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SEISMIC AND MAGNETIC TRAVERSES AT MALLACOOTA INLET, 1971

by

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CONTENTS

SUMMARY

Seismic refraction and magnetic traverses were taken at Mallacoota Inlet in Victoria during December 1971. The object of the traversing was to obtain the depth to bedrock under the lake and to determine the nature of certain sub-bottom material which, through severe absorption, prevented useful sparker profile records from being obtained in specific areas.

The refraction results show that the depth to bedrock is about 100 m and that a discontinuity in the overlying unconsolidated sediments occurs at a depth of about 30 m. There are no measurable velocity variations above bedrock and thus the interfering layer which hindered sparker profiling could not be characterized by the refraction results. However, refraction shooting in one such area demonstrated that this layer of sediments is capable of absorbing all the energy from 2 kg of gelignite when generally only one-tenth of this charge was required to give good results.

The magnetic profiles show anomalies of up to 100 gammas throughout the lake but the anomalies do not coincide with regions of high absorption.

Bottom samples in different areas give some indication of the cause of absorption and it is concluded that the absorbing layer is composed of fine silt and possibly organic material. Very good correlation exists between areas of poor sparker penetration and areas having a mud bottom.

INTRODUCTION

A sparker survey was carried out in co-operation with the Geological Branch of BMR at Mallacoota Inlet in Victoria during November and December of 1971 (Cook, in prep.). Mallacoota is a small town situated on an estuary in the southeast corner of Victoria, a short distance south of the New South Wales border. Water depths in the inlet range from 1 to 6 m and specially developed shallow-water profiling equipment was used quite successfully for the survey (Dolan, in prep.). Although the technical problems associated with shallow-water profiling were largely overcome there remained certain areas within the inlet where absorption by a shallow sub-bottom layer of sediments prevented any useful data being obtained. The sparker coverage of the lake was very extensive (BMR, 1972) and the results are reported in a separate Record by Cook.

Six different regions of the lake were investigated by the seismic refraction technique and four magnetic traverses were completed. The survey work was carried out on 2 and 3 December 1971 by A. Spence, (party leader), F.J. Taylor (geophysicist), and M. Dickson (technical assistant), assisted by members of the BMR Marine Phosphate Group.

The term bedrock as used in this report refers to the deepest refractor detected.

GEOLOGY

The geology of the Mallacoota sheet has been mapped by both the Victorian and New South Wales Geological Survey. The N.S.W. section has been completed in the form of a coloured map while the Victorian section is presented in preliminary form. The geology of the East Gippsland region, including Mallacoota, is described by Talant (1969) who recognized five landforms in eastern Victoria:

(1) Mountainous Tracts

(2) Monaro Tableland

(3) Piedmont Downs

(4) Coastal Dunes

(5) Intermontane Basins

The Coastal Dunes consist of sand and associated swamps and lacustrine deposits of late Quaternary age distributed along the coast. They include barriers, across the mouth of streams, which are responsible for the formations of coastal lakes such as Mallacoota Inlet. An age of 3 560 BP (Talant) has been obtained for these sands and silts at Mallacoota Inlet. The surrounding shores of the lake fall into the Piedmont Downs category and consist of Tertiary deposits of gravel, sand, clay, and conglomerate together with Ordovician sandstone, mudstone, slate, siltstone and quartzite. In much of the Top Lake and upper reaches of the estuary these sediments form steep slopes to the water's edge. Granite outcrops occur within 12 km of the lake on both the mainland and on Gabo Island east of Mallacoota. Bedrock type under the lake is unknown but is suspected to be Ordovician sediments.

METHODS AND EQUIPMENT

The seismic refraction work was undertaken using SIE PSU 19 amplifiers and a 12-channel under-water hydrophone cable. Average hydrophone spacing on the cable was 6.2 m. Conventional TIC 20 Hz geophones were used for land work. The depth to bedrock under the lake was generally about 100 m and shot offset distances of 300 m or greater were required to record refracted arrivals from bedrock. The recording and shooting arrangement involved two boats. The larger one contained recording equipment with the hydrophone cable suspended on buoys and streaming from the stern. The smaller boat powered by an outboard motor was used to place and explode charges at various distances off the end of the hydrophone line. The shot instant was transmitted by radio and the distance between the shot and hydrophones was calculated from the water wave arrival using a velocity of 1530 m/s. The ideal recording arrangement is to have the amplifier gains set such that the second arrival (water wave) is not obscured by the initial energy from the bedrock arrival. Also, the shot offset distance must be great enough to allow both arrivals to be recorded, Plate 4(a). In the areas investigated there is no detectable velocity contrast within the sediments above bedrock. Hence only two arrivals are of concern. In areas where shots were fired in shallow water the air wave arrival was used to check distances. An air wave is generated only if the initial explosion breaks the water surface violently.

Plate 2 shows the locations of five marine traverses and one land traverse (traverse 6). Also shown on the plate are magnetic traverses, some sparker profile lines and the location of bottom samples.

The magnetic profiles were obtained with an Elsec proton magnetometer with the detecting head mounted on a wooden pole at the stern of the boat. This was necessary because the conventional under water head (towed 'fish') was not functioning correctly. Unfortunately the magnetometer could not be run at the same time as the sparker equipment because of interference.

Bottom samples were collected from areas of high and low seismic absorption. These samples are representative of the immediate bottom layer and have been analysed for grainsize in the BMR laboratories. The results of a comprehensive bottom sampling survey conducted by the Australian National University are presented in the overlay of Plate 2.

The sparker profile lines shown in Plate 2 were positioned by theodolite fixes. However, the magnetometer and refraction lines were located by observation from the boat and hence their location could be as much as 30 m away from the positions shown in plate 2.

RESULTS

Seismic refraction. The following velocities were detected by the hydrophones:-

(a) Bedrock seismic wave (4 900 m/s)

(b) Water seismic wave (1 530 m/s)

(c) Air seismic wave (sound) (335 m/s)

(d) Physical water wave? (100 m/s)

The calculated depths to bedrock and the recorded bedrock velocity for the six areas investigated are listed below. The depths shown must be considered an average for each area investigated.

