COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

 Record No. 1970 / 32

Jervis Bay Power Station Site Seismic Refraction Survey, A.C.T. 1970

by

E.J. Polak and P. Hill

Record No. 1970 / 32

Jervis Bay Power Station Site Seismic Refraction Survey, A.C.T. 1970

by

E.J. Polak and P. Hill

CONTENTS

ILLUSTRATIONS

SUMMARY

At the request of the Australian Atomic Energy Commission, the Bureau of Mineral Resources, Geology & Geophysics conducted a seismic refraction survey on the site chosen for construction of a nuclear power station.

The purpose of the survey was to determine the foundation conditions at the site and the properties of the rocks in relation to excavation methods and support of the proposed structures.

The bedrock of the area consists of Permian sandstone (Jervis Bay Sandstone) overlain in places by unconsolidated Quaternary beach and dune sands. During the seismic work it was found that the sandstone beds have a relatively wide range of seismic velocities; often a higher-velocity bed overlies a lower-velocity bed, and this makes seismic refraction work difficult and less accurate. This is confirmed by laboratory measurements of seismic velocities on drill cores. Thin beds of higher- and lower-velocity sandstones occur, some too thin to be resolved by the seismic method. The seismic profiles presented must be considered bearing in mind these difficulties. Material sufficiently consolidated for foundations is shallow, and the seismic velocities indicate that some blasting will be necessary to excavate to the desired depth of 10 feet above mean high water level.

1. INTRODUCTION

The Australian Atomic Energy Commission (AAEC) proposes to construct a nuclear power station at Jervis Bay, ACT, and the Electricity Commission of New South Wales has been entrusted with the site investigation. Investigations of the foundation conditions were made in 1969 and 1970. These consisted of diamond drilling by the Electricity Commission of NSW, a reconnaissance geophysical survey by the Engineering Geophysics Group of the Bureau of Mineral Resources (Taylor, 1969), and an offshore seismic sparker survey by the University of NSW (Carter et al., 1969). During this time two possible sites were investigated, but on the basis of the 1969 investigations the Murray Beach area was chosen as the site for the power station.

Following this decision a detailed seismic refraction survey was made on the Murray Beach site by the Engineering Geophysics Group of the Bureau of Mineral Resources between 12 January and 15 February 1970. The party consisted of: E.J. Polak and P. Hill, geophysicists; G. Jennings, technical officer; R. Cherry and S. Hall, field assistants; and four field hands provided by the AAEC, which also carried out topographical surveying.

The area investigated and the layout of traverses are shown in Plate 1. Traverses SL1 to SL4, SD1, and ST1 to ST10 cover the site for power station buildings; Traverses OC1 to OC3 and all T traverses have been laid out along possible routes for channels to carry coolant sea water through the power station.

2. GEOLOGY

The geology of the area was investigated by J.P. McGregor of the Electricity Commission of NSW (McGregor, pers. comm.) and by geologists of BMR (Jackson, 1969). A short description of the geology of the area was given in the BMR Record that described the reconnaissance geophysical survey (Taylor, 1969). The bedrock in the area is Jervis Bay Sandstone of Permian age. The sandstone consists of several layers of rock differing from each other in texture, composition, compaction, and colour. Each layer has different physical properties which greatly influence the geophysical results (Plate 2). This aspect will be discussed fully in Chapters 3 and 4 of this Record.

The geological interpretation of the drilling results has been done by J.P. McGregor, who recognises several types of rocks and classifies them, on visual examination, into three groups according to the degree of weathering. These are shown as 1, 2, and 3 in the plates. In Plate 3, logs of three boreholes showing McGregor's geological interpretation are compared with seismic velocities measured on cores in the BMR laboratories. The differences in velocity are small and apparently unrelated to the degree of "weathering".

3. EQUIPMENT AND METHODS

In the survey two identical 24-channel SIE seismic refraction sets were used in series giving a spread length of 460 feet (48 channels), the geophone for the last channel of one set being located at the same position as the geophone for the first channel of the second set.

One of the conditions normally encountered on seismic refraction surveys, and which simplifies the problem, is that the seismic velocities of the rock layers increase with depth. This is not the case at the Jervis Bay site.

Plate 2 shows a time/distance curve (T/D curve) obtained on the survey (Traverse ST-1; 0-420 feet). The time of arrival of the seismic wave at the geophones is plotted against the distance from shot to geophones. A best-fitting curve is then plotted through all the points, and the reciprocal of the gradient of the slope gives the seismic velocity in the layer. The "stepped" character of the T/D curve (Leet, 1950) indicates the inversion of the seismic velocity with the depth. The diagrammatic representation of the seismic ray paths (disregarding refractions crossing boundaries) is shown under the T/D curve in Plate 2.

The inversion of seismic velocities is also shown in Plate 3 on drillholes D17 and D19, where a bed with seismic velocity 5020 feet per second is shown sandwiched between higher-velocity rocks. The velocities shown were measured on cores in the laboratory, using ultrasonic equipment.

Some of the points on the T/D curve are located away from the best-fitting curve, and these are marked in Plate 2 with letters A and B. These points are the results of local changes in the structure of rocks, and thus:

A - May indicate thickening of the upper layer of rocks.

B - May indicate thinning of the upper layer of rocks. This may be the result of either a land surface depression, uplift of the refractor, or the existence of a pocket of faster-velocity rock in the upper layer.

To be able to recognise reversal of seismic velocities and discontinuities in structure, the geophones in the survey were placed 10 feet apart, but as pegging and topographic surveying was done at 50-foot intervals the depth determinations were made only at the spacing of 50 feet. More detailed determination could be made in areas of special interest if additional levels were supplied.

In the interpretation the "method of differences" was used (Heiland, 1946), the same method as was used in the reconnaissance survey (Taylor, 1969).

