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RECORD No. 1966/30

COTTER DAM SITE 'E' GEOPHYSICAL SURVEY,

A.C.T. 1964

by

E.J. POLAK and L. KEVI

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ILLUSTRATIONS

Note: This Record supersedes Progress Report No. 1964/20

SUMMARY

The object of the survey was to determine the depth and nature of the bedrock at the site of a proposed dam in the Upper Cotter Valley. Two 'borrow areas' were also investigated to gather information about the quantity of clay present that can be used in the construction of an earth dam.

The seismic refraction method was used, supplemented by resistivity and magnetic traversing. Laboratory tests were made on samples from drill holes in the area of the proposed dam site.

The results show that the overburden is relatively thin, generally less than 50 feet. Seismic velocities of the bedrock range from 7000 ft/s to 19,000 ft/s. The zones of low velocity suggest the presence of shear zones.

Sites for further investigation by drilling are suggested.

1. INTRODUCTION

The Commonwealth Department of Works proposes to construct a dam on the upper reaches of the Cotter Valley in the Australian Capital Territory. The water impounded by the dam will supplement Canberra's water supply. It is proposed to construct a dam with a wall height of about 220 feet.

The Geological Branch of the Bureau of Mineral Resources, Geology and Geophysics (B.M.R.) is carrying out the geological investigations and supervising some technical aspects of the drilling.

A short geophysical survey was made in the area in 1961 (Wiebenga, Polak, and Kirton, 1962), and in response to a request from the Geological Branch of the BMR, a further survey was made to determine the depth and nature of the fresh rock along the axis of the dam, along the ridge dividing the Kangaroo Creek from White Sands Creek, and on two borrow pits. Seismic refraction, magnetic, and resistivity methods were used. The survey was made between the 18th February and 11th March, 1964 by a geophysical party comprising E. J. Polak (party leader), L. Kevi (geophysicist), and J. P. Pigott (geophysical assistant). Field assistants were provided by the Geological Branch of the BMR. The topographic survey was made by the Department of the Interior.

It is desired to acknowledge the assistance given by the Commonwealth Department of Works and the Geological Branch of the B.M.R.

As used in this record the term 'bedrock' refers to the deepest refractor with the highest recorded seismic wave velocity. The term 'overburden' refers to soil, alluvium, scree material, and weathered rocks in situ. Soil is defined as a surface layer consisting of a mixture of organic matter with other material in situ or transported.

2. GEOLOGY

Plate 1 shows the geology of the area as interpreted by the Geological Branch of the B.M.R. (Best & Hill, 1962). The geology has been discussed in a previous record (Wiebenga <u>et al</u>, 1962). The main direction of jointing coincides with the bedding plane, which is indicated in Plate 1. Subsequent to the geophysical survey of 1962, several holes were drilled and the scree covering the area on the right abutment of the dam was stripped off. This work disclosed a shear zone underneath the Cotter River. A shear zone indicated by the geophysical survey of 1961 was also exposed.

3. METHODS AND EQUIPMENT

Seismic refraction method

The seismic refraction technique used has been described in several reports of previous surveys in the A.C.T. (e.g. Hawkins & Stocklin, 1956).

Longitudinal and transverse wave velocities were measured in the present survey. Longitudinal velocities were used to determine the depth to the bedrock using the 'method of differences'. Longitudinal and transverse wave velocities were used to determine the dynamic properties of the bedrock (Polak & Mann, 1959a). On most of the seismic traverses a 50-ft geophone spacing was used. A 25-ft spacing was used when more detailed information was required. Two shots were fired at each end of each geophone spread, one at 25 feet and one at 200 feet from the end of the spread. In addition, 'weathering spreads' using a geophone spacing of 10 feet were used to obtain the velocities of the upper layers.

The seismic velocity of a rock depends primarily on the lithological composition, porosity, and water content (Wyllie, Gregory, & Gardner, 1956). Laboratory and field experiments show that an increase in porosity results in a decrease of velocity. Because a decrease in porosity corresponds with an increase in density (assuming the same rock type) it follows than an increase in density usually corresponds with an increase in velocity. Fracturing and jointing usually decrease the velocity of the rock in bulk unless the rock is recemented. A large number of rocks show seismic anisotropy, with the larger velocities parallel to the bedding or joint planes, and the lower velocities across or perpendicular to the bedding or joint planes.

A South-western Industrial Electronics Co. 24-channel seismograph was used in the investigation with Technical Instruments Co. geophones having a natural frequency of 20 c/s to record longitudinal waves. Three-component Hall-Sears Inc. geophones with a natural frequency of 4.5 c/s were used to record longitudinal and transverse waves.

Resistivity constant-spacing method

Resistivity traversing with constant spacing has been used on previous surveys in the A.C.T. (Jesson & Kevi, 1963). At the Cotter 'E' dam site, the method was used on Traverses NN and HH. On other traverses, the presence of a dry layer of scree prevented resistivity measurements being made because of high contact resistances.

A YEW resistivity meter, manufactured by the Yekagawa Electric Works (Tokyo) and a Megger Earth Tester manufactured by Evershed and Vignoles (London) were used on the present survey.

Magnetic method

The magnetic method is described by Polak (1964).

A verticalcomponent fluxgate magnetometer manufactured by E.J. Sharpe Instruments of Canada Ltd (Type MF-1, serial number 30749) was used. The sensitivity of this instrument is 10 gammas per scale division and the accuracy is estimated as ± 5 gammas.

Magnetic traverses were made along the seismic lines, readings being taken at 50-ft intervals. Smooth magnetic profiles were obtained on all the traverses except on Traverse CC, where low magnetic values indicate demagnetised zones, probably caused by weathering on shear zones.

4. RESULTS - COTTER DAM SITE 'E'

Plate 1 shows the arrangement of the geophysical traverses and Plates 2 and 3 give the results of the interpretation of geophysical work.

Seismic velocities

The seismic velocities may be arranged in three groups, corresponding with the following three layers:

Top layer. This is interpreted as soil with a velocity of 1000 to 1800 ft/s. The thickness of the layer is about 2 to 5 feet.

Second layer. This layer, with a velocity of about 4000 to 5000 ft/s is interpreted as rock with weathered joints. During the 1961 survey, which was made during wet weather when the rock pores and joints were filled with water, the presence of water increased the seismic velocity from the range 4000 to 5000ft/s to 6000 ft/s. Wyllie et al (1956, p. 51 & 56) showed that an aggregate of glass beads increases its seismic velocity from 1300 ft/s to 4600 ft/s, and a 30% porosity sandstone from 5500 ft/s to 8000 ft/s, when becoming saturated with water. The layer described in this record seems to form an intermediate example between these two cases.

Third layer. This is interpreted as bedrock with seismic velocities of 7000 to 19,000 ft/s.

The error in depth determination is considered to be less than ± 20 percent. This estimate is based on experience of results in other areas with comparable geological conditions. The possibility of a fairly large percentage error in the depth of bedrock is due to many factors, such as abrupt lateral changes in composition of the overburden, abrupt changes in thickness, changes in water content, steep slopes, and excavations.

The properties of the bedrock

Seismic velocities. Seismic velocities in the bedrock are shown in Plates 1, 2, and 3; they vary between 7000 and 19,000 ft/s.

By comparing the seismic velocities with rock types present in the area (Plate 1), the following correlations were found:

1. Towards the western end of Traverse AA, massive sandstone, siltstone, and quartzite show seismic velocities of 15,000 to 16,000 ft/s, while the phyllites correspond to a seismic velocity of about 10,000 ft/s.

2. Finely laminated shales on the right bank of the river show a velocity of 11,000 ft/s. Interbedded shales, sandstones, siltstones, and quartzites show velocities of 10,000 to 13,000 ft/s, depending on their content of higher velocity rocks.

Velocity anisotropy is shown in places where two seismic traverses intersect. For example, the seismic velocity at the western end of Traverse NN is 12,000 ft/s, while at the south-east end of Traverse FF it is 11,000 ft/s. Traverse FF is located at right angles to the strike of the bedding, whereas Traverse NN makes a small angle with the strike. Similar differences were found on the traverse intersections JJ/AA, JJ/KK, BB/CC, CC/DD, and DD/EE.

In several places, low seismic velocities in the bedrock or a low resistivity anomaly along a resistivity traverse indicate a fault or a shear zone. On Traverse AA (near station No. 21), a subsurface gully was formed by deeper weathering and the decrease in velocity to 8000 ft/s suggests a fault or a shear zone, possiby the Cotter Fault.

On Traverse HH (stations Nos. 8 and 9) and Traverse NN (stations Nos. 10 and 11), the existence of a shear zone is suggested by low seismic velocity and by low resistivity on a constant-spacing resistivity traverse.

On Traverse BB (stations Nos. 7 to 9), Traverse JJ (stations Nos. 4 and 5), and Traverse LL (possibly stations Nos. 20 and 21), indications for shear-zones are found on seismic traverses. It is possible that these three indications belong to one shear zone.

On Traverse [illegible] (stations Nos. 3 to 5), a shear zone is suggested by low seismic velocity and low values on the magnetic profile.

Dynamic properties of rocks

Field determination. The dynamic properties of the bedrock were determined from longitudinal and transverse velocities in four localities of the dam site area. The velocities were measured along 200-ft sections of the traverse; thus the calculated values of moduli will represent an average value of the moduli along the measured length in the direction of measurements.

The elastic moduli were calculated for an average specific gravity of 2.55, which was determined from the weights and volumes of the samples.

Table 1 gives the calculated values of the dynamic properties of the bedrock at the dam site. Values of Young's modulus and Poisson's ratio are also shown in Plates 2 and 3.

Laboratory determination. Dynamic properties of the rocks were determined on several samples of cores obtained from the drill holes in the area of the dam site. The determinations were made in the BMR Laboratory at Footscray; the usual technique was used (Polak, 1963). The results are given in the Appendix.

The geological descriptions of the rock types were given by BMR Geologist, J. Hill (personal communication).

Some of the samples were saturated with water for 48 hours under partial vacuum and then retested. Table 2 gives the results of the dynamic tests made on wet samples.

Comparisons of the values of several properties of the rocks measured in the dry and wet states are shown in Plate 6. Examination of the figures indicates -

(a) Seismic velocities in wet rock show a tendency to be higher than in dry rock.

(b) Poisson's ratio for wet rock is generally higher than that for dry rock.

(c) Young's modulus for wet rock is generally equal to that obtained for dry rock except that a decrease in Young's modulus is shown by wet stilstone.

(d) Bulk modulus is higher for wet samples than dry samples.

(e) Modulus of rigidity for wet samples is lower than for dry samples (for siltstone only).

(f) Logarithmic decrement for wet rock is higher than that for dry rock.

Static properties of rocks

Plate 7 shows the results of the static tests on five samples from Cotter dam site 'E'. The tests were carried out at the Commonwealth Department of Works Laboratories, Melbourne. Philips wire strain gauges, type PR9810, were used. Stress-strain diagrams were plotted from the load and deformation measurements for each specimen tested. The tests were carried out to the destruction of the rock sample. Ultimate strength was calculated from the maximum load.

The initial modulus of elasticity (Young's modulus) was determined as the slope of a tangent at the origin on the increasing phase of the first branch of the curve. For sample No. 1371, which showed a 'false' initial modulus, the curve up to a micro-strain 300×10^{-6} was ignored following the normal practice (Liebenberg, 1962). The false initial modulus may indicate the existence of micro-cracks, the cracks being closed at the beginning of loading.

The numerical results of the tests are given below the stress-strain curves. Table 3 compares the static and dynamic results.

