GEOLOGIC SURVEY & SEISMIC REFRACTION INVESTIGATION REPORT SUPPLEMENTAL INVESTIGATION - DESERT GREENBELT UPPER REATTA PASS WASH CHANNELIZATION BETWEEN PINNACLE PEAK ROAD & EXTENSION OF DEER VALLEY ROAD

AGRA Earth & Environmental
ENGINEERING GLOBAL SOLUTIONS

GEOLOGIC SURVEY & SEISMIC REFRACTION INVESTIGATION REPORT SUPPLEMENTAL INVESTIGATION - DESERT GREENBELT UPPER REAT~~T~~A PASS WASH CHANNELIZATION BETWEEN PINNACLE PEAK ROAD & EXTENSION OF DEER VALLEY ROAD SCOTTSDALE, ARIZONA

Submitted To:

Simons, Li & Associates, Inc.
3150 Bristol Street
Suite 500
Costa Mesa, California 92626-3067

Submitted By:

AGRA Earth & Environmental, Inc.
3232 West Virginia Avenue
Phoenix, Arizona 85009-1502

Registered Professional Engineer (Civil)
CERTIFICATE NO.
25151
KEITH H.
DAHLEN
Date Signed 4/6/98
ARIZONA, U.S.A.

April 6, 1998

AEE Job No. 7-117-000062
Report No. 1A

AGRA Earth & Environmental
ENGINEERING GLOBAL SOLUTIONS

AGRA Earth & Environmental
ENGINEERING GLOBAL SOLUTIONS

AGRA Earth & Environmental, Inc.
3232 West Virginia Avenue
Phoenix, Arizona 85009-1502
Tel (602) 272-6848
Fax (602) 272-7239
Toll Free 1-800-248-AGRA

April 6, 1998
AEE Job No. 7-117-000062
Report No. 1A

Simons, Li & Associates, Inc.
3150 Bristol Street
Suite 500
Costa Mesa, California 92626-3067

Attention: **Lan Yin-Li Weber, Ph.D., P.E.**
Vice President/Senior Program Manager

Ladies & Gentlemen:

RE: GEOLOGIC SURVEY & SEISMIC REFRACTION INVESTIGATION
SUPPLEMENTAL INVESTIGATION - DESERT GREENBELT
UPPER REATTA PASS WASH CHANNELIZATION
BETWEEN PINNACLE PEAK ROAD &
EXTENSION OF DEER VALLEY ROAD
SCOTTSDALE, ARIZONA

Pursuant to the request of Lan Yin-Li Weber, Ph.D., P.E. of Simons, Li & Associates, Inc. (SLA), AGRA Earth & Environmental, Inc. (AEE) performed a geologic survey and seismic refraction investigation at the referenced project site. The results of the geologic survey and seismic investigation are submitted herewith. The object of the investigation was to define the surficial geologic conditions and the subsurface excavation conditions adjacent to two sections of the planned Upper Reatta Pass Channel, located adjacent to the flanks of the McDowell Mountains. Included herein is a description of the site geology and results of the seismic refraction investigation, and discussions regarding excavatibility of the subsurface materials.

This report incorporates both Report Nos. 1 and 2 dated 25 April 1997 and 28 July 1997, respectively. Report No. 1 presented the results of our geologic survey, and Report No. 2 presented the results of the seismic refraction.

Should you have any questions concerning this report, please do not hesitate in contacting the undersigned.

Respectfully submitted,

AGRA Earth & Environmental, Inc.

Michael L. Rucker, P.E.
Senior Engineer

And:

Keith H. Dahlen, P.E.
Senior Engineer

Reviewed by:

Lawrence A. Hansen, Ph.D., P.E.
Senior Vice President

c: Addressee (6)
njf/j2-98/4-6-98

TABLE OF CONTENTS

PAGE

APPENDIX

MAP POCKET

Registered Professional Engineer (Civil)
CERTIFICATE NO.
25151
KEITH H.
DAHLEN
Date Signed 4/6/98
ARIZONA, U.S.A.

1.0 PROJECT DESCRIPTION

It is understood that channelization of Reatta Pass Wash will occur between Pinnacle Peak Road and the eastward extension of Deer Valley Road as part of the Desert Greenbelt Project. The channelization will essentially straighten (in a northerly to southerly direction) what is now a meandering wash. Two sections of the channelized wash abut bedrock along the channel's east side. The first section, approximately 350 feet in length, is located immediately south of Pinnacle Peak Road. The second section consists of an approximate 1/4-mile stretch located to the north of the extension of Deer Valley Road. Current plans are to construct the channelization with soil-cement along the channel sides and portions of the bottom. Armor-Flex cable-tied concrete blocks also may be used along a portion of the channel bottom. According to Ms. Weber, the average depth of the channel will be approximately 5 feet below existing site grades. In order to reduce stream flow velocities during storm events, several drop structures will be constructed.

2.0 INVESTIGATION

2.1 GEOLOGIC MAPPING

Reconnaissance level geologic mapping of the project alignment in the northern and southern sections was performed by Galen Kaip, G.I.T., of AEE. The purpose of the mapping was to characterize the geologic materials exposed in these two sections with an emphasis on the nature of the bedrock units as they relate to channel construction. The characterization of the bedrock units included documentation of rock types, their surficial distribution along the alignment, and the degree of weathering, fracturing and hardness. The geologic map (map pocket) presents the surficial distribution of the various units exposed at the site.

2.2 SEISMIC REFRACTION SURVEY

Sixteen 120-foot long seismic refraction survey lines were performed at selected locations within the site, as shown on the site plan included in Appendix A. The seismic lines were completed on 24 and 25 June 1997 by Michael L. Rucker, P.E., and Mr. Steven Goodman, both of this firm, utilizing a Geometrics 12-channel signal enhancement engineering seismograph and a sledgehammer energy source. The lines typically were oriented either perpendicular to the planned channel centerline or parallel to the centerline in areas where excavation conditions might be difficult. The sixteenth line was performed in the vicinity of an existing residence to verify that blasting close to the residence would not be necessary.

Results of the seismic refraction lines are presented in Appendix A, which includes a brief description of the seismic equipment and procedures.

2.3 SURFACE RESISTIVITY SURVEY

Two surface electrical resistivity soundings were completed at the site on 1 July 1997 by Mr. Rucker. The purpose of the resistivity soundings was to verify that the measured, higher p-wave (compression) velocities were not due to the presence of groundwater in the vicinity of Line 14. The four-point Wenner array method was used. Array spacings of 2.5, 5, 10, 15 and 20 feet were used for the sounding at Lines 13 and 14, and array spacings of 2.5, 5, 10, 20 and 30 feet were used for the sounding at Lines 1 and 2. A description of the field and interpretation procedures used and the results of the readings and interpretations are presented in Appendix A.

2.4 SAMPLING & FIELD OBSERVATIONS

Bulk soil samples for use in laboratory soil-cement mix designs were obtained from the Reatta Pass Wash streambed materials at the locations of Lines 1 and 9, and from the older alluvium at Lines 6 and 9. Hand samples of bedrock were collected from the outcrops located at Lines 2, 11 and 12 in the southern portion of the project and at Line 14 near Pinnacle Peak Road. Scan lines of joints and fractures in rock exposures for distances of 7.5 to 10 feet at the outcrops were obtained. In addition, rock hand specimen relative strengths were tested in the field using the method outlined by Kirsten (1982)* at the outcrops at Lines 2 and 14.

3.0 SITE CONDITIONS

The immediate project site area is native desert. Luxury homes and residential streets are located within about 100 to 200 feet of the edge of Reatta Pass Wash. At two locations between Pinnacle Peak Road and the eastward extension of Deer Valley Road, the wash directly abuts steeply protruding ridges which are part of the western edge of the mainly northwest- to southeast-trending McDowell Mountains. Vegetation in the area consists of desert shrubs, cacti and trees, including palo verde and mesquite. The site drains in a southerly direction.

---

*References are listed at the end of this report.

4.0 SITE GEOLOGY

The site is located in the Basin and Range Physiographic Province. This province is characterized by a series of northwest- to southeast-trending mountains separated by intervening valleys. The mountains represent uplifted structural blocks that typically are composed of Tertiary to Precambrian bedrock and the intervening valleys are filled with younger (Tertiary to Quaternary) basin-fill sediments and volcanic rocks.

The geologic units exposed at the site include Precambrian bedrock and Quaternary to Tertiary sediments. The Precambrian bedrock primarily is exposed in the steeper slopes that are present along the eastern edge of the project. The steeper slopes form the western edge of the McDowell Mountain block. Bedrock also is exposed within the drainage floor at one location in the northern section of the project. Westward from the exposed bedrock in the steep slopes, it is anticipated that the bedrock surface continues to dip steeply beneath the Tertiary to Quaternary sediments, although an irregular erosional surface is expected.

The Precambrian bedrock exposures are composed of a metamorphic assemblage including quartzite, phyllite and schist rock types. The bedrock exposed at the northern section (Pinnacle Peak Road south to Station 269+00) is composed of greenish gray to gray quartzite. The exposure is hard to very hard and predominantly closely-fractured with a spacing varying from 0.2 to 1.0 foot. The outcrops are weakly foliated and generally unweathered except in joints. The primary fracture sets are oriented as follows:

Strike	Dip
N10E	50-85NW
N80W	50SW
N88E	50SW
N3W	65SW

In the southern section (south of Station 232+00), the exposed bedrock consists predominantly of bluish gray to gray schist with localized intercalated phyllite. The schist and phyllite are strongly foliated and the exposures typically are softer and more closely fractured than the quartzite unit exposed to the north. The exposures vary from moderately hard to hard and generally are very closely to closely fractured. The schist and phyllite outcrops are slightly weathered to unweathered, except for joints with an occasional moderately weathered zone. Fractures occur both along and across the foliation planes as follows:

Strike	Dip	Type
N20E	45SE	Foliation Joint
N35E	50SE	Foliation Joint
N20E	40NW	Non-Foliation Joint
N20E	35NW	Non-Foliation Joint
N50W	77-87NW	Non-Foliation Joint
N36W	89NW	Non-Foliation Joint

The foliation as shown above dips into the hill toward the southeast.

The geologic units generally exposed west of the bedrock include semi-consolidated and unconsolidated units. The semi-consolidated units consist of a coarse-grained colluvial deposit that likely is Tertiary to Quaternary in age. This unit is locally exposed along select portions of the lower steep slopes forming the eastern edge of the drainage path. The colluvial deposit overlies bedrock and forms a wedge of material that thickens toward the valley floor. The colluvium consists of moderately to strongly lime-cemented silty sand, gravel, cobbles and boulders up to 4 to 10 feet across. The material varies from soft to hard. The particles typically are angular and the deposit is brown to white.

The unconsolidated units are exposed in the flatter portions of the site and include an alluvial fan deposit and a stream channel deposit. The alluvial fan deposit consists of lenticular deposits of silty sand and clayey sand with some silty sand, gravel and cobbles layers. The alluvial fan sediments typically are low to medium in plasticity, moderately firm to hard and brown. The deposits locally are weakly lime-cemented with possible moderate cemented layers.

The stream channel deposits are the youngest unit exposed on site and occur within the active drainage floors. The stream channel deposits consist of sand and silty sand with some gravel lenses. Some cobbles and boulders also are present. The deposit is uncemented, nonplastic and light brown to grayish brown.

5.0 FIELD INVESTIGATION

5.1 RESULTS OF SEISMIC REFRACTION INVESTIGATION

Due to the nature of geophysical techniques, all depths, locations and seismic refraction velocities presented herein should be considered to be approximate. Interpretations of the seismic refraction data from the seismic lines are presented in Appendix A of this report. The maximum depth of investigation for the 120-foot long seismic lines was about 30 to 40 feet. This was considered sufficient for the present investigation, where invert grading cuts are anticipated to be the deepest construction activities beneath the present natural grade. It should be noted that softer, lower velocity layers or zones of material could underlie the moderate and high velocity materials, but would not be identified using the refraction seismic technique. It should also be noted that the interpreted subsurface material velocities from the 120-foot seismic lines are average values obtained over distances of at least 10 to 20 feet. Zones of material could have slower or faster velocities, and therefore be weaker or stronger than indicated by the average velocities interpreted from the data.

In general, a layer of low velocity material is present across the site to depths of at least 2 feet. This horizon extends to well below the proposed channel invert at Lines 4, 5, 6 and 16, and portions of Lines 1, 7, 8, 9, and 10. This soil horizon has a range of compression wave (p-wave) velocities of about 800 to 2,700 feet per second (fps). Such material velocities are consistent with uncemented to weakly cemented alluvial and colluvial soil deposits.

Beneath the low velocity surface layer, and above or near the proposed invert grade, the measured p-wave velocities increase to between about 3,000 to 5,600 fps in Lines 2, 3, 11, 12 and parts of Lines 1, 7, 9, 13 and 15, and to about 5,700 to 6,300 fps in parts of Line 10. Lines 2, 3, 11 and 12 are located along the edge of the streambed adjacent to the ridge; these velocities reflect the presence of shallow weathered bedrock at the base of the ridge. The other lines are oriented perpendicular to the ridge and indicate the down-dipping nature of the weathered bedrock as one moves away from the ridge. Such velocities are consistent with moderately to strongly cemented alluvial and colluvial soils (often referred to as caliche), soft fanglomerate, and soft or weathered rock. The higher material velocities indicate harder or stronger materials.

P-wave velocities in excess of about 7,000 fps were indicated above or near the proposed invert grade at the locations of several lines adjacent to the ridges. These included Lines 2 and 3 and portions of Lines 7 and 8. An extensive bedrock outcrop with a p-wave velocity of about 8,500 fps is present within the anticipated excavation zone at Line 14. Material p-wave velocities in excess of 10,000 fps are indicated at one end of Line 11. These velocities are consistent with less weathered, more competent bedrock or very strongly cemented fanglomerate.

5.2 RESULTS OF SURFACE RESISTIVITY SURVEY

Surface resistivity soundings were completed near Lines 2 and 14 in order to confirm that shallow groundwater was not the cause of the shallow, high p-wave velocity measured at

Line 14. Interpretations of layer depths and resistivities from the resistivity soundings are based on the assumption that a resistivity contrast was distinct rather than gradational over some depth. Interpretations of the resistivity data are included in Appendix A.

The measured apparent resistivities were in the range of about 10,000 to in excess of 150,000 ohm-centimeters (ohm-cm) to a depth of less than about 30 feet. Interpreting the soundings as a system of two layers with contrasting resistivity resulted in a near-surface layer with resistivity of about 65,000 to 170,000 ohm-cm, consistent with values for slightly moist sands and gravels. The interpreted resistivity decreased to about 10,000 to 13,000 ohm-cm at depths below about 8 and 2 feet at Soundings R-1 (Line 2) and R-2 (Line 14), respectively. These values are consistent with moist, unsaturated sands and gravels. It may be possible that a two-layer resistivity model is inadequate for interpretation of the site setting.

5.3 RESULTS OF FIELD OBSERVATIONS

Bedrock joint and fracture spacings, measured using scan lines, were similar at Lines 2, 11, 12 and 14. P-wave velocities in the adjacent near-surface bedrock horizons at Lines 2, 11, 12 and 14 were 5,300, 5,100, 5,200 and 8,500 fps, respectively. The p-wave velocity at Line 14 was considerably higher than at the other lines. Given that the joint spacings at all four lines were similar, two alternative explanations for the higher velocity at Line 14 are proposed. The first alternative is the assumed presence of shallow groundwater saturating the bedrock joints and thereby increasing p-wave velocity; the results of the resistivity soundings indicate that groundwater is not present. The second alternative is that the individual fragments comprising the bedrock mass at Line 14 are stronger, i.e., possess higher compressive strength, than the intact bedrock at the other outcrops. This theory was tested by breaking a total of ten bedrock hand samples at each of the outcrops at Lines 2 and 14, and then estimating the rock strength in accordance with Kirsten (1982). Typically, about one blow was required to break a hand sample from the Line 2 outcrop. The bedrock at this location could be described as hard rock, with an estimated particle unconfined compressive strength of about 2,500 pounds per square inch (psi). About five blows typically were required to break a hand sample obtained from the Line 14 outcrop. The Line 14 area bedrock could be described as very hard rock, with an estimated particle unconfined compressive strength of about 10,000 psi. Thus, differences in rock strength likely explain the differences in measured p-wave velocity between Line 14 and Lines 2, 11 and 12.

6.0 EXCAVATION CONSIDERATIONS & RIPPABILITY

Based on the nature of the geologic materials exposed on site and as shown on the attached Geologic Map, a variety of excavation conditions will be encountered during construction of the channelization. Exposures along the eastern edge of the channel in the northern and southern section are composed of hard materials including bedrock and moderately to strongly cemented colluvial deposits. Exposures along the western edge and in the floor of the drainage are composed of soft erodible alluvial deposits, except at one location in the northern section where bedrock is exposed in the floor of the drainage. The general anticipated excavation conditions for the various geologic units, described in Section 4.0, are as follows:

Geologic Unit	Anticipated Excavation Conditions
Stream Channel Deposit	Moderately difficult due to possible boulders, otherwise easy to excavate with some caving.
Alluvial Fan Deposit	Easy to excavate with some possible cemented zones.
Colluvial Deposit	Very difficult to excavate due to strong cementation and boulders.
Bedrock (Schist & Phyllite)	Difficult to excavate. May be able to locally excavate upper materials with hoe ram or rip with heavy dozer. Could require blasting.
Bedrock (Quartzite)	Difficult to excavate requiring blasting. May be able to locally excavate upper more fractured materials with hoe ram or rip with heavy dozer.

As indicated by the seismic refraction and resistivity data and the approximate excavation capabilities of various heavy equipment presented in Table 1, mass excavation of low velocity material in the upper few feet of the subsurface, including alluvial soils, can be effectively accomplished. More competent subsurface materials may consist of colluvial soil deposits and weathered rock, and can be considered to be equivalent to schist for excavation purposes. Areas to be mass-excavated wherein p-wave velocities exceed 7,000 fps may require heavy ripping. However, strongly to very strongly cemented soils which could be encountered beneath parts of the site can be very difficult to rip, even when compression wave velocities are less than 6,000 fps. Excavation, earthmoving and hauling techniques, and equipment used on the project may have to contend with boulders with dimensions to several feet.

