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RECORD No. 1968/18

COASTAL EROSION GEOPHYSICAL SURVEY OF THE GOLD COAST, QUEENSLAND 1967

by

G. CIFALI, G. HART, P.E. MANN, E.J. POLAK, and W.A. WIEBENGA

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CONTENTS

ILLUSTRATIONS

1968/18

SUMMARY

During January and February 1967, a 'Sonar Boomer' survey was carried out by the Bureau of Mineral Resources (BMR) in conjunction with an echo sounder survey by the Co-ordinator-General's Department, Queensland.

With the 'Sonar Boomer', only one continuous sub-bottom reflector (bedrock) was recorded. Depths to bedrock were obtained for only about 60% of the total length of traverse in zones where reefs were notpresent. Reefs could be picked on the echo sounder records. Difficulties with noise in rough weather and with masking by multiples when in shallow water were mainly responsible for the incompleteness and imperfect reliability of the bedrock depth data. A contour map of the bedrock was produced, showing a surface similar in form to the sea-bed, but more irregular and dipping more steeply to the east.

Limited land and sea seismic refraction work was also carried out. The results are of interest in their own right and also are of assistance in the interpretation of the 'Sonar Boomer' data.

Sea temperatures were also measured along the traverses. To obtain a near-surface temperature pattern, corrections were applied, eliminating short-term influences. By assuming that under the influence of the Coriolis force, water moves along temperature contours, the temperature results were interpreted in terms of currents. At various places cooler well water comes to the surface. Measurements of vertical temperature distribution are discussed in relation with the near-surface temperature pattern. The occurrence of eddy currents and cooler well water can be predicted from a depth contour plan. The results of such a prediction seem to confirm, at least qualitatively, the validity of the current pattern deduced from the temperature survey.

1. INTRODUCTION

The small section of the Queensland coastline between Coolangatta and Southport known as the 'Gold Coast' have, over the last 30 years, developed into a major tourist centre of Australia. Large expensive hotels and motels and many private dwellings have been built close to the beach. This development has focused attention on the continual changes wrought by the inexorable forces of the ocean on the coastline. The general trend of natural processes has been the erosion of the beaches, although accretion in several areas has taken place during one or more years. Also, with the increase of population the problem of sewage disposal has arisen.

The Co-ordinator-General's Department of Queensland (C.O.G.) was asked by the Queensland Government to investigate all aspects of coastal hydraulics and morphology to provide the basic data for the design of major coastal engineering projects required to alleviate the erosion. In 1964, C.O.G. secured the services of overseas authorities from the Delft Hydraulics Laboratory, Delft, The Netherlands, to examine the problem and recommend the type of investigation required for the design and execution of remedial measures. The Chief Engineer of the Site Investigation Service of the Laboratory carried out an examination in 1965. A report prepared giving recommendations for a comprehensive coastal investigation lists inter alia ten disciplines.

In response to an application from C.O.G., the Bureau of Mineral Resources, Geology and Geophysics made a geophysical survey to determine sub-bottom structure, and collected salinity and temperature data of the coastal waters. All data collected would be given to the Delft Hydraulics Laboratory for further evaluation. The 'Sonar Boomer' reflection bottom-profiling method was used at sea. Some conventional seismic refraction shooting was done on the beaches and at sea. The work was done between 13th January and 4th March 1967 by a party consisting of E.J. Polak, party leader and geophysicist: G. Cifali and G. Hart, geophysicists; A. Radeski, technical officer; and D. Tarlinton, field assistant. P.E. Mann, geophysicist, took over as party leader on 5th February, and A. Radeski left the party on 11th February.

The 'Sonar Boomer', other recording equipment, and power supplies were housed on the C.O.G. 85-ft twin diesel launch M.V. SI BON, crewed by captain, marine engineer, and deckhand. Six field assistants from C.O.G. operated the 'Hydrodist' marine position-fixing equipment; two men at each remote station and two at the master station on the ship. Mr. B. McGrath, executive engineer of C.O.G. for the coastal erosion project, was liaison officer for the survey.