Traverse	Depth to Bedrock (metres)	Velocity to Bedrock (m/s)
1	12?	3 300 (dips to the east)
2	50	4 900 (dips to the south)
3	100	4 900 (dips to the Goodwin Sands)
4	110	4 900
5	130?	6 000 (apparent)
6	16	3 600

In all cases the material above bedrock showed only one velocity 1530 m/s, which is the seismic velocity of water or water-saturated sediments. Ghosting exhibited on some of the refraction records (Plate 4a) indicate that there may be a discontinuity within the unconsolidated sediments at a depth of 30 m. This applies to those areas where bedrock lies at about 100 m. The uncertainty surrounding the results from Traverse 5 arises from the fact that the water wave was not recorded, Plate 4(b), and as a result a reliable shot-hydrophone distance was not obtainable. Bedrock velocity indicated for Traverse 5 is an apparent velocity and not true velocity.

Plate 4 shows a comparison between two refraction records obtained from two different areas in the lake. The first (a) was obtained in the region between Howe Bight and the Goodwin Sands (Traverse 3) while the second (b) was obtained in the region between John Bull light and The Narrows (Traverse 5). The differences between these two recordings are listed below.

	(a)	(b)
Water depth	4 m	6 m
Shot distance	700 m	700 m
Charge	0.2 kg	0.5 kg
Recorded energy	Good	Poor
	High-frequency	Low-frequency
Water wave	Recorded	Not recorded

The most obvious difference is the absence of the high-frequency water wave on (b). It should be noted that there are no operator errors or equipment malfunctions to which this difference can be attributed. For all practicable purposes the conditions of shooting and recording for both records are identical excepting for the locality, and the charge size which is greater for (b).

The area between John Bull and The Narrows is one of the areas where sparker penetration was very poor (Plate 2). It would seem that the mechanism which prevented penetration of sparker energy is also responsible for the appearance of the refraction record (b). The absence of a water wave on this record points to an absorbing layer on the immediate bottom. This layer through absorption prevents any direct wave travelling through the water layer. The average water depth in this area is 6 m so there is sufficient medium for the direct wave to be transmitted.

The marine sparker records for this area show a reflecting layer about 2 m below the bottom (Plate 5). There are no recorded events below this layer, suggesting that the layer must be either reflecting all the energy or that the material above the layer is substantially absorbing all the energy. In view of the fact that there is no direct water wave recorded on the refraction record it is concluded that severe absorption in the immediate bottom sediments is the more likely reason for poor penetration of the sparker energy. Combining the negative results of both the refraction record and the marine sparker record it is concluded that the absorbing material is situated between the immediate bottom and the 2-m reflecting layer.

Plates 5 and 6 show the location of bottom samples in relation to the type of marine sparker profile obtained. The geographical locations of the sample points are shown in plate 2. These bottom samples were analysed for grainsize as this was the most obvious difference in the visual appearance of the sediments. The results are shown in Table I. There is a marked contrast in grainsize between samples from the two extremes. Good sparker penetration is achieved in areas where bottom sediments are coarse-grained. The visual difference between samples I and 5 is that sample 1 is a fine black mud and sample 5 is coarse to fine sands. The screen size used to differentiate between the two sizes was a mesh size 230 or 0.0625 mm.

Table 1. Grainsize Analyses

Sample No.	Percentage by weight of coarse material	Percentage by weight of fine material
1	0.9	99.1
2	27.6	72.4
3	76.0	24.0
4	99.3	0.7
5	97.2	2.8

Various workers have published quantitative data on porosity, sediment grainsize, reflectivity, velocity, and attenuation for unconsolidated marine sediments (Shumway, 1960; Morgan, 1969; Faas, 1969). Data in these papers indicate that the reflection coefficient of the bottom sediments is greater for coarse-grained sediments and that absorption is greatest for porosities of about 50 percent. The absorption decreases to zero for higher porosities. These two facts would not account for the contrast between two different areas considered here.

Shumway (1960) in his absorption studies on unconsolidated marine sediments observed highly contrasting absorption values for samples from the same locality.

> 'Samples with high absorption contained many roots scattered throughout the sample. These roots were hollow and contained gas bubbles. When pieces of these roots were squeezed between the fingers visible bubbles were released. The samples with normally low absorption values were ones where these roots had been removed by normal water currents and general agitation of the sediments'.

These observations by Shumway are considered to be relevant in the present case. The deposition of fine black mud within an estuary is likely to be accompanied by organic material. Thus, these samples obtained from within the first 0.2 m of sediments are probably not good examples of the cause of absorption. For example, in regions of high absorption there could be as much as 2 m of fine silt containing a large concentration of organic material. This material and silt can be considered to be deposited by periodic flooding and whether or not it is removed at a later date will depend on tidal currents.

The overlay of Plate 2 shows the percentage of sand on the lake bottom as determined in a survey by the Australian National University. In general, those areas having a mud bottom show no sparker penetration. However, there are some areas where there is no sparker penetration although the bottom samples exhibit a high percentage of sand. Similarly there are some areas having a mud bottom and showing good sparker penetration. These observations tend to confirm a theory that it is enclosed gas bubbles within the mud which produce severe absorption rather than grainsize of the sediments.

The author knows of two other areas of severe absorption of high frequency seismic waves in marsh areas; the areas were the Sepik district of New Guinea and in western Papua. In land seismic work in both areas it was necessary to implant marsh geophones to a depth of 3 m in the mud in order to achieve satisfactory results.

Magnetic. Magnetic profiles are presented in Plates 7 and 8. The location of these lines are shown in Plate 2. Local anomalies of up to 100 gammas were observed and in the area of the Eight Foot Bank a sharp 80-gamma anomaly is associated with a structural feature exhibited on four sparker profiles. However the magnetic anomaly is only recorded on one traverse and no more than confirms such a feature. Assuming it is a fault it would be normal and possibly a scissor type. It runs slightly south of east and may actually be connected with The Narrows (Plate 2). Unfortunately absorption prevents tracing this feature for more than 450 m. The depth to the geological boundary exhibiting this feature is about 30 m.

