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CROSSHOLE VELOCITY SURVEY MISER'S BLUFF GROUND ZERO-2 (GZ-2) PL--ETC(U)
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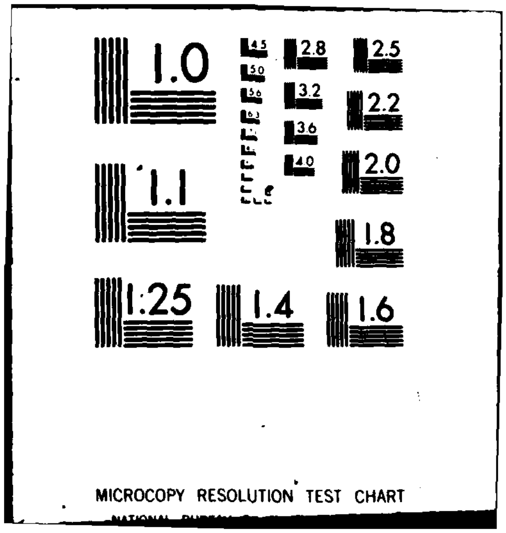
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CROSSHOLE VELOCITY SURVEY
MISER'S BLUFF GROUND ZERO-2 (GZ-2)
PLANET RANCH TEST VALLEY, ARIZONA

Prepared for:

U. S. Department of the Air Force
Space and Missile Systems Organization
(SAMSO)
Norton Air Force Base, California 92409

Prepared by:

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20 March 19~~78~~ 79

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
FN-TR-21A

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Crosshole Velocity Survey Miser's Bluff Ground Zero-2 (GZ-2) Planet Ranch Test Valley, Arizona

5. TYPE OF REPORT & PERIOD COVERED
Final
July-Aug 78

6. PERFORMING ORG. REPORT NUMBER
FN-TR-21A

7. AUTHOR(s)
Fugro National

8. CONTRACT OR GRANT NUMBER(s)
F-04704-77-C-0010

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Ertec Western Inc. (formerly Fugro National)
P.O. Box 7765
Long Beach Ca 90807

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
64312 F

11. CONTROLLING OFFICE NAME AND ADDRESS
U.S. Department of the Air Force
Space and Missile Systems Organization
Norton AFB Ca 92409 (SAMSO)

12. REPORT DATE
20 Mar ~~78~~ 79

13. NUMBER OF PAGES
9

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Distribution Unlimited

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

~~Borings~~, ~~Vertical & Horizontal Spatial~~ Control, ~~Instrumentation~~ moduli calculations, seismic survey, seismic wave velocities, geology, water level, boring, geophones, shear modulus

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Results of a crosshole seismic velocity survey at the Miser's Bluff Test Site, Arizona for the U.S. Air Force shows the bedrock material to be hard, dense, and have a high compressional wave velocity. A relatively low shear wave velocity may indicate weak cementation. Based on crosshole data the water table appears to be between 35 and 40 feet in depth.

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SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

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1.0 INTRODUCTION

1.1 BACKGROUND

A crosshole seismic velocity survey was performed by Fugro National, Inc., near ground zero for Event Number 2 at the Miser's Bluff Test Site, Arizona. The scope of work was documented in Fugro's letter F-USAF-78-4646 to Mr. Hal Waldum, MNND dated 28 July 1978. The purpose of the survey was to determine shear (S-wave) and compressional (P-wave) wave velocities of the earth materials at five foot (1.52 m) depth intervals from the surface to thirty feet (9.14 m) into the bedrock. The work was performed for the Department of the Air Force Space and Missile Systems Organization under Contract No. F-04704-77-C-0010. The field work described herein and this report are the final products of the survey.

Figure 1 shows the layout of the three boreholes drilled for the survey. Drilling was begun on 25 July 1978. Seismic data were obtained during the period of 11 August through 14 August 1978. As requested by SAMSO, no samples were taken and no detailed drilling log was maintained. Table 1 shows depths to major interfaces.

1.2 SUBSURFACE CONDITIONS

The upper 145 feet (44 m) of material near GZ-2 are primarily sands and silts. A layer of large boulders made drilling difficult, irregular and slow from approximately 145 feet (44 m) depth to approximately 170 feet (52 m). The reddish-brown sedimentary bedrock was encountered between 170 to 175 feet (52 to 53 m) in the three holes. In the source hole, the driller reported extremely soft material from 169 feet (41.5 m) to 172 feet (52.5 m). This was not encountered in the receiving holes. Drilling in the bedrock material was slow (approximately five feet or 1.5 m, per hour) but steady. Waterways Experiment Station personnel have informally reported that water level measurements in the vicinity show that the water table is approximately 12 feet (3.7 m) deep.