TABLE 1

Dynamic properties of bedrock determined in the field

Traverse	Stations	Seismic velocity (ft/s)	Poisson's Ratio	Modulus Young's	(10^6 lb/in^2) Rigidity	Bulk
AA	1 - 4	12,500	0.37	3.0	1.1	4.0
BB	0 - 3	11,000	0.30	3.1	1.2	2.6
JJ	9 - 12	11,000	0.36	2.5	0.9	3.0
OO	3 - 6	7,000	0.30	1.2	0.5	1.0

TABLE 2

Dynamic properties of wet samples of bedrock

Sample No. (field)	Longitudinal velocity (ft/s)	Poisson's Ratio	Modulus Young's	(10^6 lb/in^2) Bulk	Rigidity	Logarithmic decrement
408	16,900	0.32	7.1	6.8	2.7	0.16
411	17,800	0.10	11.0	4.6	5.0	0.13
420	15,900	0.37	4.6	5.9	1.7	0.33
431	17,900	0.18	10.0	5.3	4.3	0.08
432	17,100	0.15	9.7	4.6	4.2	0.17
243	13,800	0.41	2.9	5.4	1.0	0.54
239	17,100	0.22	9.1	5.4	3.6	0.09
235	12,200	0.39	2.4	3.9	0.9	0.46
231	11,250	0.41	1.7	3.4	0.6	0.36
232	13,400	0.36	3.6	4.4	1.4	0.36
226	13,500	0.38	3.2	4.7	1.2	0.35
271	8,800	0.41	1.1	2.1	0.4	0.24
276	11,900	0.39	2.3	3.7	0.9	0.24
277	12,400	0.41	2.3	4.3	0.9	0.23
281	11,200	0.39	2.1	3.4	0.8	0.31
284	11,900	0.29	5.7	4.7	2.2	0.08
261	13,000	0.40	3.1	5.2	1.2	0.23

TABLE 3

A comparison of the static and dynamic values

Drill Hole No. (DDH)	Sample No. (field)	Sample No. (lab.)	Poisson's ratio Static	Dynamic	Young's Modulus (10^6 lb/in^2) Static	Dynamic
2	412	1371	0.39	0.10	7.7	7.7
3	417	1376	0.12	0.10	9.5	9.6
3	419	1378	0.21	0.10	10.5	9.6
4	422	1381	0.16	0.31	10.5	8.5
4	429	1388	0.16		5.5	

Table 3 shows that the values of Young's modulus found in static tests tend to be equal to or higher than those found in dynamic tests.

Static measurements on wet samples were not carried out, but it is expected that the results would bear the same relation to those obtained on dry samples as is shown for dynamic measurements in Table 2 (Mann & Fatt, 1960).

Values of dynamic and static properties were determined using standard procedure and equipment and the results are within the ± 5 percent error accepted by the American Society for Testing Materials (Ramberg, 1952).

5. RESULTS - RED HILL BORROW PIT

Red Hill borrow pit is located approximately three miles south of Cotter dam site 'E'. It is proposed to use material from overburden in the construction of the earth dam.

Two seismic traverses (Plate 4) were made to determine the thickness and character of the overburden. Plate 4 shows the seismic cross-sections and their interpretation.

Depth to bedrock

Seismic traverses indicate a maximum depth to bedrock of 84 feet at station SS3. Along three quarters of Traverse SS, the velocity ranges from 7000 to 8000 ft/s, possibly indicating weathered shear zones. Along Traverse RR, the velocities in the bedrock are higher and reach 15,000 ft/s.

Character of the overburden

Under a thin layer of soil the overburden consists of rock of uniform velocity of 4000 ft/s. This velocity is characteristic of a 'stiff' or compacted wet clay (Heiland, 1940, p. 469; Polak & Mann, 1959b).

6. RESULTS - BRIDGE BORROW PIT

Bridge borrow pit is located approximately six miles south of Cotter dam site 'E'. It is proposed to use the overburden material in the construction of the earth dam.

Two seismic traverses (Plate 5) were made to determine the thickness and character of the overburden. Plate 5 shows the seismic cross-sections and their interpretation.

Depth to bedrock

Seismic traverses indicate that the maximum depth to bedrock is approximately 200 feet near station PP 15; here the bedrock consists of rock with a seismic velocity of 11,000 ft/s. In other places the velocity is 14,000 to 16,000 ft/s.

Character of the overburden

The overburden consists of three layers. The top layer, with a seismic velocity of 1,000 ft/s, represents the soil. The second layer, with a seismic velocity of 3500 ft/s, is interpreted as a mixture of clay and fragments of solid rock. The bed is porous and not saturated with water. The layer with a seismic velocity of 5000 ft/s is probably decomposed bedrock in situ or material of the second layer below the water table. This interpretation of the overburden velocities is based on previous experience (Polak & Mann, 1959b).

7. CONCLUSIONS AND RECOMMENDATIONS

The overburden in the area of the dam foundations reaches 57 feet at station AA 15. The weathered joints in the rock are open as indicated by an increase in seismic velocity when wet (Wiebenga et al, 1962). In places, the bedrock has seismic velocities as low as 7000 ft/s. These localities should be further investigated by drilling before the type of dam to be constructed can be decided.

Areas of low seismic velocity on the ridge between Kangaroo Creek and White Sands Creek should be further investigated by drilling to determine the possibility of water leakage from the proposed reservoir.

Young's modulus of the bedrock measured in the field is between 1.2×10^6 and 3.1×10^6 lb/in^2. Laboratory measurements show much higher values of 2.6×10^6 to 10.6×10^6 lb/in^2. The large difference in value is due to the fact that in field tests an average value for jointed rock is measured, whereas in the laboratory only a sample of the homogeneous rock material can be investigated.

Of the two proposed borrow pits, the Red Hill area is the more promising and should be further investigated, possibly with a multi-channel refraction seismograph or a 'seismic interval timer'.

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Laboratory determined dynamic properties of dry rock samples

(Core diameter 0.17 feet)

Drill Hole No. (DDH)	Depth	Sample No. (field)	Sample No. (lab.)	Description (from hand specimen)	Length (feet)	Specific gravity	Longitudinal velocity (ft/s.)	Poisson's ratio	Modulus (10⁶lb/in²) Young's	Bulk	Rigidity	Logarithmic decrement	Porosity
1	35' 0" - 35' 3"	241	1478	Almost fresh quartzite.	0.148	2.57	14,000						4.5
1	67' 8" - 68' 3"	244	1479	Fresh medium-grained quartz sandstone.	0.550	2.62	1[illegible],100					0.06	1
1	87' 0" - 87' 6"	246	1480	Slightly weathered interbedded fine-grained sandstone and siltstone.	0.240	2.49	12,000						6.5
1	95' 0" - 95' 5"	245	1481	Fresh interbedded fine-grained silicified sandstone and siltstone.	0.358	2.57	9,400						6.5
1	138' 3" - 138' 10"	243	1482	Fresh interbedded blue-grey fine-grained sandstone and siltstone.	0.496	2.67	11,800	0.395	2.39	3.82	0.88	0.111	2
1	168' 1" - 168' 6"	240	1483	Fresh slumped quartz siltstone and fine-grained quartz sandstone.	0.187	2.69	9,600						3
1	192' 2" - 192' 8"	239	1484	Fresh fine-grained blue-grey silicified quartz sandstone.	0.486	2.68	17,300					0.094	0.5
1	217' 10" - 218' 2"	238	1485	Fresh dark blue-grey siltstone.	0.146	2.74	14,600						1
1	223' 0" - 223' 4"	242	1486	Fresh blue-grey siltstone.	0.156	2.63	6,800						
2	33' 6" - 34' 0"	410	1369	Slightly weathered fine-grained quartz sandstone with numerous thin silty interbeds.	0.412	2.59	15,300	0.37	4.6	5.9	1.7	0.070	
2	41' 3" - 41' 11"	412	1371	Fresh fine-grained silicified quartz sandstone.	0.492	2.60	15,000	0,10	7.7	3.2	3.5	0.052	
2	74' 1" - 74' 11"	411	1370	Fresh fine-grained silicified quartz sandstone.	0.700	2.65	17,300	0.24	9.1	5.8	3.7	0.053	
2	96' 9" - 97' 4"	413	1372	Slightly weathered fine-grained silicified quartz sandstone with numerous thin irregular silty interbeds.	0.505	2.63	13,400	0.42	2.6	5.4	6.9	0.183	
2	112' 7" - 113' 3"	408	1367	Fresh fine-grained silicified quartz sandstone with a few silty interbeds.	0.613	2.63	16,600	0.36	5.9	7.0	2.2	0.072	
2	138' 7" - 139' 0"	414	1373	Slightly weathered fine-grained silicified quartz sandstone with quartz veins.	0.371	2.60	15,500						
2	156' 0" - 156' 7"	409	1368	Fresh fine-grained silicified quartz sandstone with irregular silty interbeds.	0.470	2.61	15,800	0.24	7.4	4.7	3.0	0.13	
3	23' 10" - 24' 5"	427	1386	Slightly weathered medium-grained silicified quartz sandstone.	0.408	2.62	17,600						
3	43' 4" - 44' 0"	417	1376	Fresh medium-grained silicified quartz sandstone.	0.468	2.63	16,700	0.10	9.6	4.0	4.4	0.089	
3	66' 10" - 67' 3"	418	1377	Interbedded fresh blue-grey fine-grained silicified quartz sandstone and siltstone.	0.119	2.66	12,300						
3	86' 7" - 87' 5"	420	1379	Fresh to slightly weathered blue-grey silicified quartz sandstone with siltstone interbeds.	0.685	2.34	15,000	0.34	4.6	4.8	1.7	0.205	
3	102' 11" - 103' 6"	419	1378	Fresh fine-grained silicified quartz sandstone.	0.428	2.63	16,700	0.10	9.6	4.0	4.4	0.082	
3	127' 3" - 127' 10"	415	1374	Fresh blue-grey massive siltstone with quartz veins.	0.444	2.57	13,100	0.15	5.6	2.7	2.4	0.304	