The magnetic anomalies shown in Plates 7 and 8 do not correlate with the shallow sand bars. The depth of water could be expected to affect the character of the magnetic profiles particularly in shallow areas, but this does not appear to be the case. Rough calculations on the depths of the magnetic anomalies at John Bull and the Eight Foot Bank give 130 and 50 m respectively. Such calculations must be regarded as rough as both anomalies are not sufficiently defined.

On Plate 7 the sparker and magnetic profiles between John Bull and The Jetty have been superimposed. Some of the magnetic highs correspond with the edges of valleys exhibited on the sparker profile (marker 9 and between markers 6 and 5). However, the two other magnetic highs do not correlate in this manner.

CONCLUSIONS

It is concluded that the areas of poor sparker penetration are effectively shielded by the deposition of fine silt and organic material and that it is the enclosed gas bubbles within the organic material which is responsible for the high absorption. The probable thickness of the interfering layer is a maximum of 2 m and occupies the region between the bottom and the first reflector in such regions. The high velocity fresh bedrock lies at a depth of about 100 m below water level. Since there is no evidence of any velocity of value between 1 600 and 5 000 m/s it is concluded that if any compacted weathered rock exists above bedrock, this layer is either very thin or has a seismic velocity close to 1 600 m/s. The layering exhibited in the marine sparker profiles (Plates 3, 5, and 6) is probably divisions within the unconsolidated material. The high absorption which is associated with entrapped gas bubbles emphasises the need to ensure that, in shallow marine sparker profiling, the hydrophone streamer is outside the stream of gas bubbles ejected by the spark.

RECOMMENDATIONS

The following recommendations are made:

(1) Bottom samples from bore-holes to a depth of 4 m below water bottom should be obtained from areas of high absorption in order to determine the exact nature of the interfering layer. Such information is considered essential for future studies of estuaries as it can be expected that interference of this type will exist in other estuaries

(2) The magnetometer should be screened to prevent interference from the sparker equipment. Should this be possible, both profiles can be obtained simultaneously. Attempting to superimpose two separate profile runs from the same line is intrinsically inaccurate because of positioning errors.

ACKNOWLEDGEMENTS

The marine seismic profiles shown in this report were made available by Dr P. Cook of the Marine Phosphate Group of the BMR. The author is indebted to the members of this group for their assistance during the survey. The map of bottom sediments was made available by the Geophysics Department of the Australian National University.