2.0 RESULTS

1. The shear and compressional wave velocities interpreted from the crosshole data are plotted on Figure 2. The S and P wave arrivals on the seismograms were generally clear and readily identifiable. Therefore, the velocity values shown on Figure 2 are considered to be reliable. The velocity data correlate well with the changes in drilling conditions. The source-to-receiver apparent velocities at 170 feet were anomalously low, probably due to the soft materials noted in the source hole. The apparent velocity between receivers was taken to be representative at this depth. The velocities (especially the shear wave) vary considerably in the boulder and bedrock zones. Even though the bedrock material is hard, dense, and has a high compressional wave velocity, its relatively low shear wave velocity may indicate weak cementation.

2. The compressional wave data are inconsistent with the report of the water table being at a depth of twelve feet (3.7 m). The velocity of compressional waves in water, and consequently in water saturated soils, is on the order of 5000 feet per second (1524 mps). This velocity is not approached above 35 feet (10.7 m). Based on the crosshole data, the water table (or zone of saturation) appears to be between 35 and 40 feet (10.7 and 12.2 m) deep.

3. For the purpose of calculating Poisson's ratio, shear moduli, Young's moduli and bulk moduli, the subsurface profile was

divided into 13 velocity layers based on apparently significant changes in one or both velocities (P or S-wave). Approximate average velocities within each of these layers were estimated from Figure 2. These velocities, together with estimated unit weights were used to calculate the moduli in Table 2.

3.0 PROCEDURES

3.1 FIELD

3.1.1 General Technique

Data were recorded in two borings and generated in a third. The three borings (one source, two receiving) were arranged in a line (Figure 1) with approximately 20 feet (6.1 m) between them. The boring locations were staked by DNA field command personnel.

A mechanical energy source was used to obtain the seismic wave travel time data. This technique generates relatively large vertically oriented shear waves (S) and much lower levels of x P-wave energy. The energy was generated by striking the top of the drill rod in the source boring while the drill bit remained in contact with the formation.

Initially, geophones were placed five feet (1.5 m) deep into borings R1 and R2. Boring S1 was drilled to a depth of five feet and the Kelly bar was disconnected from the drill rod. A metal fixture was placed on top of the drill rod to protect the threads from damage. A small geophone was lowered through the drill rod so that it rested on top of the bit. This geophone was used to record the time at which the shock wave traveling down the drill rod entered the formation. The instant of impact between the hammer and the drill rod was also recorded.

After recordings were made at the five foot (1.5 m) depth, the receiver geophones were lowered to ten feet, the source boring (S1) was drilled another five feet and the recording procedure was repeated. These steps were repeated to a depth of 205 feet (62.5 m).

Recordings were made at two amplifier gain settings so that satisfactory amplitudes could be obtained for both the P and S waves from a single impact.

3.1.2 Preparation of Borings

Borings R1 and R2 were completed prior to the start of the survey. They were cased with schedule 80, three-inch (8 cm) inside diameter plastic (PVC) pipe. Solid mechanical contact between the earth materials and the entire length of each casing was obtained by filling the annulus between the casing and borehole wall with cement grout. PVC casing was placed in the source boring after completion of the survey to ensure it would remain open for the verticality measurements.

3.1.3 Vertical and Horizontal Spatial Control

The distances between the borings at the ground surface were measured by the seismic crew with a tape. The ground elevations were essentially the same at all three borings. All measured depths were referenced to ground level. The coordinates and elevations of the borings were surveyed by DNA.

The holes were measured for amount and direction of deviation from vertical by Mollen-Hauer Surveying Company, Arizona. The source hole had drifted approximately 5.4 feet (1.6 m) to the north-northwest at 200 feet depth. The other two holes had drifted less than 1.5 feet (0.5 m) at 200 feet. The measurements were made with a pendulum and magnetic compass equipped with a multishot camera. Deviation measurements were taken at 20-foot (6.1 m) intervals. Intermediate points were obtained by interpolation. The horizontal distances between equivalent depths in the source and receiver holes were calculated by computer.