2. PHYSIOGRAPHY AND GEOLOGY

The Delft Hydraulics Laboratory did not recommend a comprehensive geological investigation of the area, although geological data are being continually used to interpret the present conditions and the effectiveness of future work proposals. An investigation may indicate unknown factors and their general effect on the coastal erosion.

Some information can be found in published geological maps and reports, viz. Beasley (1948), Gardner (1955), and Connah (1961). Surveys to study erosion and silting at Southport have been done by Connah (1946) and Brooks (1953).

Physiography

Coastal plains, one-half to three miles wide, extend over most of the area. These plains consist of swampy flats of sand, mud, peat, old dune ridges (vegetated), estuarine alluvium, and coastal dunes about 300 to 1200 feet wide. Up to twelve coastal dunes paralleling the coast have been recognised (e.g. at Broadbeach).

The coastal plains are cut by meanders of the Tweed and Nerang Rivers. Small creeks (Tallebudgera, Currumbin, and Flat Rock) also drain the coastal swamps.

A feature of the rivers is the sharp change in direction close to the ocean. The rivers approach the coast generally in an easterly direction, turn sharply, and discharge some miles northward.

Mountains form the western boundary of the coastal plains, and rock crops out as headlands at North and South Nobby, Coolangatta, Currumbin, Burleigh, and Point Danger. Hails (1964) interprets the headlands as submerged promontories. Between the headlands the beaches are in dynamic equilibrium. Submarine reefs have been found from sounding records and are known from local knowledge. Reefs are more extensive in the northern part of the area.

Geology

In the survey area the bedrock consists of the Nerangleigh-Fernvale Group (Belford, 1953) of Lower Palaeozoic age. The Group, probably of Silurian age, consists of sandstone, siltstone, and quartzite. At several places along the beach small outcrops were observed during survey work, for example at Flat Rock Creek, about 50 ft north of seismic spread S7. At this outcrop the beds strike approximately north-west and dip steeply to the east. Bedrock with about the same dip and strike was observed south of Tugun. However, no measurements were made on any outcrop. Some geology is shown in Plate 2.

Basalt of Tertiary age is widely distributed in south-eastern Queensland (Soloman, 1964) and occurs as cappings on Burleigh and Point Danger headlands in the survey area. The known geology of the Moreton District suggests that basalt may be present in the sub-bottom. Cook Island and some nearby reefs are probably basalt.

The coastal region has been subjected to a series of eustatic movements from mid-Pleistocene to Recent times (Gardner, 1955). During this period sea level has varied from 100 ft above, to 250 ft below, the present level; i.e. the coastal plains and off-shore deposits have been both exposed and submerged. During emergence, the unconsolidated sediments have been rapidly eroded and deposited in what is now quite deep water.

The area now occupied by the plain has been built progressively seaward by river and marine deposition. The initial stages of infilling have been accomplished by rivers with greater discharges and sediment capacity than those of today. The large volume of material supplied to the off-shore zone was reworked and redeposited by littoral currents. A decrease in the activity of the rivers promoted deposition with sea level changes modifying this operation. Sediment (i.e. sand) transport into the area by the northerly off-shore current has been of enormous importance to the area.

3. TRAVERSES

The survey network suggested by Delft Hydraulics Laboratory to examine the submarine topography and bottom structure consists of fifty traverses, half a mile apart, approximately perpendicular to the coastline and extending about eight miles seaward. Shorter traverses were suggested for areas of sewage outfall. The BMR added five cross-traverses (Seismic 1, 2, 2A, 3, and 4). The survey area (see Plate 1) was confined to the coastline between Tweed Heads, New South Wales, and Southport, Queensland.

Cyclonic weather reduced the number of days suitable for operating the recording equipment as the launch was available only for a limited period. After gaining experience with the 'Sonar Boomer' system many of the earlier traverses were repeated. Altogether forty eight ordinary traverses and two outfall traverses (Eta 29 and 34A) were surveyed.

