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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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Adelaide River Dam Site Geophysical Survey, Northern Territory, 1969

by

E. J. Polak and R. J. Whiteley

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SUMMARY

A geophysical survey was carried out at the request of the Water Resources Branch of the Northern Territory Administration, to determine the depth and condition of the bedrock at a selected dam site on the Adelaide River.

Seismic refraction, resistivity, dynamic rock testing and laboratory measurements have indicated that the bedrock is generally well consolidated and that a maximum of about 40 ft of alluvium occurs on the valley floor.

1. INTRODUCTION

The Water Resources Branch (W.R.B.) of the Northern Territory Administration is considering the possible development and control of the Adelaide River System. An essential part of any development would be a dam in the Adelaide River gorge. A suitable site for such a dam has been chosen by the Water Resources Branch (Plate 1).

At the request of the Water Resources Branch the Bureau of Mineral Resources, Geology & Geophysics (BMR) carried out a geophysical survey to determine the depth and character of the bedrock at the dam site.

The site was surveyed in conjunction with a nearby dam site at Stapleton Creek (Whiteley, 1969) during August and September 1968 by a geophysical party consisting of R.J. Whiteley (party leader), E.J. Polak (senior geophysicist), D. Tarlinton (technical assistant), and three field assistants provided by the Water Resources Branch.

2. GEOLOGY

Braybrooke (1967) has described the geology in detail. Graded metagreywacke and phyllite of the Finniss River Group form the bedrock in the area. This is moderately to tightly folded and has been subjected to low-grade metamorphism.

In the dam site area the left abutment consists of highly weathered phyllite and the right abutment is moderately weathered metagreywacke. Both the left and right banks are in a moderately to steeply dipping east limb of a syncline. The synclinal axis follows the top of the ridge which forms the left side of the valley and plunges NNE at between 20 and 30 degrees. Two minor anticlines are present on the right bank, and apart from minor dislocations there is no surface evidence of faulting.

A number of boreholes (ARG1 to ARG7) have been drilled along the proposed axis of the dam. These have delineated several possible shear zones especially within the phyllite.

The valley floor contains a considerable thickness of sandy to clayey alluvium.

3. METHODS AND EQUIPMENT

Seismic refraction method

The seismic refraction technique used is described by Dyson and Wiebenga (1957). Depths to bedrock were calculated using a modified version of the "method of differences" (Heiland, 1946, p. 548) which is perhaps better known as the "reciprocal method" (Hawkins, 1961).

Seismic traverses were of varying lengths (up to 1200 feet) and geophone intervals of 25 and 50 feet were used. Shortened spreads with a geophone spacing of 10 feet gave velocity information on the near-surface layers.

A 24-channel SIE (Dresser - SIE Inc.) refraction seismograph and 20-Hz geophones (Technical Instruments Co.) were used.

The traverse locations are shown on Plates 1 and 2.

Dynamic rock testing

The elastic constants of the bedrock in the dam site area were determined in situ at three locations by the use of three-component geophones (Hall-Sears Inc.) with a natural frequency of 8 Hz. These geophones record the vertical and two horizontal components of ground motion. The theory is outlined in Appendix A. Shots were fired at distances large enough to ensure that the elastic properties measured relate only to the bedrock.

Resistivity method

Three Wenner resistivity depth probes were completed using a Megger Earth Tester manufactured by Evershed and Vignoles Co. These were used to determine alluvial thicknesses and to provide an additional control for the seismic work. The positions of the probes are shown in Plate 2.

Laboratory measurements

In addition to the field methods, laboratory measurements were made on a number of drill cores from the dam site.

Both compressional velocity and specific gravity were measured. The velocity testing was carried out using an Ultrasonic Material Tester manufactured by Cawkell Research and Electronics Ltd.