TABLE 1
Approximate Excavatability of Materials Using Various Ripping & Trenching Equipment

Material & Range of Marginal Rippability by Seismic Velocity (Cat, 1984; 1993)	Typical Bulldozer Used as Ripper (Cat, 1984; 1993)	Equivalent Backhoe (Kirsten, 1982; 1988)
"Caliche"		
4,000 - 6,000 fps	D7G, 200 HP	235
6,300 - 8,600 fps	D8L, 335 HP	245
6,300 - 8,700 fps	D9N, 370 HP	-
7,200 -10,300 fps	D9L, 460 HP	RH 40
7,200 -10,300 fps	D10N, 520 HP	-
7,400 -10,600 fps	D10, 700 HP	-
7,600 -11,000 fp	D11N, 770 HP	-
Breccia		
4,300 - 5,100 fps	D7G, 200 HP	235
7,300 - 9,300 fps	D8L, 335 HP	245
7,300 - 9,300 fps	D9N, 370 HP	-
8,300 -10,500 fps	D9L, 460 HP	RH 40
8,300 -10,500 fps	D10N, 520 HP	-
8,800 -11,000 fps	D10, 700 HP	-
9,000 -11,500 fps	D11N, 770 HP	-
Schist		
4,300 - 5,300 fps	D7G, 200 HP	235
7,200 - 9,000 fps	D8L, 335 HP	245
7,200 - 9,000 fps	D9N, 370 HP	-
7,700 - 9,500 fps	D9L, 460 HP	RH 40
7,700 - 9,500 fps	D10N, 520 HP	-
8,000 -10,000 fps	D10, 700 HP	-
8,300 -10,500 fps	D11N, 770 HP	-

Note: Bulldozer and backhoe power are presented by Kirsten (1982, 1988) as a measure of equivalent performance for excavation. The Caterpillar D6D bulldozer and 225 backhoe and D4E/D5B bulldozer and 215 backhoe are considered equivalent. Seismic velocities below marginal indicate that the material is rippable. Seismic velocities above marginal indicate that the material is non-rippable. All velocities are approximate and represent a typical range. See the Caterpillar Performance Handbook (Cat, 1984, 1993 or current edition) for details on use of this information. Different model configurations include variations in weight and horsepower.

Effective excavation of portions of the less weathered bedrock, individual boulders or isolated zones of very hard cementation may require blasting or mechanical methods such as hoe ramming. Areas of concern include the outcrop of quartzite bedrock near Pinnacle Peak Road in the vicinity of Station 269, next to the ridge in the general area of Stations 227 to 230 and 223, and possibly in the vicinity of Stations 224+60 and 221+30. Should blasting be required, loud reports and flyrock should be expected, and local regulations will govern blasting activities. These activities will significantly increase the costs of site grading and excavation, within the limited areas.

REFERENCES

Caterpillar Tractor Company, (Cat), 1984, Caterpillar Performance Handbook, Edition 15, Peoria, Illinois, October.

Caterpillar Tractor Company, (Cat), 1993, Caterpillar Performance Handbook, Edition 24, Peoria, Illinois, October.

Kirsten, H.A.D., 1982, A Classification System for Excavation in Natural Materials, Civil Engineer in South Africa, Vol. 24, No. 7, July, pp. 293-308.

Kirsten, H.A.D., 1988, Case Histories of Groundmass Characterization for Excavatibility, Rock Classification Systems for Engineering Purposes, ASTM STP 984, Louis Kirkaldie, Ed., American Society for Testing and Materials, Philadelphia, Pennsylvania, pp. 102-120.

APPENDIX A

SEISMIC REFRACTION SURVEY DATA
SURFACE RESISTIVITY SURVEY DATA

AGRA Earth & Environmental
ENGINEERING GLOBAL SOLUTIONS

REFRACTION SEISMIC EQUIPMENT & PROCEDURES

Seismic Equipment - Refraction seismic surveys are performed using an EGG Geometrics Nimbus ES-1225 signal enhancement seismograph. This instrument has the capability to simultaneously record 12 channels of geophone data and produce hard copies of that data. Signal enhancement capability permits the use of a sledgehammer as the seismic energy source. A timing sensor is attached to the hammer, and for compression waves a metal plate is set securely on the ground surface and struck. Generating shear waves involves setting the plate against a wooden plank or railroad tie oriented horizontal and perpendicular to the axis of the geophone array and striking with the sledgehammer. A truck is usually driven onto the tie in order to effectively couple the tie to the ground.

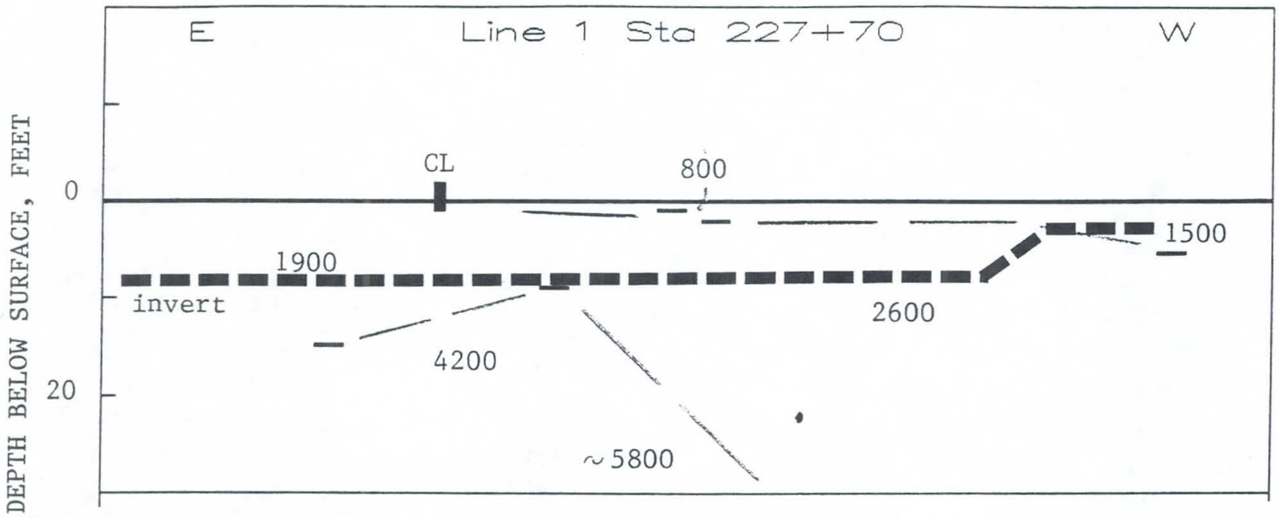
Because of the signal enhancement capability, signals from several or many strikes can be added together to increase the total signal available to obtain the seismic record. Although explosives can also be used as a compression wave seismic energy source, a sledgehammer does not require licenses or permits, or involve special limitations or regulations. A cable with 12-geophone takeout positions at 10 or 25-foot intervals with vertical and, if needed, horizontal geophones are used. The seismograph system is extremely portable. In areas where vehicular access is not possible, the equipment can be mobilized by hand or packhorse.

Field Procedures - Refraction seismic lines are generally laid out using the standard spacings on the geophone cables. A maximum depth of investigation on the order of 100 feet may be possible using the entire cable as a 300-foot array. Shorter spacings can also be used. For shorter lines with improved near-surface resolution, 10-foot spacings between geophones result in a 120-foot array with a maximum depth of investigation on the order of 30 to 40 feet. To improve the resolution of near-surface interfaces, sledgehammer source positions generally are set at 12.5 feet from the ends of a 25-foot spacing geophone array, or at 5 feet from the ends of a 10-foot spacing geophone array. Three shots usually are obtained for a refraction line: a foreshot, a backshot and a midshot. The midshot is usually placed midway between the two center geophones so that it is the same distance from the nearest geophone as the foreshot and backshot. This permits interpretation of near-surface interfaces at the center of a refraction line as well as at the endpoints. It also implicitly separates a 12-geophone refraction line into two 6-geophone refraction lines, which permits more refined interpretations of shallow and mid depth subsurface interfaces.

Compression waves are recorded for general exploration work. Shear waves are also recorded when dynamic soil properties are desired. A shear wave arrival is verified by obtaining two sets of horizontal data that are 180 degrees out of phase. The phase reversal is obtained by either reversing the horizontal geophone orientation or reversing the sledgehammer impact direction. Hard copy printouts of all field data are made and inspected as the information is collected.

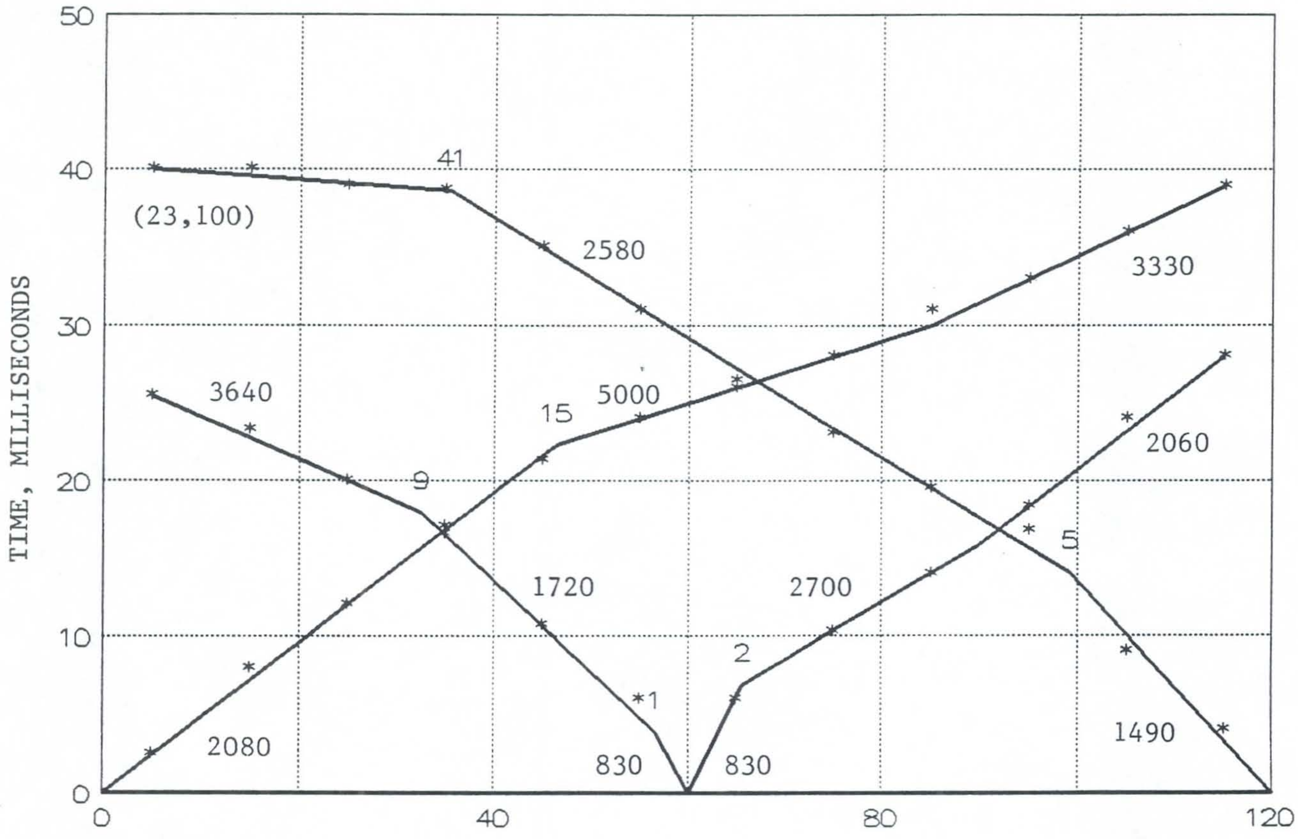
Records & Interpretation - The operations are directed by our engineer, who operates the equipment, prepares the records and examines the data in the field. Seismic data is interpreted in the office. When appropriate, preliminary interpretations are made in the field.

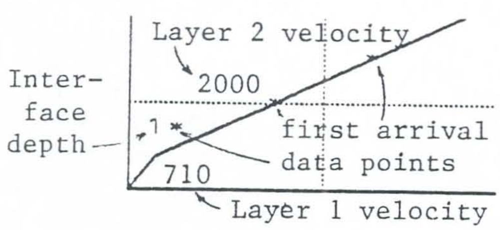
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



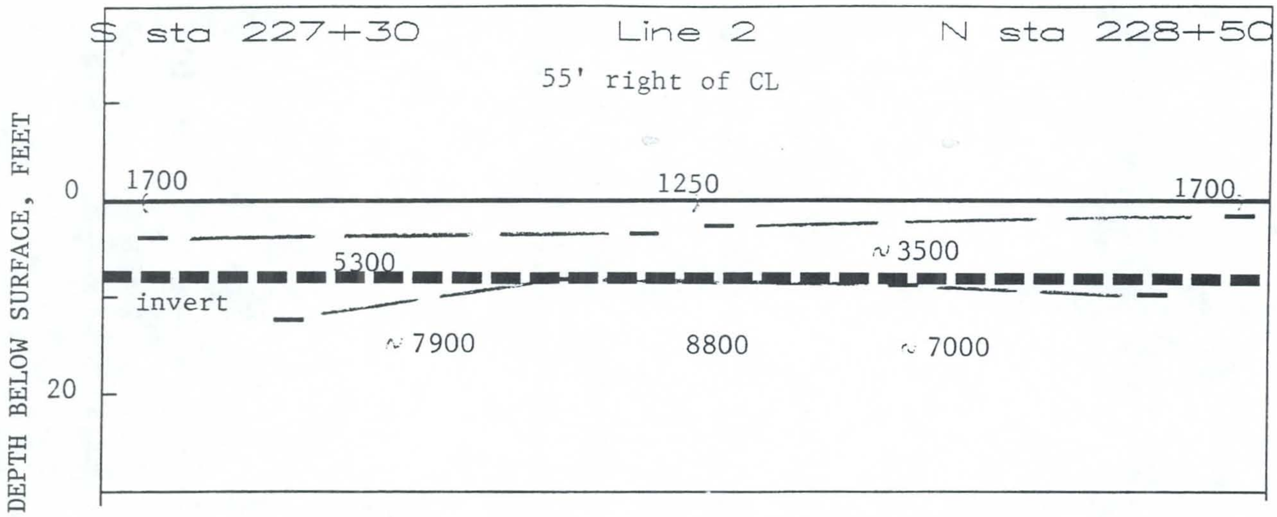


LEGEND

AEE Job No. 7-117-000062

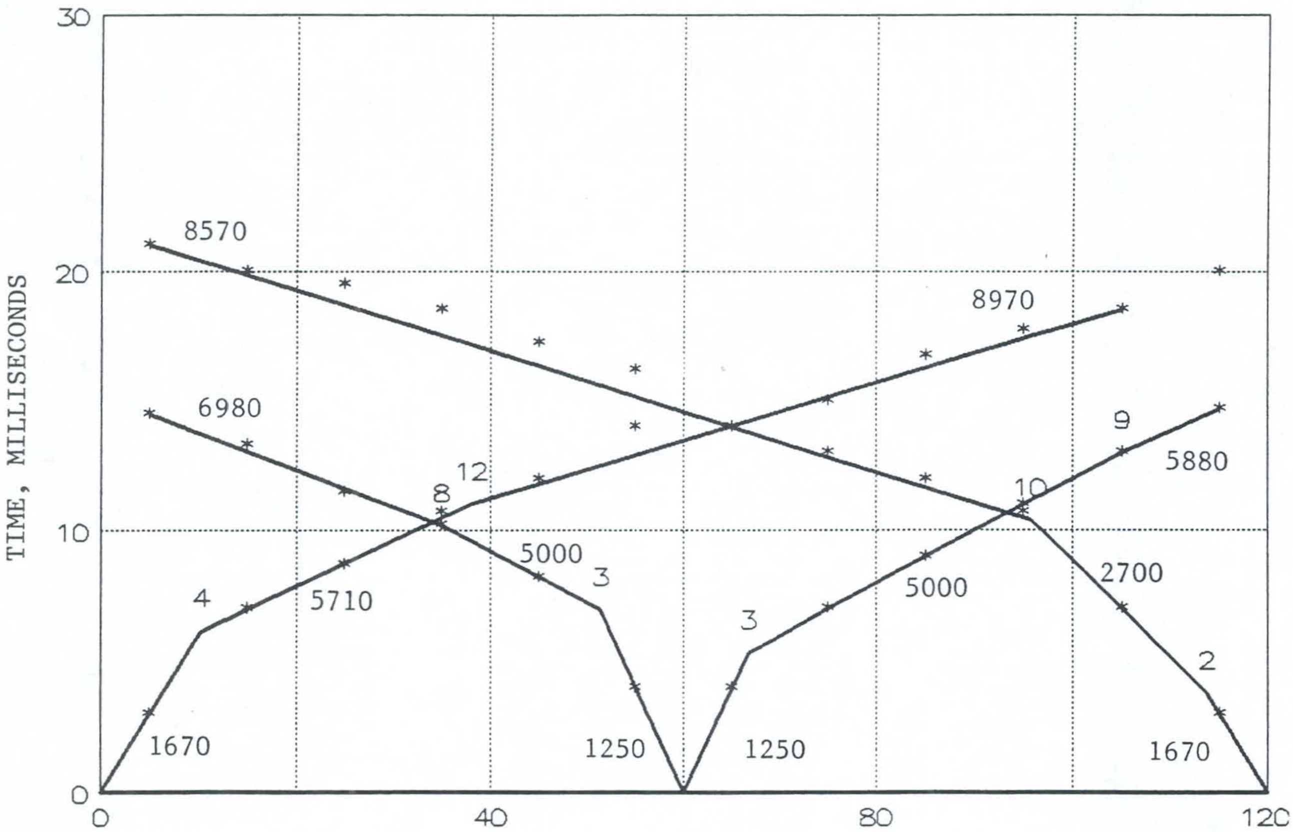
AGRA A-2
Earth & Environmental Group

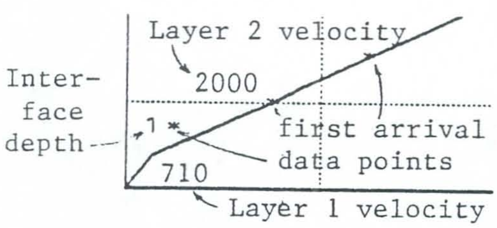
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



