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GEOPHYSICAL SURVEY OF THE WHIRLPOOL REACH BRIDGE SITE, TAMAR RIVER, TASMANIA.

by

E.J. POLAK and F.J. MOSS

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CONTENTS

ILLUSTRATIONS

ABSTRACT

Results are given of seismic refraction and of magnetic surveys conducted on the north-east bank of the River Tamar at Whirlpool Reach, the site of a proposed bridge. The survey was requested by the Department of Public Works, Tasmania, to assist in an assessment of the depth to a suitable foundation rock (bedrock) and of the extent of any unweathered basalt in the area.

Previous geological investigations indicated that the north-eastern bank consists of soft Tertiary sediments and decomposed basalt boulders. The seismic surveys give the depths of layers and the velocity of seismic energy in the various layers. The magnetic surveys assist in determining horizontal discontinuities in the rock types.

On the north-western section of the Main Traverse (Plate 1) rocks with a seismic velocity of about 6,500 ft/sec. which are probably Tertiary clays extend to a minimum depth of 190 feet. Towards the south-eastern end of the Main Traverse a higher velocity bed with a velocity of 11,000 ft. per second lies within 40 feet of the surface at one point.

1. INTRODUCTION

The Department of Public Works of Tasmania proposes to erect a bridge across the River Tamar to connect the East and West Tamar Highways. A site at Whirlpool Reach, some 7 miles south of Bell Bay Aluminium Works, was chosen for further investigations (see Plate 1 Inset).

The geology of the area was partly mapped by Mr.T.D.Hughes of the Mines Department, Hobart, (Hughes, 1957) and two boreholes and one test-pit have been put down.

The Department of Public Works requested the Bureau of Mineral Resources, Geology and Geophysics to conduct a geophysical survey to determine the depth to the bedrock on the north-eastern bank of the river.

The survey was done in February 1958 by a geophysical party consisting of E.J. Polak (party leader) and F.J. Moss, geophysicists. The Department of Public Works provided additional assistants and did the topographical surveying required.

2. GEOLOGY

At Whirlpool Reach the River Tamar is approximately 1,000 ft. wide. The left (south-west) bank of the river consists of dolerite either outcropping at the surface, or underlying a cover of boulders and soil no more than 5ft. in thickness. There is no difficulty in finding a good foundation there.

The right (north-east) bank of the river consists of Tertiary sediments of unknown thickness underlying soil, boulders and recent alluvium. Drill hole No. 1 near station 1200 on the Main Traverse (Plate 1) intersected 164 ft. of Tertiary sediments without penetrating them fully. The sediments are predominantly clays, which in a part of the drillhole showed considerable compaction. During the Tertiary period a basalt flow covered these sediments. The extent of the flow is not known as this basalt was subsequently partly eroded, leaving, in some places only, an accumulation of basalt boulders. There is no direct evidence of the types of rock underlying the Tertiary sediments. They may be pre-Tertiary sediments and/or dolerite. It is possible that basalt flows older than the one mentioned above may be interbedded with the Tertiary sediments or immediately underlie them.

3. METHODS AND EQUIPMENT

Seismic refraction and magnetic methods were used.

A. Seismic method.

The seismic method of exploration depends for its success on the degree of contrast between the velocities of propagation of seismic waves in the geological formations. A seismic wave source is produced by exploding a charge in the ground and the time taken for the wave to arrive at points at known distances from the source is measured. Hence velocities of propagation can be calculated.

Hard unweathered rocks have higher longitudinal wave velocities than their weathered counterparts. The velocity in soil and alluvial material is again considerably lower than in the weathered and fractured rock.

The seismic refraction technique employed was that known as the "method of differences" (Heiland, 1946, p.548).

The following types of geophone spreads were used :

(i) Weathering spread.

These were used to obtain seismic wave velocities in, and the thickness of, the soil and other near surface layers. Geophone interval was 10ft. and shot points were usually at distances of 10 and 100 ft. from both ends of the spread.

(ii) Normal spreads.

The usual geophone interval was 50 ft. and shot points were usually at distances of 50 ft. and 250 ft. or greater from each end of the spread.

The geophysical equipment in the survey consisted of a Midwestern twelve channel seismograph suitable for shallow reflection and refraction surveying and Midwestern geophones having a natural frequency of about 8 cycles per second.

B. Magnetic Method.

This method depends for its success on different rock types having different magnetic susceptibilities. The strength of the earth's magnetic field measured at the surface will depend on the magnetic susceptibility of the rocks present. Measurements of the magnetic field strength at the surface were made with a Watts vertical force variometer along selected traverses and the variations in magnetic intensity noted.