Positioning at sea was done with the 'Hydrodist' equipment; two units were on the ship and two units at selected land stations. C.O.G. had prepared, by computer, tables of the sets of distances from the land stations required to pilot a straight course. These distances were monitored continuously and read every 100 metres on traverse. Correctionsto bring the ship back on course were determined by the navigator and applied by the captain. Every 100 metres the navigator impressed fiducial distance marks on all records by manually operating a simple electrical circuit. Several traverses could be covered by using the same land stations; other traverses required the positions of the land stations to be changed. The 'Hydrodist' equipment proved very accurate and any repreated traverse probably differs by not more than a few metres from the position of the original traverse. The traverses show small divergences from straight lines generally at their ends only.

Traverses perpendicular to the coast were sailed seaward or landward with echo sounder, 'Sonar Boomer,' and temperature systems operating simultaneously. Landward, the traverses were run to a navigable limit; seaward, the traverses were run until the ship lost contact with the land station or the end of the traverse was reached.

Water depth was continuously recorded by an 'Elac' high-frequency echo sounder. Some reefs were detected by the echo sounder. Tidal corrections, obtained from continuous recording tide gauges along the coast, were applied to obtain the sea-bed elevation (Plate 2).

The first few traverses were run at about three knots. Later the speed was increased to six knots because it was then easier to keep on the traverse in the prevailing bad weather conditions.

For convenience, the notation OM 5;7000 , meaning the 7000-metre mark (station) on traverse Omega 5, will be used.

4. MARINE PROFILING

Equipment

A description of the 'Sonar Boomer' system is given by Polak (1965). The equipment used consisted of two power units Model 232, two capacitor banks Model 231, and a trigger unit. The spark gap in the trigger unit is triggered in synchronism with the rotation of the recorder helix. The capacitor banks discharge via the spark gap through the coil of a Model 236 transducer. The equipment was operated at full power, i.e. 1000 watt-seconds. Some experimenting with 500 watt-seconds was carried out but the results were worse than with full power. Pressure pulses in the water were detected by a hydrophone Model 262-G, a 2-inch diameter, 10-ft-long oil-filled hose containing the pressure sensitive element. Signals from the hydrophone were amplified and filtered in a Model 254 unit incorporating an 'Alden' wet paper, helical wire recorder.

Method

The transducer assembly was suspended amidships on the port side from a temporary rigid beam and pulled through the water by steel cable from a derrick.

Initially the suspension was rigid but later it was converted to a spring. This arrangement kept the aluminium transducer plate about three feet below the water surface and stopped the transducer from 'porpoising' when the ship rolled excessively. The hydrophone trailed astern on the port side. The hydrophone depth was about three feet and the distance between transducer and hydrophone was about 65 ft. The depth, separation, and the relative position of the hydrophone and transducer were varied to obtain the optimum operating conditions.

Records

Two sample 'Sonar Boomer' recordings are reproduced in Plates 5 and 6. The horizontal lines are timing lines impressed on the record at 10-millisecond intervals. On both plates the time scale is shown, giving the total travel time of the pulses. The vertical lines are distance marks manually impressed on the record by the navigator; they indicate successive 100-metre intervals along the traverses measured from the baseline.

A pressure pulse arriving at the hydrophone triggers the printing circuit and a dark mark is made on the record. Pressure pulses may originate from the hydrophone or from random sources such as the ship's propeller. Since the pulses from random sources are not synchronised with the sweeps of the helix, they do not give rise to continuous horizons. Continuous horizons arise mainly when pulses are reflected from continuous surfaces. The group of parallel traces near the top of the record is probably connected with the triggering of the spark gap. The group of traces starting about 14 ms down the record consists of arrivals from the transducer direct and reflected only at the water surface.

Generally the weather throughout the survey was poor. Strong south-east winds blew and seas were moderate to rough. Two periods of cyclonic weather were experienced. This survey showed that record quality deteriorated as the sea conditions worsened. Although different techniques were applied to maintain record quality in deteriorating weather, they were unsuccessful and several traverses were abandoned until the weather improved.

The depth scales available in the Model 254 recorder are not consonant with the water-depth encountered on the traverses. As the firing rate is governed by the number of power units used, only the 50-ms and 250-ms (240-ft and 600-ft) sweep speeds could be used. In-shore, sub-bottom structure was better displayed on the 50-ms time scale; where the water depth was greater than 100 ft the 250-ms time scale was more suitable.