Drill Hole No. (DDH)	Depth	Sample No. (field)	Sample No. (lab.)	Description (from hand specimen)	Length (feet)	Specific gravity	Longitudinal velocity (ft/s)	Poisson's ratio	Modulus ($10^6 lb/in^2$) Young's	Bulk	Rigidity	Logarithmic decrement	Porosity
3	146' 9" - 147' 4"	428	1387	Fresh dark blue to grey fine-grained silicified quartz sandstone with quartz veins.	0.500	2.68	17,700	0.20	10.0	5.7	4.2	0.114	
3	151' 4" - 151' 9"	426	1385	Fresh dark blue fine-grained silicified quartz sandstone.	0.365	2.59	16.700						
3	173' 11" - 174' 7"	424	1383	Fresh dark blue to grey fine-grained silicified quartz sandstone with silty interbeds.	0.494	2.63	15,800						
3	180' 8" - 181' 1"	425	1384	As for 424 but with numerous quartz veins. Probably recemented breccia. Pyrite present. Also cavities due to leaching.	0.305	2.66	15,900						
3	197' 4" - 197' 11"	416	1375	Fresh dark blue fine-grained silicified quartz sandstone with quartz veins.	0.414	2.62	18,300	0.20	10.6	5.9	4.3	0.066	
				- -									
4	13' 9" - 14' 0"	234	1488	Slightly weathered silicified fine-grained quartz sandstone.	0.196	2.44	10,900						8
4	32' 6" - 33' 1"	430	1389	Slightly weathered fine-grained silicified quartz sandstone.	0.452	2.55	15,500	0.32	5.8	5.4	2.2	0.098	
4	57' 4" - 57' 8"	233	1487	Slightly weathered intersected fine-grained silicified quartz sandstone and siltstone.	0.211	2.46	7,200						13
	67' 10" - 68' 5"	429	1388	Slightly weathered fine-grained silicified quartz sandstone.	0.408	2.51	14,000						
4	92' 3" - 92' 9"	423	1382	Slightly weathered fine-grained silicified quartz sandstone with numerous thin siltstone interbeds.	0.354	2.55	14,500						
4	106' 8" - 107' 2"	422	1381	Slightly weathered fine-grained silicified quartz sandstone.	0.483		16,800	0.31	8.5	7.5	3.2	0.085	
4	127' 3" - 128' 0"	421	1380	Slightly weathered fine-grained silicified quartz sandstone.	0.520	2.57	15,900	0.13	8.4	3.8	3.7	0.032	
4	141' 5" - 142' 3"	432	1391	Slightly weathered fine-grained silicified quartz sandstone.	0.742	2.60	16,400	0.16	8.9	4.4	3.8	0.066	
4	168' 0" - 168' 10"	431	1390	Slightly weathered fine-grained silicified quartz sandstone.	0.667	2.62	17,200	0.115	10.0	4.3	4.5	0.074	
				- -									
6	18' 4" - 18' 9"	253	1505	Pale brown siltstone.	0.210	2.63	11,200						
6	32' 9" - 33' 2"	254	1506	Buff siltstone with fine quartz veins.	0.372	2.61	13,000						
6	108' 10" - 109' 4"	260	1512	Slightly weathered fine-grained brown sandstone.	0.385	2.59	12,500						
6	126' 6" - 127' 1"	261	1513	Slightly weathered fine-grained sandstone with pyrites.	0.472	2.64	11,300	0.39	2.21	3.53	0.82	0.075	
6	156' 6" - 156' 11"	255	1507	Fresh dark grey siltstone with quartz vein.	0.380	2.66	17,100						
6	179' 1" - 179' 1"	256	1508	Fresh dark grey siltstone with pyrites.	0.342	2.76	18,300						
6	191' 5" - 191' 11"	257	1509	Fresh dark grey siltstone.	0.293	2.67	17,500						
6	217' 0" - 217' 6"	258	1510	Fresh dark grey sheared siltstone.	0.296	2.68	17,400						
6	249' 0" - 249' 1"	259	1511	Fresh dark grey brecciated siltstone.	0.370	2.72	15,100						
				- -									

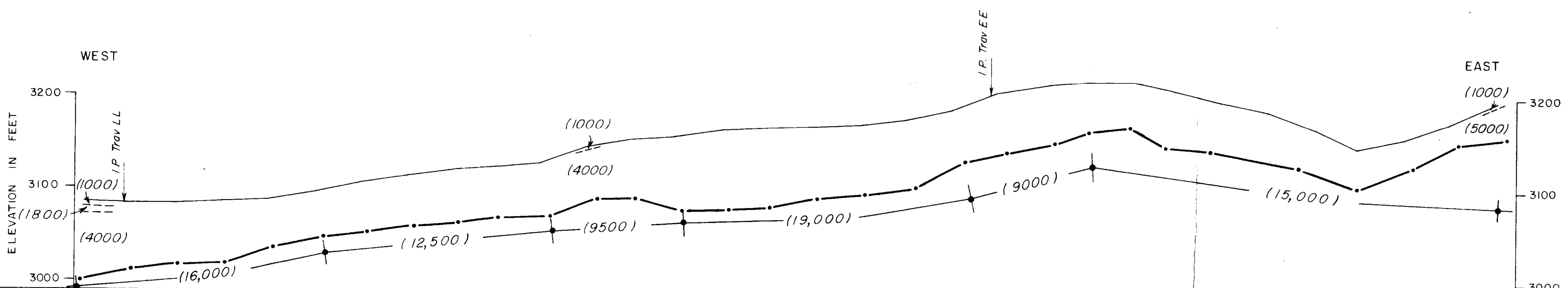
Drill Hole No. (DDH)	Depth	Sample No. (field)	Sample No. (lab.)	Description (from hand specimen)	Length (feet)	Specific gravity	Longitudinal velocity (ft/s)	Poisson's ratio	Modulus (10^6 lb/in^2) Young's	Bulk	Rigidity	Logarithmic decrement	Porosity
7	78' 6" - 79' 1"	274	1526	Fresh dark grey siltstone.	0.460	2.84	13,300						
7	115' 9" - 116' 4"	375	1527	Fresh dark grey laminated siltstone.	0.290	2.72	11,300						
7	131' 4" - 131' 8"	273	1525	Fresh dark brown non-laminated siltstone.	0.296	2.60	14,100						
8	17' 0" - 18' 1"	250	1495	Moderately weathered fine-grained quartz sandstone.	0.384	2.23	10,300						15
8	23' 8" - 24' 3"	249	1496	Moderately to very weathered medium-grained quartz sandstone.	0.430	2.12	7,620						
8	31' 4" - 31' 10"	248	1497	Moderately weathered fine-grained quartz sandstone.	0.493	2.38	13,900					0.027	
8	57' 10" - 58' 5"	247	1498	Moderately to very weathered thinly bedded to laminated, interbedded siltstone and shale.	0.563	2.36	12,100	0.395	2.25	3.6	0.83	0.128	13
8	70' 8" - 71' 1"	229	1499	Fresh blue-grey silicified quartz siltstone, thinly bedded to laminated, with well developed cleavage.	0.285	2.60	13,900						7
8	100' 0" - 100' 6"	228	1500	Fresh blue-grey silicified quartz siltstone, thinly bedded to laminated, with well developed cleavage.	0.404	2.63	13,800						4.5
8	126' 8" - 127' 4"	227	1501	" " " " " "	0.590	2.60	14,700	~~0.175~~	~~6.89~~	3.65	2.89	0.058	4.5
8	152' 0" - 152' 7"	226	1502	" " " " " "	0.512	2.55	14,500	0.155	6.89	2.99	3.10	0.091	6.5
9	12' 1" - 12' 8"	262	1514	Moderately weathered pale brown fine sandstone.	0.406	2.50	13,300						
9	34' 3" - 34' 11"	271	1523	Moderately weathered brown coloured siltstone.	0.568	2.28	8,100	0.116	1.67	1.09	0.67	0.056	
9	43' 4" - 43' 10"	270	1522	Moderately fresh pale grey non-laminated siltstone.	0.267	2.44	8,900						
9	65' 1" - 65' 6"	269	1521	Fresh brown coloured medium-grained sandstone.	0.331	2.57	14,200						
9	90' 7" - 91' 1"	268	1520	Fresh grey coloured medium-grained, silicified sandstone.	0.440	2.60	16,400						
9	125' 3" - 125' 6"	266	1518	Fresh grey coloured quartzite.	0.325	2.65	16,700						
9	193' 6" - 194' 0"	263	1515	Fresh dark grey, fine-grained sandstone.	0.390	2.62	14,000						
10	34' 5" - 35' 0"	236	1489	Fresh medium- to coarse-grained sandstone.	0.516	2.51	11,600					**0.125**	5
10	56' 7" - 57' 3"	235	1490	Slightly weathered fine-grained silicified quartz sandstone.	0.623	2.37	10,500	0.36	2.06	2.47	0.77	0.102	11
10	78' 4" - 78' 10"	230	1491	Moderately weathered impure coarse-grained quartz sandstone.	0.488	2.52	14,000					0.044	4
10	103' 4" - 103' 9"	231	1492	Moderately weathered coarse-grained quartz sandstone.	0.417	2.33	9,630	0.19	2.61	1.44	1.08	0.325	10
10	126' 1" - 126' 8"	232	1493	Fresh blue-grey silicified fine-grained quartz sandstone.	0.513	2.59	12,700	0.17	5.10	2.70	2.14	0.139	3.5
10	159' 8" - 160' 1"	237	1494	Slightly weathered fine-grained silicified quartz sandstone.	0.389	2.40	9,330						9.5
12	12' 1" - 12' 11"	276	1528	Moderately weathered coarse-grained sandstone.	0.563	2.51	10,200	0.23	2.95	1.8[illegible]	1.13	0.042	
12	22' 6" - 23' 0"	283	1535	Moderately weathered pale brown medium-grained sandstone.	0.263	2.26	7,220						

Drill Hole No. (DDH)	Depth	Sample No. (field)	Sample No. (lab.)	Description (from hand specimen)	Length (feet)	Specific gravity	Longitudinal velocity (ft/s.)	Poisson's ratio	Modulus (10^6 lb/in^2) Young's	Bulk	Rigidity	Logarithmic decrement	Porosity
12	57' 5" - 58' 0"	282	1534	Weathered fine-grained sandstone.	0.375	2.28	8,340						
12	82' 4" - 83' 0"	284	1536	Moderately weathered brown medium-grained sandstone.	0.539	2.55	14,500	0.25	5.83	3.98	2.31	0.023	
12	63' 5" - 63' 11"	279	1531	Weathered fine-grained sandstone.	0.438	2.30	10,000						
12	100' 3" - 100' 9"	280	1532	Slightly weathered buff coloured laminated siltstone.	0.362	2.42	9,400						
12	126' 5" - 126' 11"	278	1530	Moderately fresh buff coloured fine-grained sandstone.	0.436	2.42	12,600	0.17	4.68	2.48	1.96	0.032	
12	152' 2" - 152' 8"	277	1529	Fresh dark grey laminated siltstone.	0.437	2.56	13,200	0.24	5.02	3.26	2.01	0.045	
11	167' 1" - 167' 9"	281	1533	Fresh buff coloured laminated siltstone.	0.562	2.51	11,700	0.20	4.09	2.31	1.68	0.086	


PLATE I
LOCALITY MAP
CANBERRA
MOLONGLO RIVER
N.S.W.
A.C.T.
COTTER DAM
MURRUMBIDGEE RIVER
REFERENCE TO AUSTRALIA STANDARD MAP SERIES
N.S.W.
Canberra
Sydney
COTTER RIVER
BENDORA DAM
DAMSITE 'E' OF UPPER COTTER VALLEY, A.C.T.
WHITE SANDS CK
KANGAROO CK
RED HILL BORROW AREA
BRIDGE BORROW AREA
MILES
SHEAR ZONE ?
SHEAR ZONE?
COTTER FAULT APPROX.
COTTER RIVER
LL 23
KK 14
JJ 1
AA 26
AA/BB
AO
A 1750
FF 2
HH 1
HH 12
NN 15
NN 1
FF 20
CC 12
CC 1
BB 29
DD 1
DD 32
EE 20
EE 9
DDH 13
DDH 15
DDH 2
DDH 4
DDH 8
DDH 12
(8000)
(9000)
(10,000)
(11,000)
(12,000)
(12,500)
(13,000)
(13,500)
(15,000)
(16,000)
(19,000)
(9500)
(7000)
(10,500)
LEGEND
Soil and scree — no outcrop or no information
Coarse blocky scree — scattered outcrops
Alluvium
Massive silicified sandstone — Tidbinbilla quartzite
Interbedded massive sandstone, siltstone and quartzite
Finely laminated shale, slate, siltstone, and fine sandstone
Phyllite
Dip and strike of bedding
Fault
Seismic traverse 1961
Seismic traverse 1964
Preliminary diamond-drill holes
Diamond-drill holes
(13,000) Seismic velocity ft/s
COTTER DAM SITE "E" A.C.T.
GEOPHYSICAL SURVEY 1964
FEET
0
200
300
400
Kangaroo Creek
TO ACCOMPANY RECORD NO. 1966/30
GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
I55/B5-25