4. RESULTS

Seismic refraction results

In this Record the deepest refractor with the highest recorded seismic velocity is referred to as the "bedrock". Bedrock depths were calculated at each geophone position and reproduced as a continuous profile. Depths to intermediate horizons were calculated at shot-points and interpolated between them. The results are shown in Plate 3.

The layers encountered can be conveniently grouped as follows

(Table 1):

TABLE 1

Velocity	Rock Type
1000 ft/s	Soil
4500 - 5000 ft/s	Scree material, completely weathered rock, or saturated alluvium.
7500 - 12000 ft/s	Partially weathered and saturated bedrock.
13000 - 17000 ft/s	Unweathered bedrock.

Velocity anisotrophy is not marked in the dam site area. As a general conclusion the bedrock velocities along Line G are slightly lower than on the cross traverses (except Line 4). This is to be expected, as the strike of the rocks is generally parallel to the cross traverses.

Where possible, the seismic work has been compared with the drilling results. The comparisons are tabulated below (Table 2). The geological core and jointing logs were used to obtain depths to bedrock.

TABLE 2

Drill hole	Rock type	Depth to bedrock from drilling: Slant depth, ft	Depth to bedrock from drilling: Vertical depth, ft	Depth to bedrock from seismic results, ft	Seismic velocity in bedrock ft/sec
ARG 1	Slightly weathered phyllite	96.5	96.5	95	14000
ARG 2	Moderately to weakly weathered meta-greywacke	70	61	50	10500
ARG 3	Moderately to weakly weathered meta-grewacke	52.5	45	45	10500
ARG 3	Slightly weathered metagreywacke	83	72	75	15000
ARG 4	Moderately to heavily weathered phyllite	66	57	45	9000
ARG 5	Moderately weathered phyllite	40.5	35	30	8500
ARG 7	Heavily weathered phyllite	44	38	40	9000

Table 2 shows that there is good agreement between the seismic and drilling results. Alluvial thicknesses are well defined by the seismic work with an error of less than 20 percent.

Laboratory measurements

The results of the velocity and specific gravity measurements on cores are listed in Table 3. Indicated drill-hole depths are slant depths.

TABLE 3

Drill-hole	Rock type	Depth, ft	Velocity, ft/s	Specific gravity
ARG 3	Metagreywacke	57	13300	2.75
	"	65	13600	
	"	100	13000	2.72
	"	140	15000	
ARG 5	Phyllite	-	16000	2.77

The velocities obtained on the cores from ARG 3 are in good agreement with the seismic refraction results from Line 4. The phyllite core from ARG 5 was only slightly weathered and thus gave a rather high velocity. More highly weathered phyllite cores which fractured along the cleavage planes during cutting were not suitable for laboratory testing.

Dynamic rock testing

Poissons' ratio (P), Young's modulus (E), Modulus of rigidity (G), and bulk modulus (B) were calculated for the bedrock at each of three locations (A, B, and C, Plate 1) using the methods and formulae outlined in Appendix A. The results are tabulated below (Table 4).

TABLE 4

Location	Direction	Velocity (ft/s)	P	E(lb/in^2)	G(lb/in^2)	B(lb/in^2)
A	NNW-SSE	17000	0.270	8.54×10^6	3.38×10^6	6.25×10^6
B	NE-SW	17000	0.260	8.74×10^6	3.50×10^6	6.07×10^6
C	NE-SW	13000	0.295	4.64×10^6	1.83×10^6	3.76×10^6

At locations A and B, the elastic properties indicate that the rock is well consolidated. At location C where the bedrock velocity is lower Young's modulus is still higher than for concrete in bulk (3-3.5 x 10^6 lb/in^2), and must indicate consolidated bedrock.

Resistivity results

The results of the Wenner depth probes are shown in Plate 4. Interpretation was done using the method of superpositioning of standard curves (Dyson & Wiebenga, 1957).

Three layers are indicated in the interpretation, with the resistivity decreasing with depth. Fluctuations on the shallow regions of the curves are attributed to variations in electrode contacts as well as possible lateral charges within the alluvial material.