To convert time sections to depth sections, the velocity of sound in the layers above a given boundary must be known or estimated. For water or water-saturated sediments the velocity is about 5ft/ms: i.e. a time of 5 ms is equivalent to a depth of about 25 ft. The velocity of harder or more consolidated material is greater and the equivalent depth will be greater.

Generally, sub-bottom reflections were poorly recorded and many traverses were repeated to eliminate recording faults.

Repetitions

A disadvantage of the equipment arises from the repetition on the record of continuous horizons that correspond to a single boundary.

The output wave train of the transducer is not a single pulse and has at least three main peaks (Hersey et al, 1960). The production of these is ascribed to the movement of the transducer plate, the collapse of cavitation bubbles produced at the back of the transducer plate, and the reflection of the pulses from the water surface. Ideally these pulses reflected at each boundary will give rise to two sets of pulses at the hydrophone, one direct, and one reflected from the water surface, to produce continuous horizons on the record. Alternatively, repetitions may be caused by 'rattle' or 'ringing' of the filter stage in the recorder. Records taken in good weather conditions early in the survey, with low amplification of the hydrophone output, generally showed three continuous horizons corresponding to the sea bed. Deeper boundaries were intermittently and poorly recorded. When the weather deteriorated, the transducer was run deeper to prevent it leaving the water and the receiver amplification was increased. The number of repetitions increased to six. The effect of repetitions is to conceal, at least partly, a boundary that is less than a certain depth below another. The thickness of the concealed zone depends on the seismic velocity of the layer and the number of repetitions. Interference of repetitions from the sea bed with those from the sub-bottom was troublesome on traverses Seismic 1 and 4, but generally not so troublesome on the Omega traverses. Boundaries determined on the Omega traverses were used to control interpretation of the Seismic traverses. Between traverse intersections it was sometimes possible to follow a boundary when the first arrival from the boundary was amongst repetitions of a shallower one (i.e. the sea bottom).

Multiples

Multiples, a common feature of recordings with 'Sonar Boomer', are signals which have undergone more than one reflection. The multiple most easily distinguished is that due to the reflection of a signal from the sea bottom to the water surface, back to the sea bottom, and then back again to the hydrophone. This multiple will normally be recorded with a travel time about twice that of the water-bottom reflection and therefore will show any bottom feature in exaggerated relief. Figure 1 of Plate 4 shows some of the many paths resulting in multiples. However, energy considerations limit the number of multiples recorded.

Multiples, normally easily recognised, may mask sub-bottom reflections. Figure 2 of Plate 4 can be used to predict the approximate arrival time of the first two water-bottom multiples from the water-bottom reflection travel-time, for a hydrophone-transducer spacing of 70 ft. This figure predicts that in shallow water, severe masking by multiples will take place; this was confirmed by the survey records. Usually multiples were weakly recorded, and were not of use in record interpretation.

Noise

Throughout the 'Sonar Boomer' work, noise was the greatest problem in the detection of reflected arrivals from sub-bottom discontinuities (signal). Since noise is synchronised neither with the sweeps of the recorder helix nor with the signal from a stationary surface, it does not give rise to continuous horizons on the record. However, noise obscures the signal and often compels the use of undesirably low amplification of the hydrophone output. Noise sources may be classified as belonging to the sea, the ship, or the receiving system.

Sea noise was found to increase rapidly with wave height and probably increased with wave frequency also. For 2-ft waves, wave noise was negligible; for large waves (greater than 8 ft) it was excessive. It is to be expected that wave noise will increase towards the coast owing to the breaking of the waves. This is not obvious on the records, probably because the receiver gain was decreased inshore when the signal became stronger to avoid the records being printed too darkly. It is possible that large waves or short-period waves are responsible for some signal-induced random noise by diffraction of the signal to the hydrophone. Reflection of signals from a wave to the hydrophone directly from the transducer is probably not possible.

Some noise, serious at times, was produced by the survey ship. Sources were the ships wake, propellers, and main diesels (all acoustic). Possibly, severe electrical noise was produced by a petrol-driven generator used intermittently to power the ship's refrigerator.

Noise from the ship's propeller and main diesels was probably unimportant owing to filter settings used in the receiving system: the ship's engine speed was approximately 20 rps, and that part of the spectrum below 200 c/s was filtered out in the receiving system.