3.1.4 Instrumentation

Receivers: Downhole sensor packages (Mark Products Model L-10-3D-SWC) containing three geophones with a natural frequency of 4.5 Hz were placed in borings R1 and R2. The geophones within the packages were arranged so that one was vertical and two were horizontal and mutually perpendicular. The triaxial arrangement was used so that at least one geophone would provide favorable orientation to detect the incoming waves regardless of travel path or wave type. The geophone packages were mechanically coupled to the casing or wave conversion between the wall material and the water in the borings.

Recording System: The recording system was an SIE model RS-44 refraction recording system modified to provide timing lines at five millisecond intervals and paper speed of approximately 42 inches per second (100 cm/sec). The timing resolution provided by this combination permitted record times to be read within plus or minus 0.25 milliseconds. Timing line error was less than one percent. The RS-44 amplifiers are capable of providing up to 120 db of gain.

3.2 OFFICE

3.2.1 Data Reduction

The basic travel time data for both waves were read from the records. Time was measured between the trace deflection representing the energy at the bottom of the drill rod and the points of wave arrivals at the geophones in the sensor holes. The times were plotted on time versus distance graphs and tabulated on a data sheet with the appropriate source to geophone distance.

Four apparent velocities were calculated for each data set as follows:

1) The distance between S1 and R1 was divided by the travel time to R1.
2) The distance between S1 and R2 was divided by the travel time to R2.
3) The difference obtained by subtracting distance S1-R1 from distance S1-R2 was divided by the difference in travel times to R1 and R2.
4) A "best fit" line was calculated by least squares using the origin and the two travel times.

3.2.2 Analysis

The four apparent velocities were compared for consistency and for the progressive increase in apparent velocities 1, 2, and 3 which is indicative of refractd data. Similarly, the plotted data were analyzed graphically to judge whether refraction had affected the travel times. The true velocities, as determined by the analysis, were plotted versus depth in Figure 2.

3.2.3 Moduli Calculations

The seismic wave velocities and estimated values for density of the materials are used to calculate Poisson's ratio and elastic moduli. The density estimates are based on the values used in Fugro's report FN-TR-21D, "Geotechnical Investigation Miser's Bluff Test Program Planet Ranch Test Valley, Arizona". The equations are:

Poisson's ratio, μ, (dimensionless number)

$$\mu = \frac{V_p^2 - 2V_s^2}{2\ (V_p^2 - V_s^2)}$$

Shear modulus, G, (in kN/m^2)

$$G = CDV_s^2$$

Young's modulus, E, (in kN/m^2)

$$E = 2G\ (1 + u)$$

Bulk modulus, K, (in kN/m^2)

$$K = CD\ (V_p^2 - 4/3\ V_s^2)$$

where:

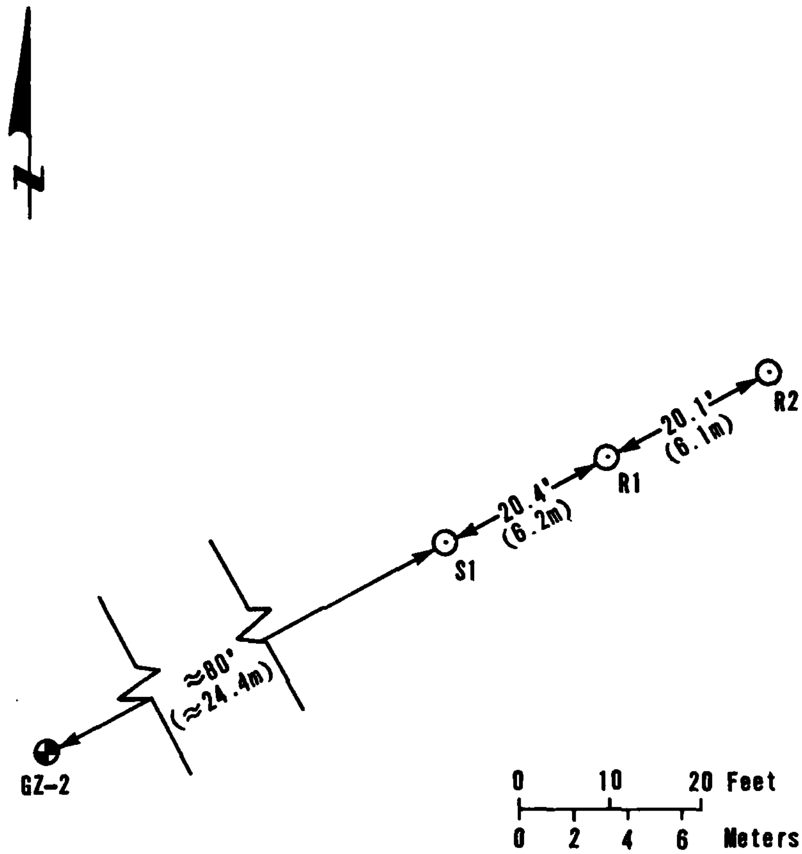
V_p = compressional wave velocity (meters per second)