Depths to the top of the third layer are within 20 percent of the seismic depths to weathered bedrock.

5. CONCLUSIONS

The seismic refraction work has delineated bedrock and indicated the condition of the overburden in the dam site area. Where comparisons have been possible the seismic results show good agreement with the drilling. On only one traverse (Line 4) did the bedrock have a lower than average velocity; even so, dynamic rock testing has shown that bedrock in this region is still of good quality for a concrete dam.

Thicknesses of alluvium have also been obtained with fair accuracy from the resistivity work.

6. REFERENCES

BRAYBROOKE, J.C., 1967 - Geological investigation of Adelaide River Gorge Dam Site No. 1, Northern Territory, 1966. Bur. Miner. Resour. Aust. Rec. 1967/120 (unpubl.).

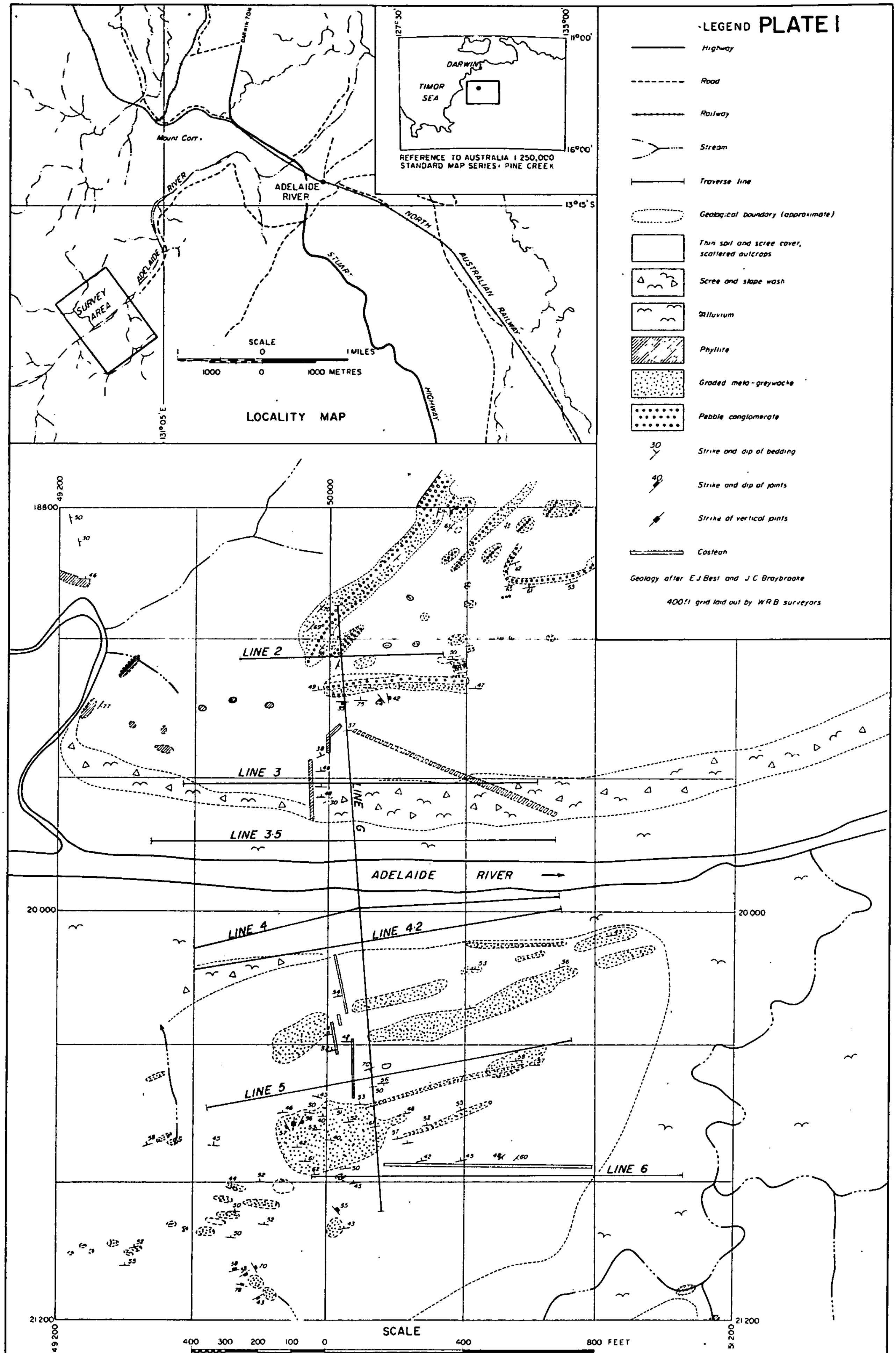
DYSON, D.F., and WEIBENGA, W.A., 1957 - Final report on geophysical investigations of underground water, Alice Springs, Northern Territory, 1956. Bur. Miner. Resour. Aust. Rec. 1957/89 (unpubl.).