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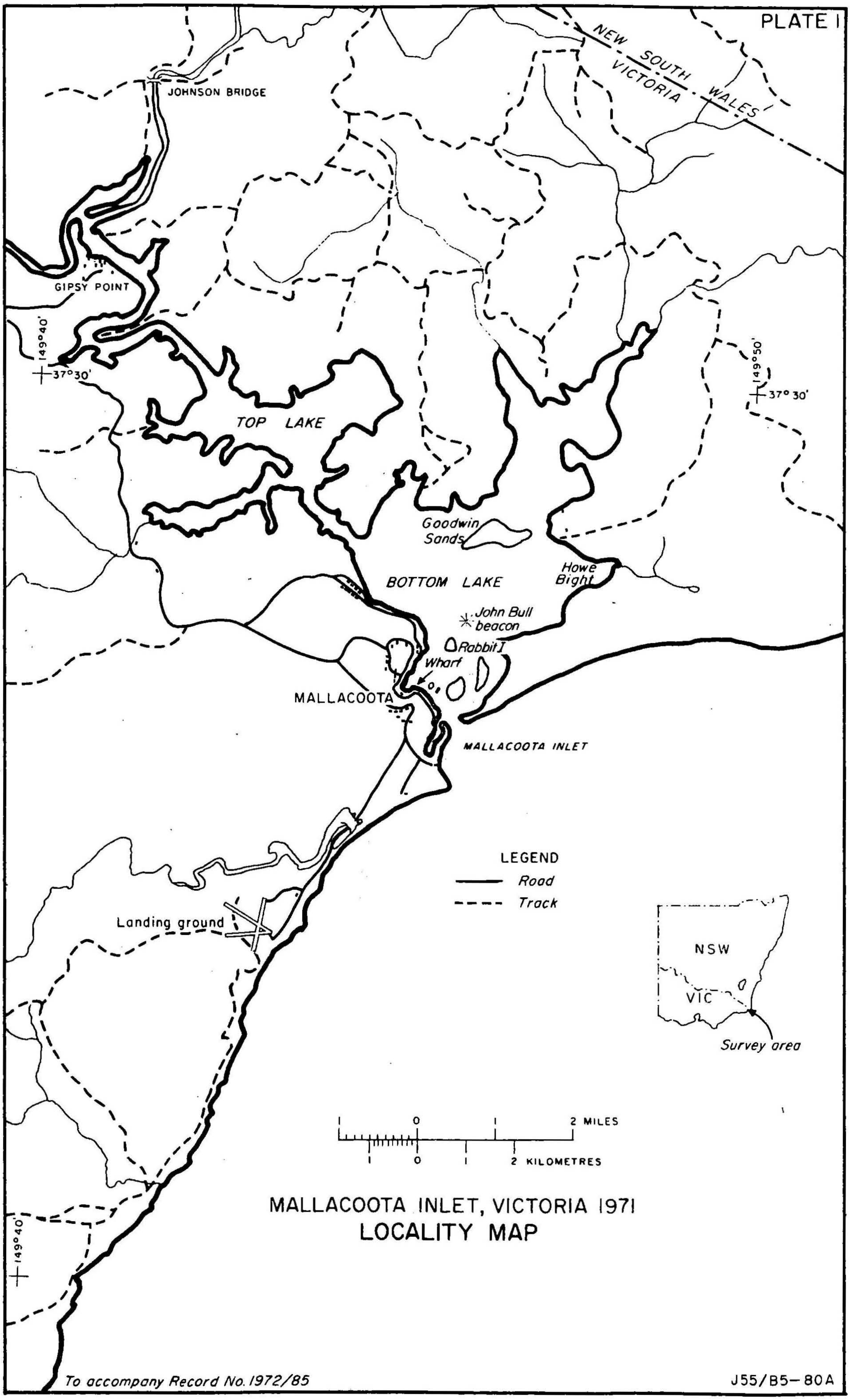
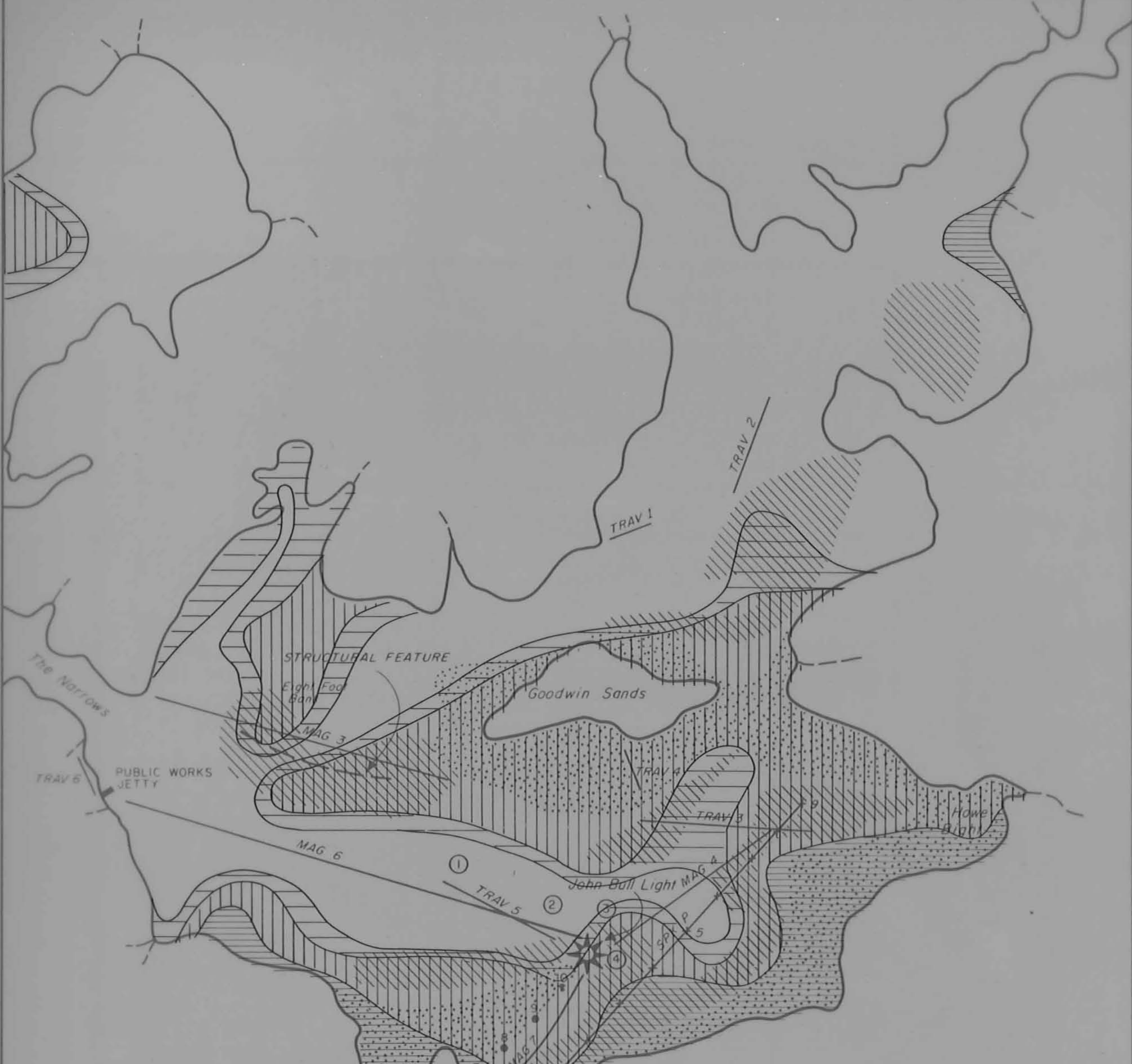