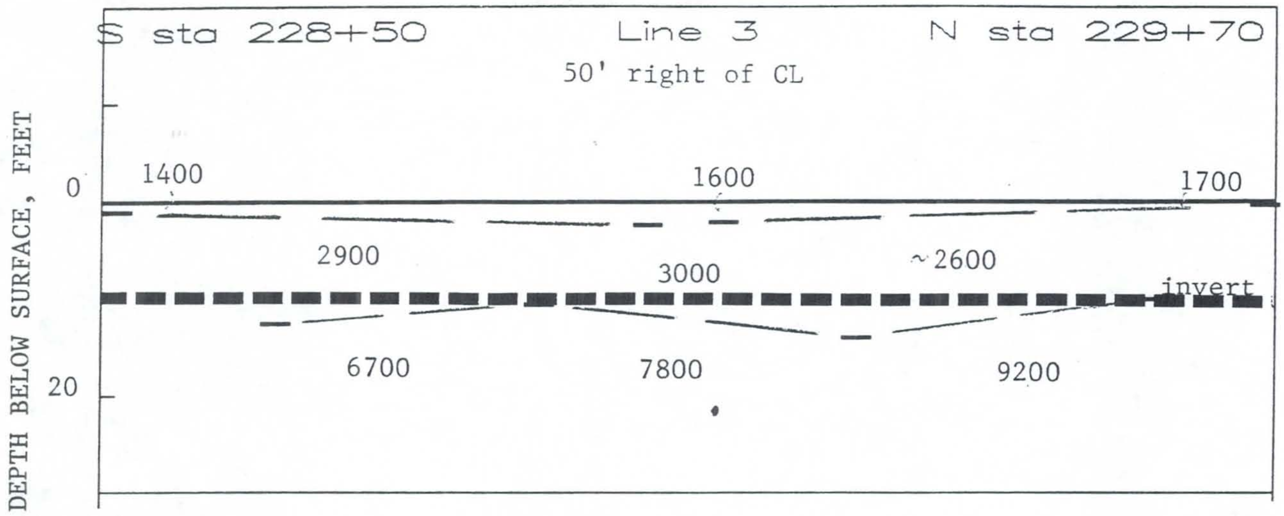


LEGEND

AEE Job No. 7-117-000062

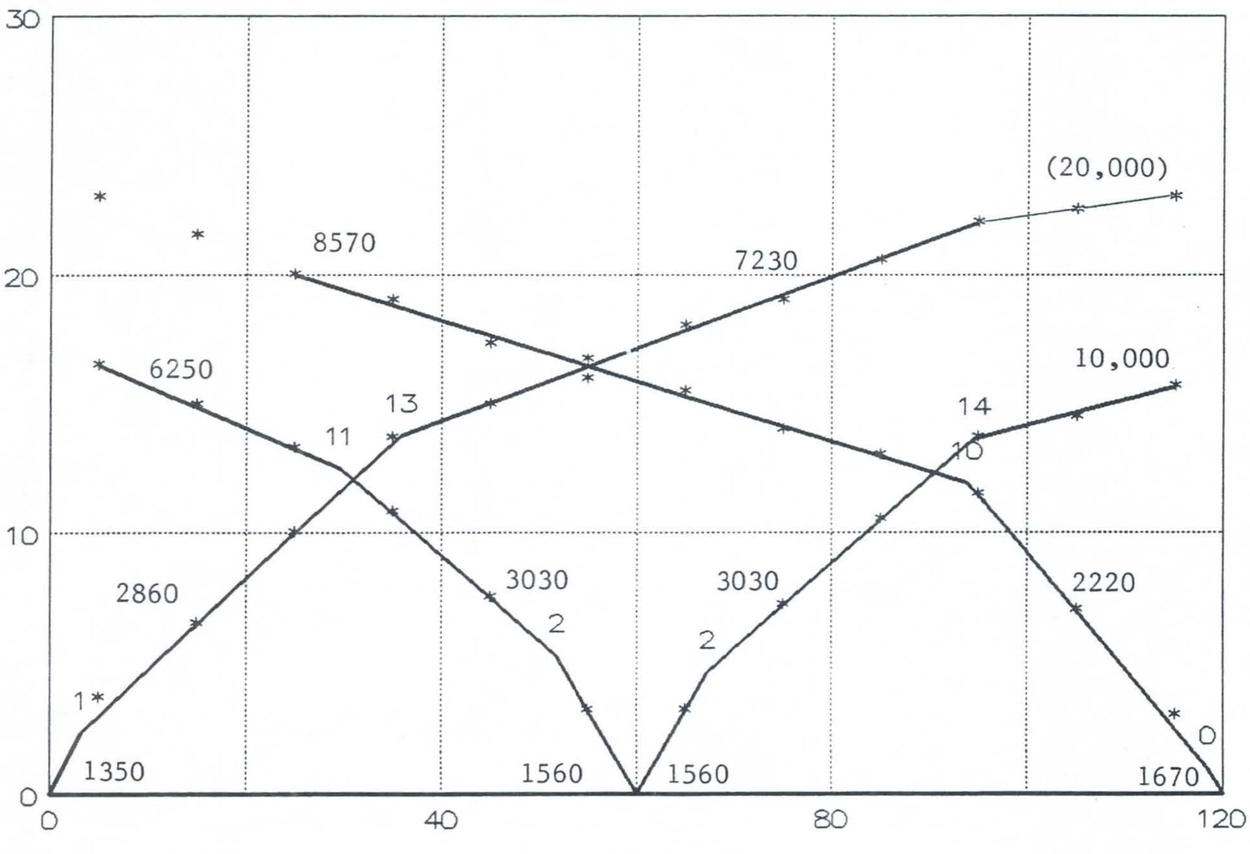
AGRA A-3
Earth & Environmental Group

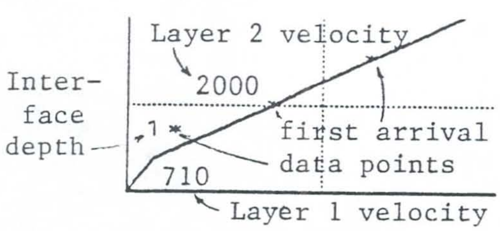
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



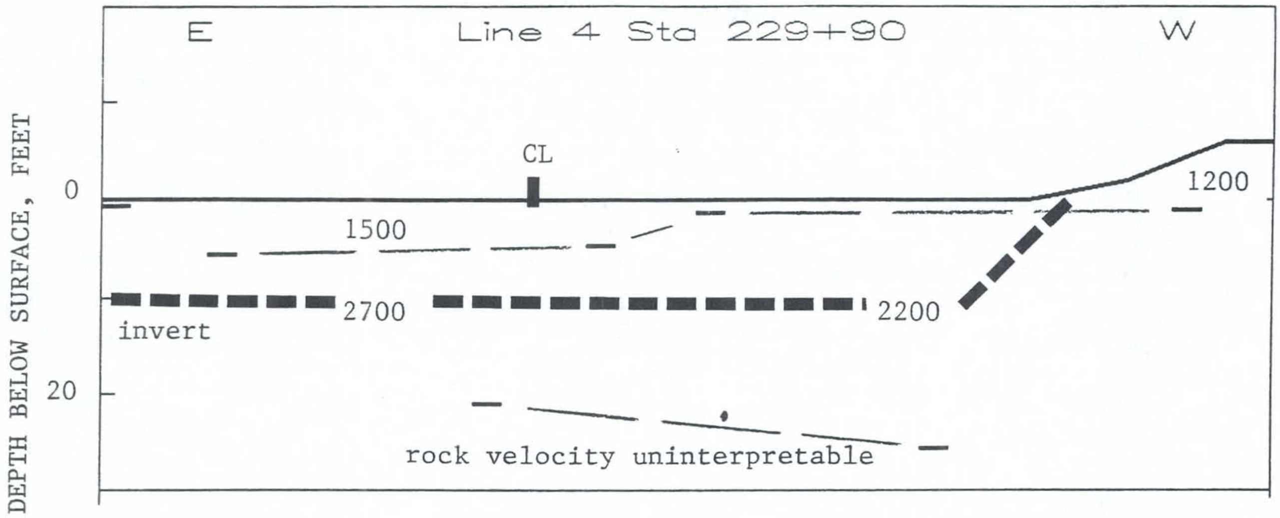


LEGEND

AEE Job No. 7-117-000062

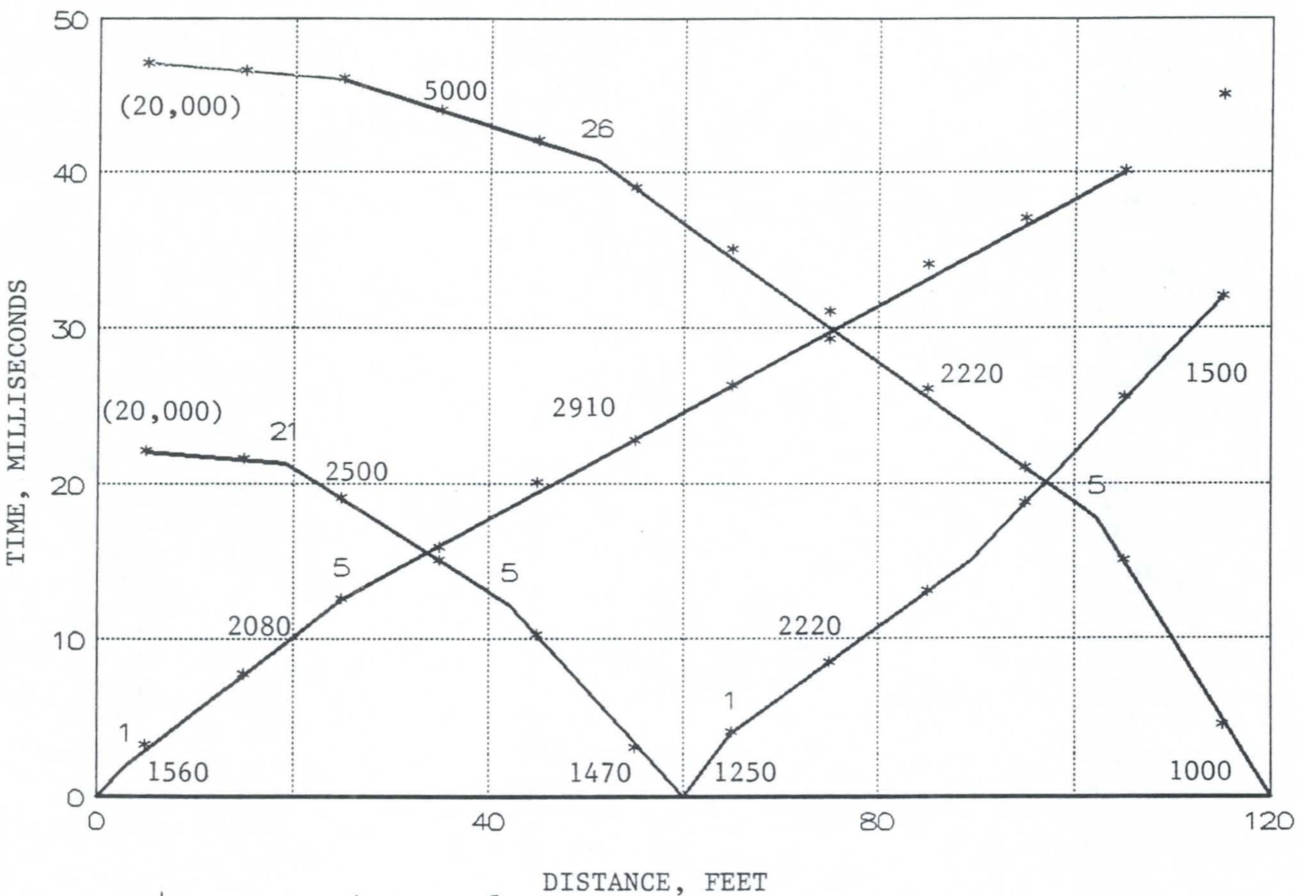
AGRA
Earth & Environmental Group

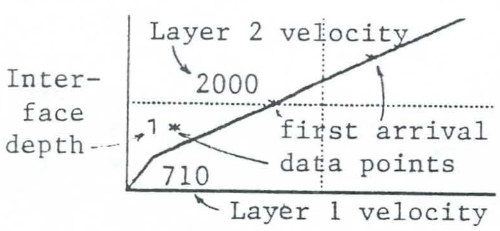
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



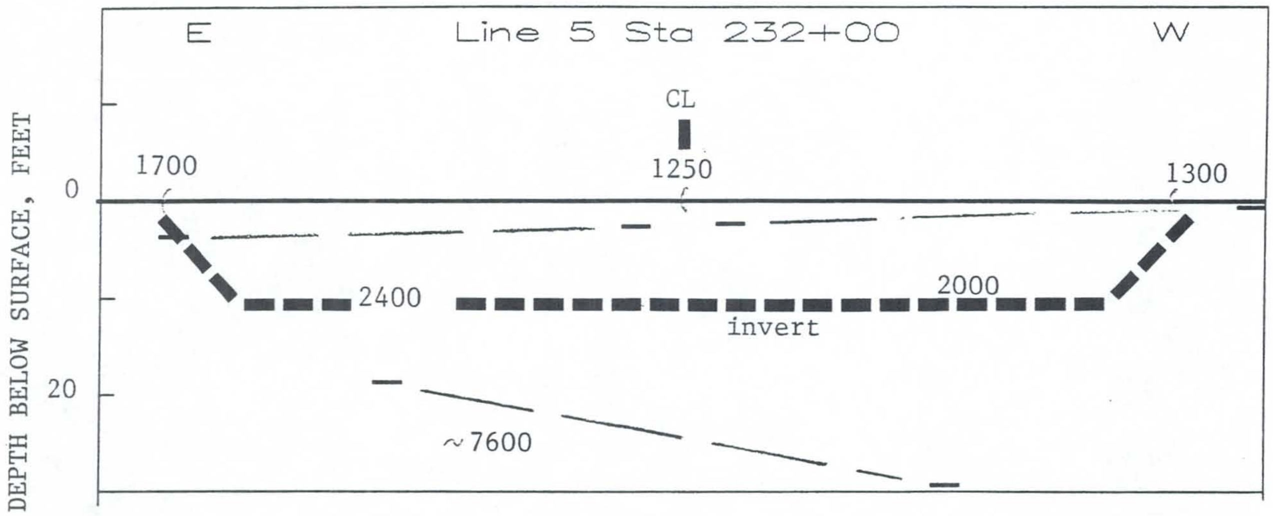


LEGEND

AEE Job No. 7-117-000062

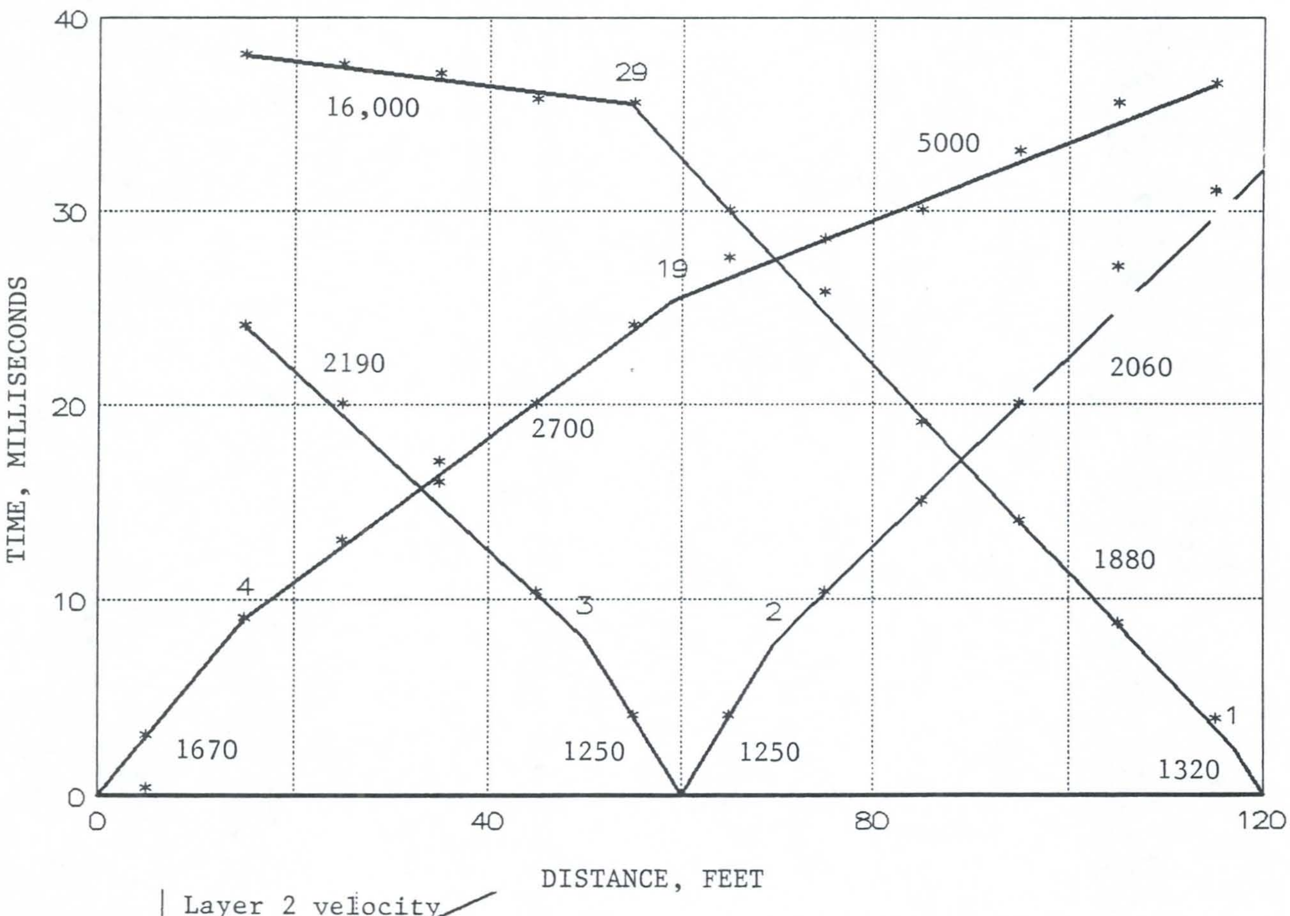
AGRA
Earth & Environmental Group

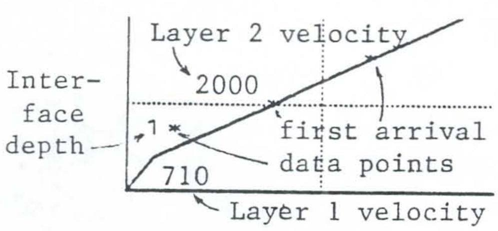
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