HAWKINS, L.V., 1961 - The reciprocal method of routine shallow seismic refraction investigations. Geophysics, 26(6), 806-819.

HEILAND, C.A., 1946 - GEOPHYSICAL PROSPECTING. Prentice Hall Inc. New York.

LEET, L.D., 1950 - EARTH WAVES. Harvard University Press, Cambridge, Mass.

WHITELEY, R.J., 1969 - Stapleton Creek dam site geophysical survey, Northern Territory 1968. Bur. Miner. Resour. Aust. Rec. 1969/86 (unpubl.).



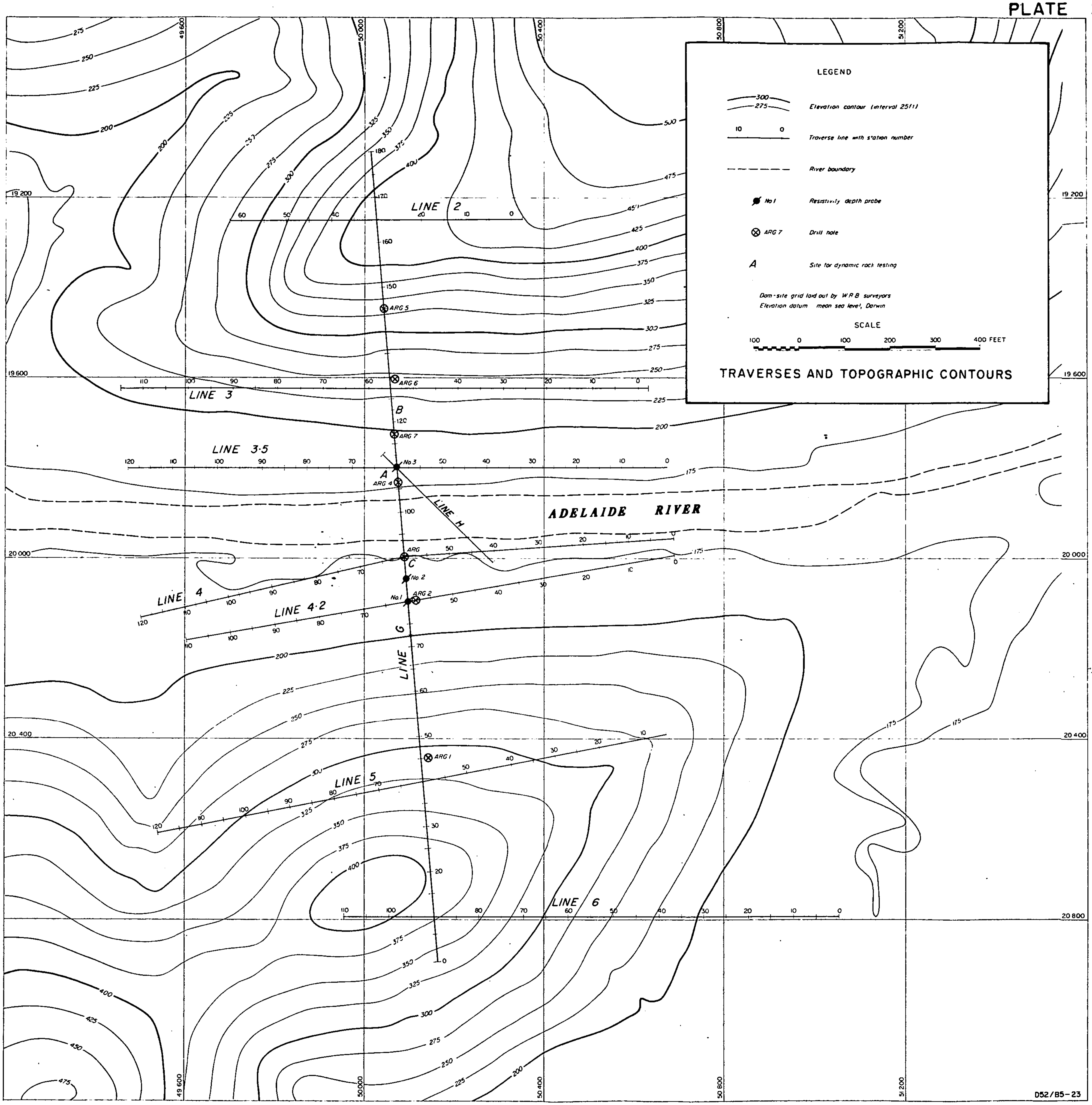
ADELAIDE RIVER DAM SITE N.T., 1969

LOCALITY MAP AND SURFACE GEOLOGY

(BASED ON D52/A8-234) TO ACCOMPANY RECORD NO 1971/21

D52/B5-22

PLATE 2



TO ACCOMPANY RECORD NO 1971/21

PLATE 3

SEISMIC REFRACTION PROFILES

LINES 2, 3, 3·5, and G.