4. RESULTS

Plate 1 shows the location of the geophysical traverses, and the seismic cross-sections along the traverses are shown in Plates 4 to 12. The symbols used in these plates are explained in the legend included in each plate. The elevation is in feet, and zero elevation represents mean high water at St Georges Basin.

Seismic velocities

In the seismic sections two broad categories of rocks can be resolved on the basis of seismic velocities: (1) unconsolidated deposits, and (2) consolidated rocks.

Unconsolidated rocks. Unconsolidated rocks consist of beach, dune sand, and marsh deposits. Their seismic velocities are low. The uppermost layer has a characteristic velocity of 1000 ft/s, and underneath there is generally a layer of 1400- to 2000-ft/s material which is slightly more compacted sand.

The underlying layers with velocities between 2000 and 3000 ft/s may represent compacted and/or cemented sands or, where the velocity is close to 3000 ft/s, weakly consolidated rocks.

Consolidated rocks. Consolidated rocks are characterised by seismic velocities between 4000 and 14,000 ft/s. However, there may be exceptions in certain low-lying areas, where a velocity of 5000 ft/s may indicate sand fully saturated with water. In these areas it is impossible to decide the character of the beds from their seismic velocities: e.g. on Traverse SL1 (500 to 600 ft), ST1

(0 to 400 ft), and SL3 (0 to 300 ft).

The beds of sandstone indicating a seismic velocity of over 6000 ft/s may really represent a laminated rock of thin layers of alternate higher and lower velocity, since so long as the layers are thin the beds will be characterised by a mean velocity for the section. With an increase in thickness of these layers separate beds become "visible", the stepped character of the T/D curve is obtained, and the velocity measured will be a true velocity of the rock (White, 1965).

Velocity anisotropy was clearly shown on several traverses, e.g. OC3 - T10 and T11, OC1 - T10 and T11.

Depth determination

The thickness of the low-velocity unconsolidated material can be determined from seismic data with a high accuracy at the locations of the shots. These positions are indicated in Plates 4 to 12, which show complete sections with velocities. Extrapolation between shot-points cannot be made, since depth to bedrock is so variable along the traverses.

The reversal of seismic velocity with depth makes the depth determinations in the consolidated rock less reliable, and it is probable that some beds have been completely missed because they were too thin to transfer enough energy to be picked up by the geophones. This may be indicated on the seismic traverses by a sudden change in the depth to the main refractor which, after being recorded for some distance, has been missed because it is probably now included as a thinner bed in a section characterised by only a medium average velocity. Also, from discrepancies in depth at the intersection points of seismic traverses it is evident that refractions from different beds have been followed. The seismic velocity anisotropy in these beds has further complicated interpretation and made correlation between intersecting traverses more difficult.

Plates 4 to 12 should be looked at with these comments in mind. The heavy line representing the depth to the main refractor does not necessarily represent depth to a particular bed; in fact the refractor followed may cross from one bed to another depending on conditions such as those discussed above. Where such crossovers almost certainly occur, breaks have been left in the line representing depth to the main refractor. In making use of these plates consideration should also be given to the actual recorded velocities above and below the main refractor and the velocities recorded at adjacent shot-points.

Character of the rocks

The rippability of the rock. Information on the rippability of rocks in relation to their seismic velocities is very scarce, the guide most often used in practice being a table prepared by the Caterpillar Tractor Company for use with their Caterpillar D9 with a hydraulic No. 9 ripper. According to their table a sandstone with velocities up to 8400 ft/s should be rippable without blasting.

The sections in Plates 4-11 show that there are sandstone layers characterised by a velocity higher than 8400 ft/s more than 10 feet above mean high water level (the limit of excavation for the power station), and therefore explosives would have to be used to fracture the rock before excavation.

The provision of a hydraulic ripper seems very important as a beach-deposited sand, when consolidated into sandstone, has a thin hard skin which is especially resistant to scraping.

The anisotropy in the sandstones may also mean that the rippability may vary in different directions.

The supporting qualities of rocks. The estimation of compressive strength of a rock from its seismic velocity has been done for igneous and metamorphic rocks, but so far as is known by the authors it has not been done for low-velocity sandstones such as those found at Jervis Bay. However, the following comments can be made from surveys within the experience of the Engineering Geophysics Group of BMR:

When investigating foundations for the Upper Repulse Dam in Tasmania, a sandstone with velocity 7500 ft/s was considered strong enough to support the dam.

In the construction of the Batman Bridge on the Tamar River, Tasmania, lake deposits consisting of thin beds of sandstone, mudstone, and siltstone with velocities of less than 6000 ft/s were not considered good enough to support the bridge on piles driven into these beds. The bridge was therefore suspended from an A-frame anchored in dolerite, which crops out on one bank of the river.

Rock as material for a breakwater. The 11000-ft/s sandstone is not readily available on the site, since it is too deep to excavate. The lower-velocity rock would not stand up to the weather and wave action of a breakwater environment.

5. CONCLUSIONS

The survey has shown that the rock in the surveyed area consists principally of: unconsolidated rocks with velocities below 2000 ft/s; and consolidated sandstone with velocities between 3000 and 14,000 ft/s. Blasting will have to be used to excavate material on both the power station site and the channel lines.

Rock strengths as indicated by seismic velocities are marginal over much of the area, for material that may have to support heavy loads. There is also considerable variation in velocities both horizontally at the proposed depth of excavation and vertically. In view of this, use of in situ load tests may be advisable, particularly in areas where seismic velocities are low. The possibility of differential settlement under load should also be considered.

Rock suitable for construction of a breakwater is below the planned excavation depth.

6. REFERENCES

CARTER, A.N., ALBANI, A.D., and JOHNSON, B.D., 1969 - Bedrock topography in south eastern Jervis Bay. University of NSW, unpublished report.