4. RESULTS

Three traverses, called the Main Traverse and Traverses A and B and totalling 4,400 feet in length were surveyed with both the seismic and magnetic methods. The traverses are shown on plate 1 and the results in the form of profiles and sections are shown on plates 2 and 3.

In the interpretation of the seismic results the following velocities were assumed as characteristic for different rock types.

Rock type	Velocity ft/sec.	Basis for Velocity Assumption.
Soil	1000 ± 100	measured on weathering spreads.
Soft Clays, decomposed basalt	2500 - 5000	measured near boreholes D2 D3.
Hard or compact clays	5000 - 7500	measured near boreholes D2 D3.
Pre-Tertiary sediments or older basalt flow	9000 -12000	inferred from seismic and magnetic results.

Rock type	Velocity ft/sec.	Basis for Velocity Assumption
Partly decomposed to fresh basalt	5000? - 12000	inferred from seismic and magnetic results.
Dolerite	18000 - 20000	

At present it is not possible to identify a bed showing 9000 - 12000 ft/sec. velocity. This velocity is tentatively interpreted as representing pre-Tertiary sediments or an older basalt flow underlying or interbedded with the Tertiary sediments.

The allocation of a specific velocity to the basalt is difficult on the Whirlpool Reach bridge site, as there are no outcrops on or near the traverse and no solid basalt was reached in the drillholes.

The seismic velocity of two samples of basalt from Whirlpool Reach boulders has been determined at the Hydro-Electric Commission Soil Testing Laboratory. The samples gave very high velocities namely 19,200 and 17,000 ft/sec. The velocities measured on boulder samples in the Laboratory can be expected to be substantially higher than those met with in the field, where bulk velocities of boulders in a weathered matrix are measured.

The magnetic susceptibilities of the rocks on Whirlpool Reach bridge are not known, but by correlating the magnetic and the seismic results some conclusions may be reached regarding the rock types present.

On all the traverses the near surface material comprising soil, boulders and recent alluvium has a low velocity ranging from 1,000 ft. per sec. to 5,000 ft. per sec. In places, for example at stations 650 and 2850 on the Main Traverse, this near surface material comprises three distinct layers with velocities increasing from 1,000 ft/sec. at the surface to 5,000 ft/sec. for the lowest layer; the middle layer having an intermediate velocity. At other places only two near surface layers are indicated. Beneath these near surface layers other layers with higher seismic velocities were detected.

From zero to station 700 on the Main Traverse (0-700ft.) a layer of rock with a velocity of 6500 ft/sec. was detected at depths ranging from 43 ft. (station 700) to 87 ft. (station 300). This bed is correlated on the basis of seismic velocity with hard, or compact clay reported in bore hole DD1 near station 1200. Seismic velocities suggest that this bed continues from station 700 to station 2300. The relatively undisturbed magnetic profile also indicates a general continuity of structure and rock type between stations 0 and 2300. Beneath this postulated hard clay layer a deeper layer of 9000 - 12000 ft/sec. velocity was recorded. This may be pre-Tertiary sediments or an older flow of basalt. Deeper still (at about 410 ft.) a refractor with a very high velocity (up to 20,000 ft/sec.) was recorded; this may be unweathered dolerite.

The section from stations 2300 to the end of the traverse (station 3150) is characterised by changes in velocity ranging from 6000 ft/sec. to 11,000 ft/sec. in the layer immediately beneath the low velocity surface layers and by a very disturbed magnetic profile.

Of particular note is the velocity of 11,000 ft/sec. recorded between stations 2300 and 2600 and at a depth of 40 feet near station 2400. The type of rock responsible for this high velocity is not known. It may be basalt or perhaps pre-Tertiary sediments. A refractor with a similar velocity underlies the Main Traverse between stations 300 and 1700 at depths ranging from 190 ft. to 275 feet and is possibly rock similar to that at a depth of only 40 feet beneath station 2400. There is, however, no seismic evidence to suggest a sudden or continuous shallowing of this deep refractor between station 1700 and 2400 and it seems likely therefore that the 11,000 ft/sec. refractor beneath station 2400 is quite distinct geologically from the other.

It is considered that the most likely explanation for the 11,000 ft/sec. refractor beneath stations 2300 to 2600 is that it is a basalt flow of limited horizontal extent interbedded with the Tertiary clays. The magnetic results would be consistent with this interpretation if reversed permanent magnetisation is assumed; the magnetic intensity between 2300 and the end of the traverse at 3150 is anomalous and generally lower than that measured over the rest of the main traverse.

Traverse AA' and BB' cross the Main traverse at stations 2400 and 3139 respectively. Each was pegged from the bank of the Tamar, extending inland from it.