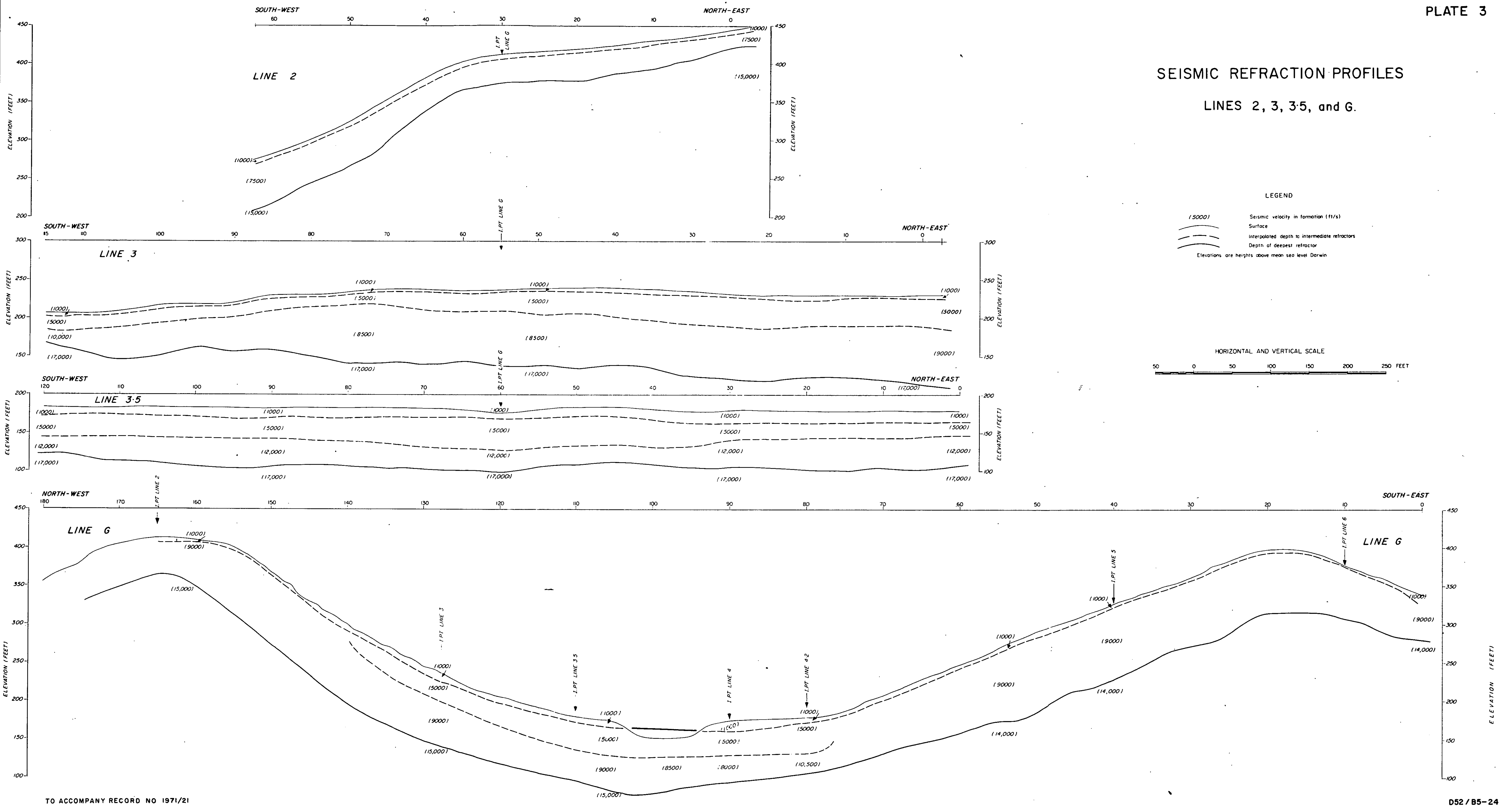


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