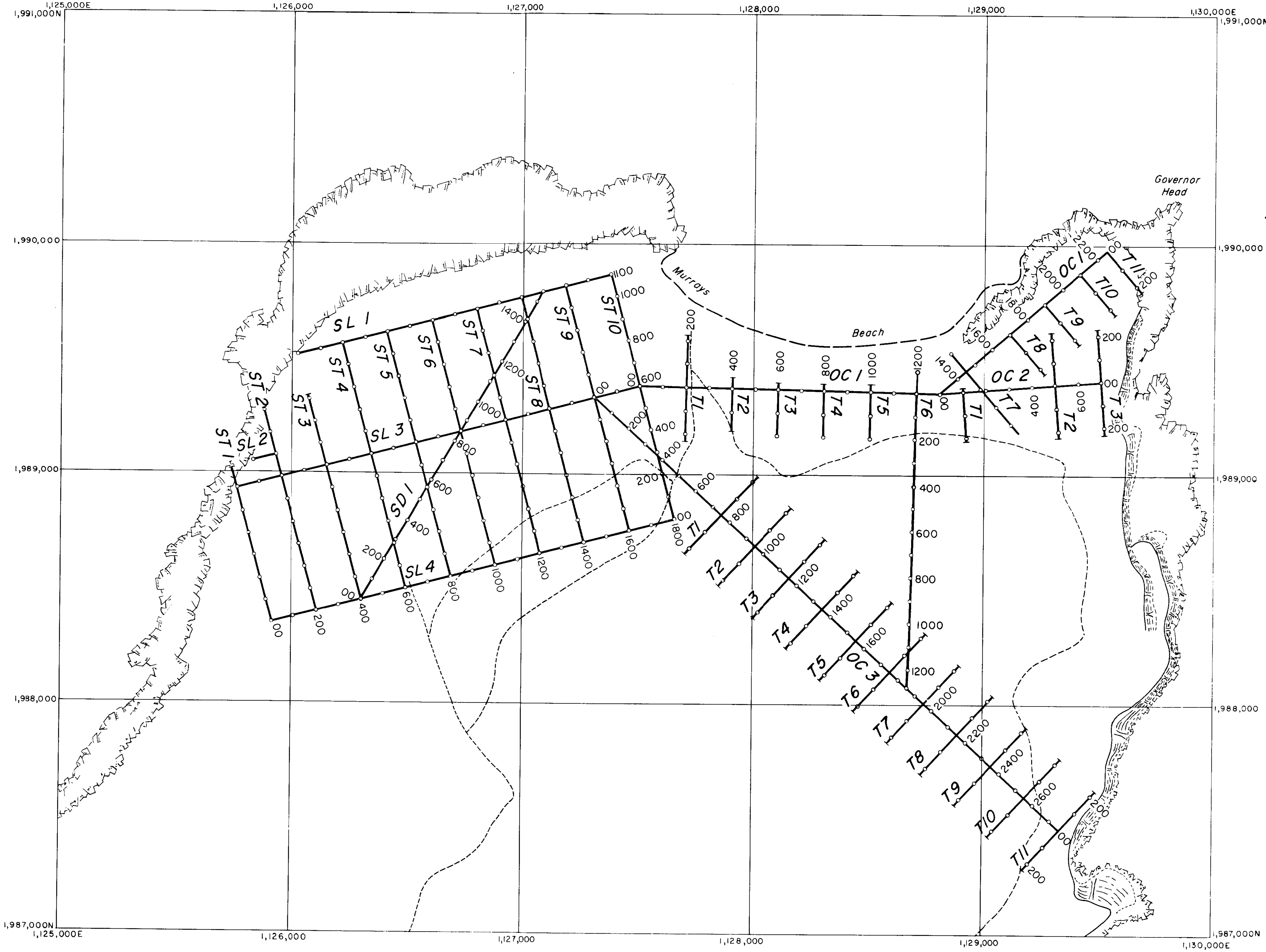
HEILAND, C.A., 1946 - GEOPHYSICAL EXPLORATION. New York, Prentice Hall Inc.

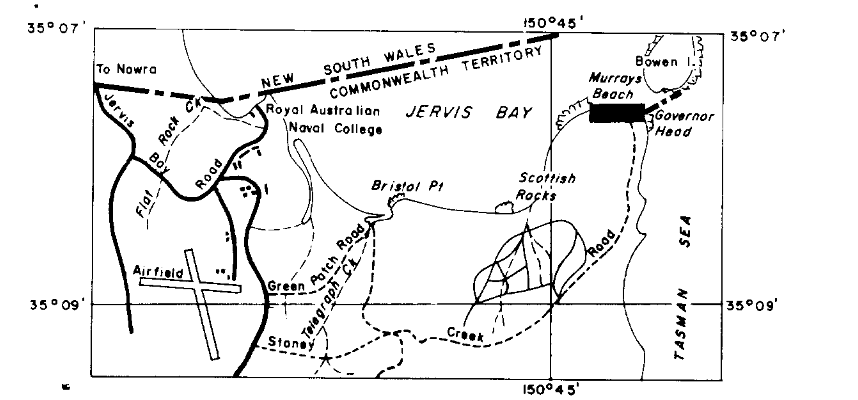
JACKSON, M.J., 1969 - Engineering geology and economic resources of Commonwealth Territory, Jervis Bay. Bur. Min. Resour. Aust. Rec. 1969/88 (unpubl.).

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

TAYLOR, F.J., 1970 - Jervis Bay reconnaissance seismic survey, A.C.T. 1969. Bur. Min. Resour. Aust. Rec. 1969/146 (unpubl.).

