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# PRELIMINARY REPORT ON A GEOPHYSICAL INVESTIGATION OF LONGREACH BRIDGE SITES, TASMANIA

by

W.A. WIEBENGA and P.E. MANN

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## ABSTRACT

This report records the results of a geophysical investigation on three proposed bridge sites across the Tamar River, Longreach, near Rowella, for the Department of Works, Tasmania.

The survey discloses the presence of a platform of solid rock, interpreted as "basalt", within a sequence of river sediments. A gap in the lateral extension of this "basalt" along the north-eastern bank of the river is possibly an old erosion channel of the Tamar River.

The maximum depth to good foundation rock is the depth to the "basalt" or dolerite. Depth to the "basalt" is least at the most south-easterly site, referred to as Pines.

The depth estimates may be within ± 20%.

## I. INTRODUCTION

The Department of Works of Tasmania is planning to build a bridge near Rowella across the part of the Tamar river called Longreach. Three potential bridge sites were selected, named, Pines, Great Dragon and Sunny Point. The approximate width of the river at the three sites is respectively: 2260, 3200 and 3020 feet. The Department of Works considered that Pines was the best site.

The approximate positions of the sites, given as co-ordinates on the Devonport four-mile map sheet, are Pines and Great Dragon: 485929; Sunny Point: 484930.

The Bureau of Mineral Resources, Geology and Geophysics, was requested by the Department of Works to make a geophysical survey, before test drilling in the river bed was done.

A geophysical party consisting of D.F. Dyson, party leader, P.E. Mann and B.J. Bamber, geophysicists and five assistants supplied by the Hydro-Electricity Commission, carried out the field work from 16th March to 9th April, 1959.

D.Coombs, bridge engineer of the Department of Works, assisted with the field work and acted as liaison officer. The topographical survey was carried out by surveyors of the Department of Works.

The Department provided a 40 feet cabin-cruiser, powered by a 90 h.p. diesel engine, a 17 feet fishing boat powered by a petrol engine, two dinghies and boat crews. The cabin-cruiser served as seismic recorder-boat and the fishing-boat as shooter's boat for exploding gelignite charges in water.

## II. GEOLOGY

The geology of the area is described in an unpublished report by Blake, 1959. The following includes a summary of his report. Geological details are shown on Plate 1.

The geological history may be approximately visualised as follows:-

Local Jurassic dolerite was faulted, and, in relation to the faulting, a valley or depression with north-westerly trend was formed. Subsequently Tertiary lake sediments were deposited within the valley; then the sediments were capped by basalt lavas. In the following erosion period the river Tamar cut a channel along the eastern periphery of the basalt, and re-exposed the Tertiary lake sediments on the western bank of the river. The results of the geophysical investigation, as shown later in this report, suggest that the basalt along part of the north-eastern bank of the river is also missing or has been eroded away. In late Tertiary, or Quaternary time deposition of sediments was renewed. These sediments form the present bottom of the river.

## III. METHODS

In this preliminary report a detailed description of the geophysical methods is omitted. Reference may be made to a standard textbook (Dobrin, 1952, p.218-225, 246-248, 294-297, 303).

The main method used in this survey was the seismic refraction method. A few of the seismic reflections which were recorded were attributed to reflections of seismic energy from sub-surface rock discontinuities. These data are plotted on the profiles together with the seismic refraction data (Plate 2).

To compute the depth to geological formations ("refractors") to which a specific range of seismic velocities can be assigned, the seismic velocity of the overlying bed (or beds) must be known or measured. The computation technique used is called the "intercept method" (Dobrin, 1952, p.220).

In most instances of the present survey the velocity of the upper bed(s) could not be measured and was estimated at 5500±500 ft/sec. (See section IV (1) which discusses velocities). It can be shown that the possible error of 500 ft/sec. in the velocity of the upper bed(s) may result in a possible error of 20% in the depth computation. The possible errors resulting from the uncertainty in estimating the velocity of the upper beds are indicated on the profiles of Plate 2.

The resistivity method used on this survey is referred to as "resistivity traversing" or "continuous profiling". (Dobrin, 1952, p.297).

Unweathered dolerite and basalt usually have high resistivity, but sedimentary rocks such as sands, silts and shales have low resistivity because of their much higher porosity.

Hence, resistivity traversing was used in an attempt to disclose the sub-surface lateral boundary of the basalt, or to confirm the results of the seismic survey. In the practical adaptation of the resistivity method to traversing in rivers, a Wenner configuration of electrodes (Dobrin, 1952, p.297), was towed along the river bottom. Unfortunately, the spacing factor used to convert the measured resistances (in ohms) into apparent resistivities (in ohm/meters) was uncertain by an unknown constant error, not detected during the field work.

