filled with alluvium. The results are being used to select sites for drilling to investigate hydrologic conditions.

Much more work must be done to delineate adquately the many subsurface features of Yucca Valley. The results here reported outline a

few of these features and demonstrate the applicability of the gravity and seismic-refraction techniques. Reflection-seismic methods should be tried because they may prove to be better and faster for mapping the bedrock surface. Furthermore this technique may prove to be applicable in delineating subsurface faults. The small aeromagnetic coverage available (V. R. Wilmarth and others, 1959, written communication) indicates that magnetic methods may have some promise, but much more must be known about the magnetic properties of the rocks, particularly about the tuffs, before the method can be assessed.

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Appendix 1.--Driller's logs of shot holes

Shot hole number	Latitude	Longitude	Profile	Depth (feet) From	Depth (feet) To	Material
1	37° 11' 38"	116° 09' 48"	1	0	30	Crystalline dolomite
2	37° 11' 30"	116° 09' 51"	1	0	20	Gravel containing large boulders
3	37° 11' 24"	116° 09' 54"	1	0	15	Dolomite with chert stringers
4	37° 11' 29"	116° 08' 63"	2	0	4	Quartzite
5	37° 11' 25"	116° 08' 59"	2	0	7	Gravel containing large boulders
6	37° 11' 23"	116° 09' 04"	2	0	15	" " " "
7	37° 11' 21"	116° 09' 08"	3	0	15	" " " "
8	37° 11' 46"	116° 08' 36"	3	0	10	" " " "
9	37° 11' 50"	116° 08' 29"	3	0	10	" " " "
10	37° 11' 54"	116° 08' 23"	3	9	15	" " " "
11	37° 11' 58"	116° 08' 18"	3	0	11	Welded tuff
				11	12	Quartzite
12	37° 11' 21"	116° 09' 08"				Redrill of No. 7
13	37° 07' 59"	116° 05' 50"	4	0	30	Gravel containing a few boulders
14	37° 08' 00"	116° 06' 02"	4	0	30	" " " "

Appendix 1.--Driller's logs of shot holes (cont'd)

Shot hole number	Latitude	Longitude	Profile	Depth (feet) From	Depth (feet) To	Material
15	37° 08' 07"	116° 06' 38"	4	0	20	Gravel containing a few boulders
16	37° 08' 14"	116° 07' 15"	4	0	15	" " " "
17	37° 08' 19"	116° 07' 39"	4	0	15	Mostly large boulders with gravel
18	36° 58' 42"	116° 01' 46"	6	90	100	Loose gravel
19	36° 58' 19"	116° 01' 42"	6	0	60	Fine sand, silt, and clay
20	36° 57' 51"	116° 01' 34"	6	0	60	" " " "
21	36° 57' 26"	116° 01' 29"	6	0	60	" " " "
22	36° 57' 00"	116° 01' 22"	6	0	15	" " " "
23	37° 11' 24"	116° 10' 29"	5	0	10	Gravel containing boulders
24	37° 11' 25"	116° 07' 35"	7	0	6	" " "
25	37° 11' 26"	116° 07' 46"	7	0	15	" " "
26	37° 11' 28"	116° 08' 01"	7	0	15	" " "
27	37° 08' 48"	116° 06' 27"	8	0	15	" " "
28	37° 08' 36"	116° 06' 27"	8	0	15	" " "