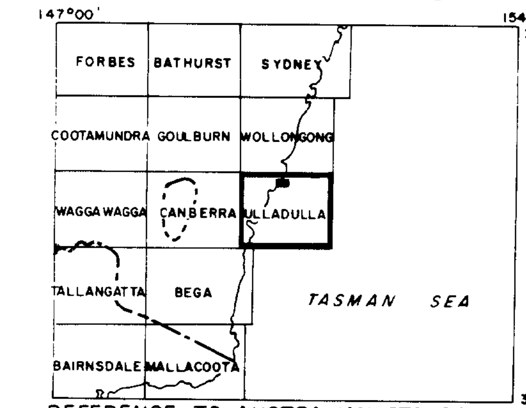
WHITE, J.E., 1965 - SEISMIC WAVES, RADIATION, TRANSMISSION AND ATTENUATION. New York, McGraw Hill.





LOCALITY MAP

SCALE: 2 1 0 2 MILES; 3 2 1 0 2 KILOMETRES



REFERENCE TO AUSTRALIAN STANDARD 1:250,000 MAP SERIES

Co-ordinates are in feet and are based on the Australian National Grid Zone 8

LEGEND

- Rock
- Cliff
- Track
- Geophysical traverse
- 1200 Chainages in feet

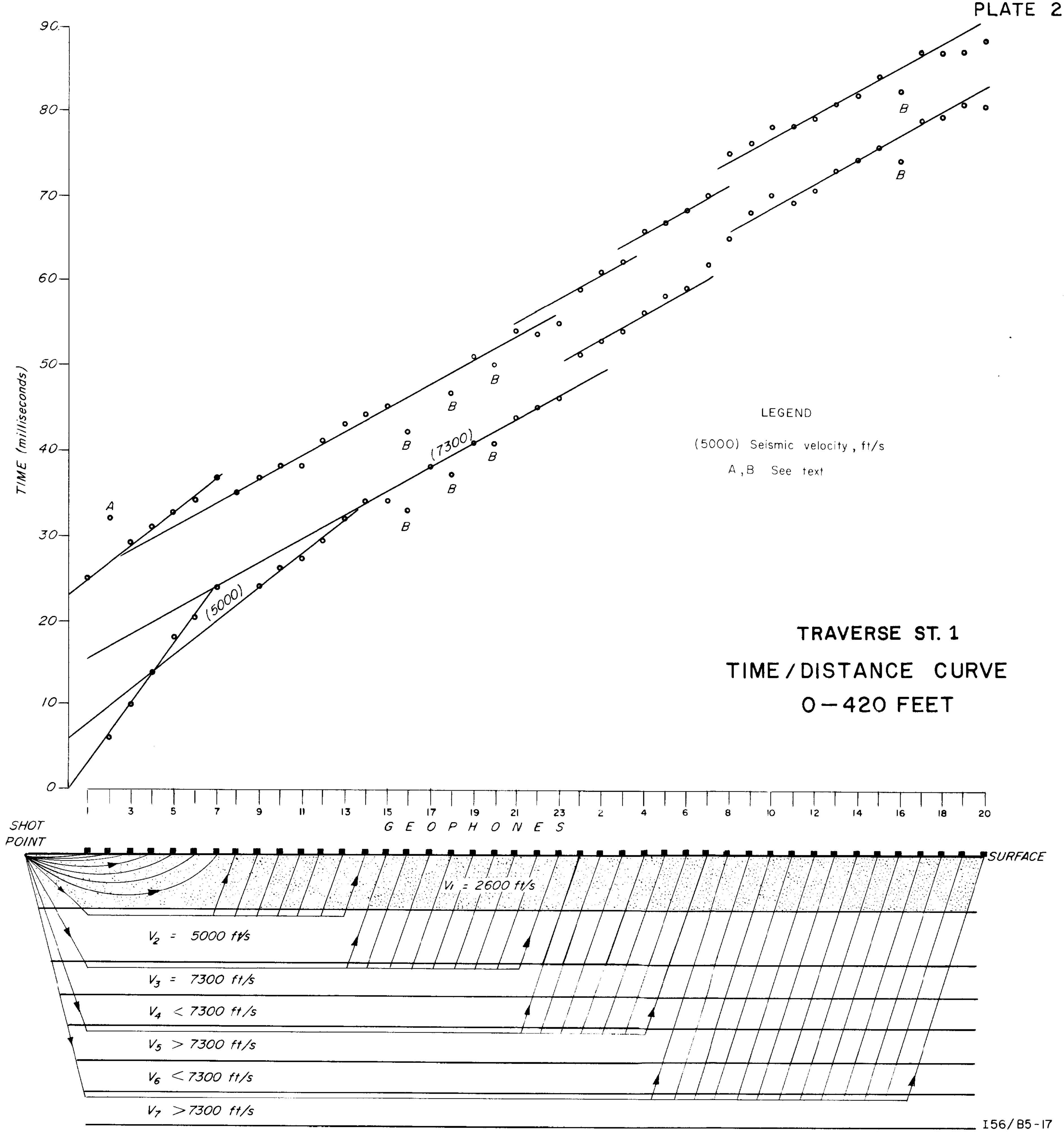
JERVIS BAY A C T
SEISMIC SURVEY 1970
FOR A POWER STATION SITE
LOCALITY MAP AND TRAVERSE LAYOUT