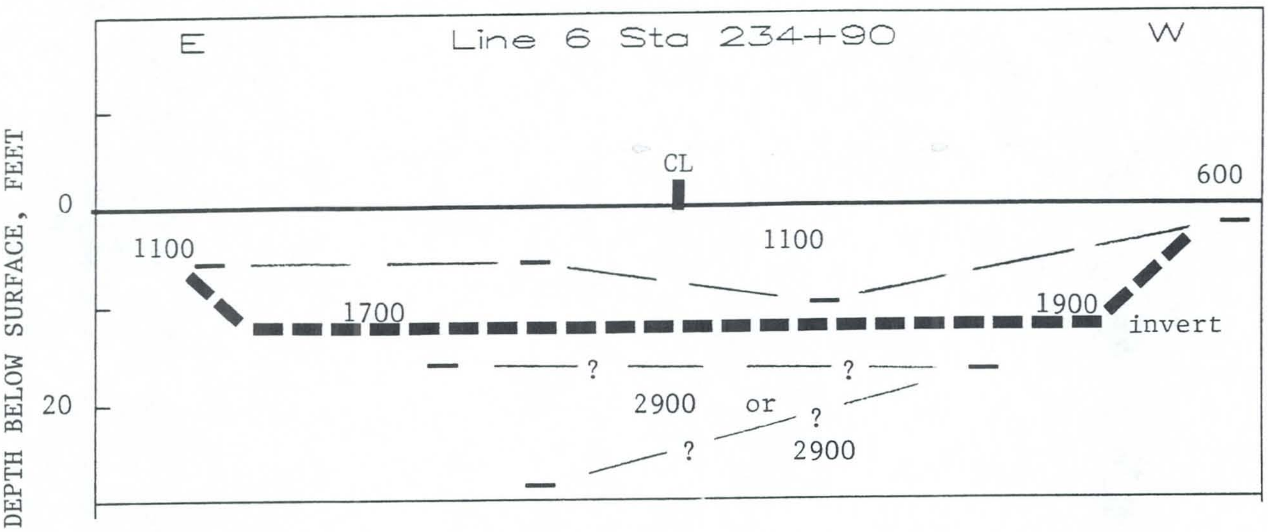


LEGEND

AEE Job No. 7-117-000062

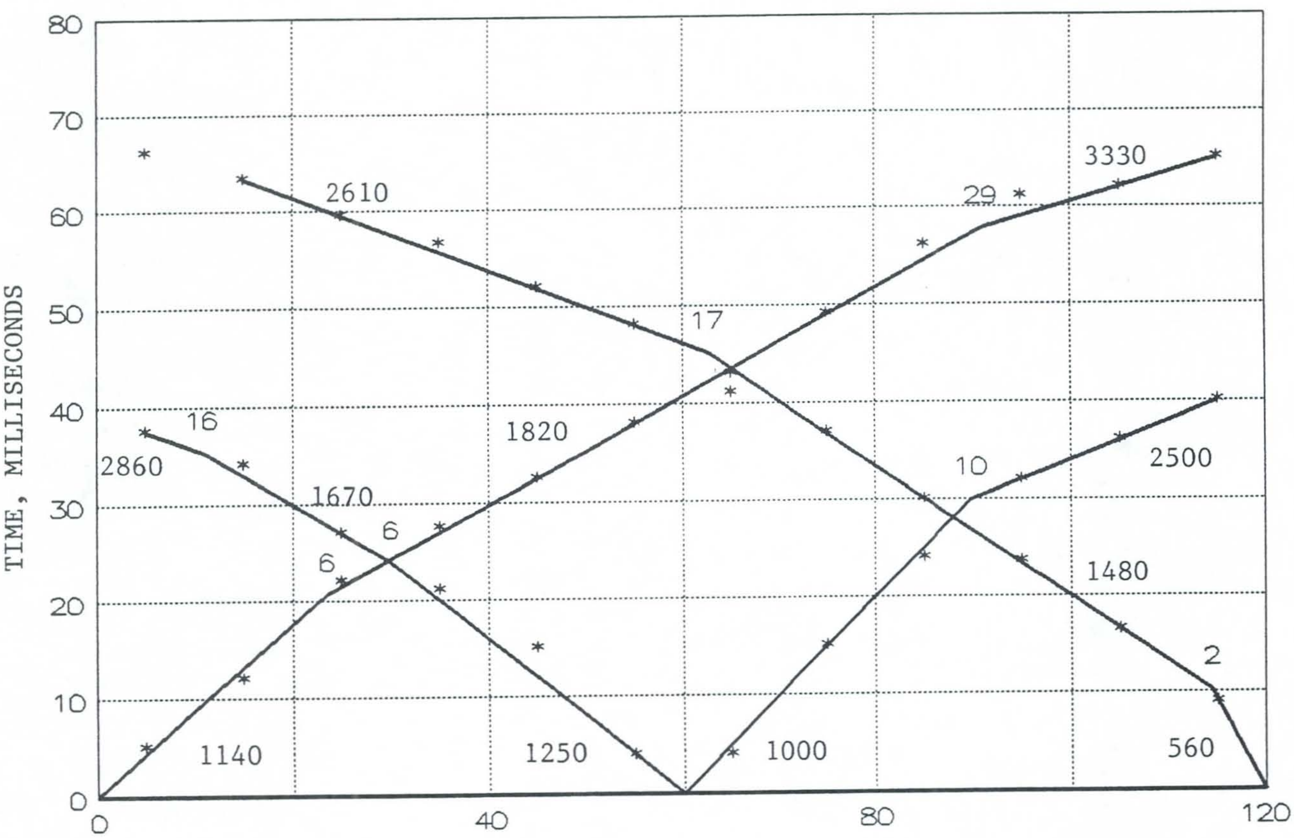
AGRA Earth & Environmental Group

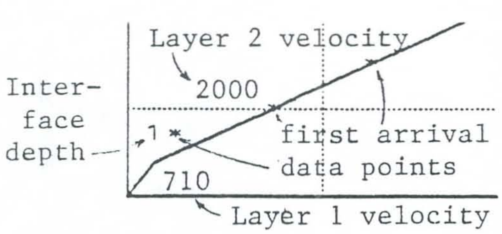
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



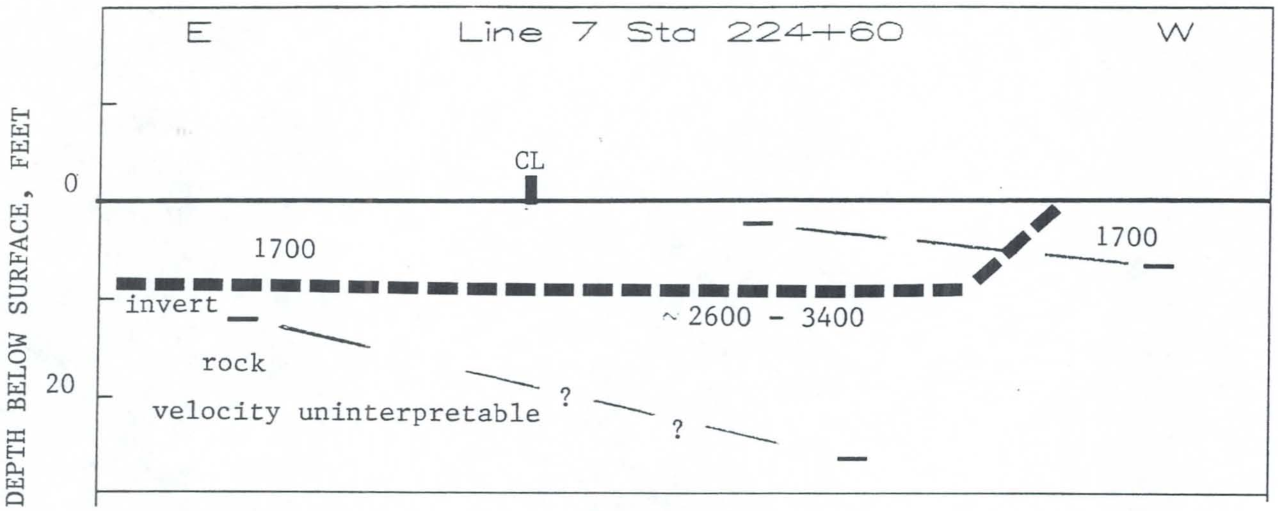


LEGEND

AEE Job No. 7-117-000062

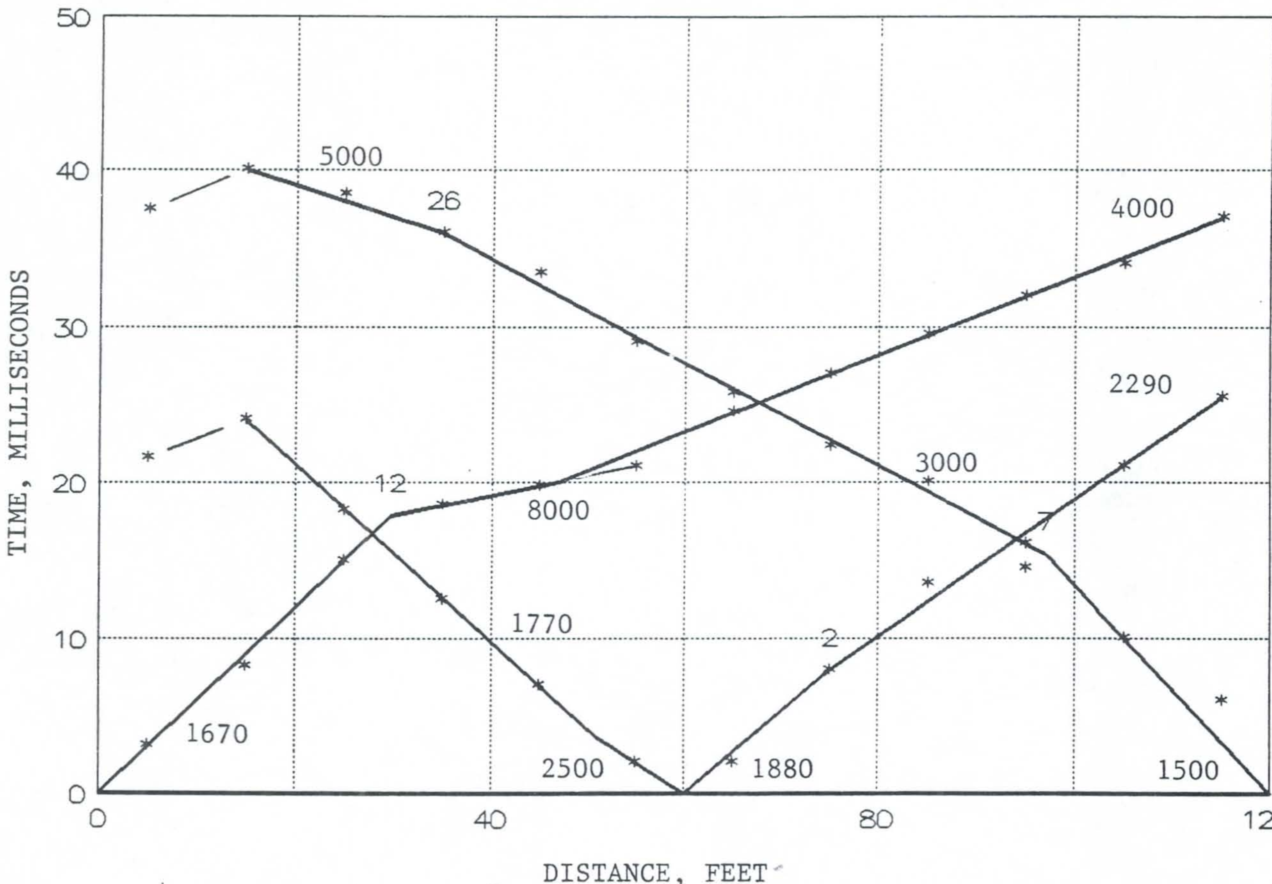
AGRA
Earth & Environmental Group

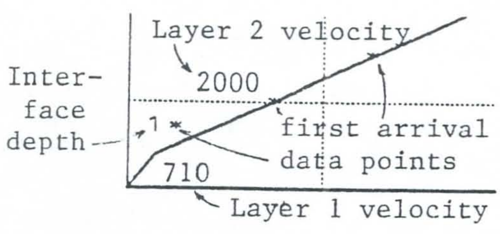
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



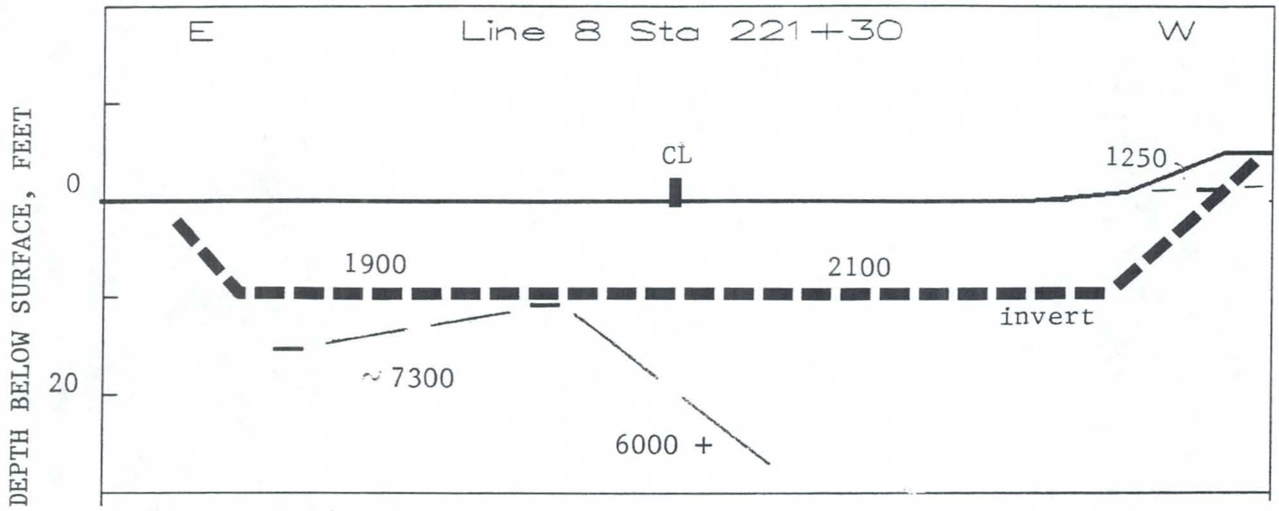


LEGEND

AEE Job No. 7-117-000062

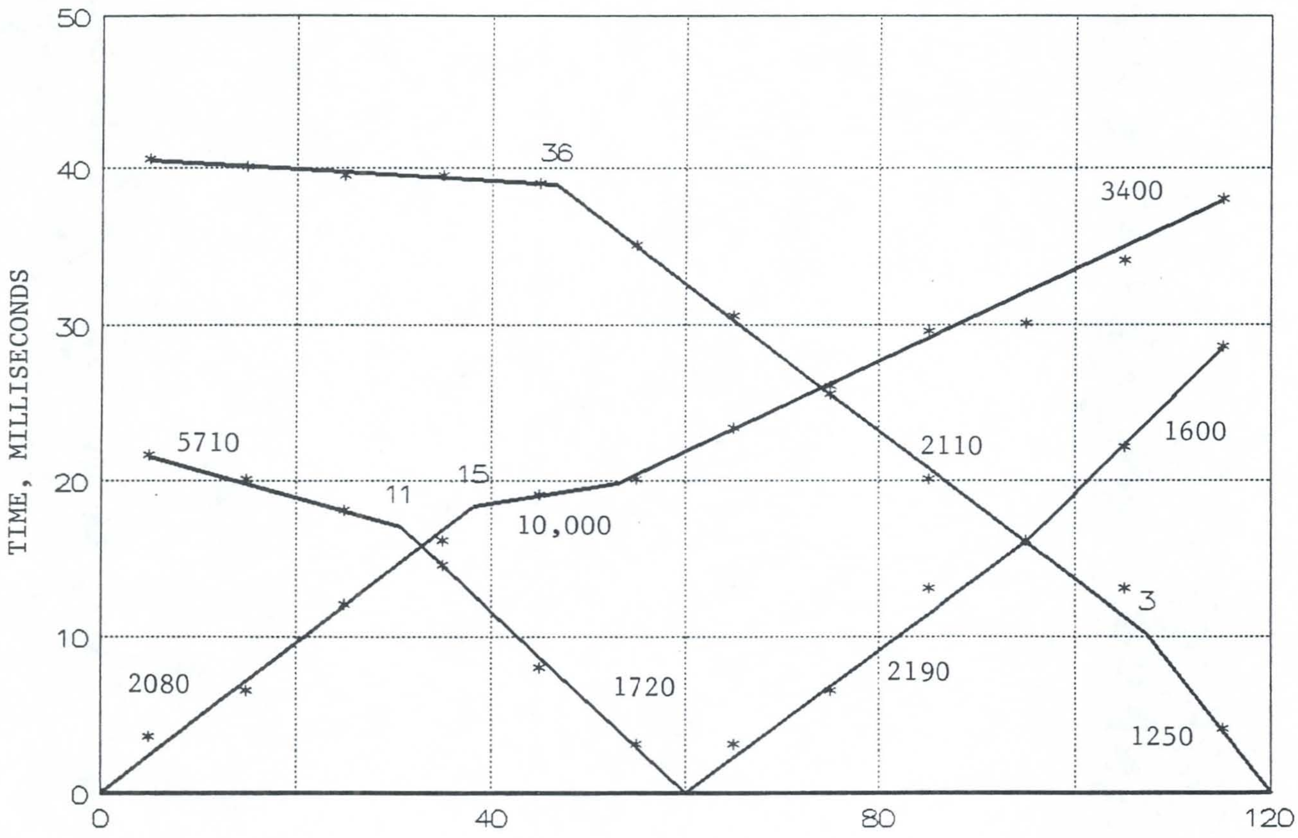
AGRA Earth & Environmental Group

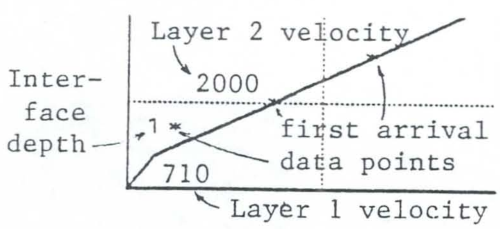
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