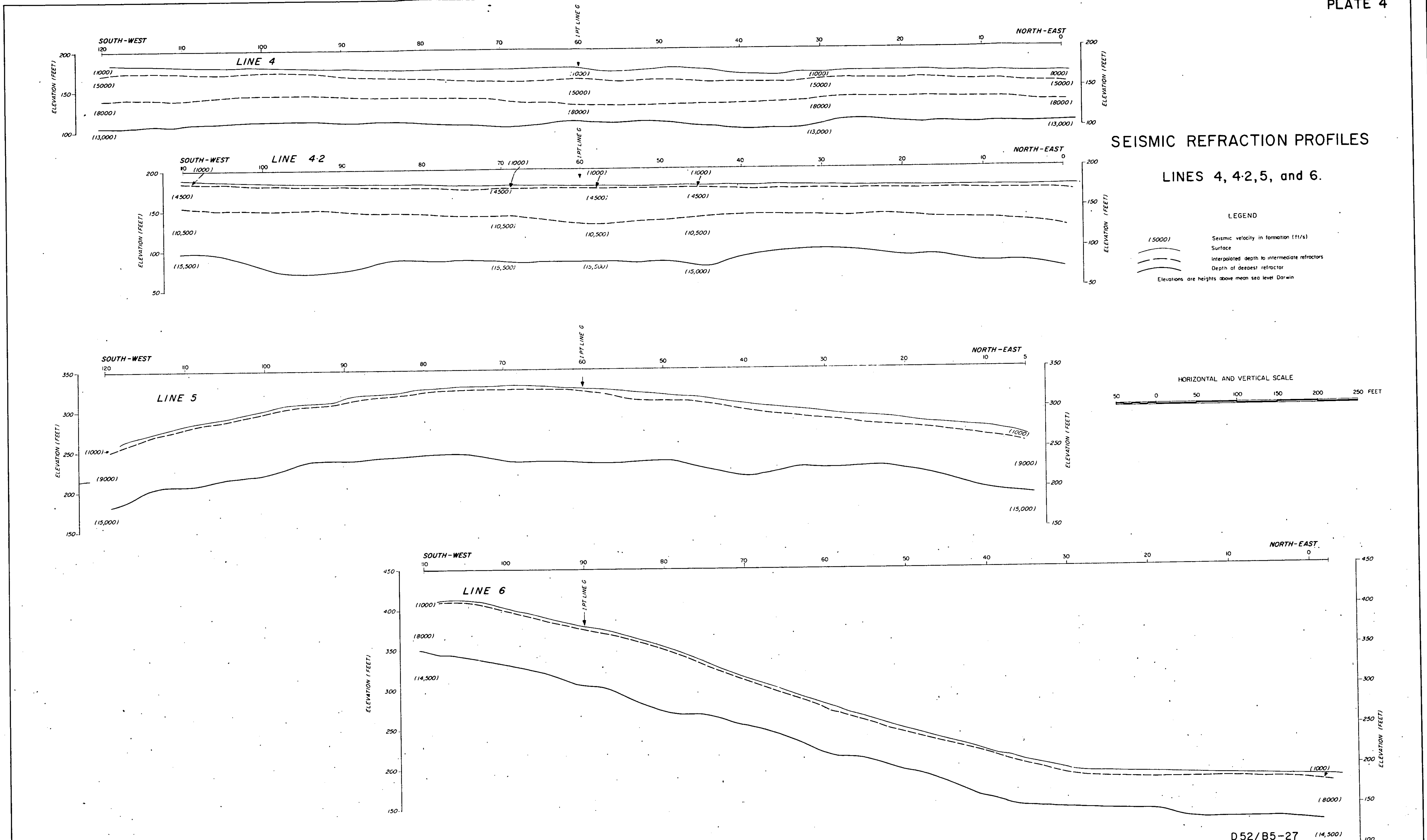
PLATE 4

SEISMIC REFRACTION PROFILES

LINES 4, 4·2, 5, and 6.