SCALE: 400 200 0 400 800 1200 FEET; 100 50 0 100 200 300 METRES

To Accompany Record No. 1970/32

I56/B5-16

PLATE 2



TRAVERSE ST. 1

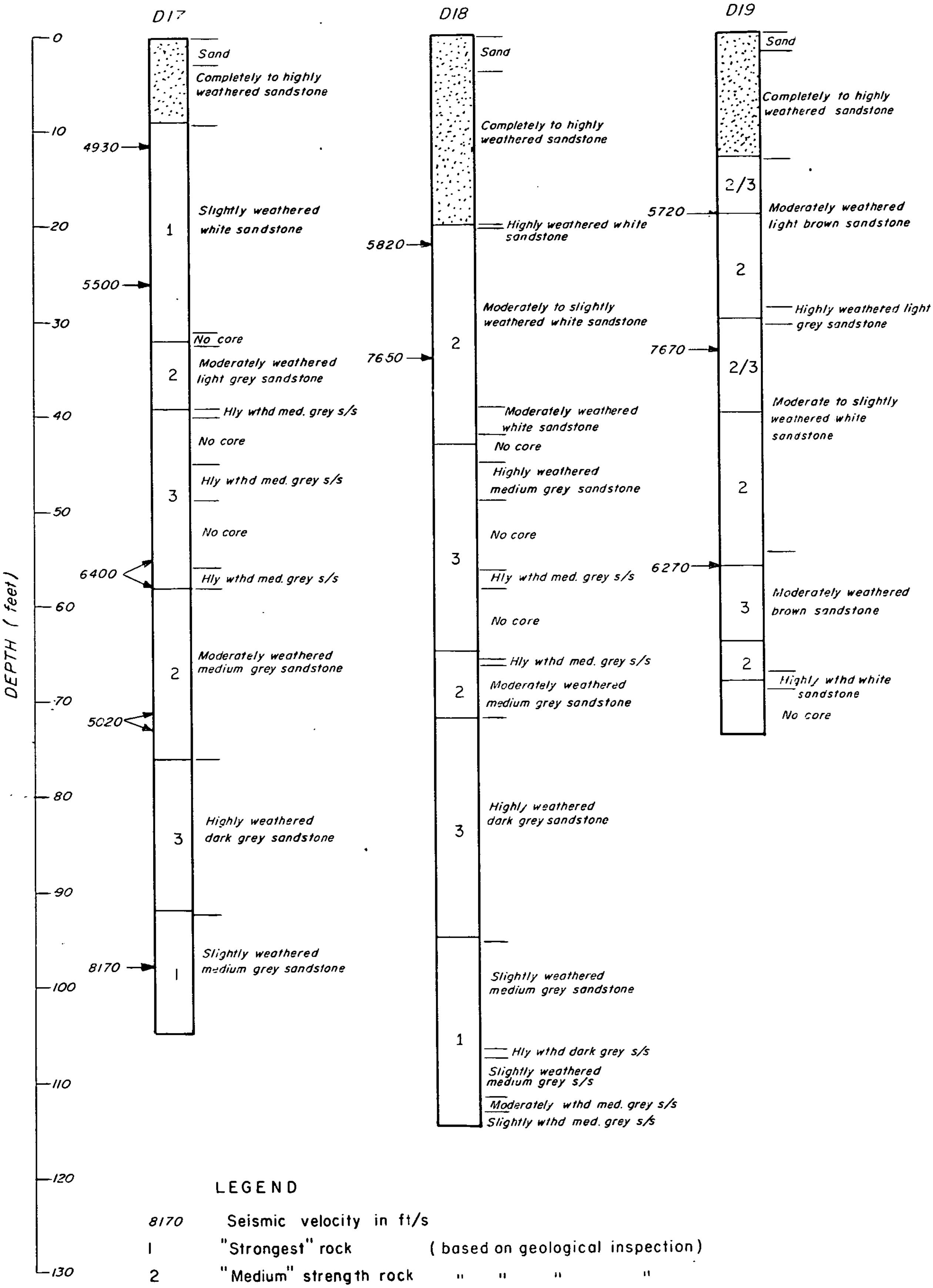
TIME / DISTANCE CURVE

0 – 420 FEET

I56/B5-17

To Accompany Record No. 1970/32

PLATE 3



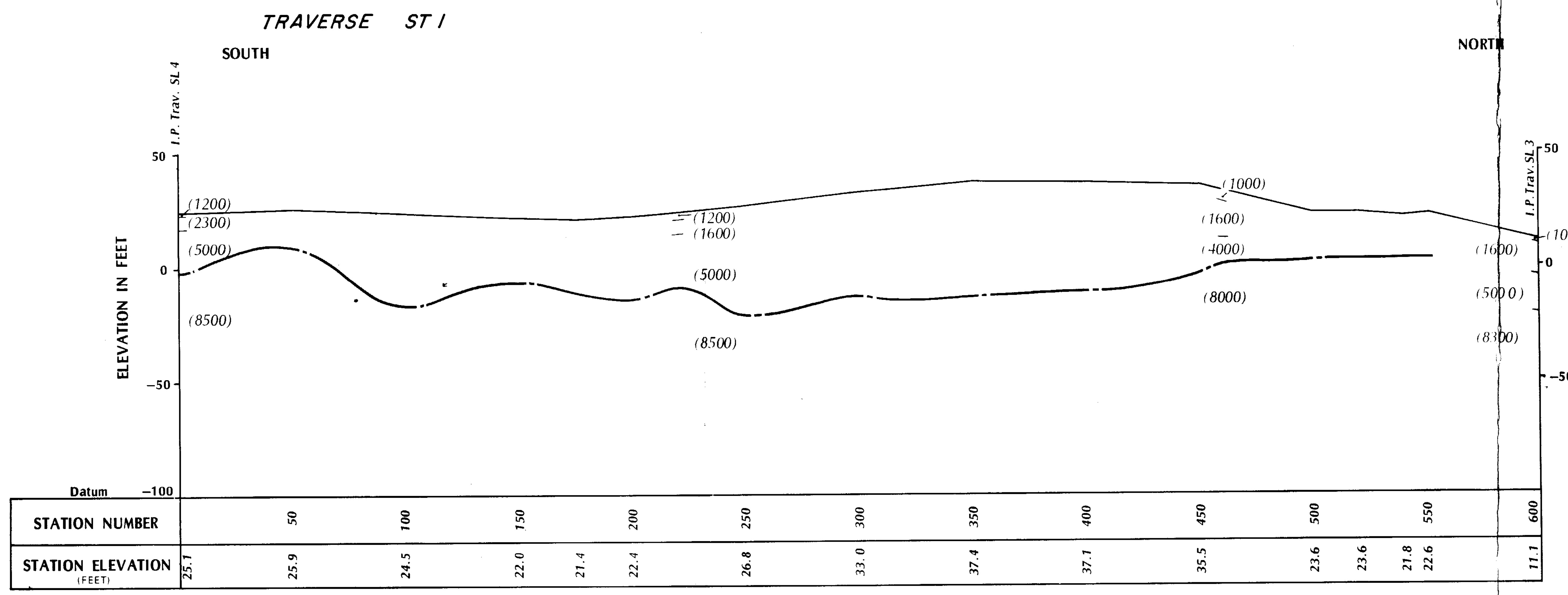
LEGEND

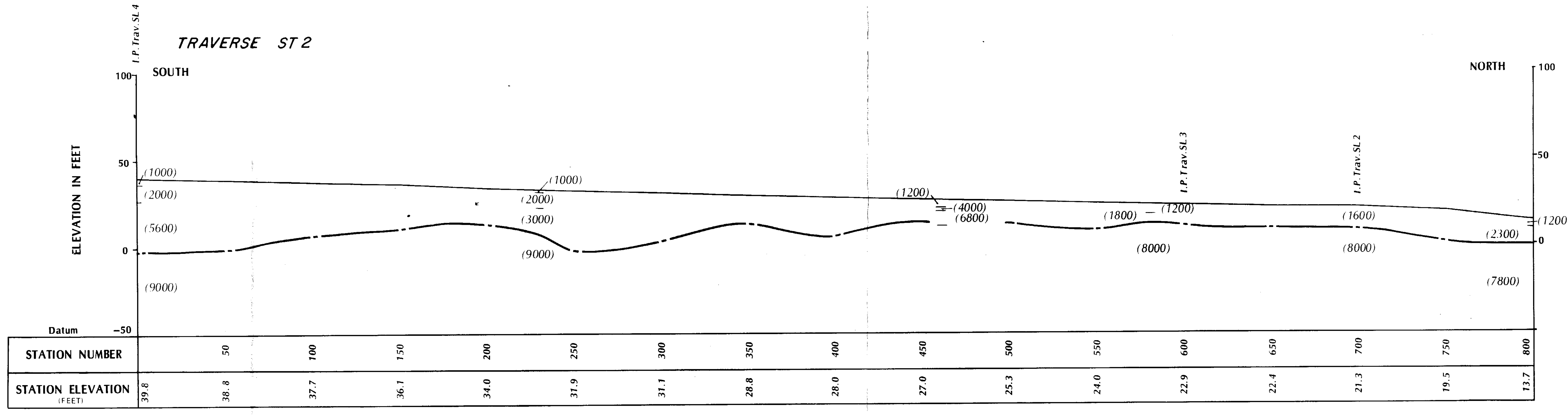
8170	Seismic velocity in ft/s	
1	"Strongest" rock	(based on geological inspection)
2	"Medium" strength rock	" " " "
3	"Poorest" rock	" " " "

BOREHOLE SECTIONS AND LABORATORY MEASURED PROFILES

To Accompany Record No. 1970/32 I 56/B5 – 18 A


PLATE 4
TRAVERSE SL1
WEST
EAST
ELEVATION IN FEET
Datum
STATION NUMBER
STATION ELEVATION (FEET)
500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800
14.1 18.5 22.2 20.9 21.2 19.9 20.8 21.5 22.2 21.8 22.3 22.4 22.9 23.0 23.0 24.2 24.9 24.4 24.1 25.2 29.4 35.0 40.4 46.8 52.6 59.8 63.4 61.4
TRAVERSE SL 2
WEST
EAST
100 150 200
3.5 13.9 18.6 21.3
LEGEND
(2000) Seismic velocity in ft/s
I.P. Trav. Traverse intersection point
Unweathered bedrock boundary