MALLACOOTA INLET, VICTORIA 1971
LOCALITY MAP



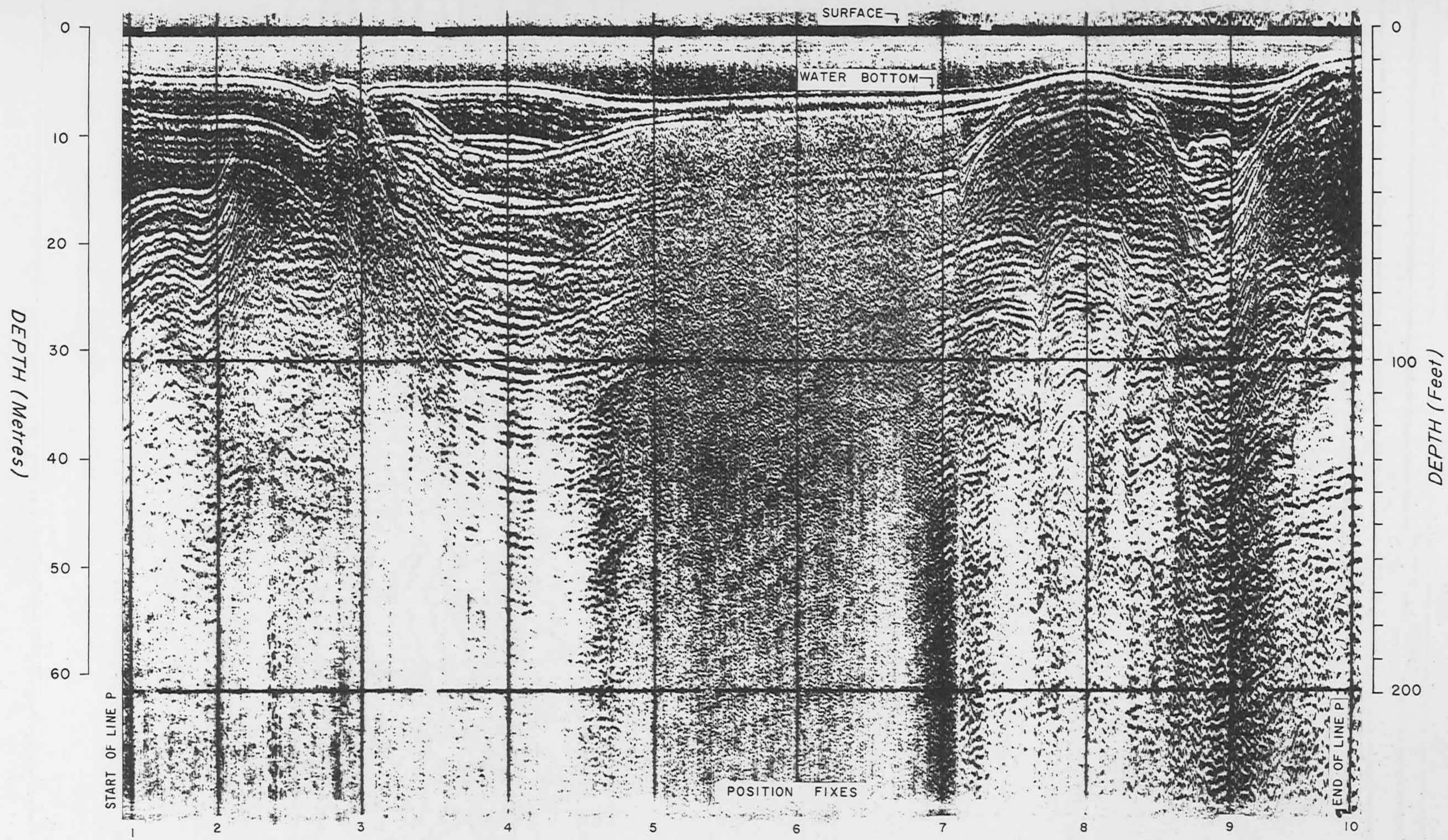
TRAVERSE PLAN

(Overlay to J55/B5-81A) To accompany Record No 1972/85

J55/B5-81A -1A

MALLACOOTA ESTUARY STUDY

To accompany Record No. 1972/85

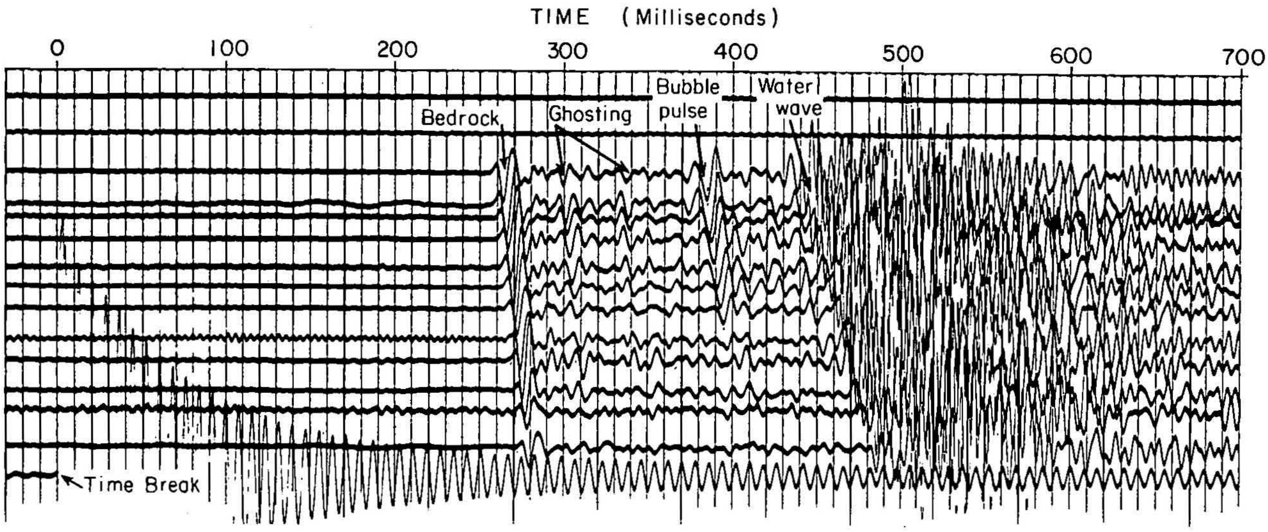


MALLACOOTA 1971

MARINE SPARKER PROFILE LINE P

PLATE 4

(a) REGION OF LOW ATTENUATION



MALLACOOTA 3-12-1971