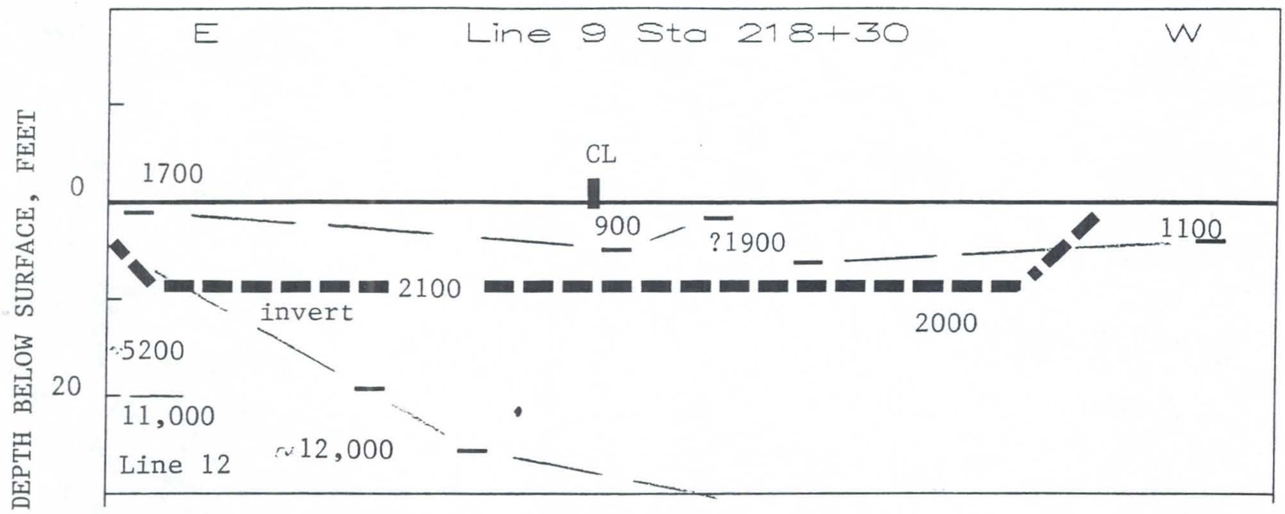


LEGEND

AEE Job No. 7-117-000062

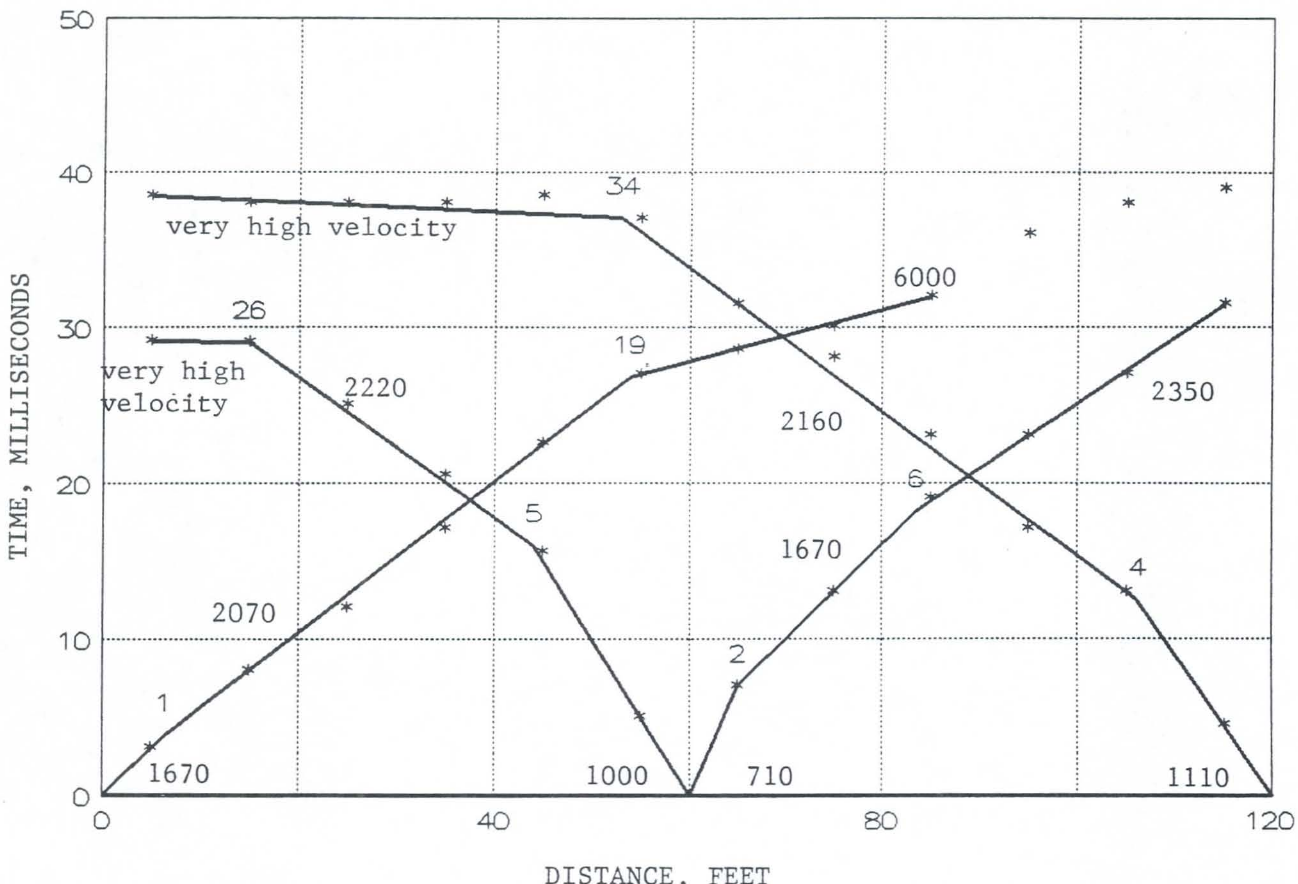
AGRA Earth & Environmental Group

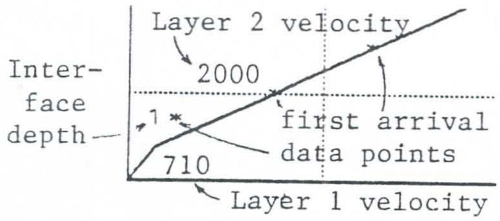
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



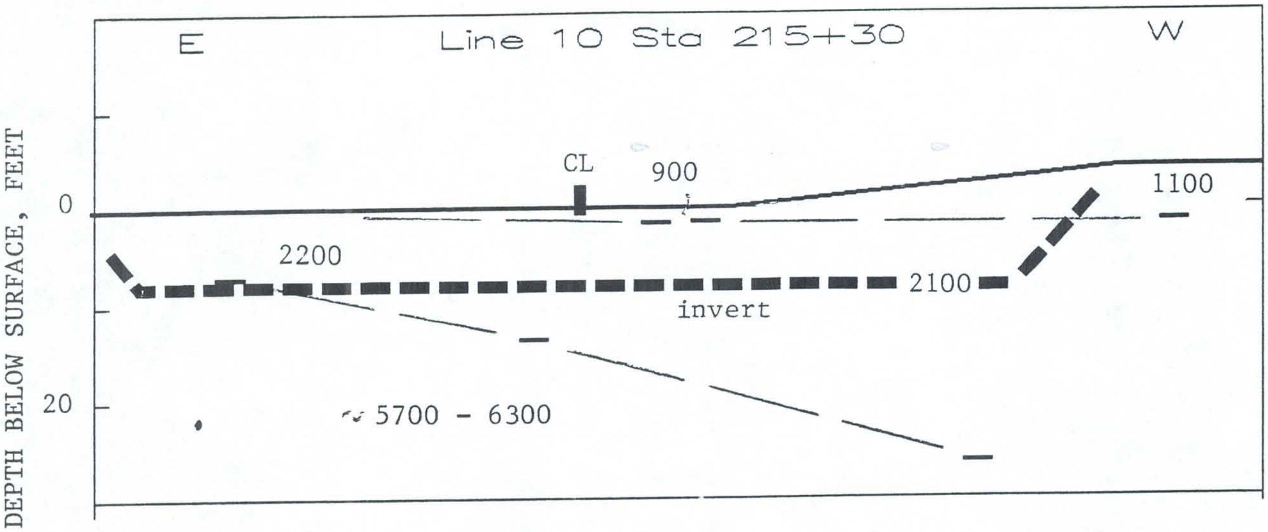


LEGEND

AEE Job No. 7-117-000062

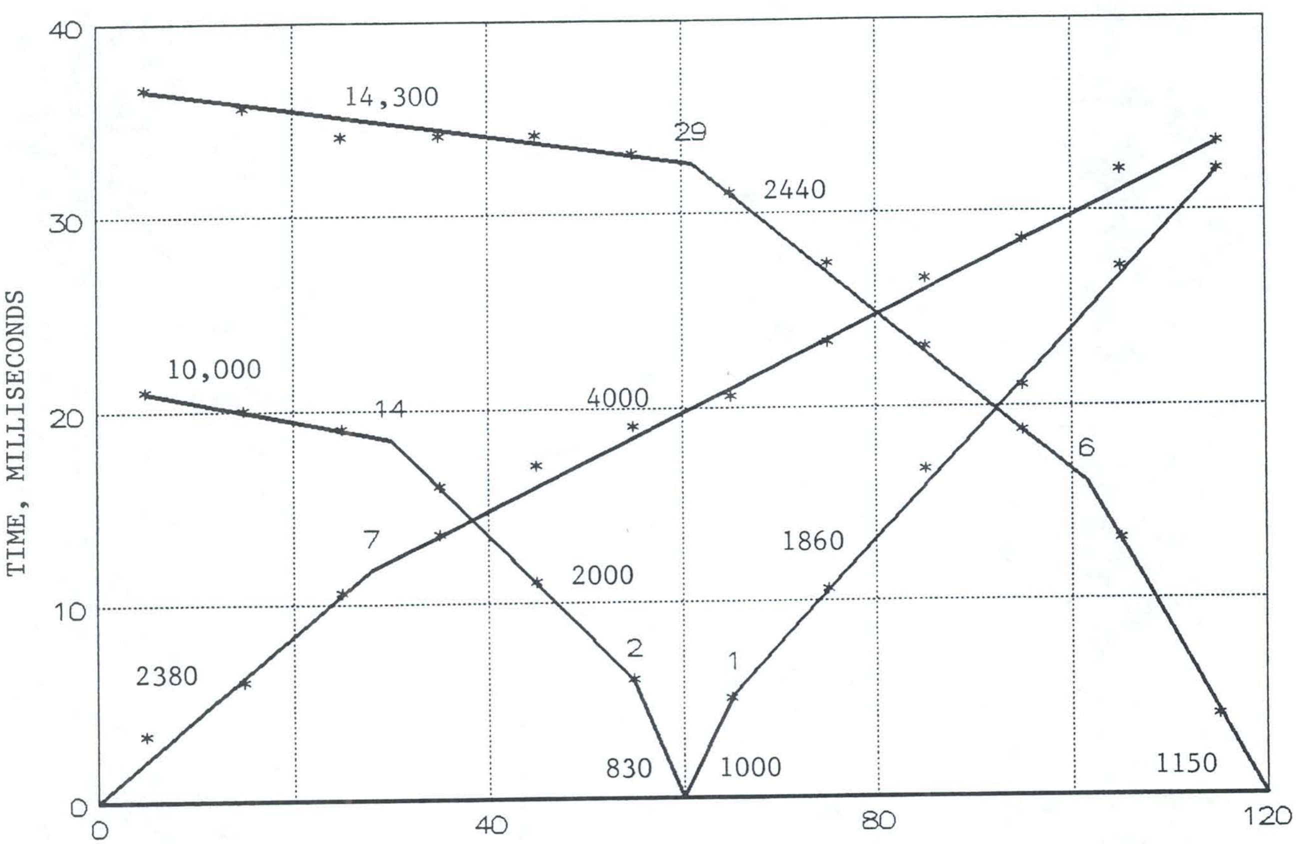
AGRA Earth & Environmental Group

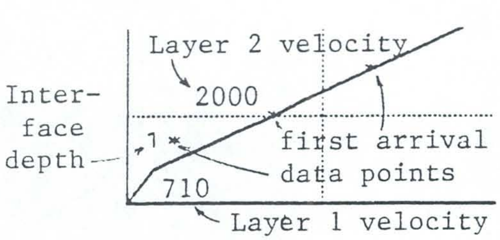
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



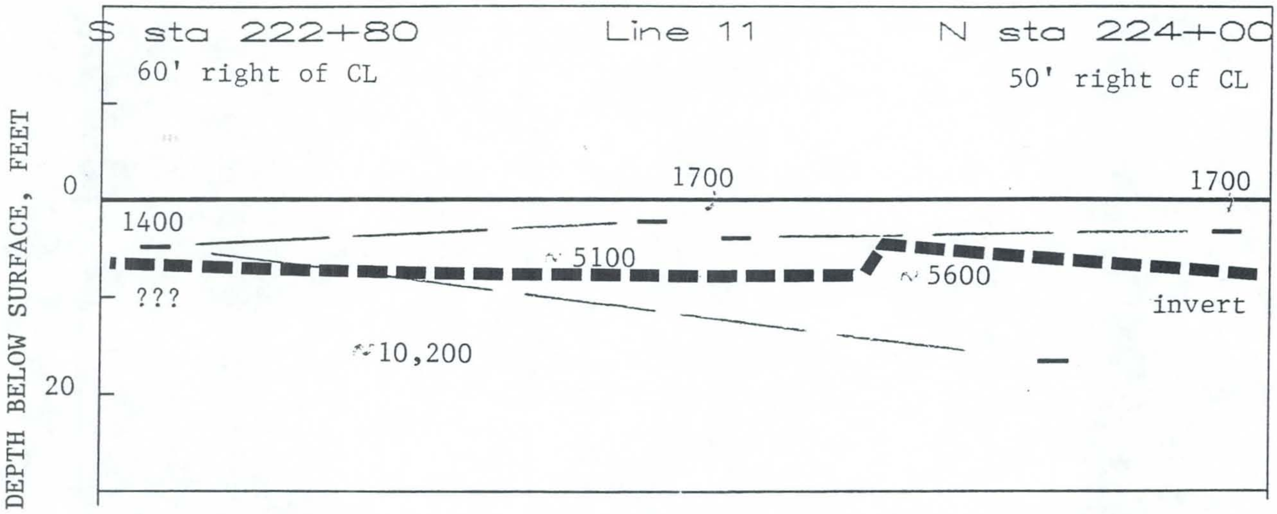


LEGEND

AEE Job No. 7-117-000062

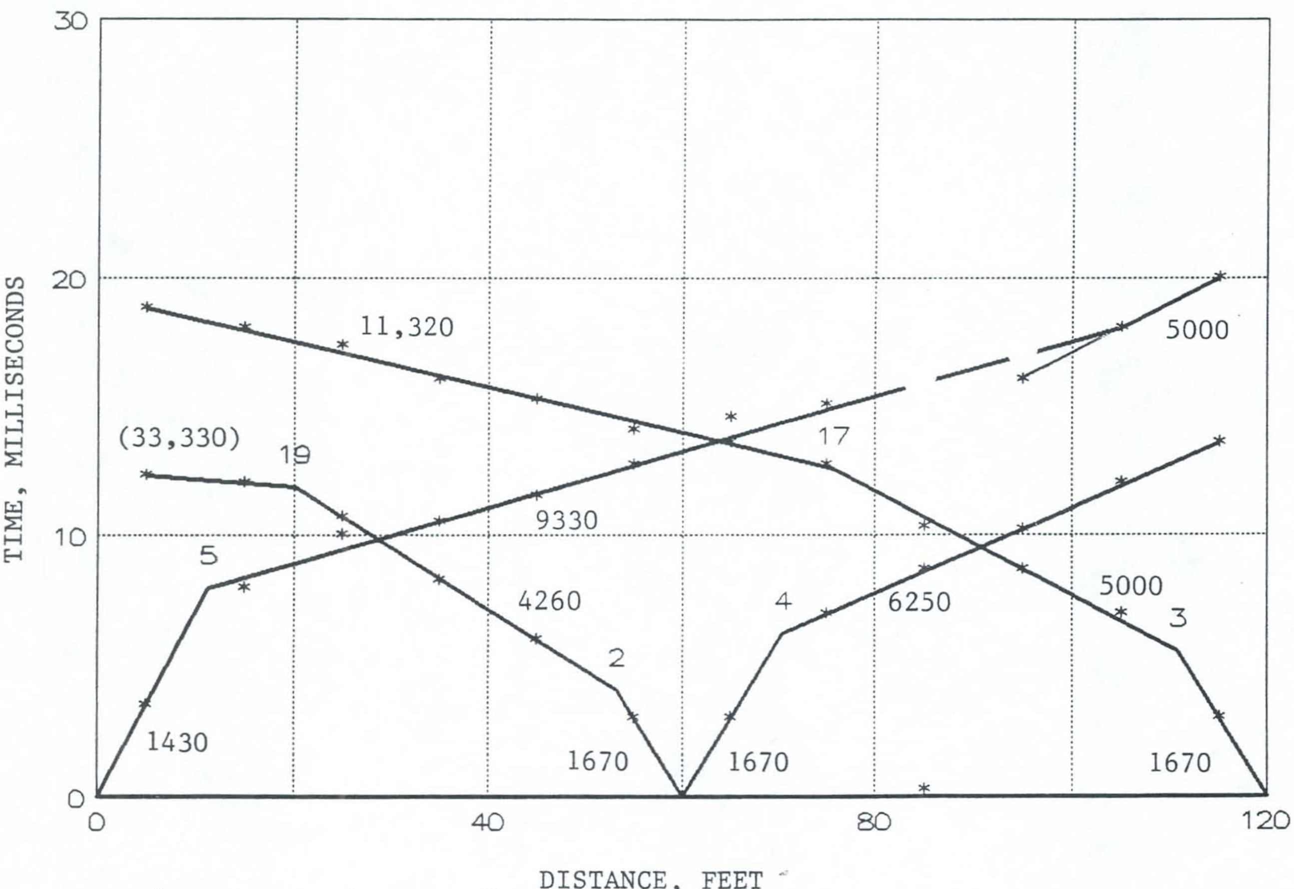
AGRA
Earth & Environmental Group

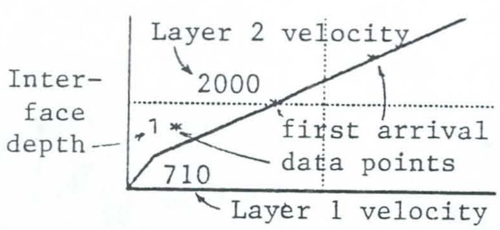
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