Therefore, the resulting apparent resistivities shown in the resistivity profiles on Plate 2 are expressed in arbitrary units. However, the results can still be used in a qualitative way.

## IV. RESULTS

### (1) Seismic velocities.

The seismic velocity of a rock is an indication of the rock type, and the physical character and condition of the rock. To interpret the geological significance of the seismic velocities, sufficient geological information must be available (Wiebenga, 1958). For engineering purposes it is not usually necessary to identify the rock formations precisely because longitudinal seismic velocities are a sufficiently good indication of rock quality. In general the stronger rocks have the greater seismic velocity.

It is sometimes desirable to know the Young's modulus of a rock. If in addition to longitudinal velocities, Poisson's Ratio and the density of the rock can be measured or reliably estimated, Young's modulus and shear modulus can be computed.

In this survey, Young's modulus was estimated from an empirical formula:

$$E = 68.9 \quad V^{2.34}$$

in which E, Young's modulus, is in dynes/cm$^2$ and V, velocity of longitudinal waves, in ft/sec. The formula is derived from data by Birch, Schairer and Spicer (1950) and Heiland (1946), and gives values of Young's modulus accurate to within ± 30% for silicate rocks. The above formula is not applicable to mud, silts and fine sands with porosities greater than 40% and saturated with water. (Hamilton, 1956).

Table 1 shows a correlation between seismic velocities and rock types, based on the available geological data. In the 3rd column an estimate of Young's modulus is given, based on the above formula and Hamilton's data (Hamilton, 1956).

On theoretical grounds a sonic method of determining Young's modulus (which includes the seismic method) will always give values higher than those obtained by mechanical tests (Wuerker, 1953).

TABLE 1.

| Rock type | Longitudinal seismic velocity (ft/sec) | Young's modulus (in $10^{11}$ dyne/cm$^2$ | |
|---|---|---|---|
| Water | 5000± | 0 | |
| Mud or Quaternary Silt, saturated with water | 4600 - 5500 | 0.04 | * |
| Fine sand, silt or sandy/clay saturated with water | 5500 - 6000 | 0.04± | * |
| Gravel | 4000 - 5000 | 0.28 - 0.47 | |
| Tertiary sediments | 6000 - 8000 | 0.75 - 1.4 | |
| Weathered basalt or weathered dolerite | 6000 - 8000 | 0.75 - 1.4 | |
| Basalt, fractured or jointed | 8000 -11000 | 1.4 - 3.0 | |
| Basalt, amygdaloidal or vesicular | 11000 -15000 | 3.0 - 6.0 | |
| Basalt, massive | 13000 -17000 | 4.5 - 8.0 | |
| Dolerite, jointed and weathered on joints | 7000 -10000 | 1.05 - 2.5 | |
| Dolerite, jointed | 10000 -17000 | 2.5 - 8.0 | |

NOTE: * indicate that the data were taken from Hamilton, 1956.

(2) <u>Profiles</u> (see Plate 2)

In the following paragraphs the sub-surface structure below the river bottom will be discussed for the three profiles Sunny Point, Great Dragon and Pines.

The location of a point on the profiles is referred to by a number, indicating the distance in feet from a survey station on the south-western bank. (Plate 1).

Depth of a formation characterized by a certain seismic velocity refers to depth <u>below the river bottom</u>.

(3) <u>Sunny Point</u>.

The data between 290 and 630 indicate a north-westerly dipping bedrock (velocities between 9000 and 13000 ft/sec.) at depths between about 54 feet at 290 and 140±30 feet at 630. This bedrock must be dolerite because it underlies the Tertiary sediments which crop out on the south western bank.

Between 630 and 1250 a formation with velocities between 7000 and 8500 ft/sec. at depths between approximately 120 and approximately 150 feet, is interpreted as basalt because this interpretation fits the geological data. This formation was also found at Great Dragon and Pines where the basalt crops out on the south western bank.

A formation with a velocity of 6000 ft/sec. is about 70 feet deep at 840, and about 40 feet deep at 1280. This formation may be interpreted as partly consolidated sediments, or perhaps as weathered "basalt".

The continuation of the "basalt" was not found between 1250 and the north-eastern bank of the river. This is consistent with a similar situation at Great Dragon and Pines. The gap in the basalt may be explained by assuming that during one stage in the geological history basalt was eroded.