Formation with different seismic velocity
D15 Drillhole
Sand
N/C No core
1 Strongest rock (based on geological inspection)
2 Medium strength rock (based on geological inspection)
3 Weakest rock (based on geological inspection)
TRAVERSES SL1, SL2, and SL3
SEISMIC CROSS-SECTIONS
FEET
METRES
TRAVERSE SL 3
WEST
EAST
ELEVATION IN FEET
Datum
STATION NUMBER
STATION ELEVATION (FEET)
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500 1550 1600 1650 1700 1750 1800
11.7 21.3 24.7 23.7 21.5 20.6 22.0 22.9 23.0 24.7 25.9 26.8 26.9 27.7 30.1 31.8 34.2 35.9 37.8 38.3 36.8 36.2 35.8 36.4 36.7 37.9 37.4 38.2 38.2 38.3 38.2 39.7 39.9 39.8 38.5 37.7 36.0 35.3 33.5 33.0
To Accompany Record No. 1970/32
156/B5-19





LEGEND

(20,000)	Seismic velocity in ft/s
I.P. Trav.	Traverse intersection point
—·—	Unweathered bedrock
- - -	Formation with different seismic velocity
D7	Drillhole
	Sand
N/C	No core
1	Strongest rock (based on geological inspection)
2	Medium strength rock (based on geological inspection)
3	Weakest rock (based on geological inspection)