The 11,000 ft/sec. refractor recorded at station 2400 on the Main Traverse was also recorded on Traverse AA' extending from a station 67 feet north east from the Main Traverse to the bank of the Tamar at depths ranging from in excess of 40 feet to only a few feet on the bank of the river. A refractor with a slightly lower velocity (10,000 ft/sec.) was recorded on Traverse BB' extending throughout the traverse at depths ranging from 110 feet at the northern end to only a few feet near the river. Over that portion of Traverse BB' which lies to the north from station 154 south of the Main Traverse this 10,000 ft/sec. refractor is overlain by another with a velocity of 6,000 ft/sec. Throughout each traverse the near surface layers have low velocities ranging from 1,000 ft/sec. at the surface to about 5,000 ft/sec. These layers include soil, decomposed basalt, boulders and recent alluvium.

The 11,000 ft/sec. and 10,000 ft/sec. refractors on traverse AA' and BB' respectively are most probably basalt; disturbed magnetic readings support this interpretation. There is a possibility however that this refractor is dolerite which crops out on the south-western side of the Tamar.

The determination of the thickness of the soil and low velocity layers is considered to be within ± 15% of the true thickness. The estimated thicknesses of the lower beds have a greater probable error, perhaps ± 15-20%. The accuracy is influenced by the lateral continuity of the beds. The accuracy on the section from stations zero to 700 on the Main Traverse will probably be slightly less than the rest of the traverses due to large differences in elevation between geophones and shots. On this section the depths are more likely to be overestimated than underestimated.

The results on the south-eastern end of the Main Traverse and on traverses AA' and BB' suggest that adjacent to the river bank there is an area shown on plate 1 underlain at a depth of 60 feet and less by rock with a seismic velocity of 10,000 ft/sec. or greater, and which is sufficiently magnetic to disturb the earth's magnetic field. Such a rock may be basalt or possibly dolerite. If the rock is basalt it is presumably a flow of limited areal extent, lying at a lower level than the basalt flow which crops out nearby. It could be part of the same flow occupying an old erosion or River channel or alternatively it may be part of a basalt flow older than the surface flow and separate from it. In either case it is to be expected that such basalt would be underlain by clays and weathered rock.

If on the other hand this high velocity refractor is dolerite it could be expected to pass at depth into pre-Tertiary sediments which are unweathered and with an equally high velocity. However, dolerite with velocity of 10,000-11,000 ft/sec. may be jointed and partly weathered.

Elsewhere on the main traverse the near surface layers, comprising soil, boulders and recent alluvium pass at depths ranging from 27 feet to 87 feet into material with a velocity of only 6000-7000 feet per sec. From borehole evidence it is concluded that this is Tertiary clay, partly compacted. Beneath these clays is a layer with a velocity of 9000 to 10,000 ft/sec. at depths ranging from 190 feet to in excess of 275 feet. This may be an older basalt or pre-Tertiary sediments.

5. DISCUSSION OF RESULTS

The object of the survey was to obtain data on the physical properties of the rocks underlying a proposed bridge site with a view to assessing their suitability or otherwise for foundations. The seismic velocities are a good guide as to the elastic moduli of the rocks, and experience in other areas has shown that rocks with velocity of 6000-7000 ft/sec. and less would most probably be unsuitable for foundations of a large bridge structure, but that rocks with a velocity of approximately 10,000 ft. per sec. or more may be suitable.

If this is assumed to be correct then, except for a short section of the Main traverse between stations 2300 and 2600, the depth to rocks suitable for foundations would be greater than 190 feet.

Rocks with a velocity of 10,000 feet or more appear to be present at depths ranging from a few feet up to 60 feet over a portion of the area adjacent to the bank of the river at the south-eastern end of the Main traverse. This area is indicated on plate 3. Although these rocks are believed to be basalt underlain by weathered material it is possible that it is dolerite, slightly jointed and weathered. This would appear to be the only area that offers any prospects of rocks suitable for foundations at a relatively shallow depth and a test drill hole may be warranted.

6. CONCLUSIONS

The geophysical survey provided information of the depth and the possible type of the strata.

On the north-western part of the Main Traverse the rocks apparently consist of Tertiary Sediments, mostly clays. At depths in excess of 190 feet there is a bed showing a velocity of 9000 ft/sec or greater; it is interpreted as pre-Tertiary sediments or an older flow of basalt.

Towards the south-eastern end of the traverse a bed of high velocity (11,000 ft/sec) was detected nearer to the surface. This bed has been interpreted as basalt but may possibly be dolerite. This, however, could only be determined by test drilling.