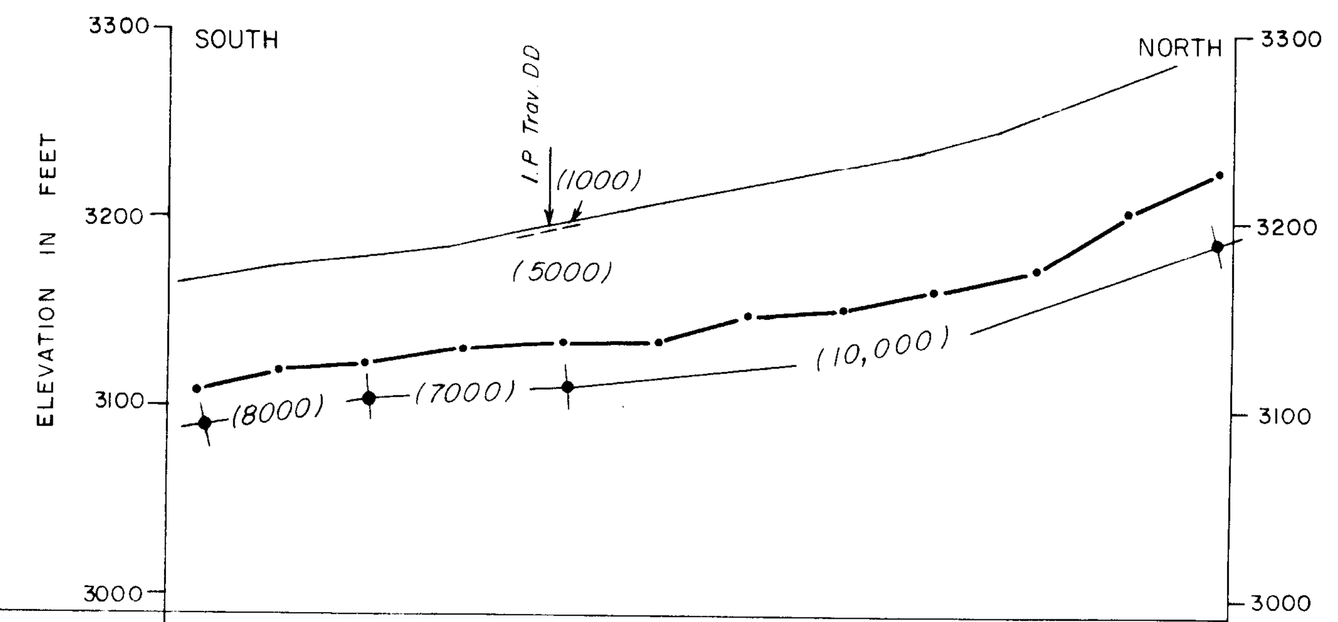
PLATE 2

TRAVERSE DD



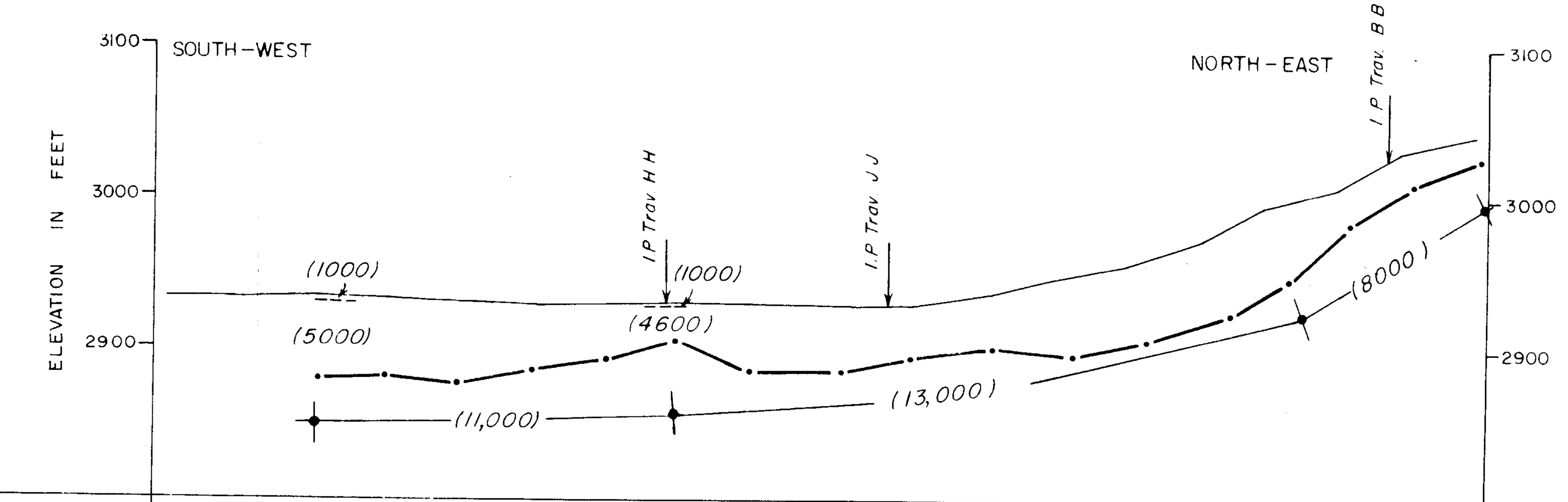
STATION NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
STATION ELEVATION	3083	3081	3082	3085	3088	3096	3105	3113	3120	3122	3128	3143	3151	3156	3163	3166	3168	3170	3175	3188	3203	3213	3218	3217	3207	3194	3183	3165	3146	3156	3172	3196
DEPTH TO BEDROCK	84	72	67	67	50	50	55	55	59	55	59	59	62	80	86	87	78	76	74	58	66	63	53	50	60	53		43	43	30	23	40

TRAVERSE EE



STATION NUMBER	9	10	11	12	13	14	15	16	17	18	19	20
STATION ELEVATION	3165	3172	3179	3186	3195	3206	3213	3223	3233	3248	3265	3285
DEPTH TO BEDROCK	59	56	56	53	63	73	69	73	73	79	66	63

TRAVERSE FF

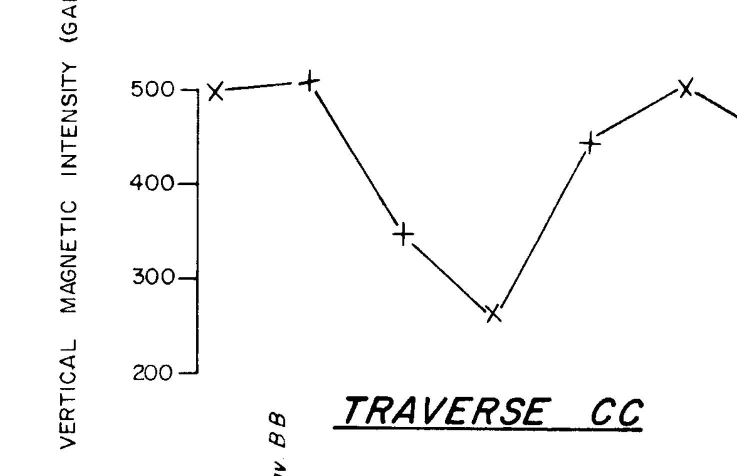


STATION NUMBER	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2
STATION ELEVATION	2932	2932	2933	2931	2930	2928	2929	2930	2929	2928	2929	2935	2947	2956	2972	2996	3007	3032	3043
DEPTH TO BEDROCK			54	50	55	43	36	24	45	42	33	33	51	51	51	51	24	24	15

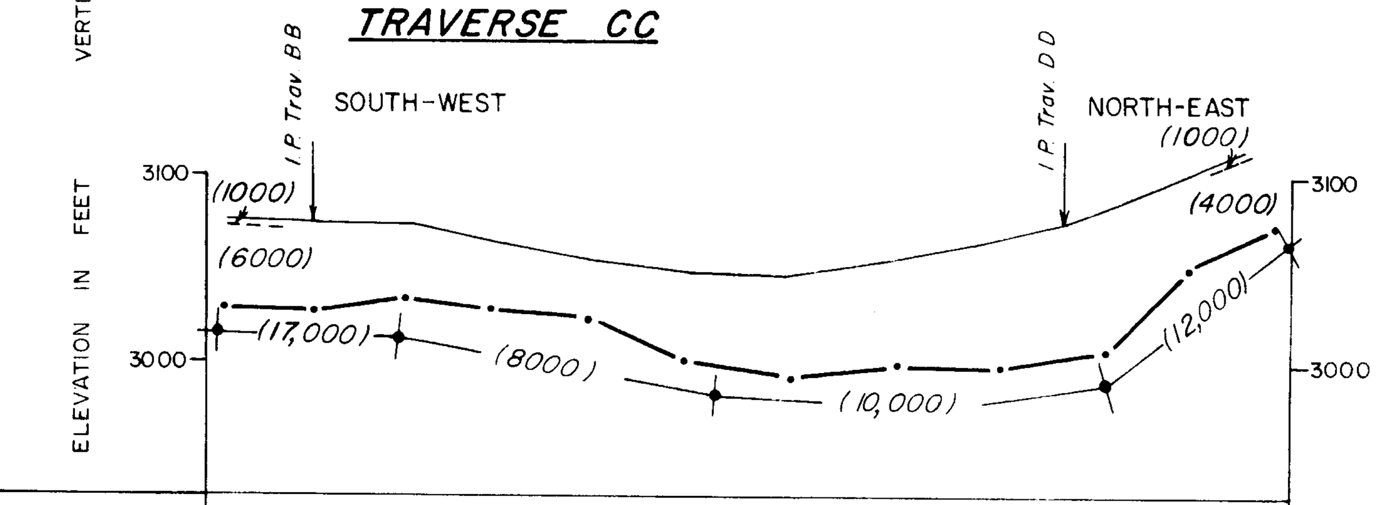
TRAVERSE AA — TRAVERSE BB

STATION NUMBER	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
STATION ELEVATION	3382	3357	3336	3314	3296	3276	3263	3252	3236	3222	3209	3194	3175	3156	3137	3120	3098	3075	3056	3036	3015	2995	2973	2952	2932	2925	2923
DEPTH TO BEDROCK	18	36	45	33	36	54	45	54	51	51	51	57	54	48	48	39	39	27	39	33	39	33	30	45	39	27	18

STATION NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
STATION ELEVATION	2946	2972	2996	3032	3056	3081	3107	3133	3153	3172	3192	3212	3220	3223	3232	3243	3254	3258	3256	3243	3224	3202	3174	3146	3123	3103	3075	3057	3035
DEPTH TO BEDROCK	27	27	24	24	39	33	30	42	27	39	50	53	58	53	56	78	87	90	94	89	84	74	72	74	50	55	47	47	



TRAVERSE CC



STATION NUMBER	1	2	3	4	5	6	7	8	9	10	11	12
STATION ELEVATION	3076	3074	3072	3062	3053	3049	3048	3054	3063	3088	3093	3114
DEPTH TO BEDROCK	47	47	39	34	30	47	52	56	69	72	47	43