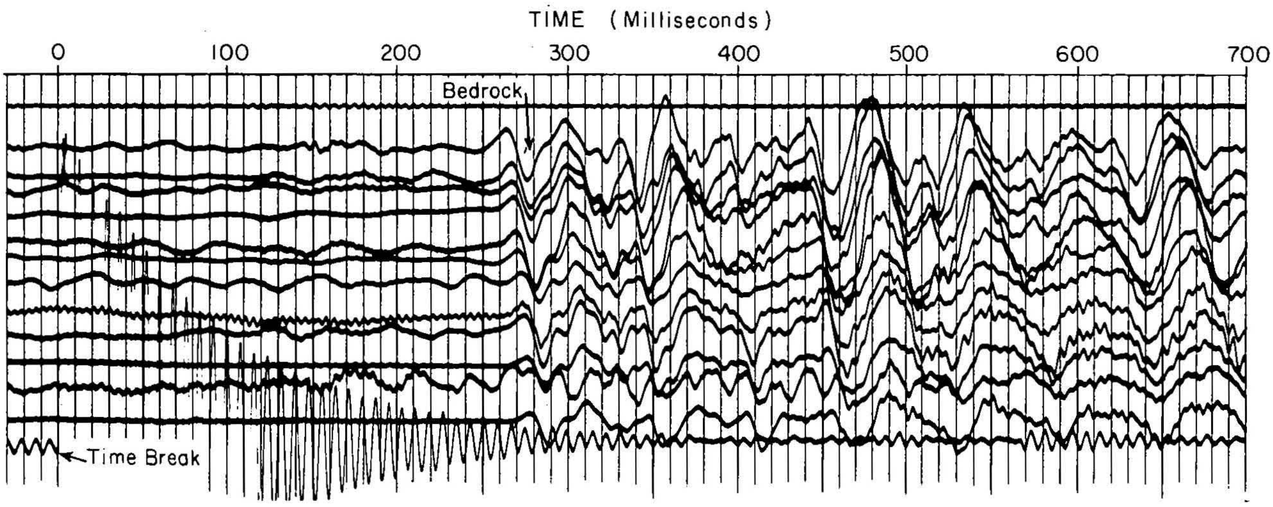
SHOT 8C

LOCATION HOWE BIGHT

CHARGE 0·2 kg

HYDROPHONE SPACING 6·8 m

(b) REGION OF HIGH ATTENUATION



MALLACOOTA 3-12-1971

SHOT 15 B

LOCATION JOHN BULL LIGHT

CHARGE 0·5 kg

HYDROPHONE SPACING 6·8 m

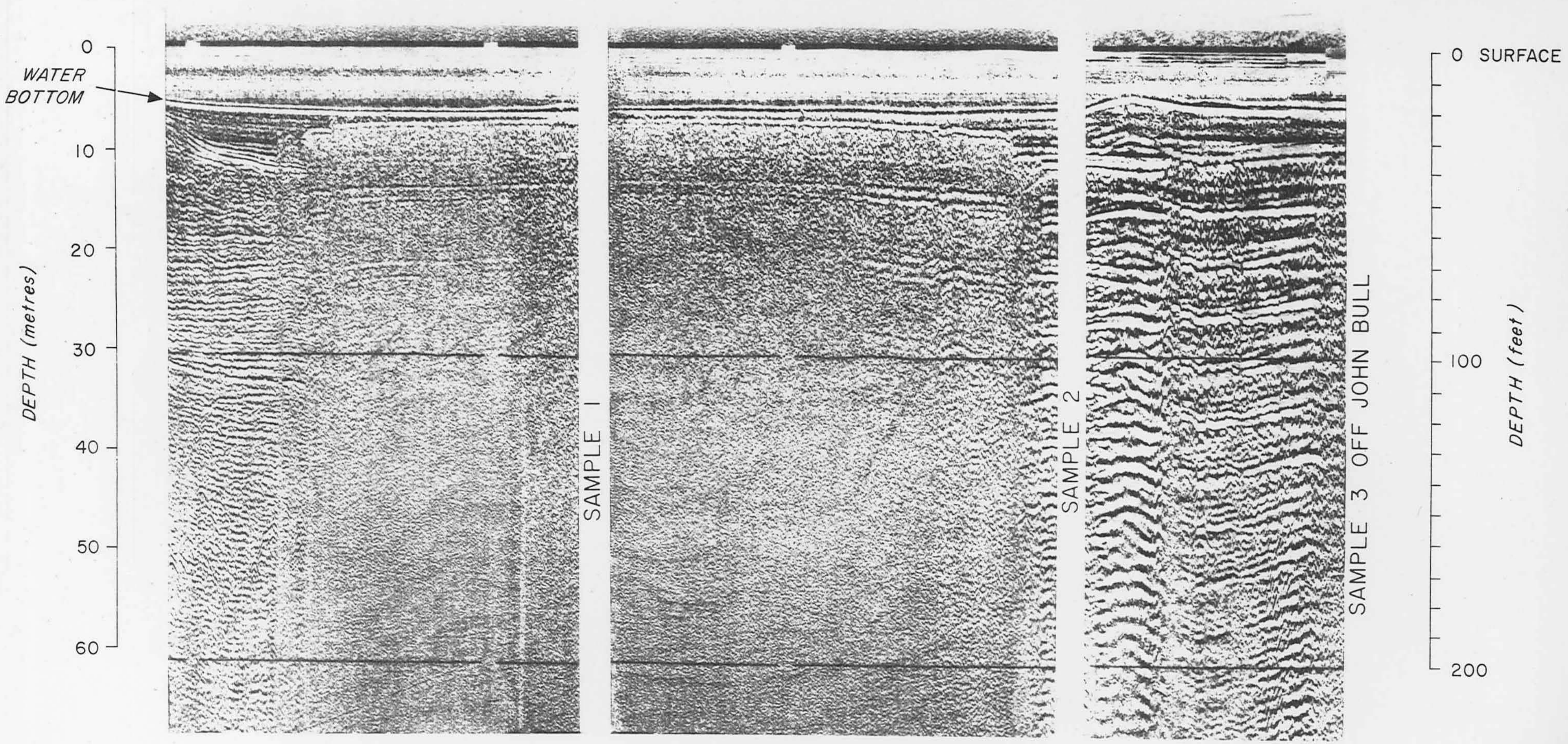
COMPARISON OF SEISMIC REFRACTION RECORDS

MALLACOOTA VIC 1971

To accompany Record No. 1972/85

J55/B5-84A

To accompany Record No. 1972/85