When conditionswere bad, noise from the ship's wake was not so severe as that from other sources. However, when weather conditions were good, as in the earlier part of the survey, the noise of the wake may have predominated. Filters probably remove much of this noise.

Noise from the receiving system could be produced in the amplifiers but for practical purposes the hydrophone is probably the only part of the receiving system responsible for noise. Presumably this noise is caused by turbulent flow past the hydrophone body (although streamlined to minimise this) and by suspended solids striking the hydrophone. This noise increases rapidly with boat speed. In fact, it is recommended by the manufacturers, Edgerton, Germeshausen and Grier Inc, that the boat speed be kept as low as possible, preferably three knots or less.

Errors

As continuous monitoring of the ship's path was done by 'Hydrodist', error in positioning the boat on a traverse is considered negligible. Thus direct comparisons can be made between the original and subsequent records for any repeated traverse.

The error in determining the depth of different sub-bottom reflectors depends on the quality of the record and the velocity of the different layers. The nature of the 'Sonar Boomer' records at shallow depth, where there is considerable confusion caused by multiple reflections and by repetitions, is such that large errors may arise from an incorrect interpretation of the trace. This is particularly the case where no control is available. It was proposed to use refraction seismic control, but insufficient time and bad weather prevented this being done fully. Other errors in depth calculations can be placed on a more quantitative basis. The error in reading the time of a given trace would not be more than a half-millisecond, one millisecond being the maximum thickness of the trace observed. Larger errors of the order of 2 ms will arise if a first repetition is interpreted as an initial trace. Errors also arise when incorrect estimates of velocity are made and depths are calculated from these estimates. Consider a layer of thickness $w = vt$ where t is the one-way travel time across the layer and v is the velocity of seismic waves in it. Then the error dw in w is given by

$$\frac{dw}{w} = \frac{dv}{v} + \frac{dt}{t}$$

As noted above, dt for a layer defined by two boundaries will be one millisecond. In practice the velocity ranges from about 4.8 to 5.3 ft/ms with occasional higher values. A velocity of 4.8 ft/ms was adopted for computation. Generally only one reflector was recorded and an estimate of the error in determining the depth of a deeper horizon is not developed here.

Interpretation

There is little published material on the interpretation of 'Sonar Boomer' records in shallow conditions and experience will help formulate the technique of interpretation. Some of the techniques evolved are described and may possibly be useful for the future.

A mean line was drawn across the record through the strongest trace of the repetitions of the bottom and the corresponding repetition of the first sub-bottom reflector. This procedure smooths the wave action and is simple for records with three repetitions only. Records taken in rough weather can be difficult to read because wave motion gives illusory dips to the continuous traces and consequently false structural features in the reflectors. Also, multiples may be present in critical places.

Over reef areas (zones where the sea-bottom is hard rock) the traces become jagged. A character change from records with smooth sedimentary bottom is obvious. The change was particularly noticeable on the echo sounder records which were, for this reason, used to give bedrock depths in reef areas.

On some records, the bedrock came close to the sea-bottom and was obscured by bottom repetitions, but the echo sounder gave no reef and only a slightly irregular sea-bottom. These zones are interpreted as very shallow bedrock.

In this report the term bedrock is used to indicate the only observed continuous sub-bottom reflector. The bedrock probably consists of weathered Nerangleigh-Fernvale Group or Tertiary basalt (Polak and Kevi, 1965) but any hard rock with seismic velocity well above 6000 ft/s could fit the interpretation.

On other traverses where no sub-bottom reflections were observed (and where recording quality was not the cause) clay probably grades into unweathered bedrock through an extensive transition zone without sharp discontinuities, or the absorption of seismic waves is so great that no significant amount of energy reaches the hydrophone after reflection from the bedrock. Both effects may be present. On the records the sea bottom is taken to be the same as that identified from the echo sounder records.