LEGEND

(11,000) Seismic velocity (ft/s) in formation

— — Depth to formation with different seismic velocity

E Youngs modulus in lb/in² determined by dynamic method

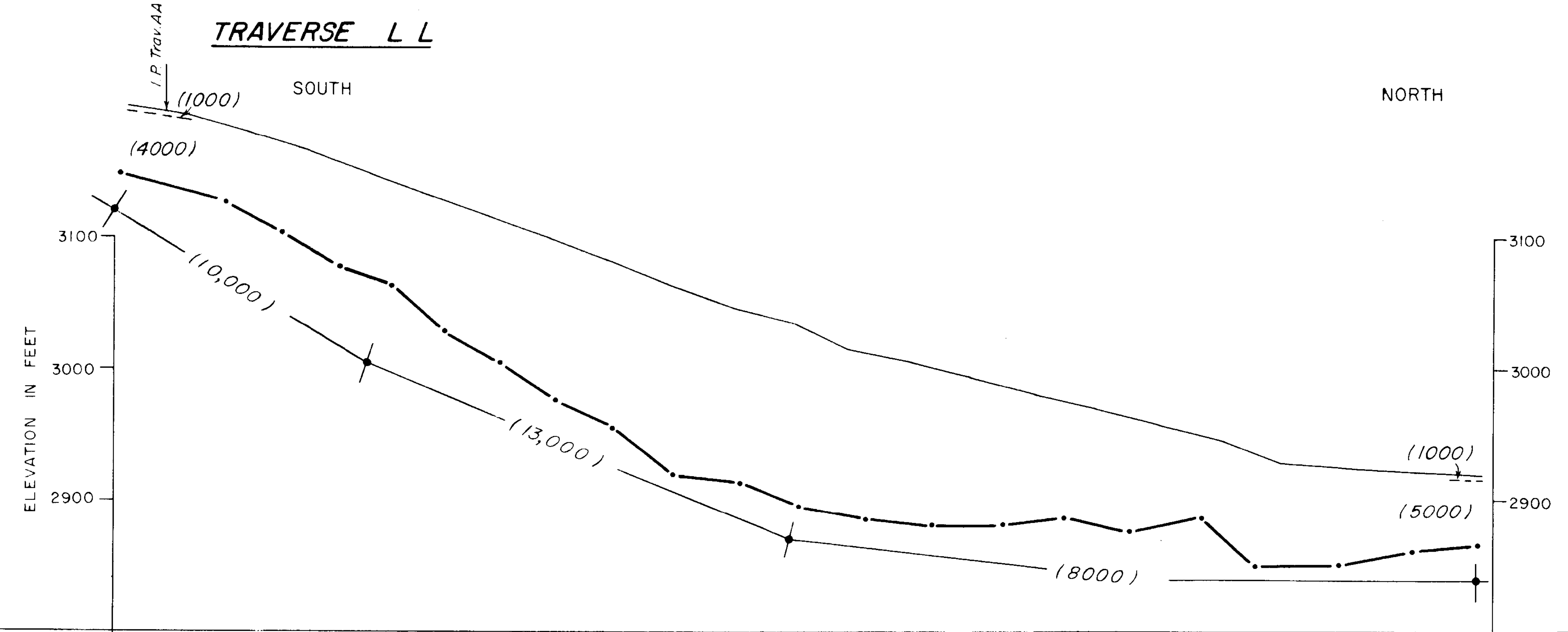
σ Poisson's ratio

—•— Unweathered bedrock boundary

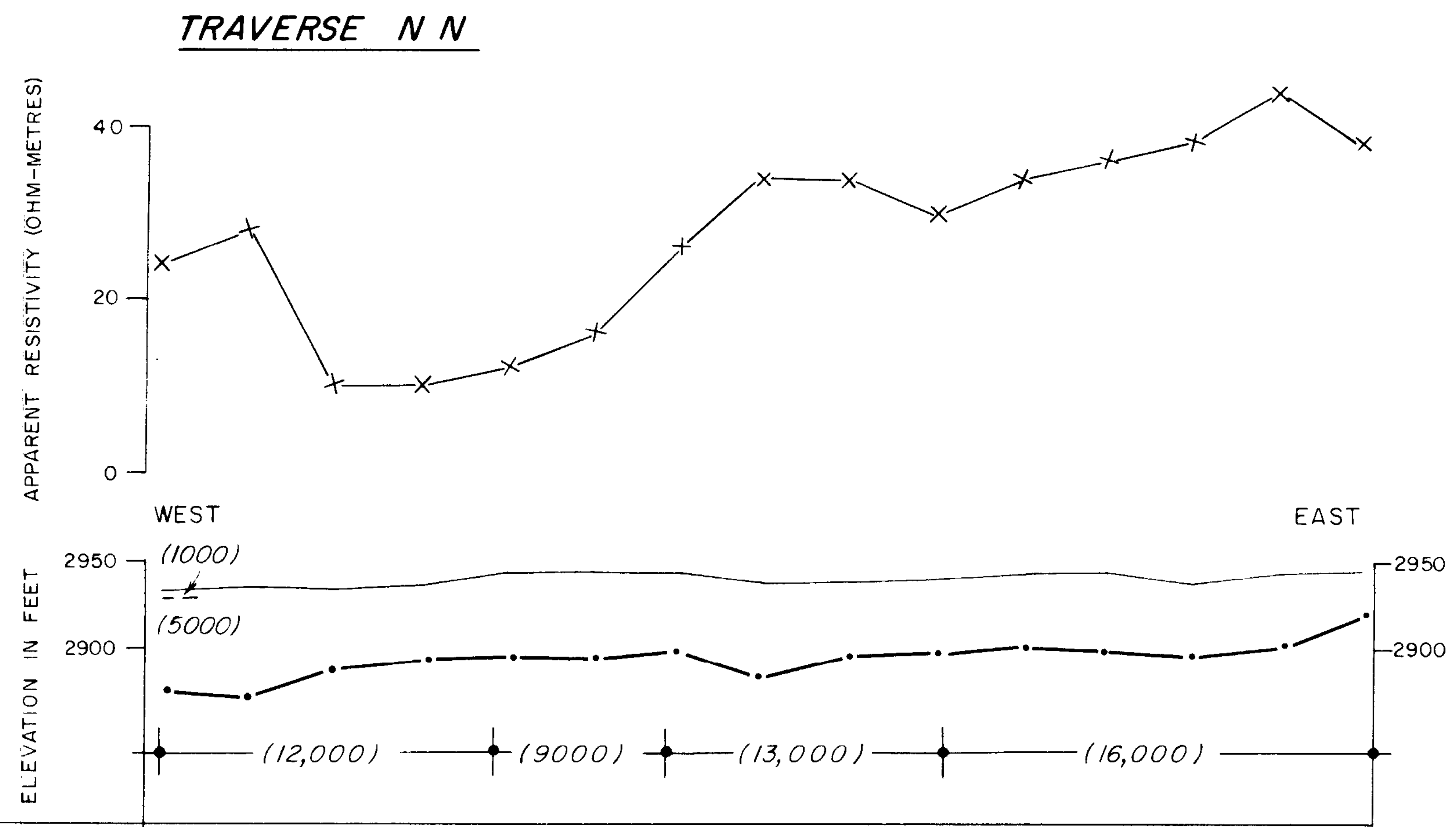
SEISMIC CROSS-SECTIONS
TRAVERSES AA to FF

TO ACCOMPANY RECORD NO. 1966/30 — GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS — I55/B5-29

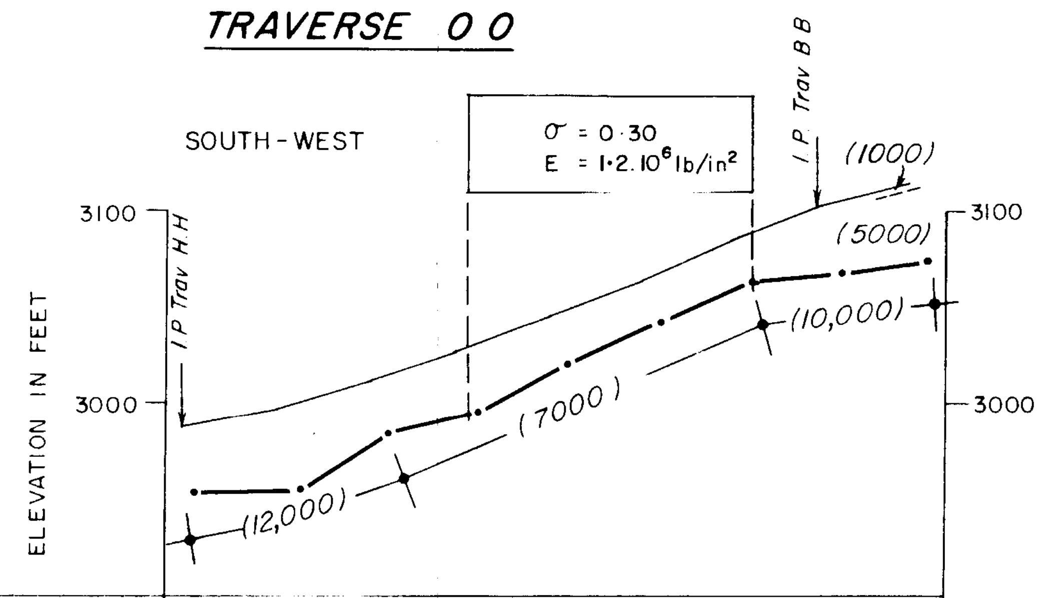
COTTER 'E' DAM SITE CANBERRA, 1964



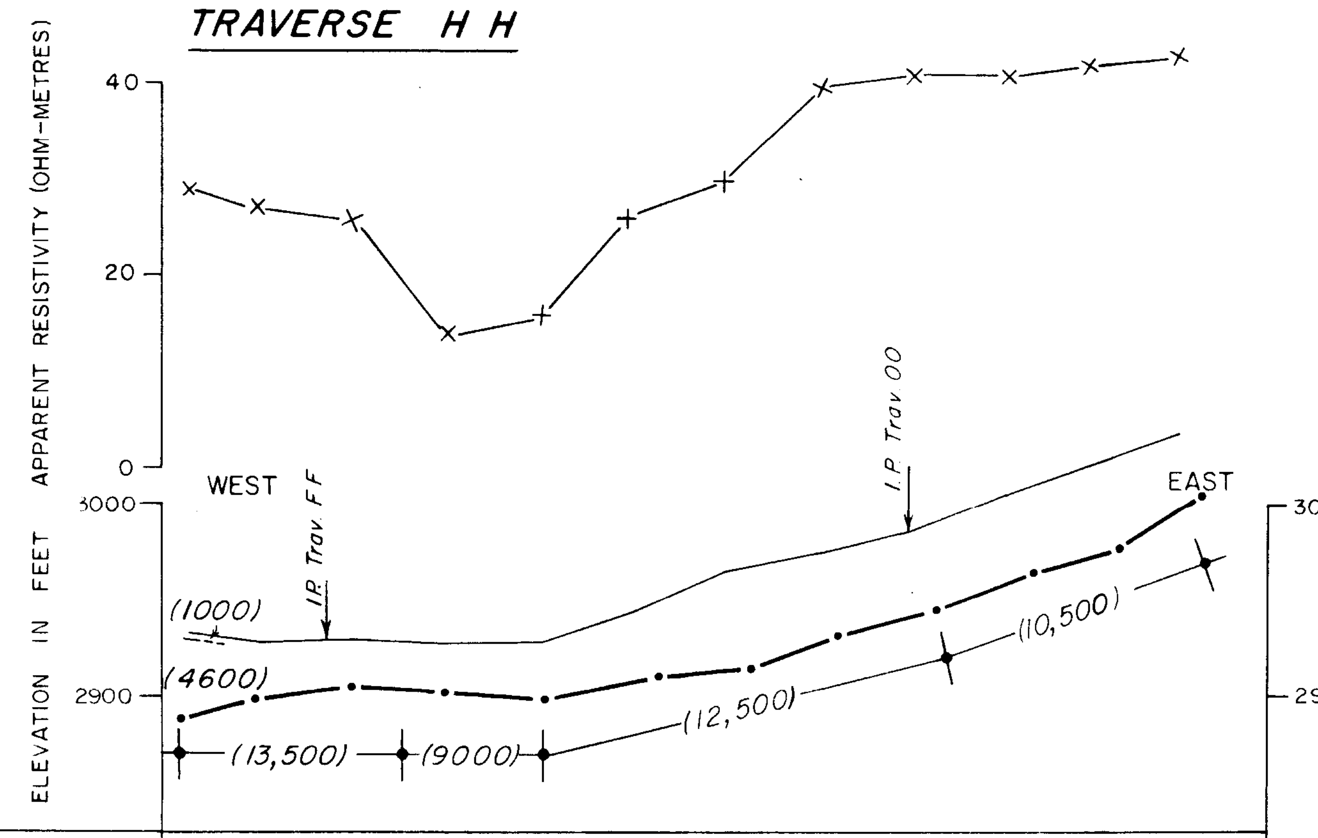
STATION NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
STATION ELEVATION	3200	3192	3180	3165	3149	3132	3117	3100	3082	3066	3046	3033	3015	3004	2993	2980	2970	2958	2946	2930	2923	2921	2920
DEPTH TO BEDROCK	51		57	66	75	72	96	102	114	117	135	129	126	123	117	102	87	84	60	81	75	60	54