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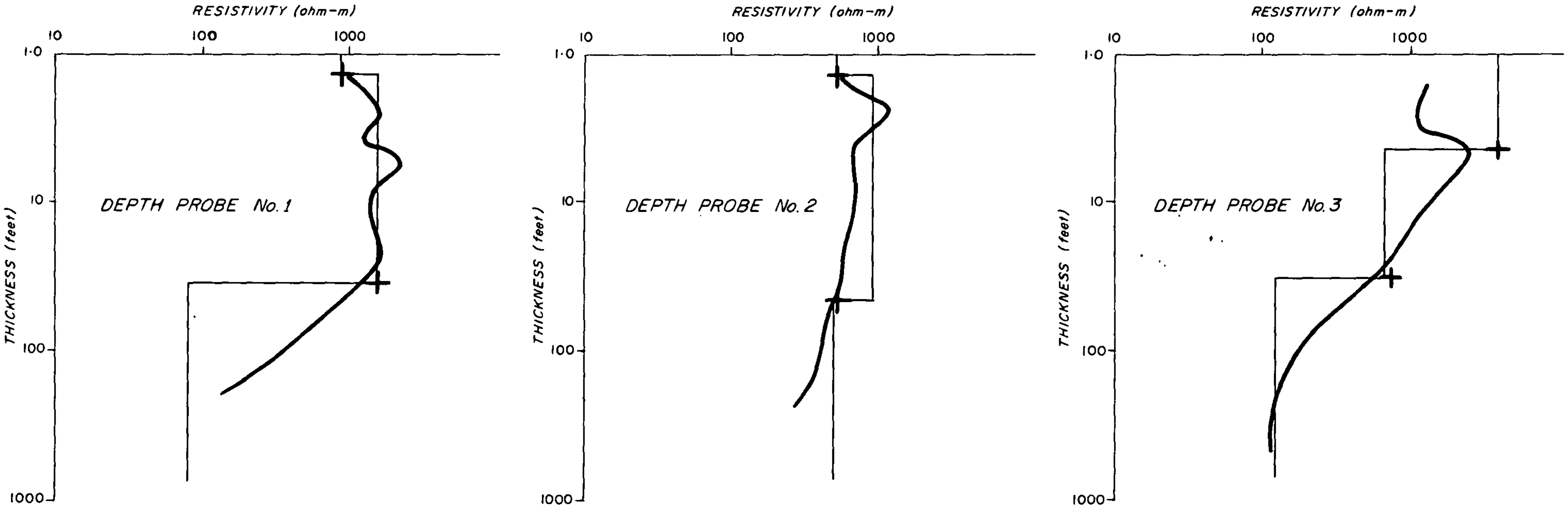