Results

The known off-shore 'bedrock' depth data are given in Appendix 1. This table consists of depths (below State Datum), rounded off to the nearest foot, at each hundred-metre mark on sounding traverses of bedrock as given by (a) the 'Sonar Boomer', where a sub-bottom reflector was detected, and (b) the echo sounder, where 'reef' was detected. The depths to reef can be obtained from SC plan numbers 206A, 207, 208A, 209, and 210 of C.O.G. No information was obtained on outfall traverses. Plate 3 shows contours at 10-ft intervals of the depths given in Appendix 1.

Altogether, the 'Sonar Boomer' work was not nearly as successful as anticipated. This can be attributed to: (a) the bottom profiling system, which is really designed for much deeper work (e.g. off-shore oil exploration); (b) the conditions experienced during the survey (noise, bad weather, and the probable partial absence of sufficiently good seismic discontinuties); and (c) equipment breakdowns and malfunctions.

Where sub-bottom reflectors were not recognisable, it was probably due to one or more of the following reasons:

(a) Water depth was less than about 30 ft (bottom multiples, always strong in shallow water, obscured the signal).

(b) Noise was excessive (e.g. in bad weather)

(c) The sub-bottom reflector was obscured by water bottom repetitions.

(d) Reef was present

(e) Suitable seismic discontinuities were absent

(f) The attenuation of signal in the sub-bottom was too great.

Mainly because of these factors, the 'Sonar Boomer' gave depths to bedrock on only about 70% of the total length of traverse over sedimentary sea-bed. About 27% gives no values and about 3% is doubtful (See Appendix 1).

Despite the general low quality of the records, there is reason to believe that there is probably no main reflector of seismic energy of frequency 1Kc/s at depths in the range 60 to 100 ft below the sea bottom. The sediment thickness, or depth from sea bottom to bedrock, increases quite consistently seawards along traverses and a maximum of 54 ft was encountered at the end of OM13. Nowhere is the bedrock seen to dip under 50 ft below the sea-bottom and then disappear owing to low signal amplitudes. Some of the signal amplitudes, for sediment thicknesses of 50 ft, are quite high. However, the nature of the sediment layer could be highly variable, except that the degree of consolidation must be fairly small.

Concerning the contouring of bedrock depths in Plate 3, the following points should be noted: (a) The contouring may be ambiguous, e.g. at OM6; 11000; (b) the reef areas near Cook Island and The Spit are either not contoured or contoured in a rather doubtful fashion, because of their irregularity.

Plate 3 shows that there is a marked similarity between the sea-bottom and the bedrock topographies. Bedrock contours, like sea-bed contours, show a trend similar to the coastline. The sediment thickness (unconsolidated) therefore increases mainly with distance from the coast. Also, bedrock gradient is, like the sea-bottom gradient, greatest near the coast and also at about seven miles east of Point Danger. However, bedrock topography is more irregular and the easterly dip is steeper than that of the sea-bed. Other features of the bedrock topography can be noted:

(a) A small number of hills is present, e.g. the one 30 ft high at OM22;6000. These hills are probably not very significant owing to their limited areal extent and height.

(b) Minor 'valleys' appear to be present, e.g. between OM 33;2000 and OM 33;5000. Owing to the inaccuracies, these may not all be real.

(c) Overall, the bedrock topography is quite flat.

(d) Major bedrock 'lows' appear to be absent.

It is possible that the pre-Quaternary basement topography is more irregular than that of the bedrock, owing to infilling by consolidated or partly consolidated alluvial, estuarine, littoral, or continental shelf deposits of, say, Pleistocene to Recent age.

5. SEISMIC REFRACTION TRAVERSES AT SEA

Method and equipment

Three refraction spreads were fired at sea: two on traverse Seismic 1 and one on traverse Omega 37. The shot-to-geophone layout is based on the method of differences (Heiland, 1946).

Twelve hydrophones attached to a buoyed cable were towed astern of the ship into position on a traverse. A weighted charge was placed overboard and fired below the ships stern, on the bottom or at an intermediate depth, when the ship stopped. The location and water depth were determined by the 'Hydrodist' and echo sounder respectively. A reversed profile was obtained by shooting after reversing the ship's direction. By paying out the hydrophone cable, shot distances of 50 and 300 ft could be obtained. The error in position of the reversed spreads is considered negligible because of the accuracy of the 'Hydrodist' equipment and the straightness of the hydrophone cable. Because of time limitation, other spreads were not surveyed.