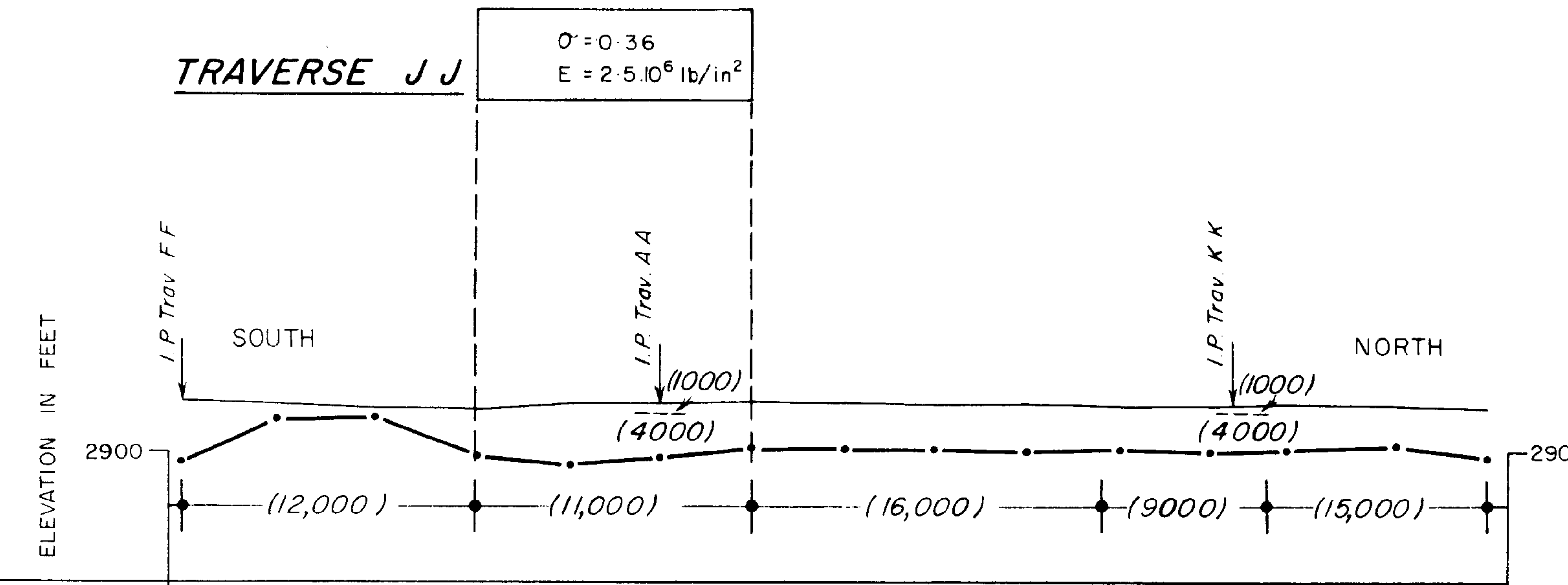
STATION NUMBER	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
STATION ELEVATION	2931	2934	2931	2935	2942	2944	2942	2938	2939	2940	2941	2942	2938	2943	2944
DEPTH TO BEDROCK	59	62	45	41	50	50	45	54	41	41	41	45	41	41	27



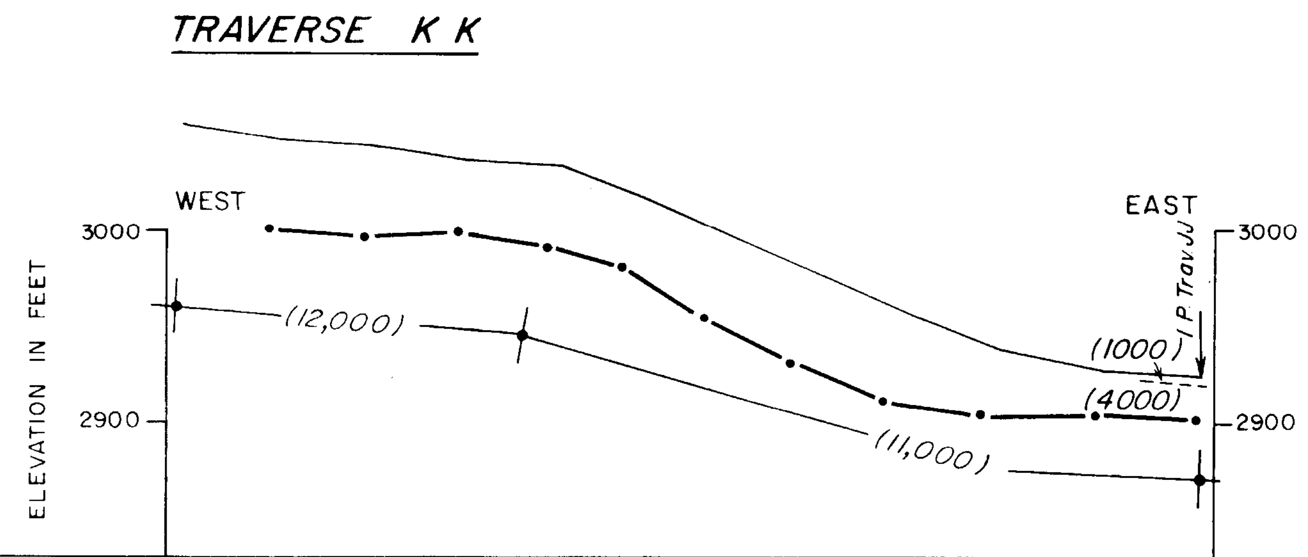
STATION NUMBER	9	8	7	6	5	4	3	2	1
STATION ELEVATION	2989	2996	3011	3027	3045	3063	3082	3102	3115
DEPTH TO BEDROCK	36	42	30	33	27	21	21	33	42



STATION NUMBER	12	11	10	9	8	7	6	5	4	3	2	1
STATION ELEVATION	2932	2928	2930	2928	2929	2944	2963	2973	2986	3004	3020	3036
DEPTH TO BEDROCK	45	30	24	24	30	36	51	42	42	42	48	33



STATION NUMBER	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
STATION ELEVATION	2927	2926	2923	2922	2926	2926	2927	2927	2926	2925	2924	2923	2924	2923	2922
DEPTH TO BEDROCK	33	9	6	27	33	30	24	27	24	24	24	24	24	21	27



STATION NUMBER	14	13	12	11	10	9	8	7	6	5	4	3
STATION ELEVATION	3054	3048	3043	3036	3032	3015	2993	2973	2952	2938	2928	2923
DEPTH TO BEDROCK		48	48	39	42	39	45	48	48	36	24	21

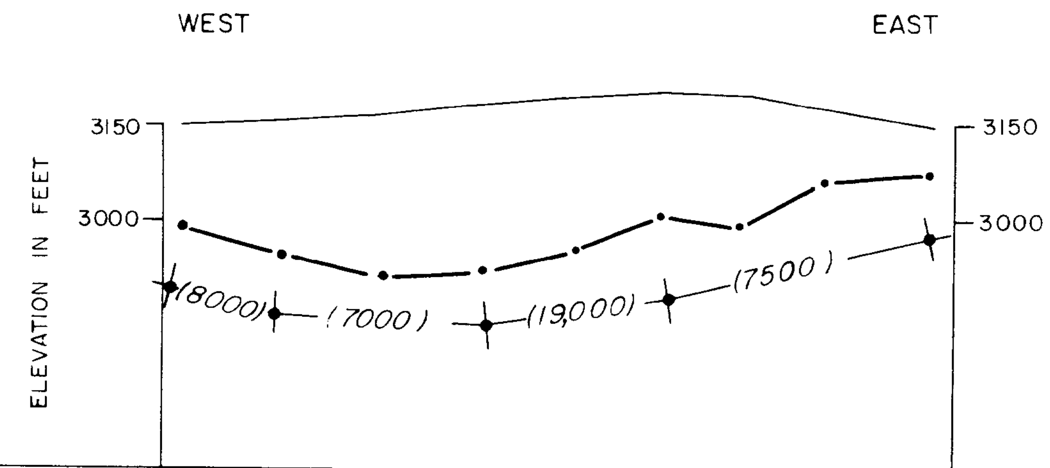
LEGEND

- (10,000) Seismic velocity (ft/s) in formation
- – – – Depth to formation with different seismic velocity
- •——• Unweathered bedrock boundary
- E Youngs modulus in lb/in² determined by dynamic method
- σ Poisson's ratio