The errors in calculations of depths are generally expected to be no more than ± 20%.

7. REFERENCES.

Heiland, C.A., 1946 - Geophysical Prospecting. Prentice Hill Inc. New York.

Hughes, T.D., 1957 - Proposed Bridge over Tamar River at the Whirlpool Reach, Department of Mines, Tasmania. (Unpublished).

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics

G 313-1

GEOPHYSICAL SURVEY,
WHIRLPOOL REACH BRIDGE SITE,
TAMAR RIVER, TASMANIA.

LEGEND

(6000) REFRACTOR VELOCITY IN FT/SEC

—70'— DEPTH TO REFRACTOR

E. J. Polak
GEOPHYSICIST

SCALE IN FEET
100 0 100 200 300

MAGNETIC PROFILE AND SECTION BASED ON SEISMIC REFRACTION ALONG MAIN TRAVERSE.

G 313-2

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics

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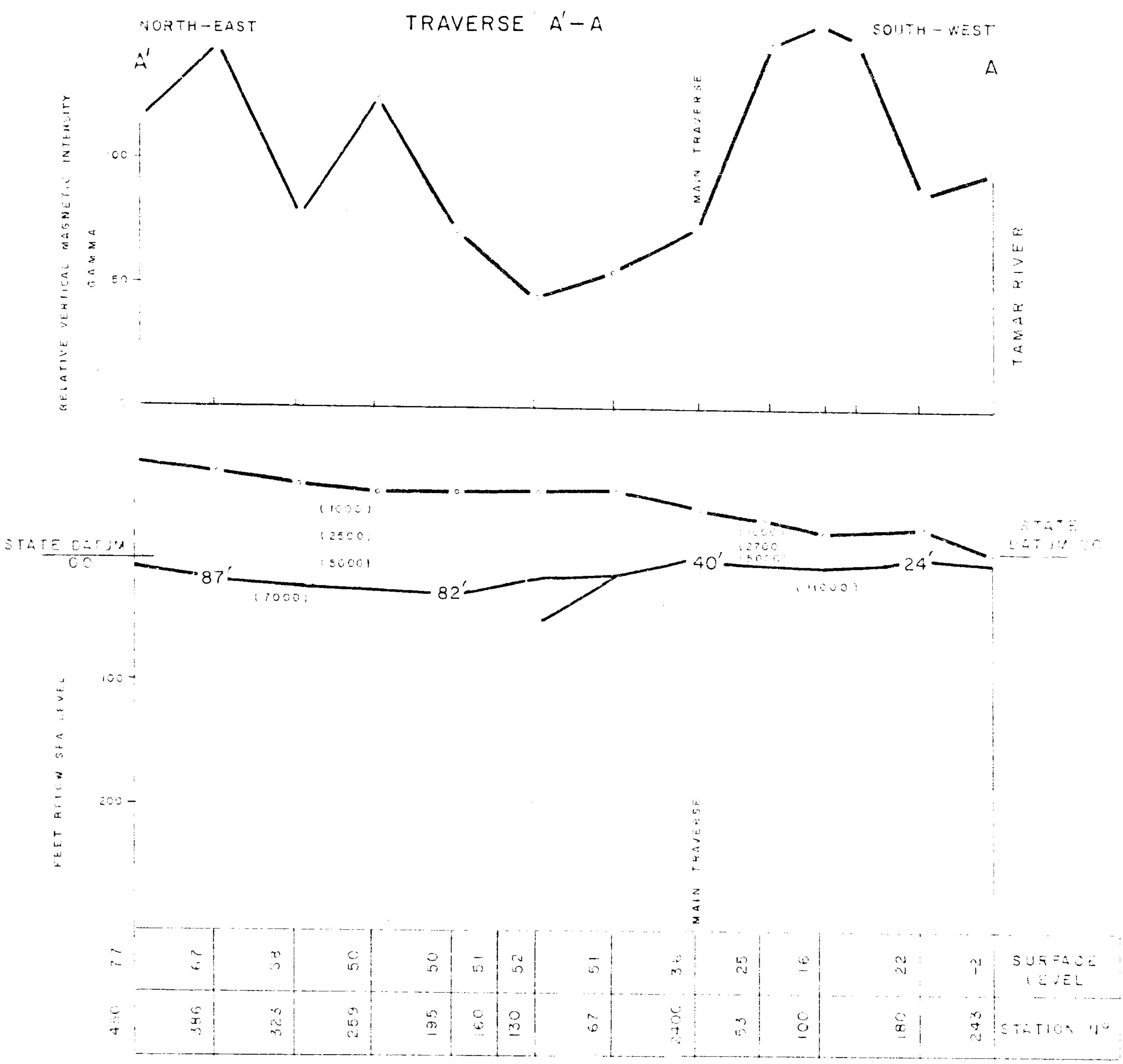