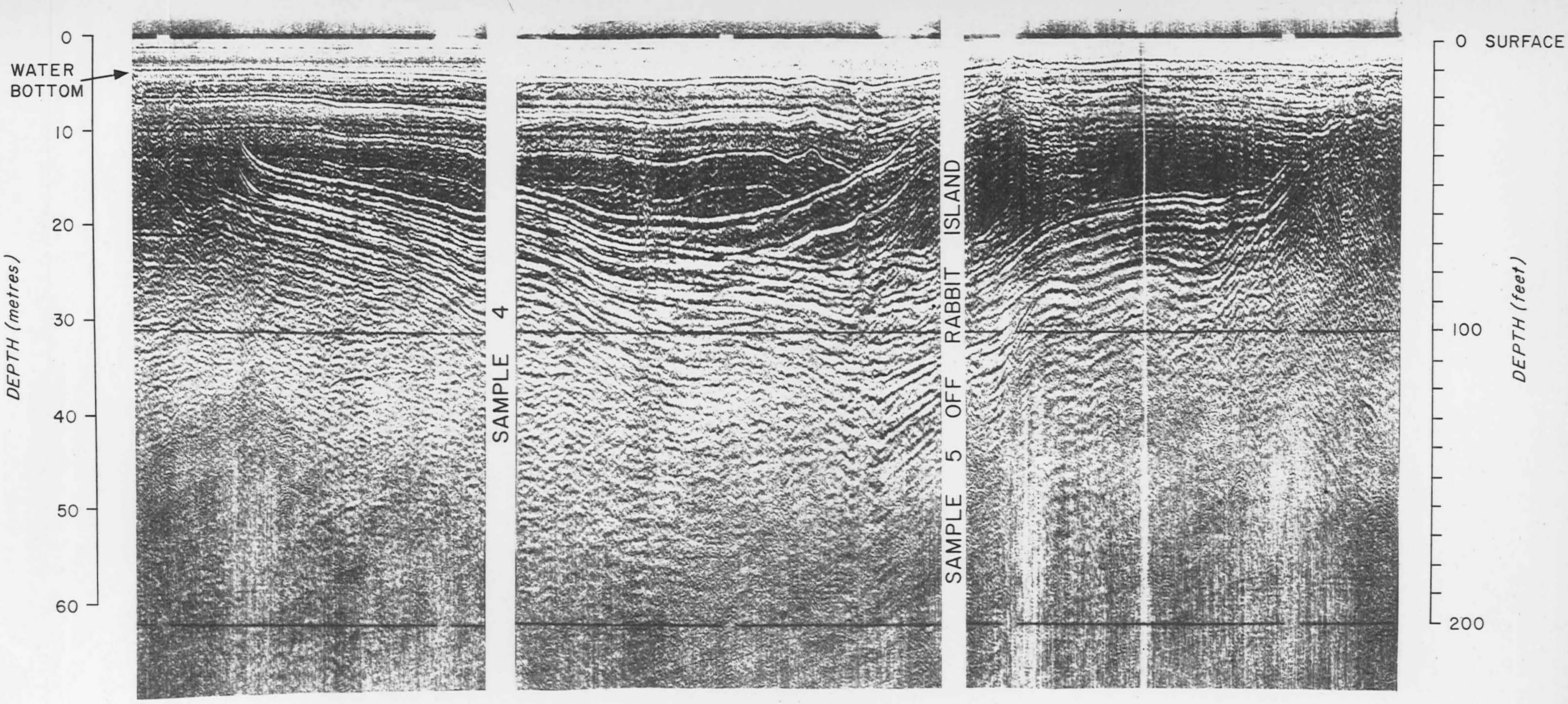


BOTTOM SAMPLES 1, 2, AND 3 RELATIVE TO SPARKER PROFILE

PLATE 5

J55/B5-86A

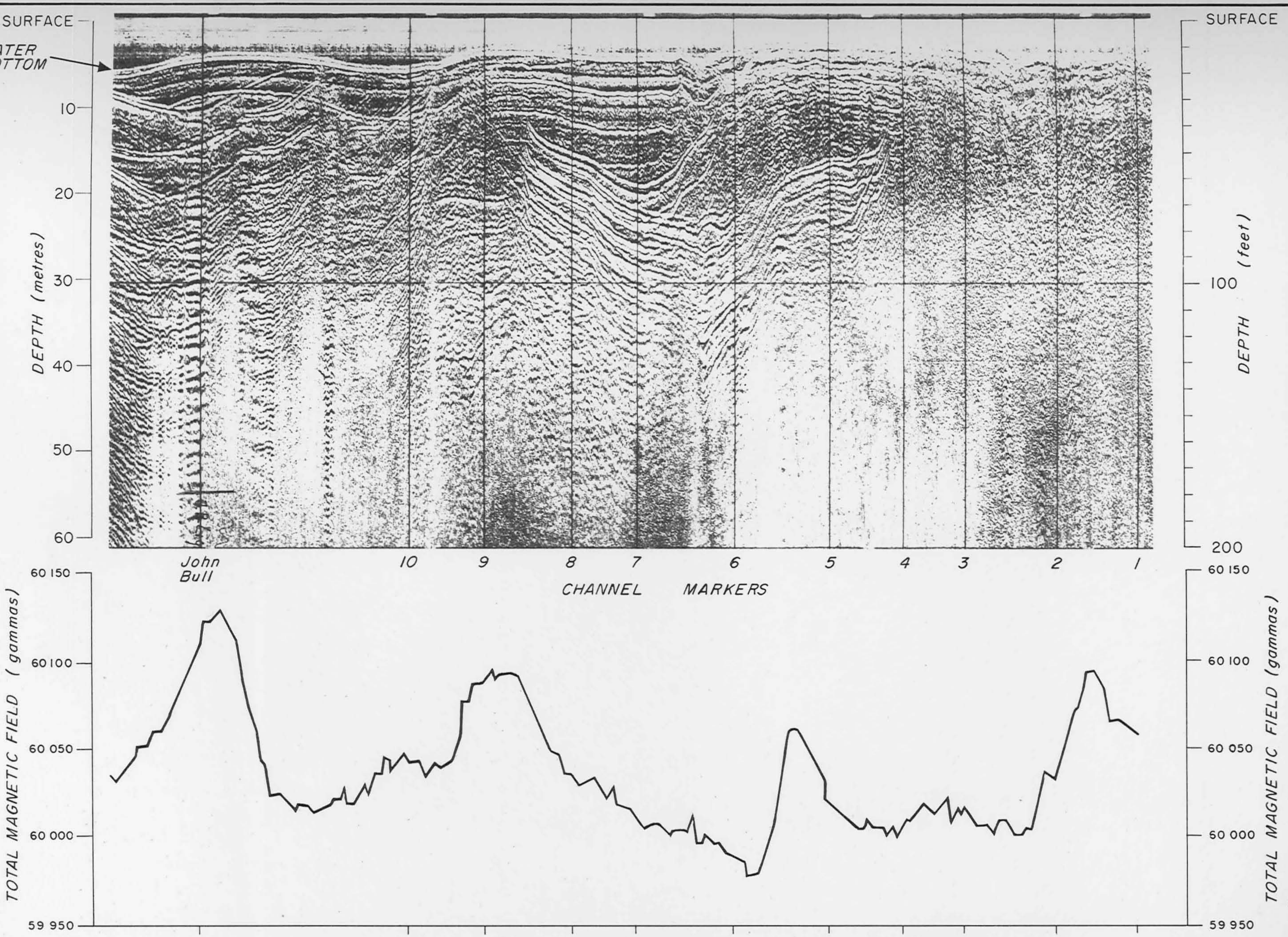
To accompany Record No. 1972/85



BOTTOM SAMPLES 4 AND 5 RELATIVE TO SPARKER PROFILE

PLATE 6

J55/B5-87A

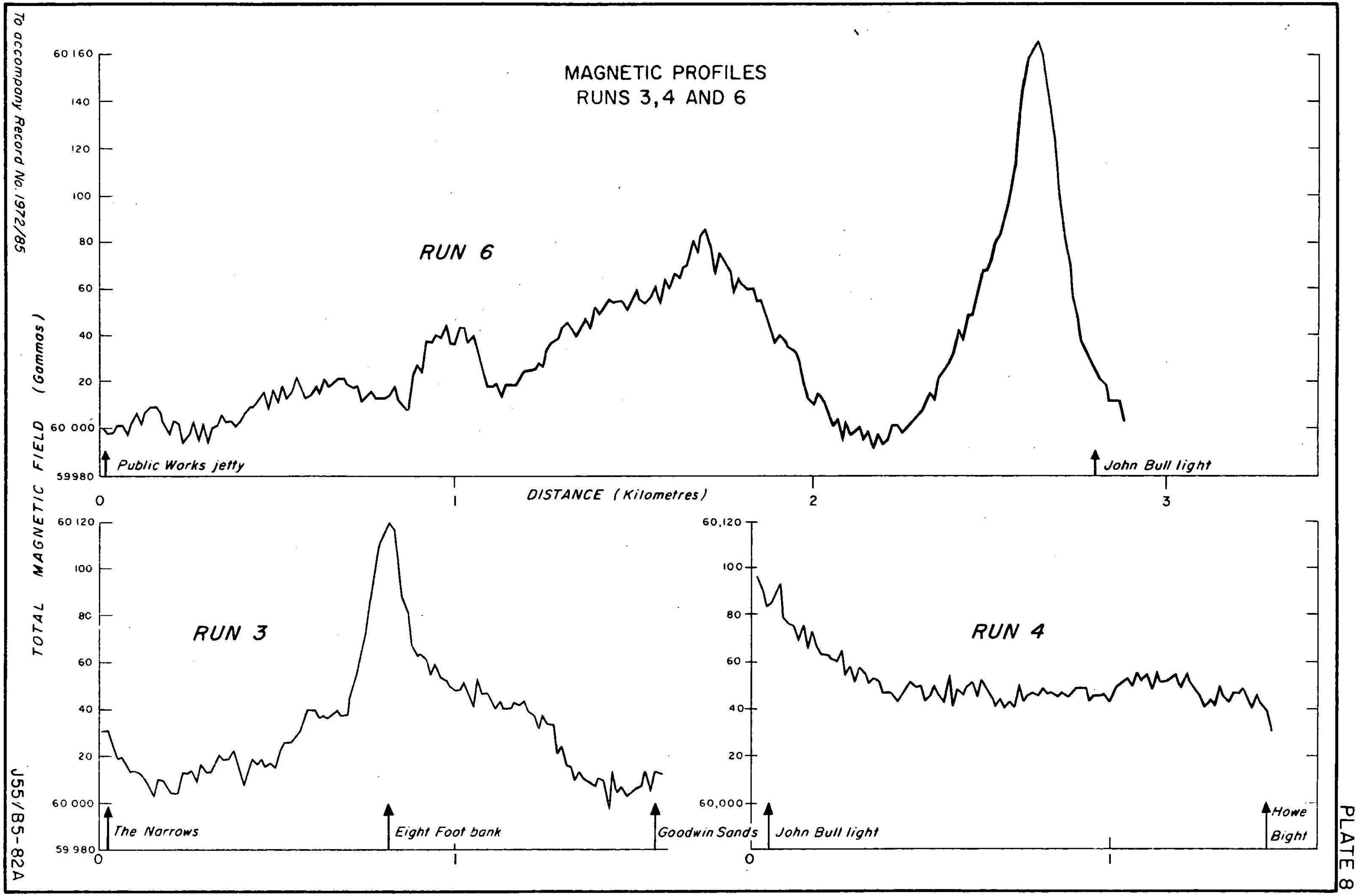


RUN 7 MAGNETIC PROFILE
AND LINE U SPARKER PROFILE

To accompany Record No.1972/85

PLATE 7

J55/B5-83A



To accompany Record No. 1972/85
MAGNETIC PROFILES
RUNS 3,4 AND 6
RUN 6
60 160
140
120
100
80
60
40
20
60 000
59980
Public Works jetty
John Bull light
0
1
DISTANCE (Kilometres)
2
3
TOTAL MAGNETIC FIELD (Gammas)
RUN 3
60 120
100
80
60
40
20
60 000
59 980
The Narrows
Eight Foot bank
Goodwin Sands
RUN 4
60,120
100
80
60
40
20
60,000
John Bull light
Howe
Bight
J55/B5-82A
PLATE 8