The same explanation may apply to the results between 290 and 630.

Between 1250 and the north-eastern bank, a formation dipping south-west and having velocities between 8000 and 14000 ft/sec. is interpreted as the bedrock of the original valley.

At 1500 a formation with 7000 ft/sec. velocity at about 110 feet depth is interpreted as consolidated Tertiary sediments.

At 1850 and 2000, formations with 7600 and 7000 ft/sec. velocities at depths of about 125 and 105 feet, are interpreted as either part of the "weathered" dolerite bedrock, or as partly consolidated Tertiary sediments.

(4) <u>Great Dragon</u>.

Interpretation of the data at Great Dragon shows the same structural pattern described for Sunny Point except that the formation interpreted as basalt (velocities between 7000 and 10000 ft/sec.) is much shallower. Depths are between about 30 and 85 feet.

Between 950 and 1220, the formation interpreted as basalt, is considered to be a continuation of the basalt outcropping at the south-western river-bank. This formation dips steeply towards the middle of the river.

The rock interpreted as "basalt" is relatively shallow between 1270 and 1380 (depths less than 40 feet) and is deeper beyond 1380. Its depth is greatest near 1700.

This is confirmed by resistivity measurements which discovered a resistivity minimum at the same point.

The seismic data indicate that a gap in the lateral extension of the basalt occurs between 2200 and the north-eastern river-bank. This is confirmed by a reduction in resistivity values between 2180 and 2240.

On the north-eastern side of the river, the seismic data prove the presence of bedrock, interpreted as dolerite, dipping towards the middle of the river. The unweathered dolerite is less than 50 feet deep between about 2660 and the north-eastern bank. The few observations on the south-western side of the river confirm the geological interpretation that dolerite is the bedrock in this area.

(5) Pines.

Interpretation of the data at Pines shows the same structural pattern described for Sunny Point and Great Dragon. The formation interpreted as "basalt" (velocities 8000 to 12,500 ft/sec.) is shallowest close to the south-western bank (depth 32 ft. at 150). From the bank it dips towards the middle of the river. The dip is not as steep as at Great Dragon. The seismic data suggest that the basalt is deepest between 700 and 800 (depth about 63 ft.). This appears to be confirmed by a local minimum in the resistivity values.

The seismic data indicate that a gap in the lateral extension of the basalt occurs between 1200 and the north-eastern bank. This is confirmed by a reduction in resistivity values near 1200.

On a short section near 300, perpendicular to the main profile, evidence was obtained that the upper surface of the basalt may be very irregular in some areas. Depths to basalt varied 50 feet over a profile length of 200 feet. This could be caused by weathering. However, no further evidence of such irregularity was found.

(6) Summary.

The above discussion discloses that the geological structures of the three sites, interpreted from geological and geophysical data, show striking similarities, namely:-

(a) The presence of a rock platform, probably "basalt", underlying river mud and sediments, and overlying Tertiary sediments.

(b) A relatively wide gap in the basalt, near the north-eastern river-bank.

(c) On the north-eastern side of the river, the bedrock interpreted as dolerite, is clearly indicated and dips towards the middle of the river.

The basalt platform is about 120 to 135 feet below the river bottom at Sunny Point but it is only about 30 to 85 feet below the river bottom at Great Dragon and Pines.

The formations immediately underneath the river bottom and indicated on the profiles as "Mud and Sediments" may contain gravel or sand lenses, or other beds strong enough to support bridge foundations. Unless these beds show sufficient velocity contrast with overlying beds, and are also thick and extensive enough, it would be difficult to discover them with the seismic methods, ordinarily used by the Bureau.

## V. CONCLUSIONS

A selection of the best of three sites for further investigation can now be made using as main criteria the geophysical evidence of depth to foundation rock and the width of the river.

Maximum depth to foundation rock is taken as the depth to rocks interpreted as "basalt" or dolerite, that is, rocks with longitudinal seismic velocities of 7000 ft/sec. or more, and having Young's modulus greater than $10^{11}$ dynes/$cm^2$.

It is concluded that of the three proposed bridge sites, Pines is the most favourable one for the following reasons:-

(a) The depth to the rocks interpreted as basalt or dolerite is on the average probably less at Pines than at Great Dragon, and very much less than at Sunny Point.

(b) The width of the river at Pines is less than at Great Dragon or Sunny Point.