V_s = shear wave velocity (meters per second)

C = 1.0 x 10 (constant for units conversion)

D = density (kilograms per cubic meter)

kN/m^2 = kiloNewtons per square meter



EXPLANATION

R1 ⊙ BORING FOR CROSSHOLE SURVEY

NOTE: R1 and R2 RECEIVER (GEOPHONE) HOLES
S1 ENERGY SOURCE HOLE

CROSSHOLE SEISMIC VELOCITY SURVEY ARRAY PLAN
PLANET RANCH, ARIZONA

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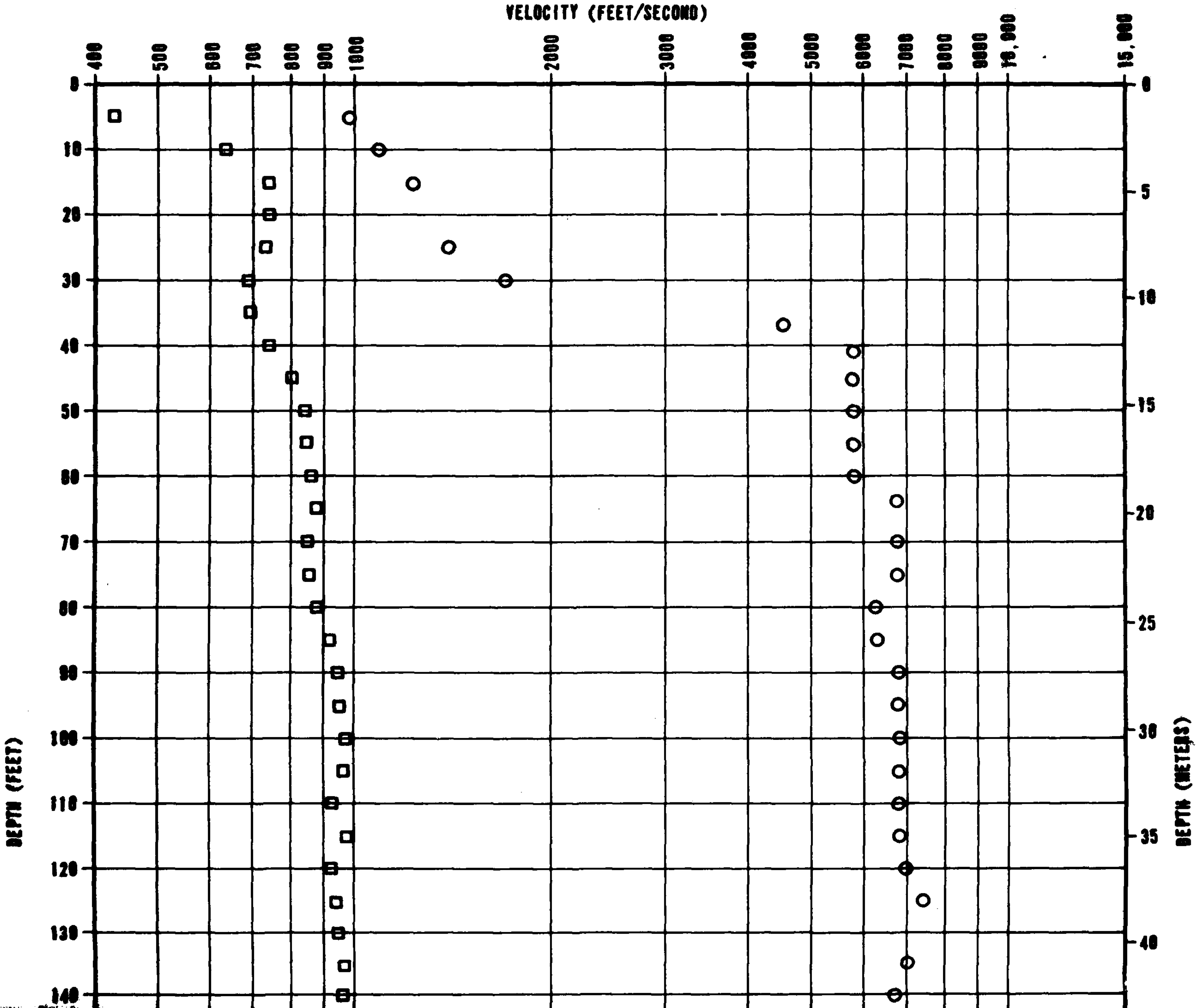
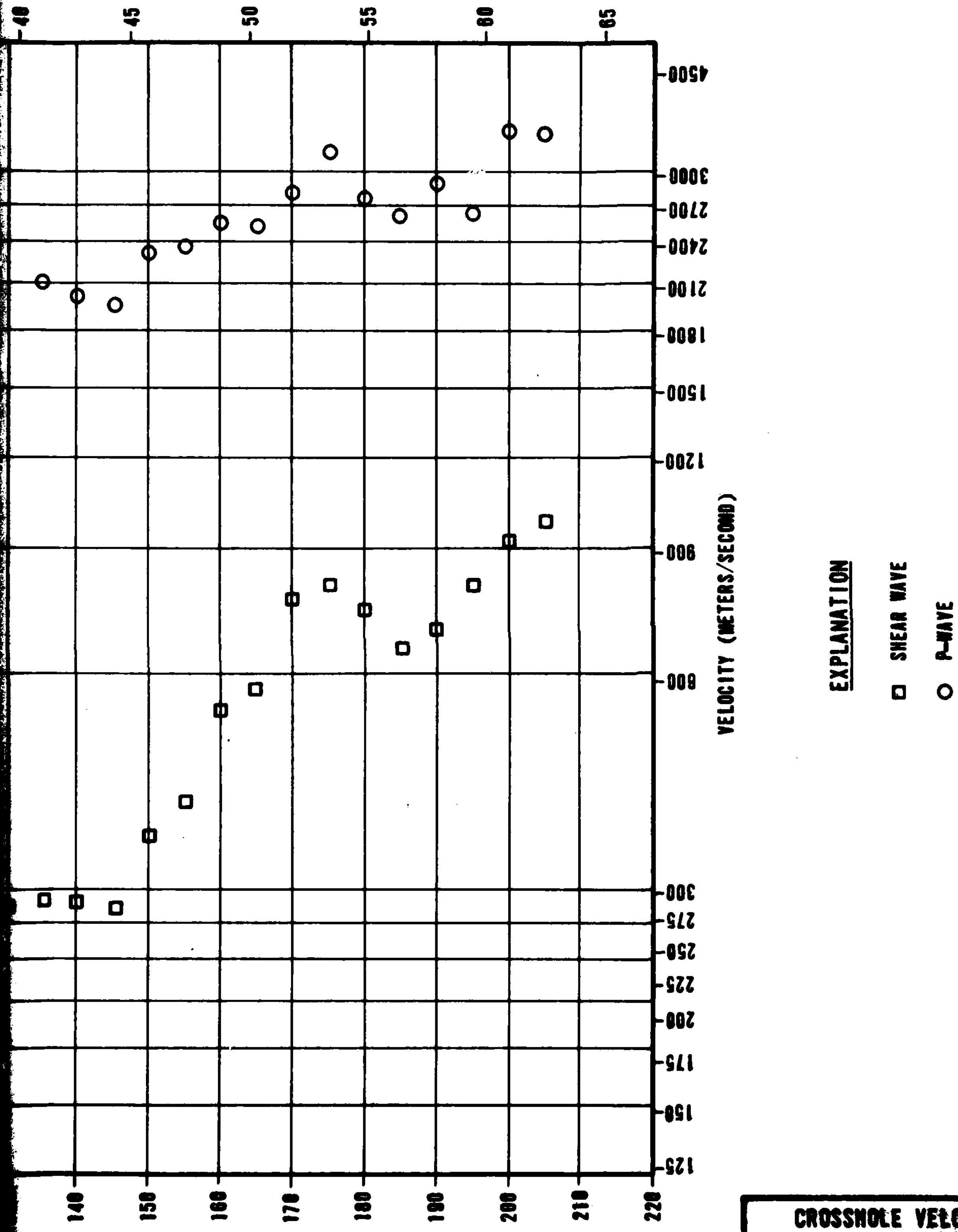
FIGURE 1

FUGRO NATIONAL, INC.