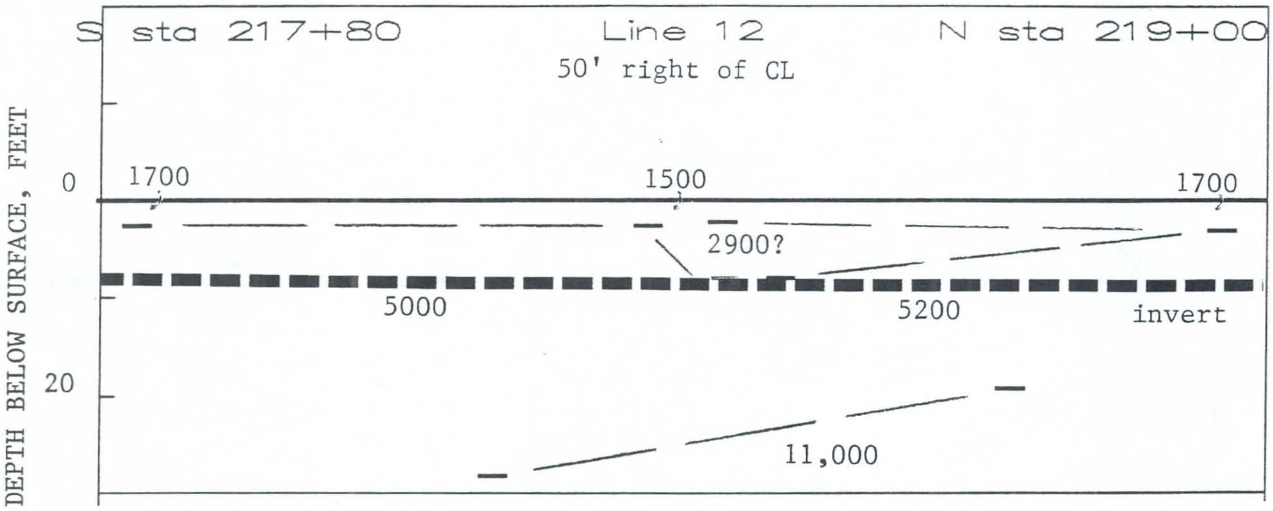


LEGEND

AEE Job No. 7-117-000062

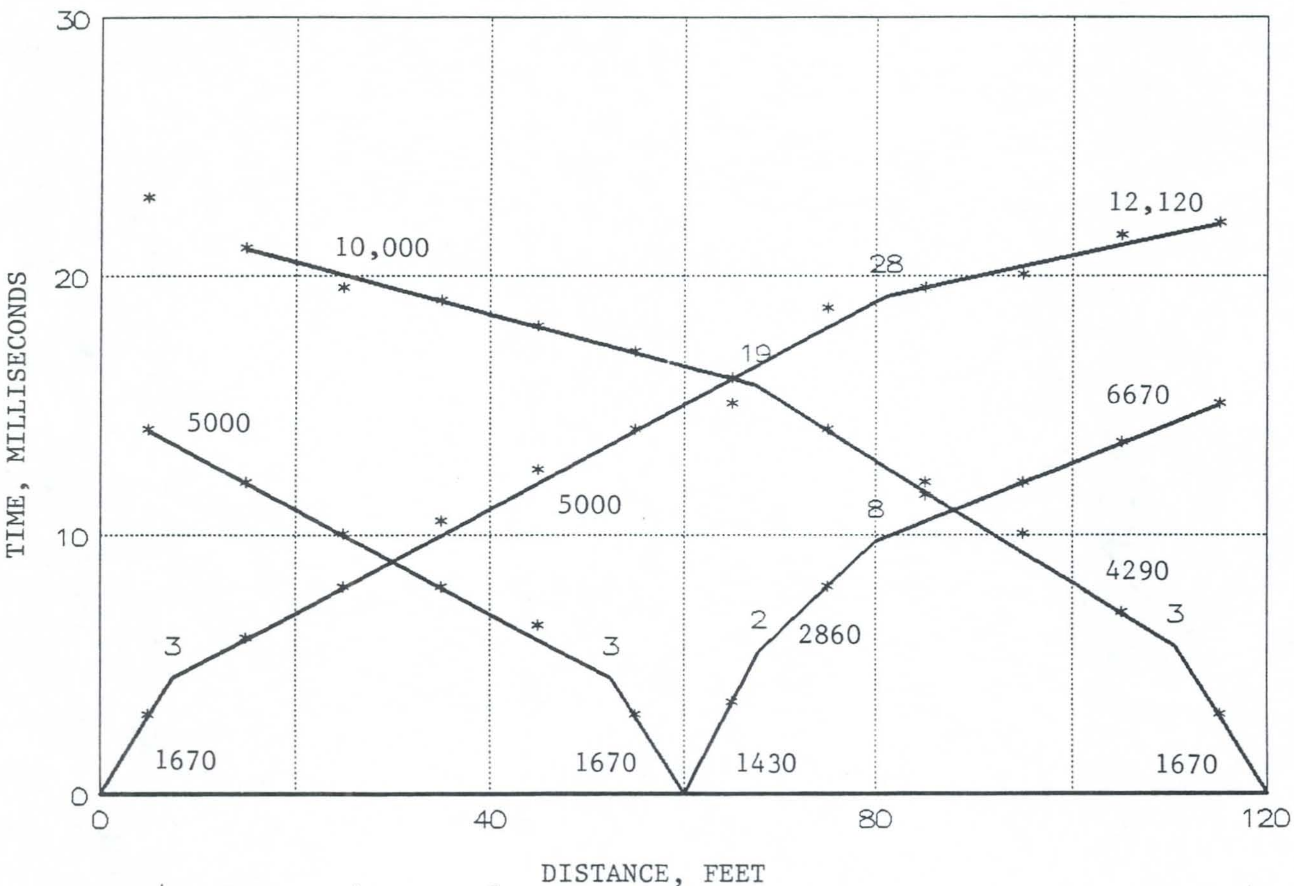
AGRA Earth & Environmental Group

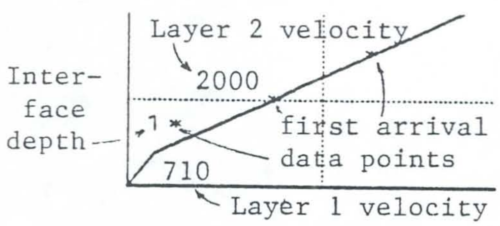
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



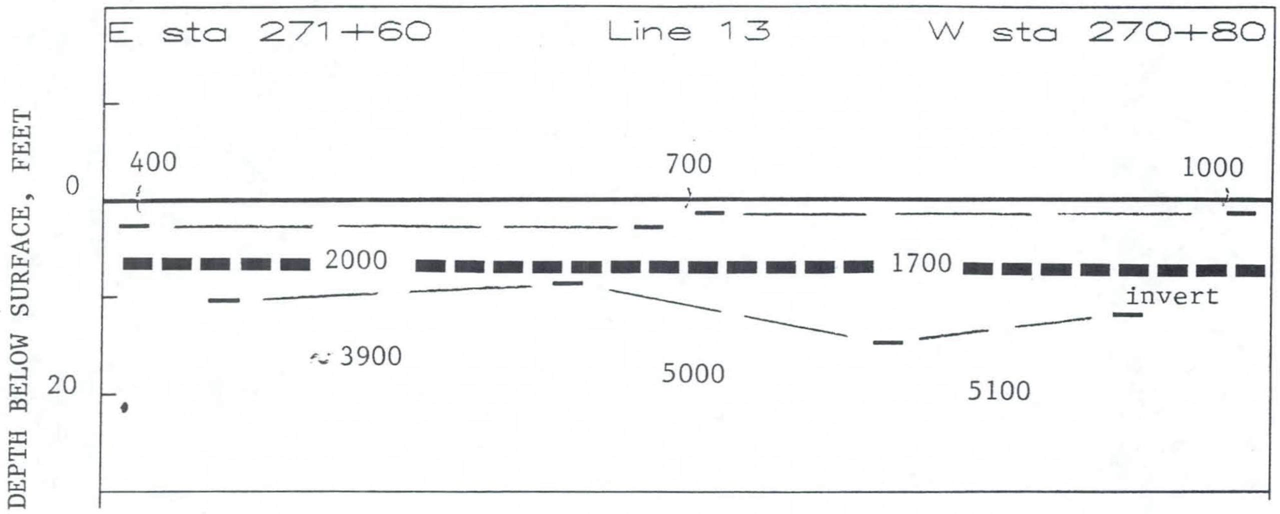


LEGEND

AEE Job No. 7-117-000062

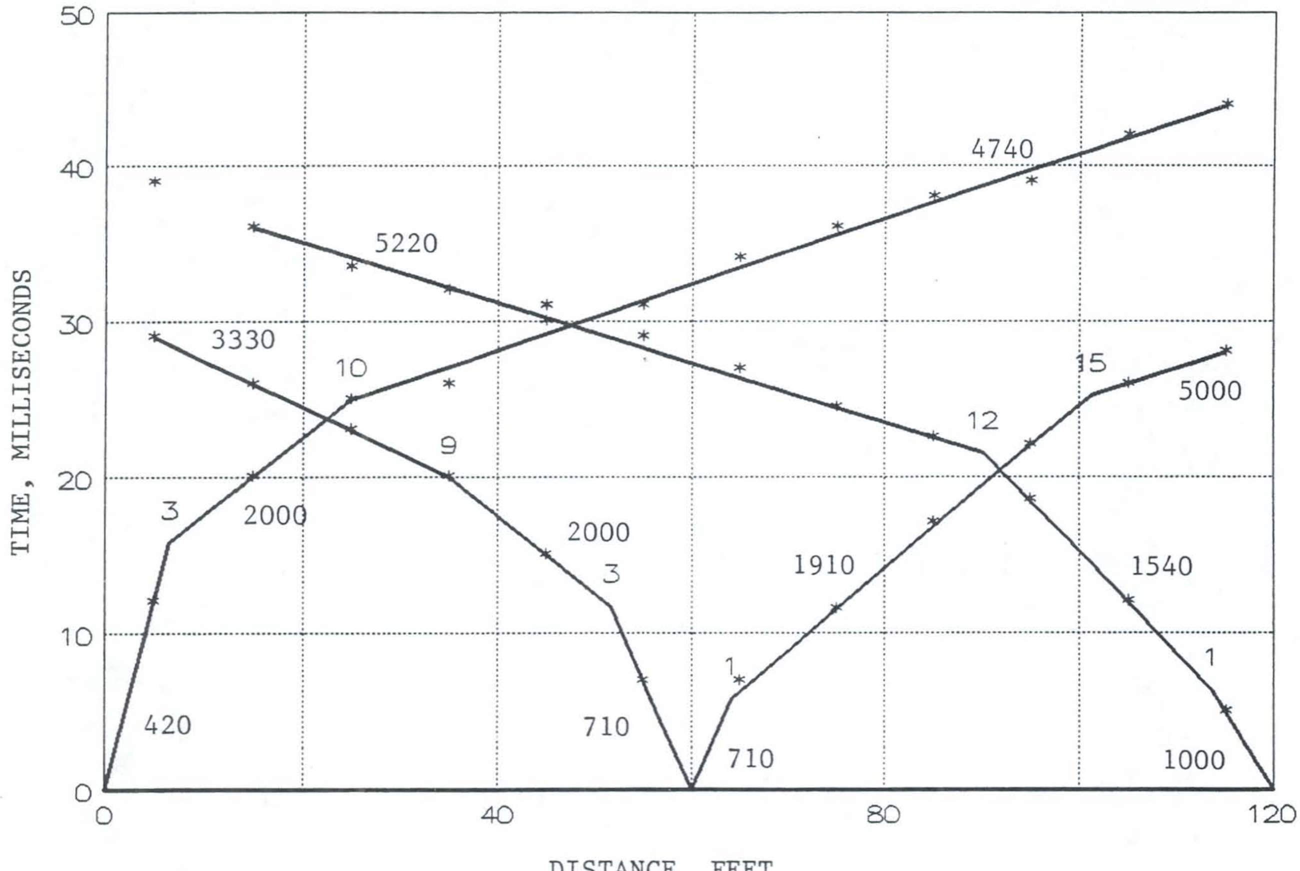
AGRA Earth & Environmental Group

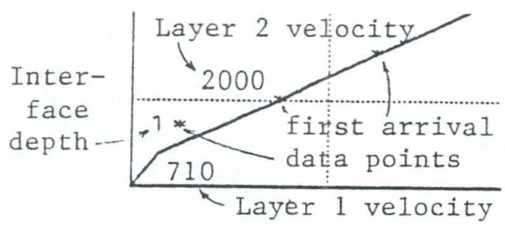
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



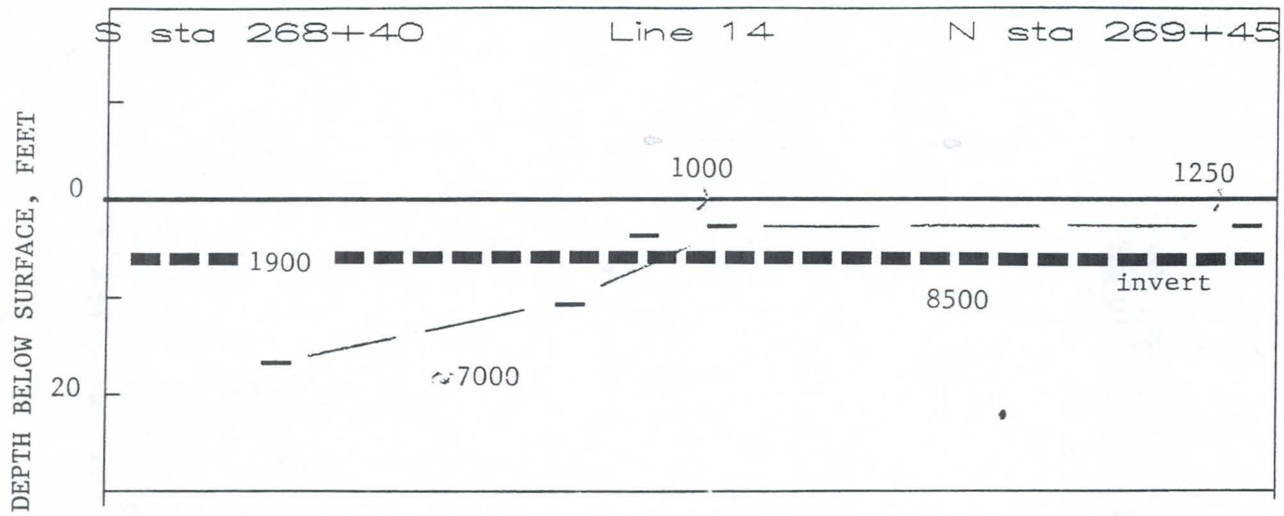


LEGEND

AEE Job No. 7-117-000062

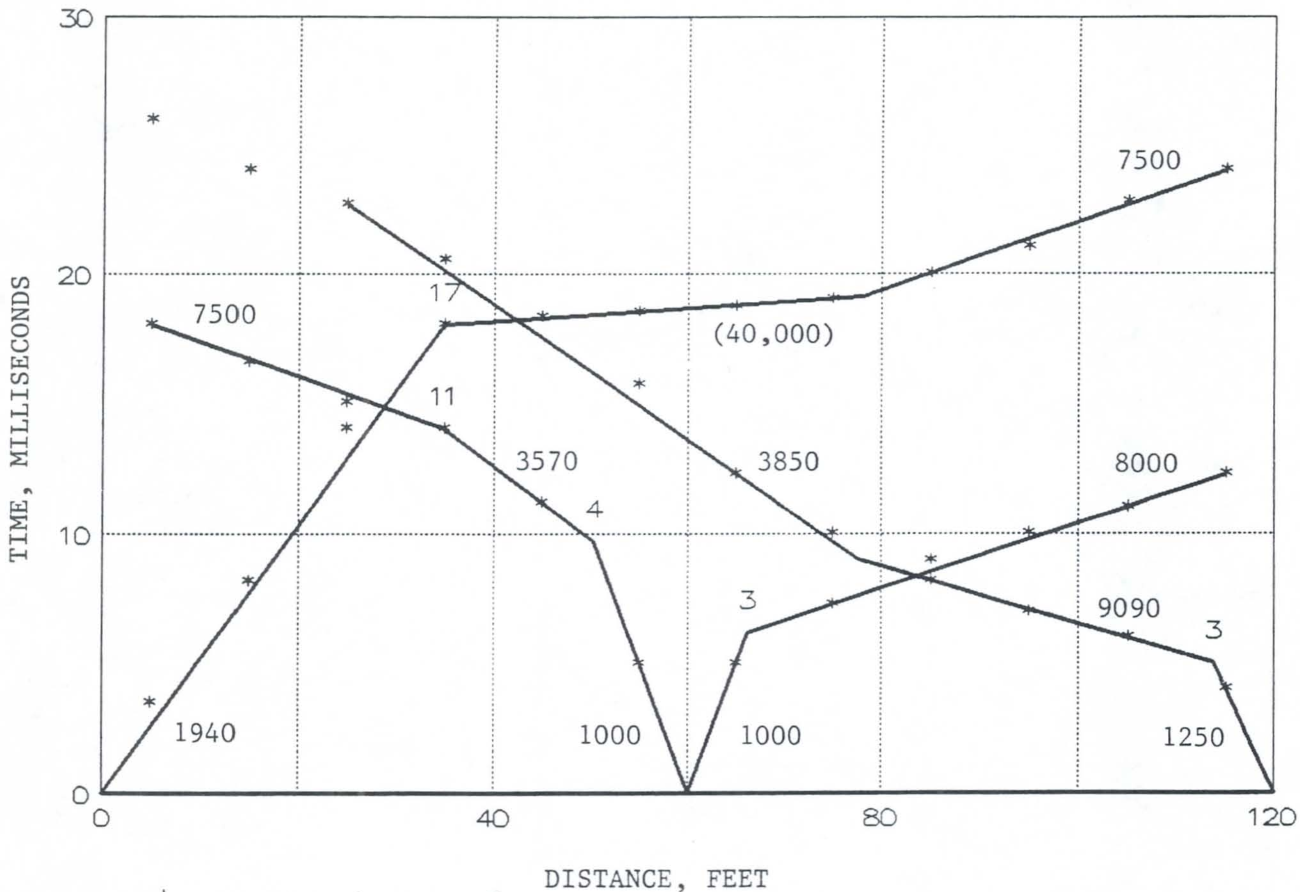
AGRA
Earth & Environmental Group

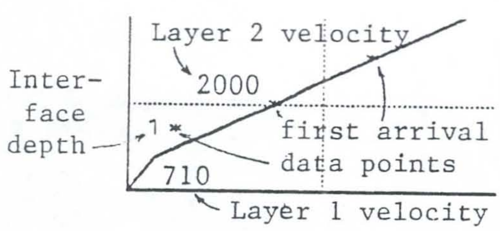
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