To check the geophysical results and interpretation at Pines, drill holes should be selected above the rocks interpreted as "basalt", between 1100 and the south-western river-bank, and in the area between 1200 and the north-eastern bank where no basalt was found. The exact position of the drill-holes could be chosen to suit the location of the projected foundations.

## VI. REFERENCES

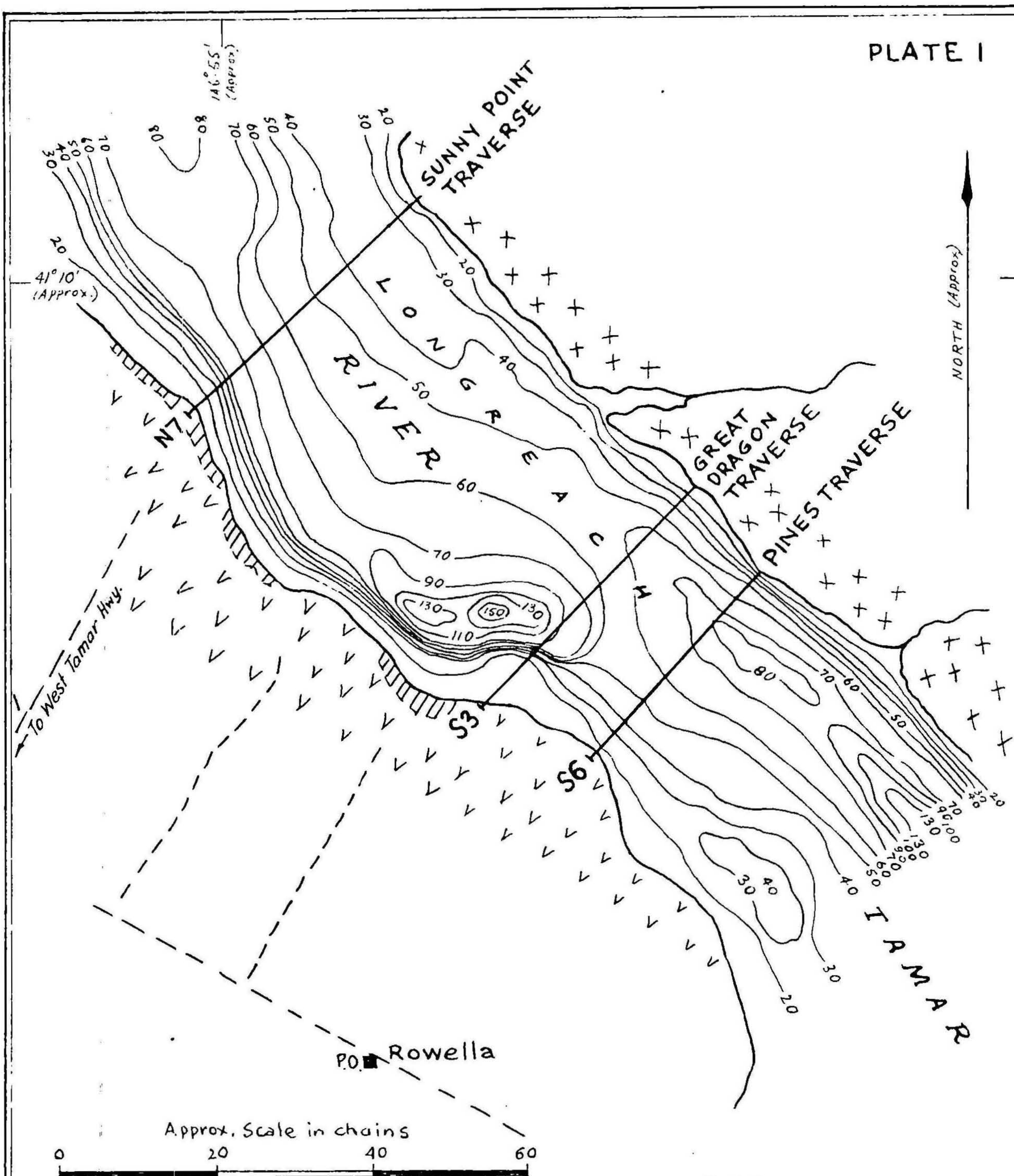
DOBRIN, M.B., 1952 - Introduction to Geophysical Prospecting, McGraw Hill, New York, p.218-225, 246-248, 294-297, 303.

HAMILTON, E.L., 1956 - Low sound velocities in high porosity sediments, J. ACOUST.SOC. AMER., 28, (1), 16.