TRAVERSES SL4, ST1, and ST2
SEISMIC CROSS-SECTIONS

Scale: 50 0 50 100 150 200 FEET; 10 0 10 20 30 40 50 60 METRES

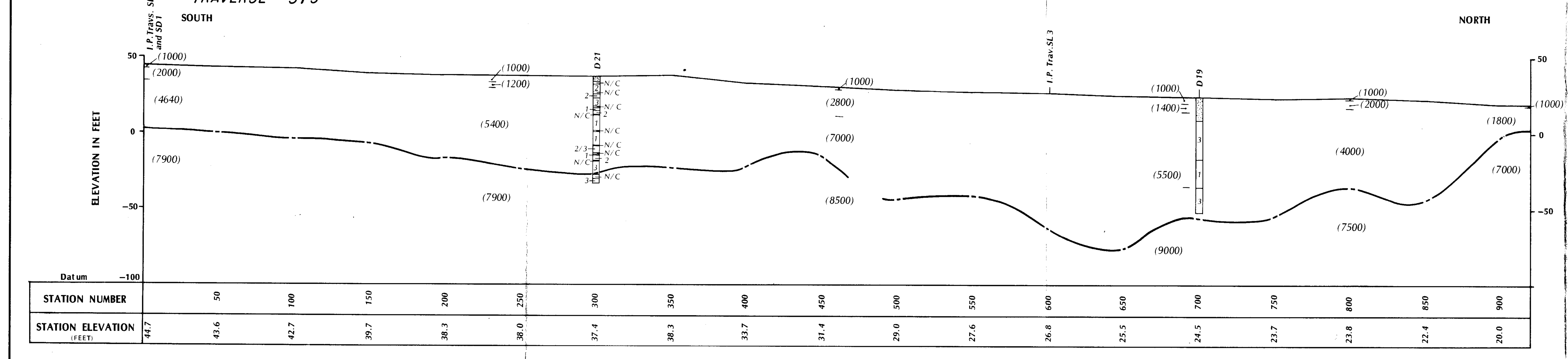
To Accompany Record No. 1970/32

156/B5-20

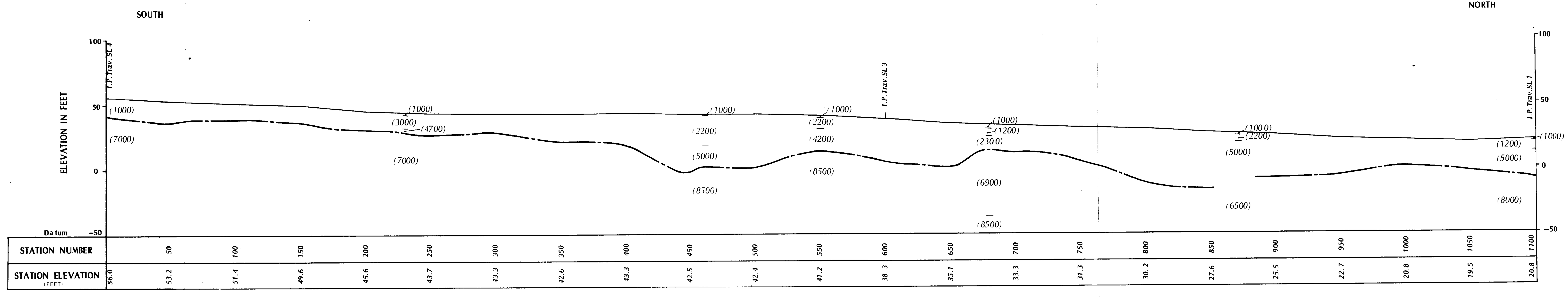
TRAVERSES ST 3 to ST 6

SEISMIC CROSS-SECTIONS

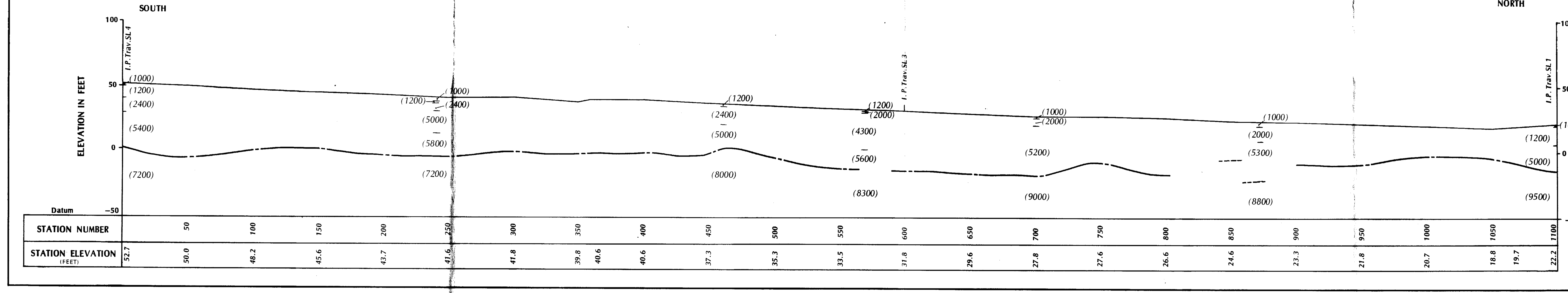
TRAVERSE ST3



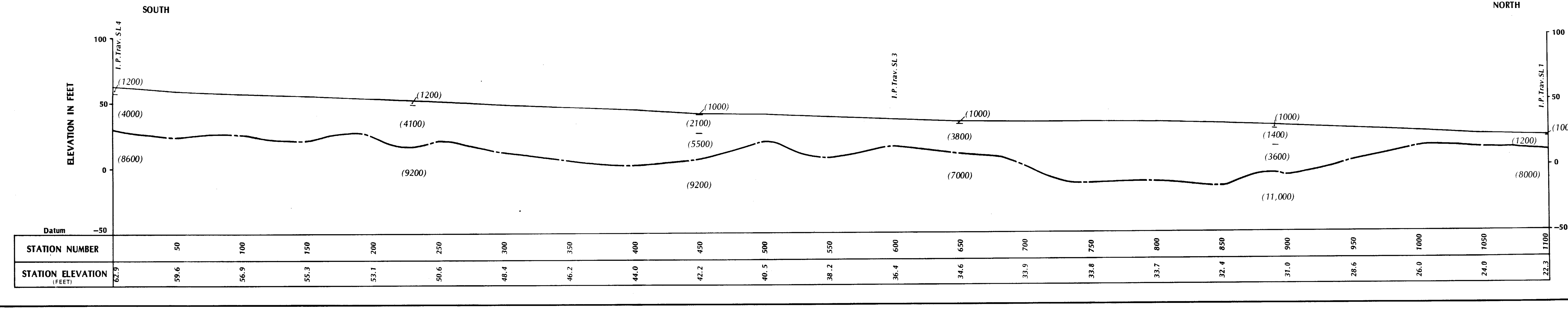
TRAVERSE ST5



TRAVERSE ST4

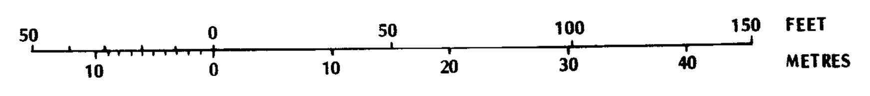


TRAVERSE ST6



LEGEND

(4200)	Seismic velocity in ft/s
I.P. Trav.	Traverse intersection point
—·—	Unweathered bedrock boundary
D 17	Drillhole
	Sand
1	Strongest rock (based on geological inspection)
2	Medium strength rock (based on geological inspection)
3	Weakest rock (based on geological inspection)

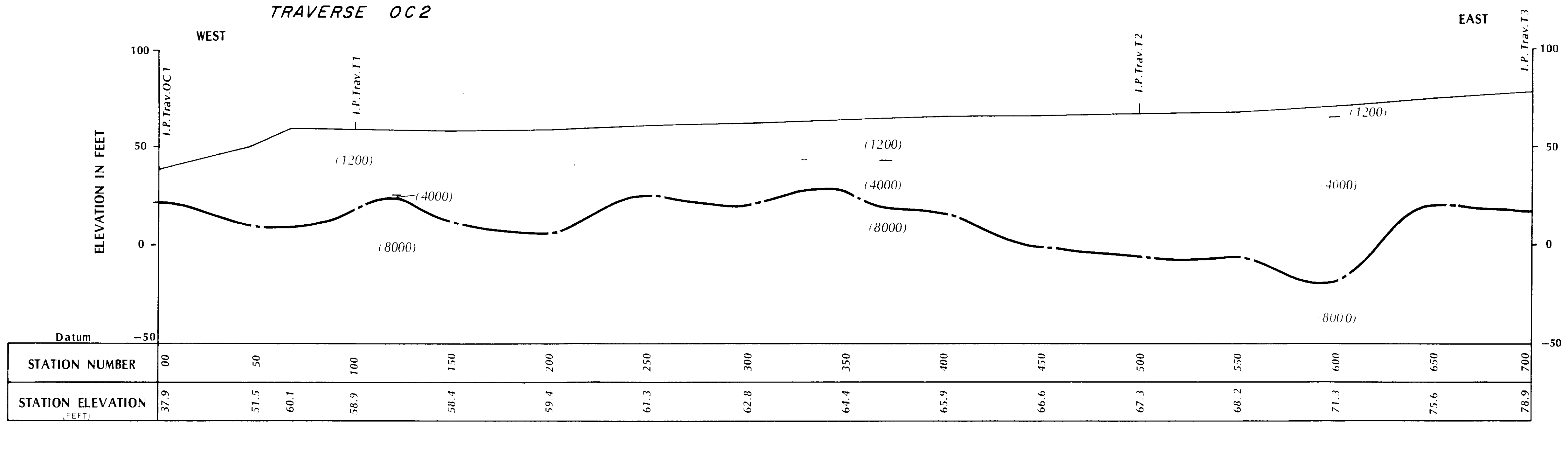


LEGEND

(2000)	Seismic velocity in ft/s
I.P. Trav.	Traverse intersection point