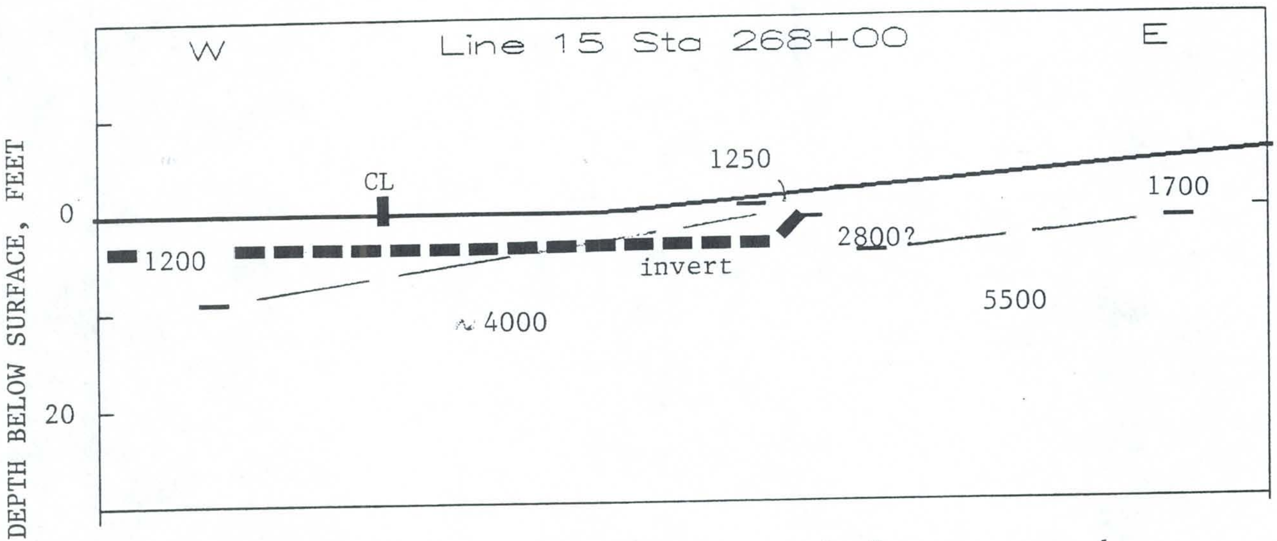


LEGEND

AEE Job No. 7-117-000062

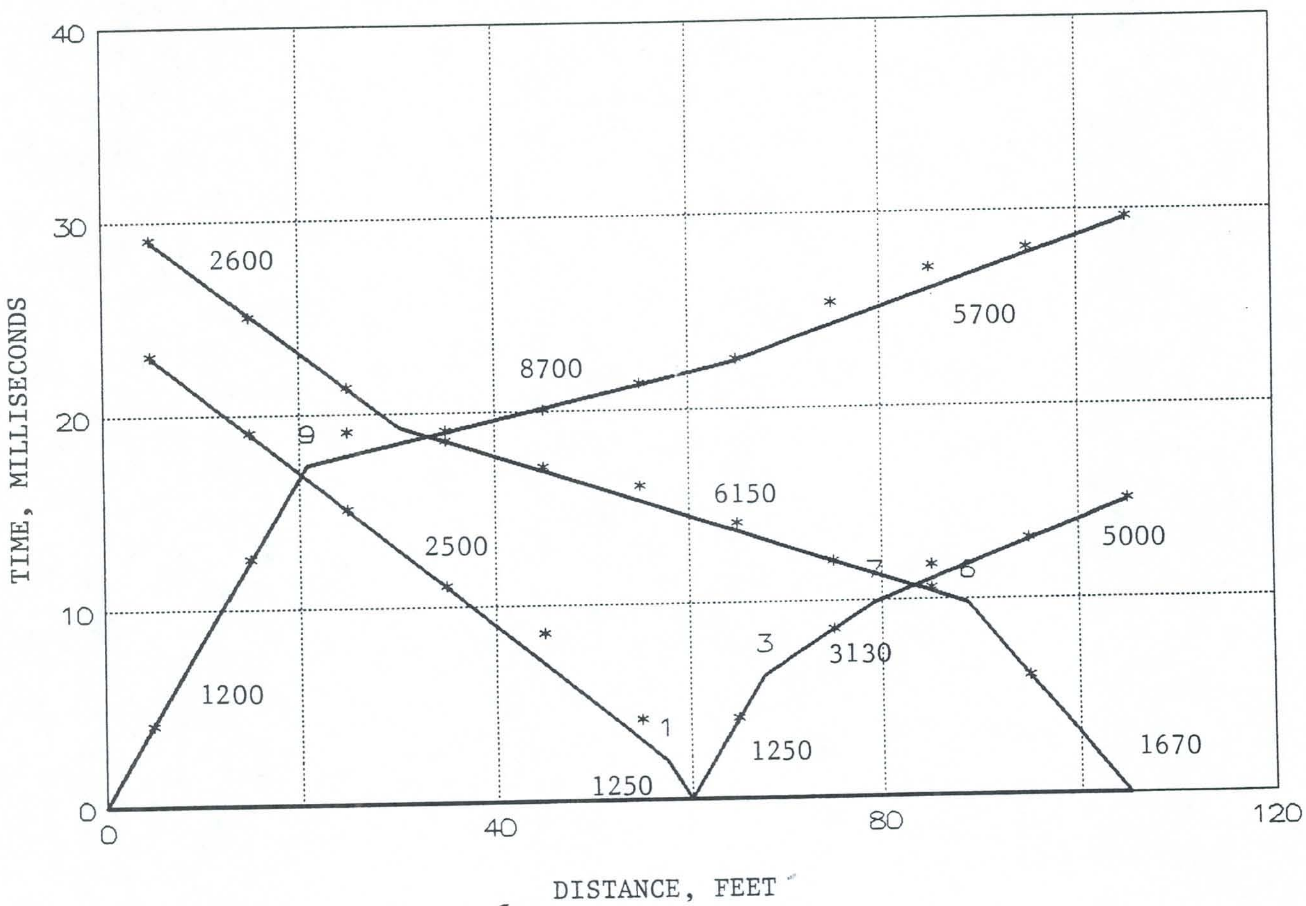
AGRA
Earth & Environmental Group

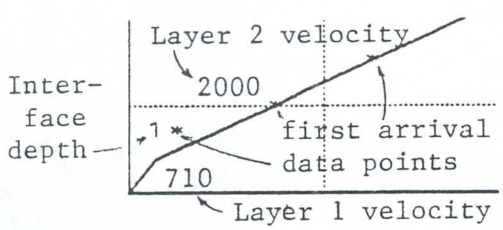
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS



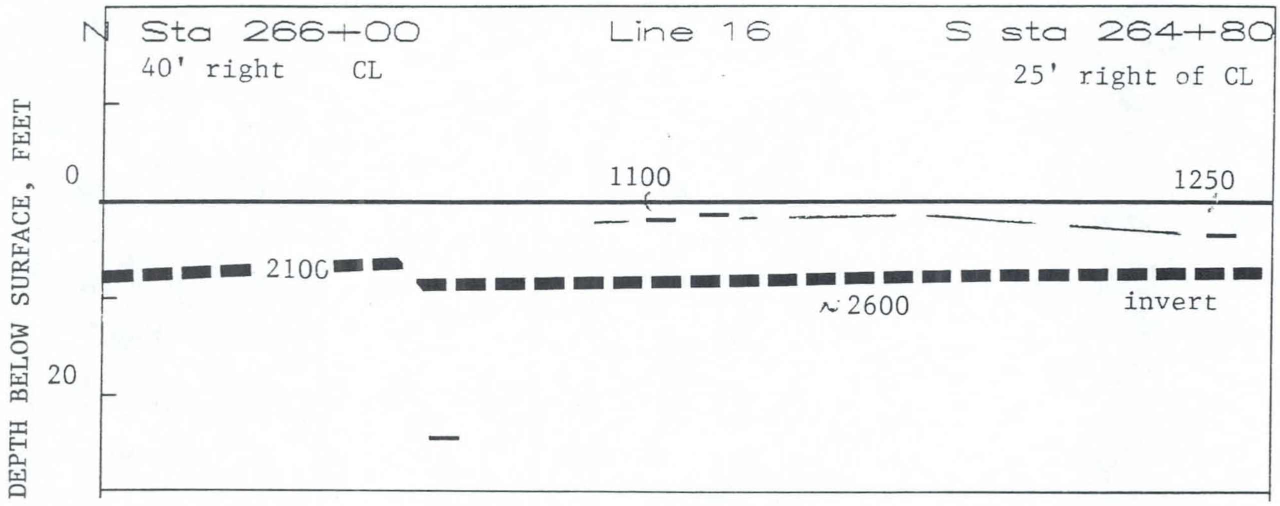


LEGEND

AEE Job No. 7-117-000062

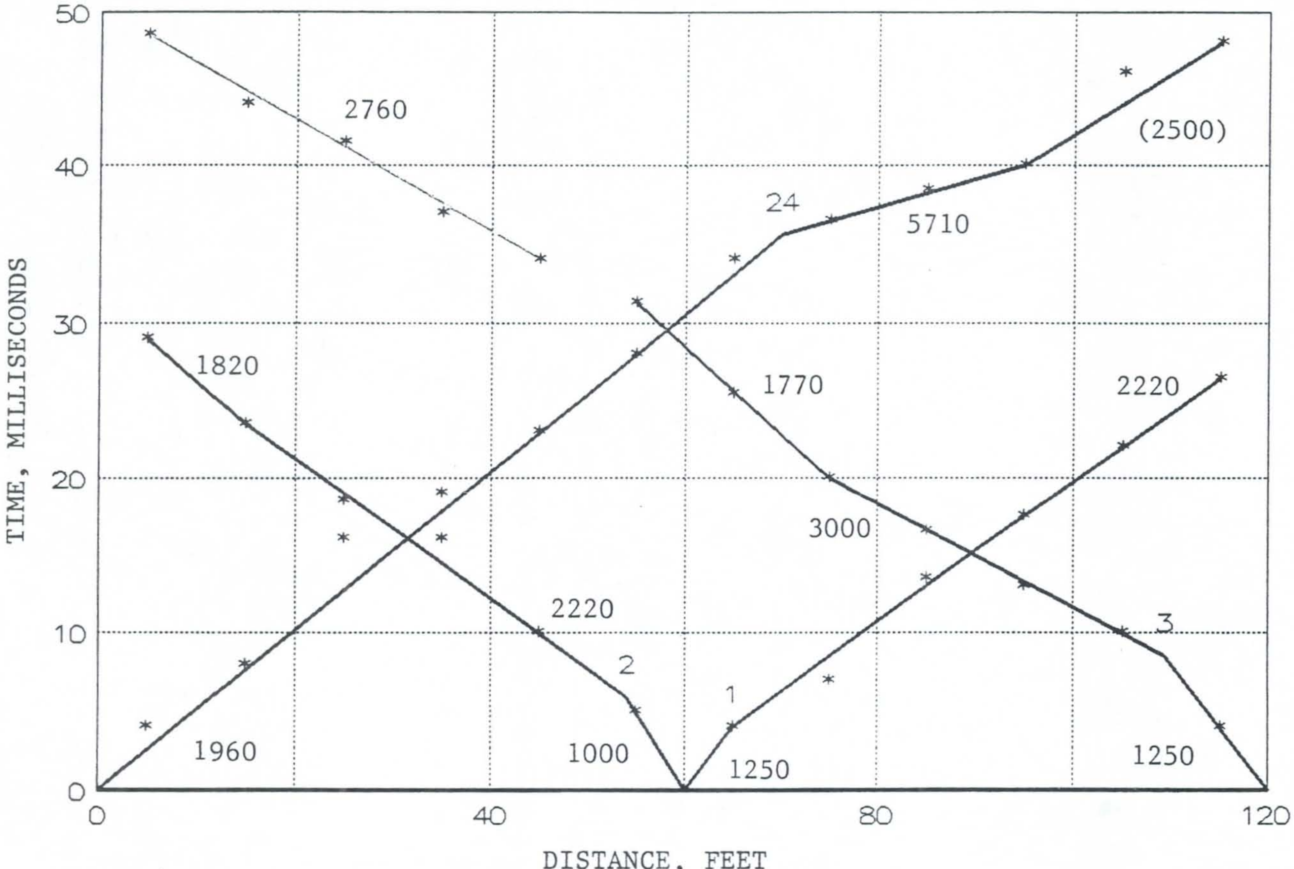
AGRA
Earth & Environmental Group

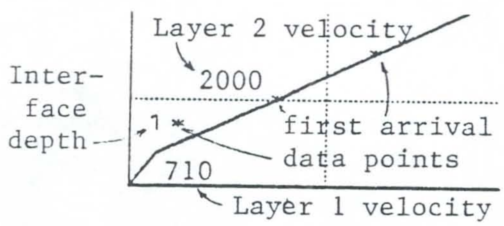
GEOLOGIC INTERPRETATION OF REFRACTION SEISMIC DATA



Notes: Depths are in feet, velocities are in feet per second
Topography, when shown, is approximate

REFRACTION SEISMIC TIME-DISTANCE PLOTS





LEGEND

AEE Job No. 7-117-000062

SURFACE RESISTIVITY

Surface resistivity measurements are normally used in civil engineering work to assist in determining parameters for electrical grounding conditions or the potential for corrosion of metal constructions, such as pipes or culverts, at a site. Under some conditions, surface resistivity measurements may be used for subsurface exploration, especially estimation of depth to groundwater and groundwater conductivity.

Resistivity is the inverse of conductivity and both parameters measure the same electrical property. Resistivity units of ohm-centimeters (ohm-cm) are typically used in civil engineering work. Fluids in the pore spaces provide the only electrical path in sands while clay particles also provide electrical paths in clays. Resistivities may be as low as several hundred ohm-cm in wet clays or as low as several thousand ohm-cm in wet sands. A reduction in moisture content typically results in an increase in resistivity. The difference in resistivity between a soil in a dry and saturated condition may be several orders of magnitude. Conductivity units of micromho-centimeters (umho-cm) are typically used in groundwater investigations and analysis, and water is typically considered to be brackish once the conductivity exceeds about 1,000 umho-cm. 1,000 ohm-cm is equal to 1,000 umho-cm, and 10,000 ohm-cm is equal to 100 umho-cm.

Since soil resistivity properties may vary greatly with soil moisture content and temperature changes, measured resistivity values should be considered to be approximate. In general, it can be anticipated that an increase in soil moisture results in a reduction in soil resistivity. Furthermore, resistivities of water and ion solutions may vary with the temperature of the solution. For example, a temperature increase from 50 to 100 degrees Fahrenheit nearly halves the resistivity of a water and NaCl solution (Schlumberger Log Interpretation Charts, 1972 Edition).

Equipment - Surface resistivity measurements are performed using a portable alternating current (AC) electrical energy source, AC voltage and current meters, and ground electrodes and associated cabling. The four-point Wenner array method is typically used. This method of measuring subsurface resistivity involves placing four electrodes in the ground in a line at equal distance spacings, applying a measured AC current to the outer two electrodes and measuring the AC voltage between the inner two electrodes. A measured resistance is calculated by dividing the measured voltage by the measured current. This resistance is then multiplied by a geometric factor which includes the spacing between each electrode to determine the apparent resistivity.

A subsurface resistivity profile is typically performed by making successive measurements at several electrode spacings at one location. Electrode spacings of 2.5, 5, 10, 20 and 30 feet are typically used. Water is introduced to the electrode holes as they are driven into the ground to improve electrical contact. The depth of investigation is typically less than the maximum electrode spacing.

Interpretation - After resistivities from a Wenner array profile have been calculated, further interpretation of the data may be warranted. When a large resistivity contrast is apparent, depth to groundwater or bedrock, or a change in soil electrical properties might be estimated from profiling data. Other properties which might be interpretable in non-clayey materials include porosity, groundwater conductivity and total dissolved solids. Calculating these various parameters serve as a check to verify that interpretations are consistent with known or anticipated subsurface conditions.