WIEBENGA, W.A., 1958 - Exploration geophysics applied to the dolerites of Tasmania, Dolerite Symposium, Univ. of Tas.

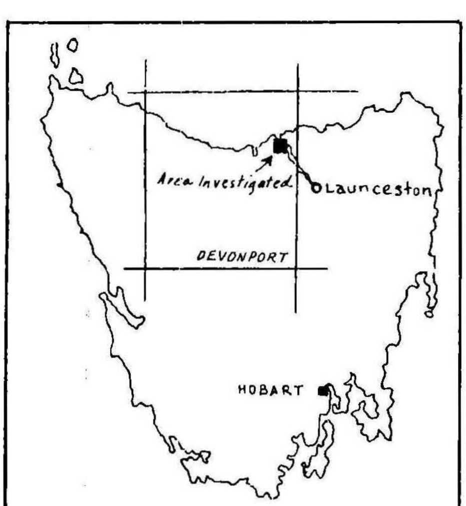
WUERKER, R.G., 1953 - The status of testing rocks, Min. Eng., 5, 1108, A.I.M.E.

PLATE I




LEGEND

- Sediments
- Tertiary basalt
- Jurassic dolerite
- —70— Riverbed contours in feet below mean water level. (From P.W.D. plan 3804-1/P1.)




REFERENCE TO AUSTRALIAN 4 MILE MILITARY MAP SERIES

# GEOPHYSICAL INVESTIGATIONS OF LONGREACH BRIDGE SITES, TASMANIA

## GEOLOGY, APPROXIMATE RIVERBED CONTOURS AND LOCATION OF TRAVERSES

(Geology after BLAKE 1959)

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics. G336-4

TO ACCOMPANY RECORDS 1959, No.106


PLATE 2
S.W.
SUNNY POINT TRAVERSE
N.E.
Distance in feet from Stn. N7
Elevation Datum: Mean Water Level
Traverse at Stn. N7
Depth in feet
WATER
MUD AND SEDIMENTS
PROBABLE UPPER BOUNDARY DOLERITE
PROBABLE UPPER BOUNDARY OF BASALT
NO BASALT INDICATED IN THIS AREA
DOLERITE
SEDIMENTS
GREAT DRAGON TRAVERSE
S.W.
N.E.
Apparent Resistivity in arbitrary units
Resistivity Profile
NO RESISTIVITY DATA IN THIS AREA
Distance in feet from Stn S3
Elevation Datum Mean Water Level
Traverse at Stn S3
Depth in feet
WATER
MUD AND SEDIMENTS
NO BASALT INDICATED IN THIS AREA
PROBABLE UPPER BOUNDARY OF BASALT
SEDIMENTS
DOLERITE
DOLERITE
PINES TRAVERSE
S.W.
N.E.
Apparent Resistivity in arbitrary units
NO RESISTIVITY DATA IN THIS AREA
Distance in feet from Stn S6
Traverse at Stn S6
Depth in feet
WATER
MUD AND SEDIMENTS
PROBABLE UPPER BOUNDARY OF BASALT
NO BASALT INDICATED IN THIS AREA
SEDIMENTS
DOLERITE
HORIZONTAL AND VERTICAL SCALES
100 0 100 200 300 FEET
Legend
67 ± 13 (7,500 – 8,300) Depth of refractor of 7500 to 8300 ft./sec. velocity at 67 feet below river bottom. Estimated maximum error in depth: 13 feet.
R 138 ± 20 Depth of a discontinuity at 138 feet below river bottom as indicated by a seismic reflection. Estimated maximum error in depth: 20 feet.
Inferred upper boundary of basalt. N.B.: No determination of basalt thickness was possible.
Inferred upper boundary of dolerite.
Apparent resistivity profile.
Note 1:- Locations on the three traverses are measured distances from P.W.D. survey stations on south-west bank of river: For Sunny Point Traverse - Station N7; For GreatDragon Traverse - Station S3; For Pines Traverse - Station S6
Note 2:- Locations of resistivity observations may be up to 50 feet in error. Distances between any two observations could be 100 feet in error.
Note 3:- Velocities exceeding 7000 ft/sec. at shallow depths generally correlate with relatively higher resistivity readings and hence were interpreted as being indicative of basalt and dolerite.
GEOPHYSICAL INVESTIGATIONS OF LONGREACH BRIDGE SITES, TASMANIA
PROFILES SHOWING GEOPHYSICAL INTERPRETATIONS
Topographical Survey information from plan 4392/T-P1, Department of Public Works, Tasmania.
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