VELOCITY (FEET/SECOND)
DEPTH (FEET)
DEPTH (METERS)



CROSSHOLE VELOCITY TEST RESULTS AT GZ-2
PLANET RANCH, ARIZONA

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FIGURE 2

FUGRO NATIONAL, INC.

TABLE 1
DEPTHS TO MAJOR INTERFACES

	BOULDERS		BEDROCK		TOTAL DEPTH	
	Feet	Meters	Feet	Meters	Feet	Meters
Borehole S_1	150	45.8	172	52.5	205	62.5
Borehole R_1	155	47.3	173	52.8	210	64.0
Borehole R_2	145	44.2	175	53.4	210	64.6

TABLE 2

SUMMARY OF VELOCITY LAYERS AND ELASTIC MODULI

DEPTH ft (m)	P-WAVE ft/sec (m/sec)	S-WAVE ft/sec (m/sec)	UNIT WEIGHT pcf (kg/m^3)	POISSON'S RATIO ---	SHEAR MODULUS Ksf ($kN/m^2 x10^4$)	YOUNG'S MODULUS Ksf ($kN/m^2 x10^4$)	BULK MODULUS Ksf ($kN/m^2 x10^4$)
0-6 (0-2)	980 (299)	425 (130)	113 (1810)	.384	.0635 (3.040)	.1758 (8.415)	.2529 (12.11)
6-15 (2-5)	1200 (366)	630 (192)	113 (1810)	.310	.1395 (6.679)	.3654 (17.50)	.3201 (15.33)
15-26 (5-8)	1400 (427)	740 (226)	113 (1810)	.306	.1925 (9.215)	.5028 (24.07)	.4323 (20.70)
26-37 (8-11)	1700 (518)	690 (210)	113 (1810)	.401	.1673 (8.012)	.4690 (22.46)	.7927 (37.95)
37-62 (11-19)	5800 (1768)	840 (256)	119 (1906)	.489	.2611 (12.50)	.7779 (37.25)	12.1032 (579.5)
62-78 (11-24)	6800 (2073)	860 (262)	119 (1906)	.492	.2738 (13.11)	.8168 (39.11)	16.75 (802.0)
78-88 (24-27)	6300 (1920)	900 274	119 (1906)	.490	.2998 (14.35)	.9932 (42.77)	14.29 (68.43)
88-148 (27-45)	6800 (2073)	950 (290)	119 (1906)	.490	.3340 (15.99)	.9955 (47.66)	16.67 (798.1)
148-158 (45-48)	7900 (2408)	1250 (381)	119 (1906)	.487	.5783 (27.69)	1.720 (82.36)	22.33 (1069)

TABLE 2 (continued)

SUMMARY OF VELOCITY LAYERS AND ELASTIC MODULI

DEPTH ft (m)	P-WAVE ft/sec (m/sec)	S-WAVE ft/sec (m/sec)	UNIT WEIGHT pcf (kg/m^3)	POISSON'S RATIO ---	SHEAR MODULUS Ksf ($kN/M^2 x10^4$)	YOUNG'S MODULUS Ksf ($kN/m^2 x10^4$)	BULK MODULUS Ksf ($kN/m^2 x10^4$)
158-168 (48-51)	8500 (2590)	1850 (564)	130 (2083)	.475	1.384 (66.26)	4.083 195.5	27.37 (.310)
168-182 (51-55)	10,000 (3048)	2550 (777)	130 (2083)	.465	2.629 (125.9)	7.705 (368.9)	36.93 (1768)
182-198 (55-60)	9000 (2743)	2100 (640)	130 (2083)	.471	1.783 (85.38)	5.247 (251.2)	30.37 (1454)
198-(206) (60-(63))	11,500 (3505)	3200 (975)	130 (2083)	.458	4.141 (98.25)	12.07 (578.1)	47.95 (2296)