—·—	Unweathered bedrock boundary
D 17	Drillhole
	Sand
N. C	No core
1	Strongest rock (based on geological inspection)
2	Medium strength rock (based on geological inspection)
3	Weakest rock (based on geological inspection)

TRAVERSES ST7 to ST10
SEISMIC CROSS-SECTIONS

50 0 50 100 150 FEET
10 0 10 20 30 40 METRES



LEGEND

(2700) Seismic velocity in ft/s

I.P.Trav. Traverse intersection point

—·— Unweathered bedrock boundary

TRAVERSES OC2 and SD1

SEISMIC CROSS-SECTIONS

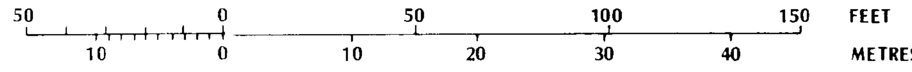


PLATE 9

To Accompany Record No.1970/32 156/B5-23

PLATE 10

TRAVERSES T1 to T6 (OCI)
SEISMIC CROSS-SECTIONS

To Accompany Record No.1970/32 156/B5-24

PLATE 11

TRAVERSES T7(OC1) to T11(OC1) and T1(OC2) to T3(OC2)
SEISMIC CROSS-SECTIONS

PLATE 12

TRAVERSES T1 to T11 (OC 3)

SEISMIC CROSS-SECTIONS

To Accompany Record No.1970/32

156/B5-26