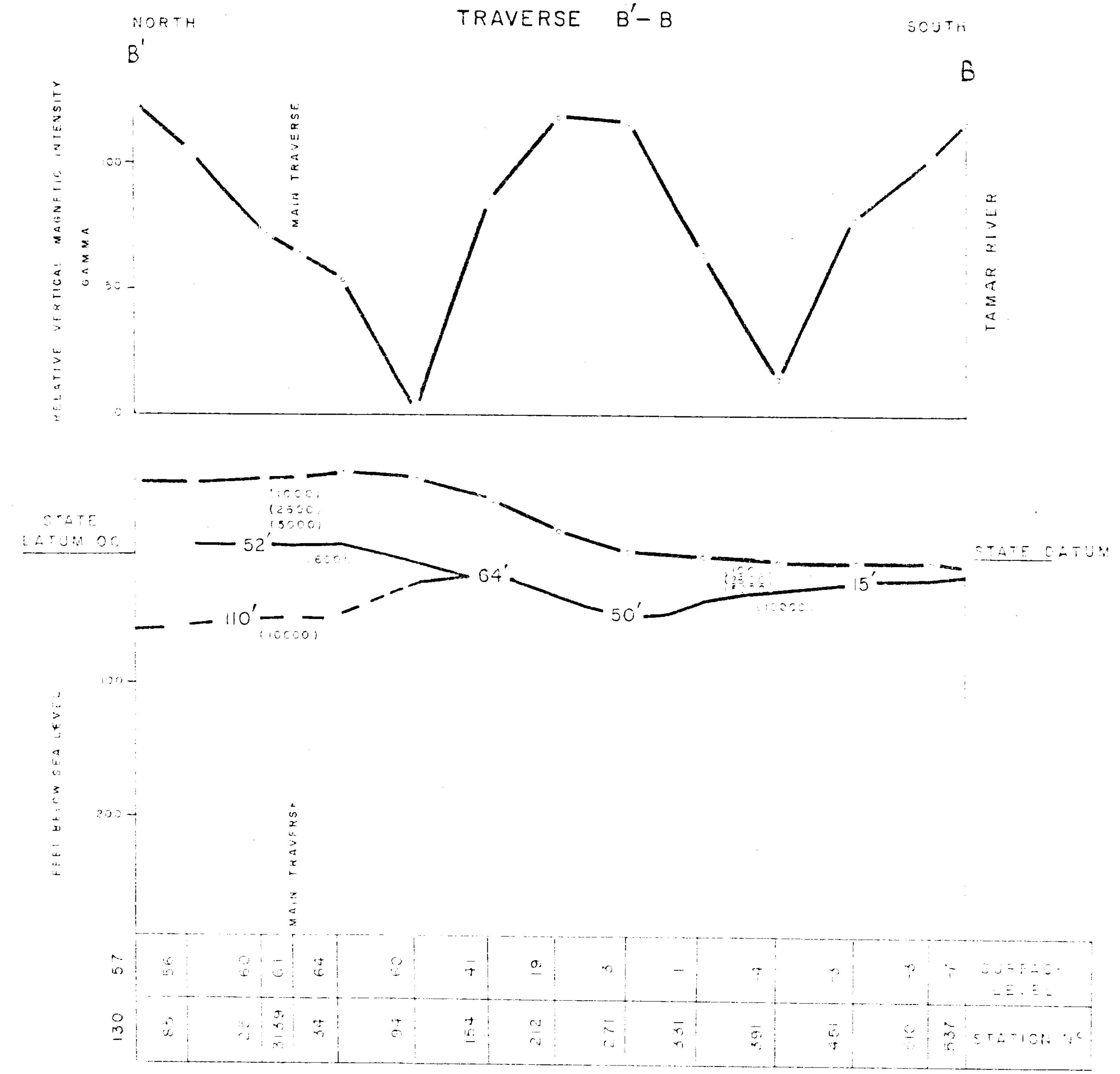

LEGEND

(6000) REFRACTOR VELOCITY IN FT. SEC

–70′– DEPTH TO REFRACTOR

GEOPHYSICIST

GEOPHYSICAL SURVEY
WHIRLPOOL REACH BRIDGE SITE
TAMAR RIVER, TASMANIA

MAGNETIC PROFILES AND SECTIONS BASED ON SEISMIC REFRACTION ALONG TRAVERSES A AND B

SCALE IN FEET