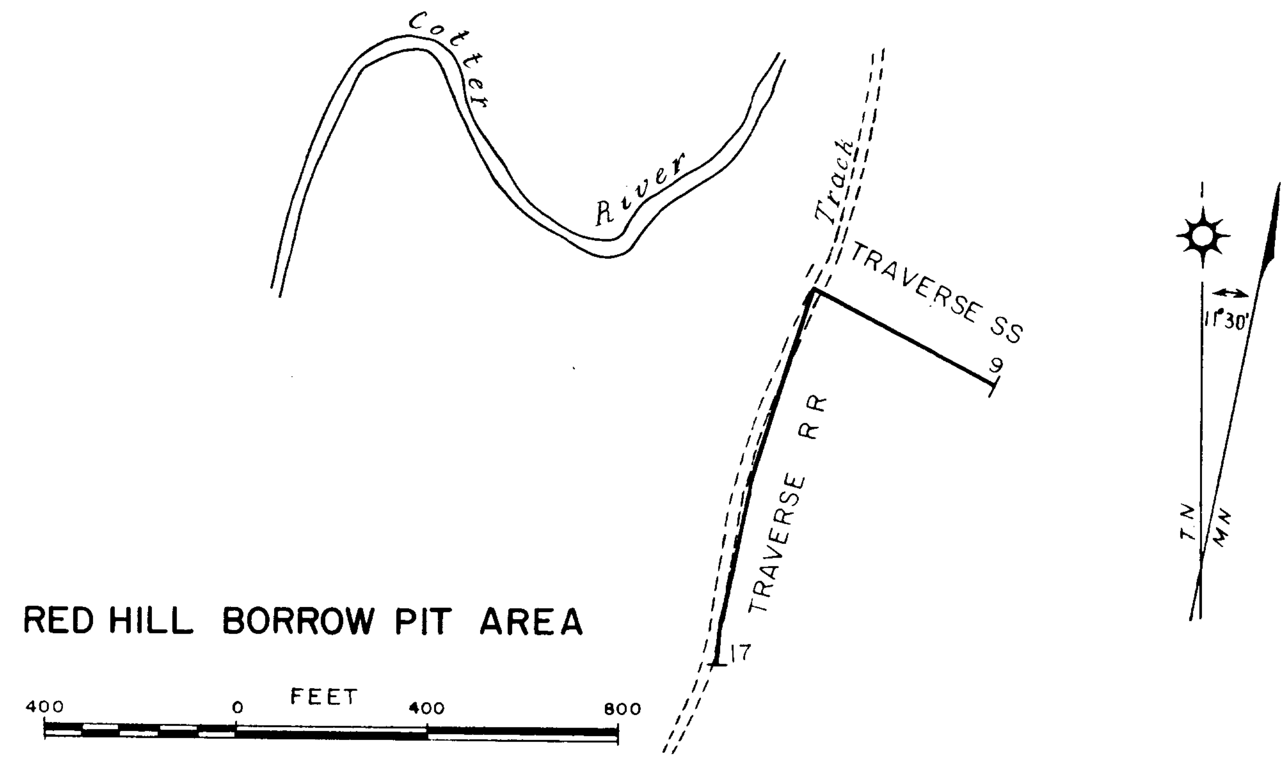
SEISMIC CROSS-SECTIONS
TRAVERSES HH to OO

FEET
100 0 100 200

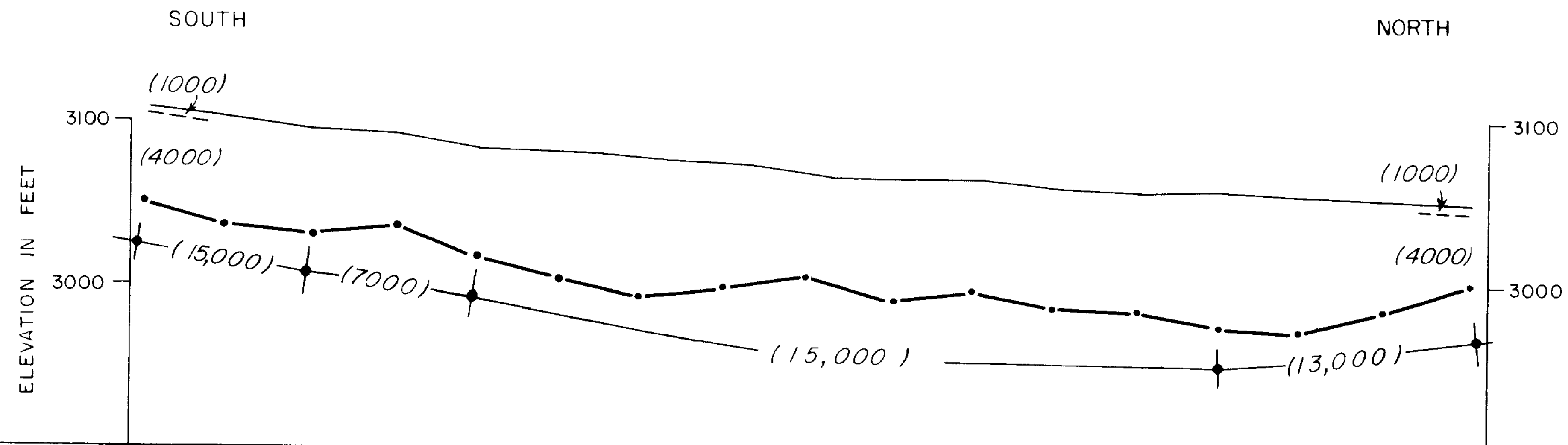
TRAVERSE SS



STATION NUMBER	1	2	3	4	5	6	7	8	9
STATION ELEVATION	3050	3052	3055	3060	3064	3068	3066	3058	3048
DEPTH TO BEDROCK	53	70	84	88	80	66	70	39	24



TRAVERSE RR



STATION NUMBER	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
STATION ELEVATION	3106	3100	3095	3090	3083	3081	3078	3073	3068	3063	3064	3060	3058	3059	3058	3052	3050
DEPTH TO BEDROCK	58	65	65	54	68	79	83	76	61	72	68	72	72	83	83	68	50

LEGEND

(7000) Seismic velocity (ft/s) in formation

--- Depth to formation with different seismic velocity

•——• Unweathered bedrock boundary

SEISMIC CROSS-SECTIONS

TRAVERSES RR AND SS

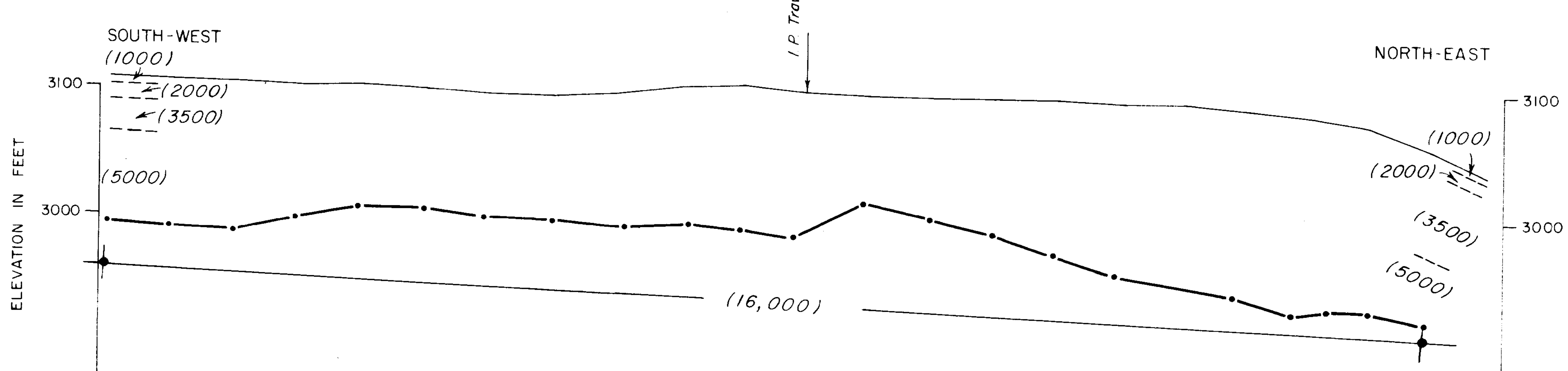
FEET 100 0 100 200

TO ACCOMPANY RECORD NO. 1966/30

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS I 55/B 5-27

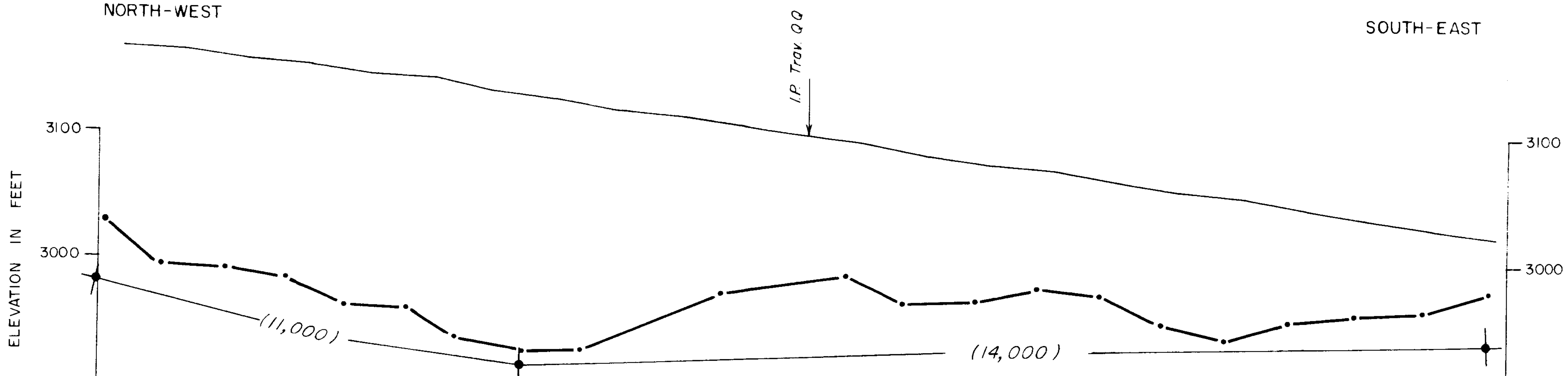
COTTER 'E' DAM SITE, CANBERRA, 1964

TRAVERSE Q Q

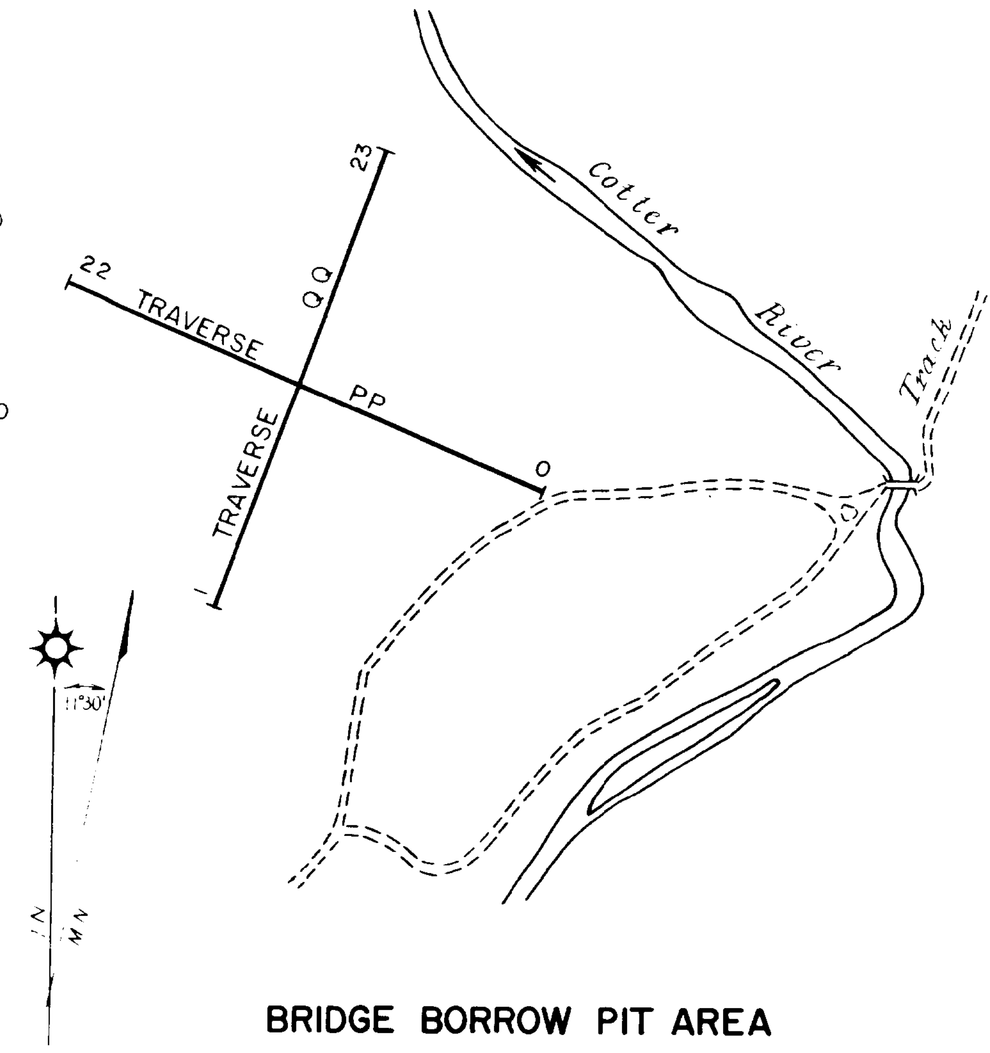


STATION NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
STATION ELEVATION	3107	3105	3104	3102	3102	3100	3097	3096	3098	3101	3103	3100	3098	3096	3096	3095	3092	3092	3087	3081	3073	3056	3037
DEPTH TO BEDROCK	114	114	118	102	97	94	97	97	104	108	112	115	83	96	108	122	136		148	158	148	136	126