Interface Depth, 2-Layer System - The surface layer resistivity (R) is assumed from the closest array spacing readings. Curves of surface layer R to measured R ratios at increasing array spacing at various assumed interface depths are plotted against computed curves (Jakosky, 1950; Tagg, 1934)* until an assumed depth curve matches a computed curve. That assumed depth becomes the interpreted depth. A ratio of surface layer R to deep layer R is associated with the computed curve. This ratio may be used to estimate the deep layer R, which may be compared against the measured R at the greatest array spacing.

Fluid Resistivity - Resistivities of non-clayey materials are controlled by the fluid resistivities in the pore spaces. Under saturated conditions, porosity and fluid resistivity may be analyzed using the concept of formation factor. The formation factor is the ratio of the resistivity of the saturated formation to the resistivity of the fluid in the pore spaces. The relationship between porosity and formation factor (Schlumberger, 1972, Chart Por-1) is shown below for various dry unit weights of non-clayey material assuming a specific gravity of 2.65.

Dry Unit Wt pcf	Moisture Content at Saturation, %	Porosity %	Formation Factor
130	10	21	18
120	14	27	11
110	19	34	6.7
100	25	40	4.8

Once a formation factor has been determined, the formation resistivity is divided by the formation factor to obtain the fluid resistivity.

***References**

Jakosky, J.J., 1950, Exploration Geophysics, Trija Publishing Company, Los Angeles, California.

Schlumberger, 1972, Schlumberger Log Interpretation Charts, Schlumberger Limited, Houston, Texas.

Tagg, G.F., 1934, A.I.M.E. Geophysical Prospecting, Vol. 110, pp. 135-145.

AEE Job No. 6-117-000062

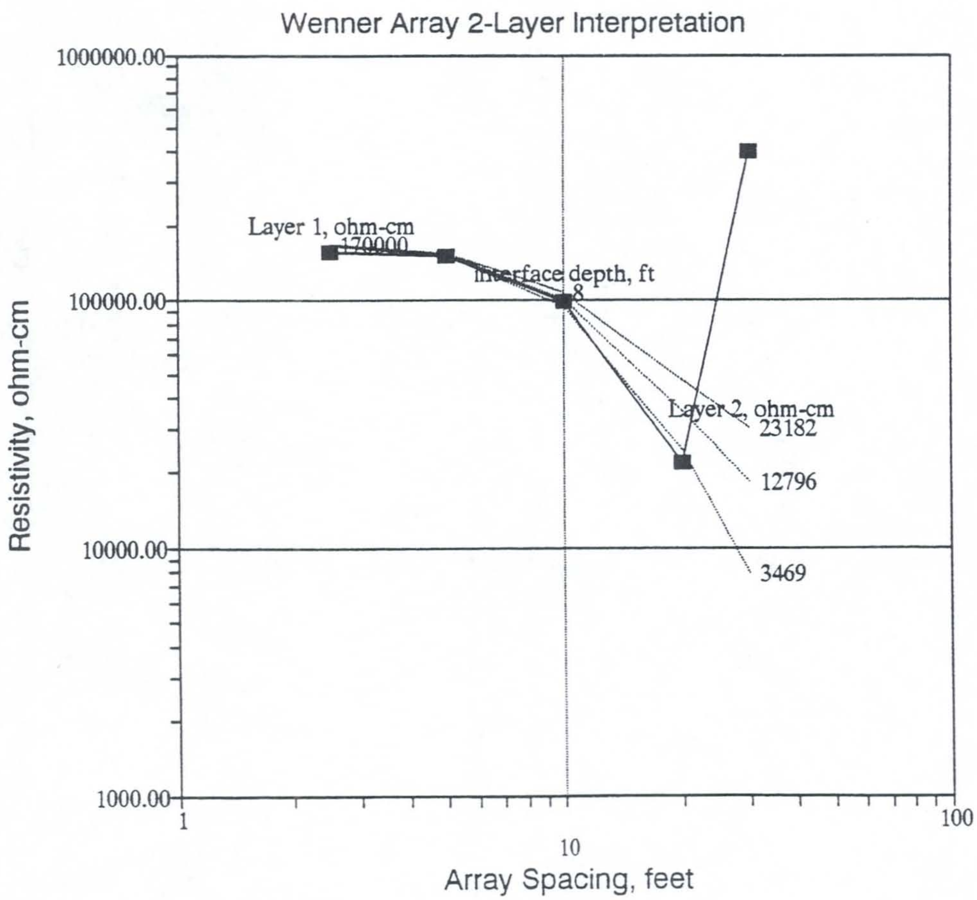
FIELD RESISTIVITY - FOUR POINT WENNER ARRAY METHOD

R-1 at Line 2 - Reading at 20' Spacing Improbable

Spacing Feet	Resistance ohms	multiplier	Resistivity ohm-cm
2.5	327	479	156551
5	158	958	151285
10	52	1915	99580
20	5.7	3830	21831
30	69.6	5745	399852

Results of 2-Layer Interpretation Q2 = -0.86

Layer 1 (surface)	170000	ohm-cm
Interface depth	8	feet
Layer 2 (deep)	12796	ohm-cm



AEE Job No. 6-117-000062

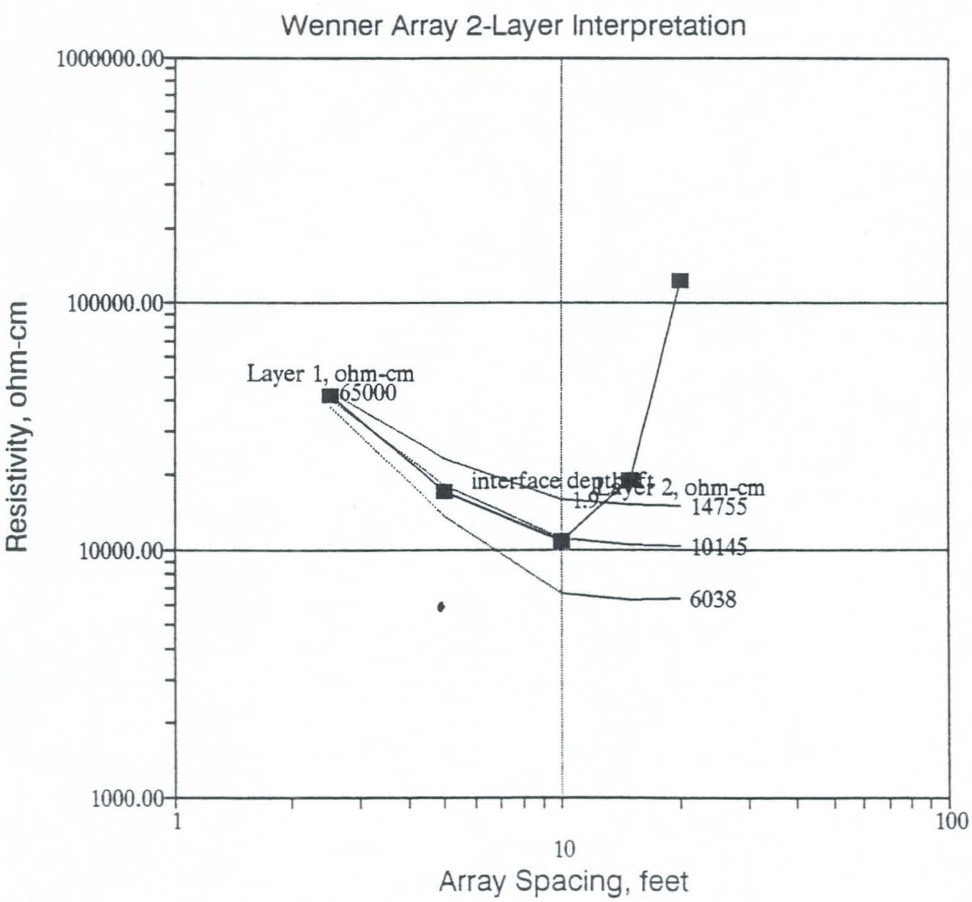
FIELD RESISTIVITY - FOUR POINT WENNER ARRAY METHOD

R-2 between Lines 13 & 14 near Pinnacle Peak Road

Spacing Feet	Resistance ohms	multiplier	Resistivity ohm-cm
2.5	87.4	479	41843
5	18	958	17235
10	5.67	1915	10858
15	6.7	2873	19246
20	32.1	3830	122943

Results of 2-Layer Interpretation Q2 = -0.73

Layer 1 (surface)	65000	ohm-cm
Interface depth	1.9	feet
Layer 2 (deep)	10145	ohm-cm



EXPLANATION

UNCONSOLIDATED UNITS

Qs — Stream Channel Deposits: Poorly graded sand to silty sand with some gravels & cobbles. Possible coarser clasts including boulders with depth. Light brown to grayish brown. No caliche/lime cementation developed.

Qf — Alluvial Fan Deposits: Silty to clayey sands and gravels with locally varying amounts of cobbles, brown. Generally weakly developed caliche/lime cementation.

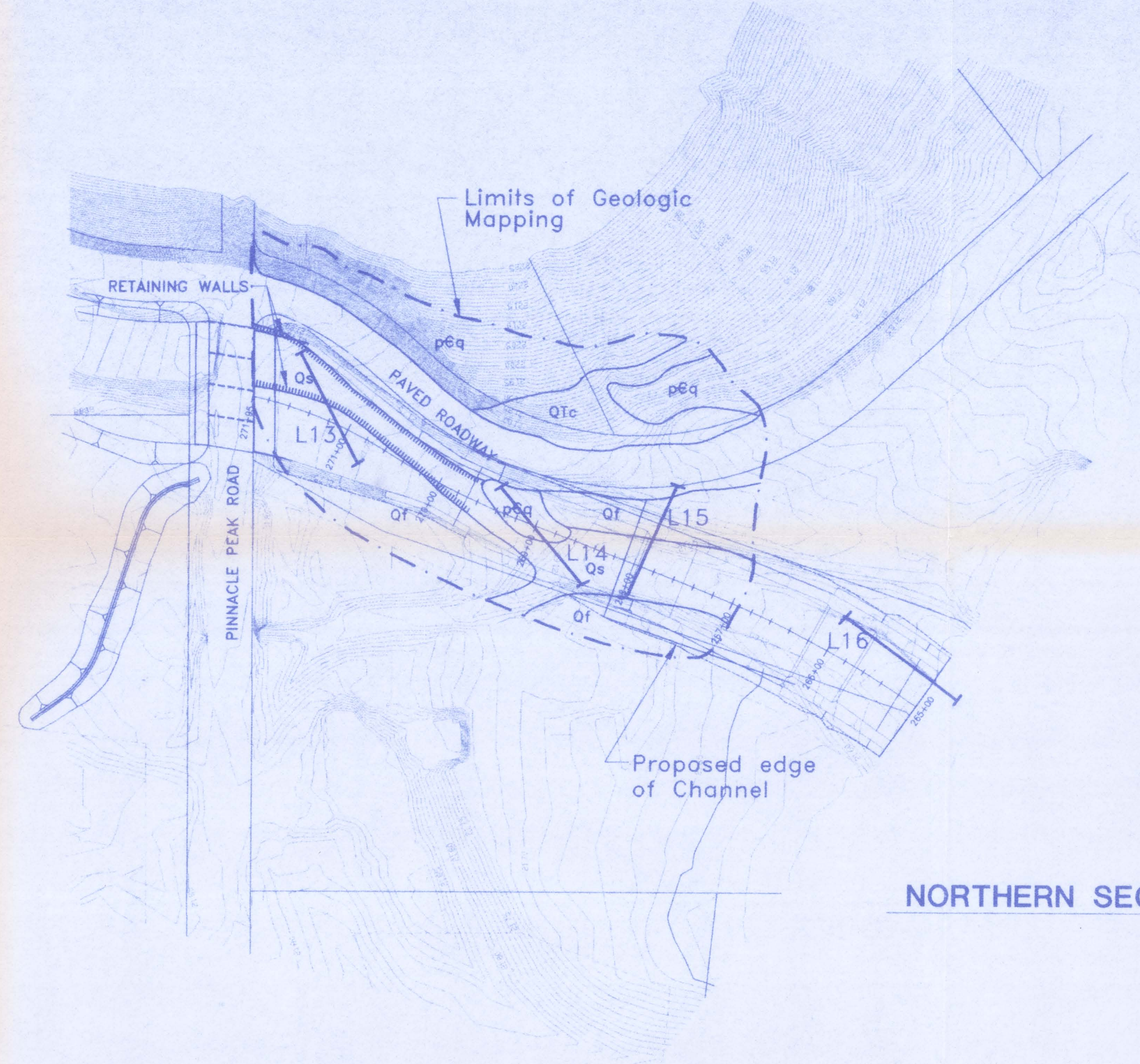
SEMICONSOLIDATED UNITS

QTc — Colluvium: Angular gravels, cobbles and boulders in silty clay matrix, brown. Caliche/lime cementation is very strongly developed and indurated.

BEDROCK UNITS

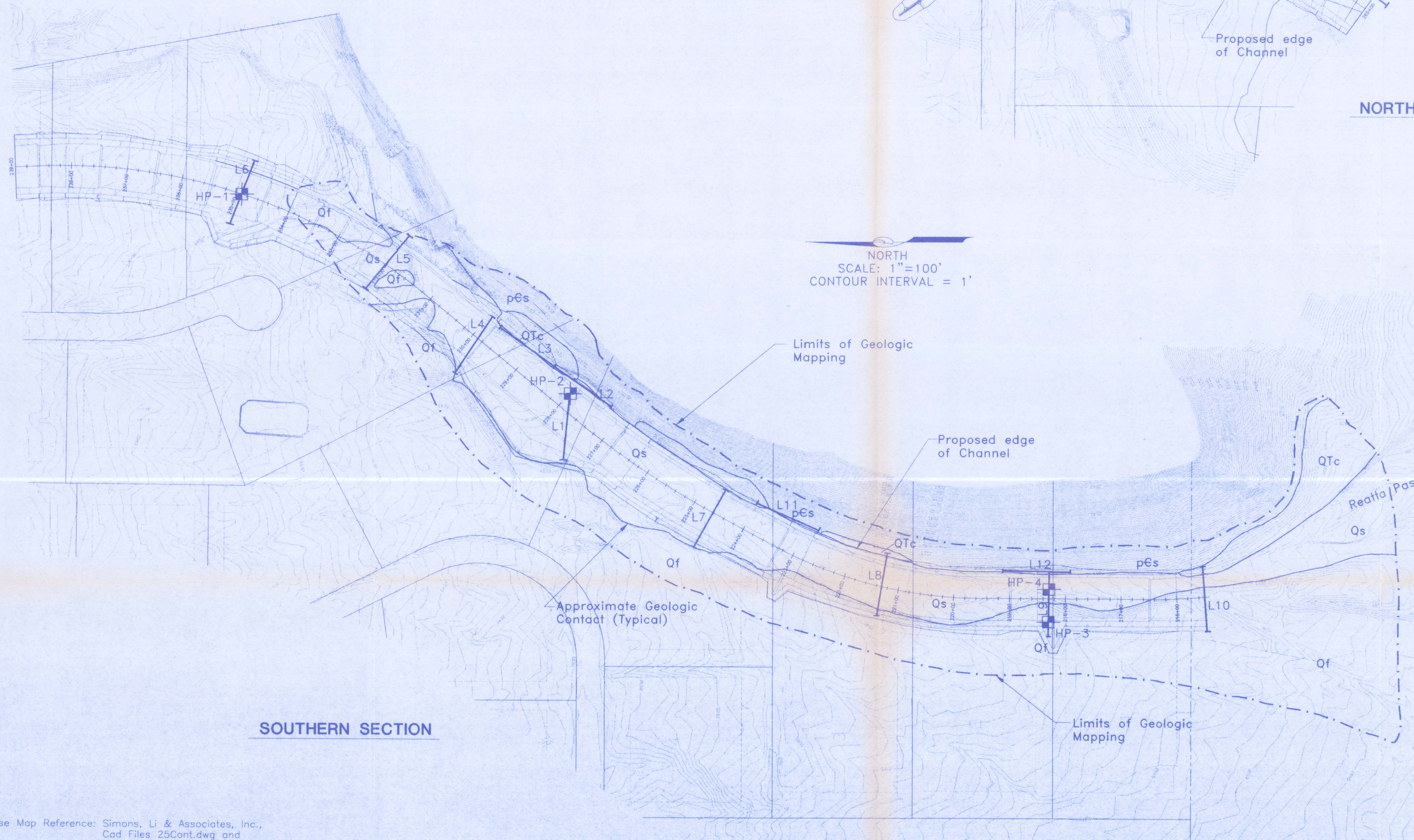
p€s — Schist Locally Intercalated with Phyllite: Strongly foliated, slightly weathered to unweathered except joints, moderately hard to hard, very closely to closely fractured, gray to bluish gray.

p€q — Quartzite: Fine grained, unweathered except joints, hard to very hard, predominantly closely fractured, gray to bluish gray.



NORTHERN SECTION

NORTH
SCALE: 1"=100'
CONTOUR INTERVAL = 1'



SOUTHERN SECTION

LEGEND

L1 — SEISMIC REFRACTION SURVEY LINE AND NUMBER

HP-4 — HAND-DUG SURFACE SAMPLE

Base Map Reference: Simons, Li & Associates, Inc., Cad Files 25Cont.dwg and Plan View. Date 4/97.

NO.	DESCRIPTION	INITIALS/DATE
3		
2		
1	Added Surface Samples (4)	TMP/8/8/97

REVISIONS

ADDITIONAL INVESTIGATION
REATTA PASS WASH – DESERT GREENBELT
SCOTTSDALE, ARIZONA

AGRA Earth & Environmental
ENGINEERING GLOBAL SOLUTIONS

SCALE	1"=100'	JOB NO.	7-117-000062
DESIGNED	KHD	DATE	7/97
DRAWN	TMP	DATE	7/97
CHECKED	NJL	SIGNED	
APPROVED		SIGNED	

GEOLOGIC & REFRACTION SEISMIC LOCATION MAP — SHEET 1