DEPTH PROBES

(WENNER ARRANGEMENT)

D52/B5-25A

PLATE 5

APPENDIX A

DYNAMIC ROCK TESTING

In situ rock testing with the seismic method allows the bulk elastic properties of material through which the seismic waves travel to be determined. The dynamic rock properties which control the velocity of the waves are measured in the direction that the seismic waves travel.

The relevant modes of propagation used in this method are:-

1. Longitudinal Mode (Compressional)

This type of wave travels faster than any other mode and therefore arrives first at all geophones. The method of propagation consists of forward and backward movement of rock particles in the direction of travel. The compressional velocity (Vc) is related to the elastic rock properties by the equation (Heiland, 1946):

$$Vc = \frac{1}{12}\sqrt{\frac{E(1-P)}{(1+P)(1-2P)}\;\frac{g}{d}} \qquad \ldots\ldots\ldots\ldots (1)$$

where Vc = compressional velocity in ft/sec

E = Young's modulus in lb/in^2

P = Poisson's ratio

g = acceleration due to gravity in ft/sec^2

d = specific gravity

2. Transverse Mode (Shear)

This wave arrives later than the longitudinal wave. The movement of the particles is at right-angles to the direction of propagation. These waves may be polarized into movement in two planes parallel to, and normal to, the stratification planes (Leet, 1950).

The velocity of this wave (Vs) is expressed by the formula:

$$Vs = \frac{1}{12}\sqrt{\frac{E}{2(1+P)}\;\frac{g}{d}} \qquad \ldots\ldots\ldots\ldots (2)$$

where Vs = shear velocity in ft/sec^2

and the other symbols are as above.

By manipulation of (1) and (2) a ratio of shear to compressional velocities can be obtained, viz:

$$\left(\frac{Vc}{Vs}\right)^2 = (1-P)/(½-P) \quad \ldots\ldots\ldots\ldots\ldots (3)$$

This ratio can be measured directly in the field by recording the arrival times of the shear and compressional waves at a single three-component geophone. Although two horizontal components are measured over the short distance used there is essentially no difference between them.

Equation (3) allows Poissons's ratio P to be calculated. Also Young's modulus may be calculated if the specific gravity of the rock is known from laboratory measurements.

Additional elastic properties related to those above may also be calculated, viz:

$$G = E/2(1 + P) \quad \ldots\ldots\ldots\ldots (4)$$

$$B = E/3(1 + 2P) \quad \ldots\ldots\ldots\ldots (5)$$

where G = modulus of rigidity (shear modulus) in lb/in^2

B = bulk modulus (modulus of incompressibility) in lb/in^2

The field procedure used to obtain these elastic parameters is straightforward although a complex seismic record can result where a considerable thickness of overburden is present. Later arrivals from intermediate horizons may mask the true shear waves from the bedrock. This problem can be overcome to a certain extent by varying the shot-to-geophone distance and repeating each test.