TRAVERSE P P



STATION NUMBER	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
STATION ELEVATION	3166	3163	3156	3152	3146	3142	3132	3126	3118	3113	3106	3100	3092	3083	3078	3072	3064	3057	3051	3042	3036	3029	3021
DEPTH TO BEDROCK	136	170	164	170	182	182	198	200	190		132		104	120	108	94	90	105	112	90	76	65	43



BRIDGE BORROW PIT AREA

FEET 400 0 400 800

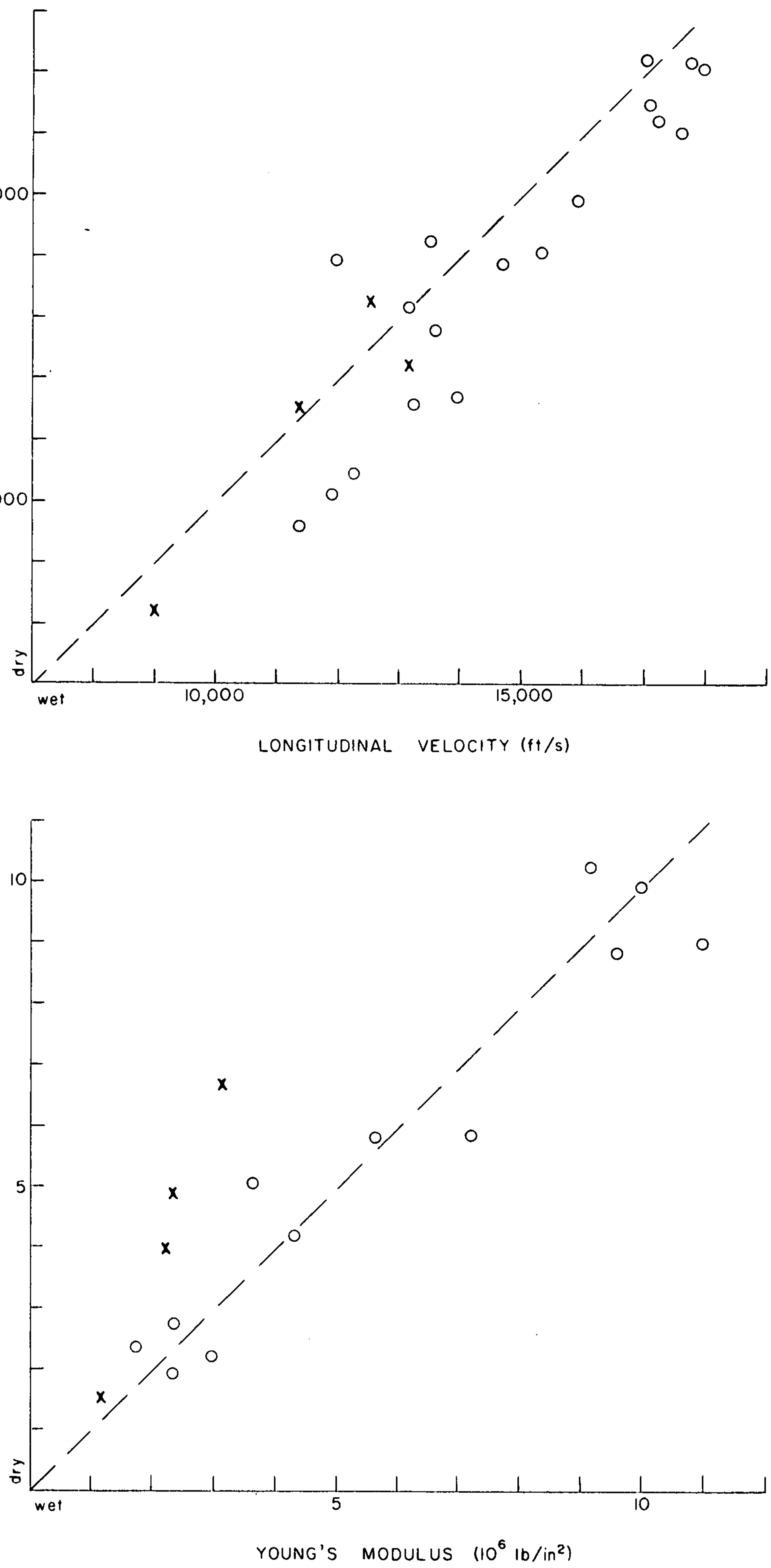
LEGEND

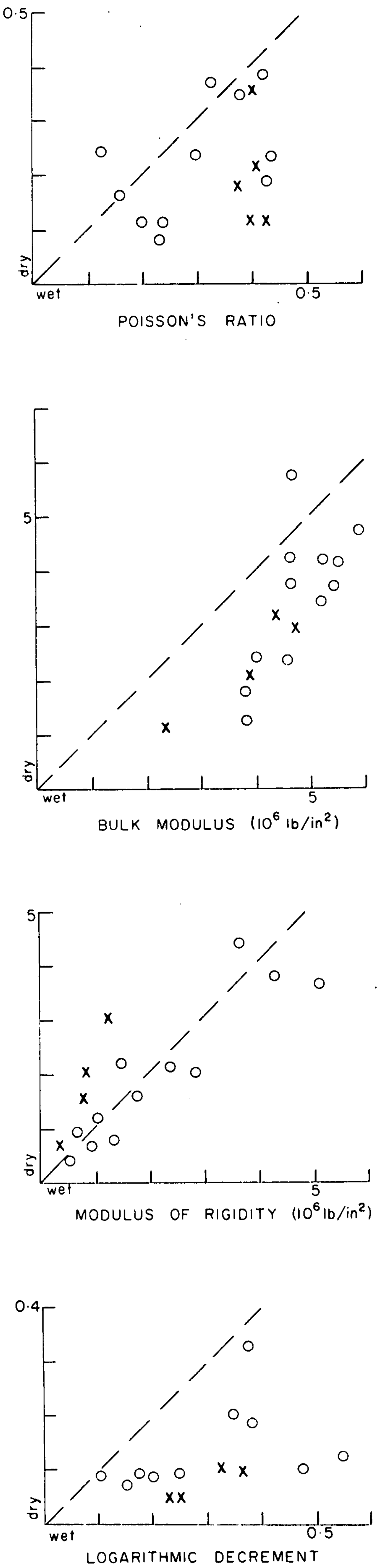
(5000)	Seismic velocity (ft/s) in formation
– – –	Depth to formation with different seismic velocity
•——•	Unweathered bedrock boundary
I.P.	Intersection point

SEISMIC CROSS-SECTIONS
TRAVERSES PP AND QQ

FEET 100 0 100 200

TO ACCOMPANY RECORD NO. 1966/30
GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS I55/B5-28

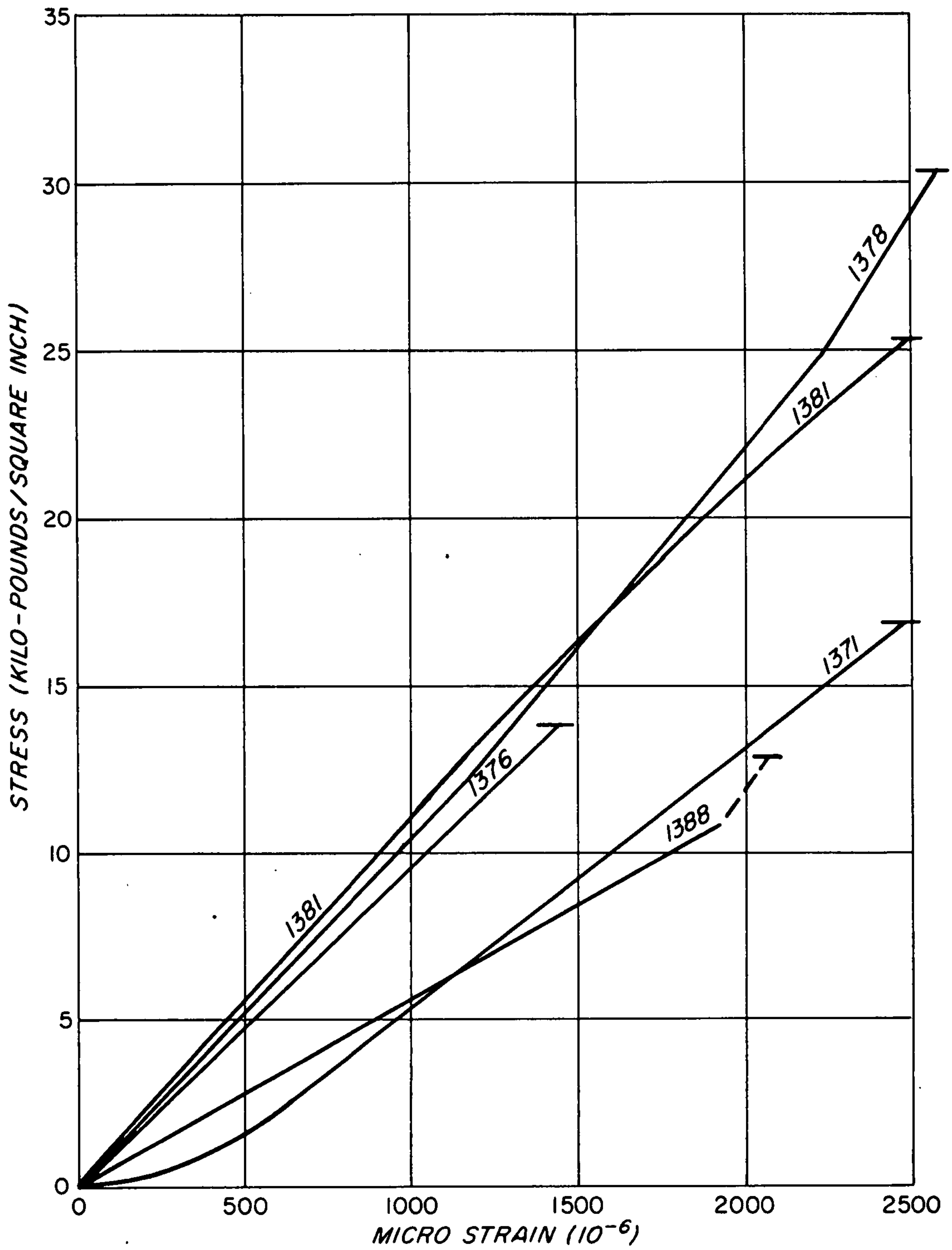




COTTER DAM SITE 'E'
COMPARISONS OF PROPERTIES OF ROCKS
MEASURED IN DRY AND WET STATES
(DYNAMIC MEASUREMENTS)

○ Sandstone

X Siltstone



SAMPLE NUMBER	1378	1376	1371	1381	1388
ULTIMATE STRENGTH (lb/in^2)	30,300	13,780	16,750	25,040	12,770
POISSON'S RATIO	0·21	0·12	0·39	0·16	0·16
YOUNG'S MODULUS (lb/in^2)	$10{\cdot}5 \times 10^6$	$9{\cdot}5 \times 10^6$	$7{\cdot}7 \times 10^6$	$10{\cdot}5 \times 10^6$	$5{\cdot}5 \times 10^6$

NOTE: Initial tangent modulus is quoted except for sample 1371 for which the curve up to a micro-strain of 300×10^{-6} is ignored.

COTTER DAM SITE 'E'

STRESS-STRAIN CURVES

To Accompany Record No. 1966/30

Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

I55/B5-37