Hydrophones manufactured by Electro-Technical Laboratories were connected to a 12-channel recording system consisting of amplifiers and oscillograph manufactured by South-western Industrial Electronics.

Results

The results are given in Appendix 3. They show, at Seismic 1;2000 and OM 37;2200, the existence of a high velocity (11,000 ft/s) layer less than a few hundred feet below sea level. Unfortunately, for both traverses, the quality of the 'Sonar Boomer' record is poor, so that it is not possible to compare the two methods directly. However, adjacent traverses give useful information for comparisons. It appears that the high velocity layer is consistently far too deep to be identified with the 'Sonar Boomer' bedrock, which must be a shallower layer (of intermediate velocity).

6. SEISMIC REFRACTION TRAVERSES ON LAND

Methods and equipment

Cyclonic weather prevented ship-borne operations between 24th February and 2nd March. Refraction shooting at eleven locations (Plate 3) along the coastline was carried out in this period. Spreads were laid out on the beach several feet above the wave wash, approximately parallel to the water line. Geophones were buried in the sand, 60 ft apart. Strong wind, rain, heavy surf, and severe electrical interference produced a high noise level. It was not possible to improve the signal-to-noise ratio by using very large charges. Although each location was carefully selected, the beach is narrow and houses are built to the edge of the first dune. Small charges were used and the seismogram quality is poor. Nevertheless, the seismograms give useful approximate depths and velocities of refractors along the coastline.

A 12-channel seismograph manufactured by South-western Industrial Electronics was used with T.I.C. geophones having a natural frequency of 20 c/s to record the arrival of the longitudinal waves.

The seismic refraction method used was the method of differences (Heiland, 1946, p. 548). Close to the geophone spread charges were fired in-line and in the sand. At larger distances, charges were fired about 3 ft deep in the surf and about 200 ft off-line.

Unfortunately it was not possible to shoot refraction spreads perpendicular to the coast, to measure the bedrock dip in the easterly direction. In computing seismic results from the arrival times, it was assumed that the easterly dip was zero. Considerable errors in velocity and depth of the deeper layer would result if, at the spread locations, this dip was large.

Results

The results are given in Plate 7. The numerous consistent features are summarised in Table 1.

TABLE 1

SUMMARY OF LAND REFRACTION RESULTS AND INTERPRETATION

Location (spread number)	Seismic velocity (ft/s)	Interpretation in geological terms
S4, S6, and S8	2000 to 3500	Sand, almost dry to nearly saturated
All but S6 and S10	4000 to 5700	Sand, water saturated
S8 and S10	5800 to 6500	Semi-consolidated sediments or weathered rocks, saturated
S3, S4, S8, and S9	9000 to 12,500	Consolidated sediments or slightly weathered rock, saturated
S1 to S11	14,000 to 18,000	Unweathered 'basement' (igneous, sedimentary, or metamorphic)

The qualitative data in Plate 7 are reasonably reliable as far as they go. Probably, the layer of weathered bedrock (9000 to 12,500 ft/s) should be present at most locations rather than at four only. The 5800 to 6500-ft/s layer is probably either partly consolidated sediments or highly weathered bedrock. The high velocity layer (14,000 to 18,000 ft/s), present at all locations, is interpreted as unweathered pre-Pleistocene basement (probably Nerangleigh-Fernvale or Tertiary basalt).

Quantitatively, the data given in Plate 7 are poor. The error in unweathered bedrock depth may often be worse than 30%. Despite this and the paucity of in-shore 'Sonar Boomer' data, the 14,000-18,000-ft/s layer is, at nearly all locations, too deep to coincide with the 'Sonar Boomer' bedrock, if the latter is extrapolated to the spread locations. An exception is at Flat Rock Creek, where the weathered layer could be absent.

The 'Sonar Boomer' bedrock is therefore probably the layer below the 4000 to 5700-ft/s layer.

7. SALINITY

It was intended to record the near-surface salinity variations continuously along the traverses to infer the presence and nature of currents, if any. Measurement of the salinity variations of sea-water involved simultaneous recording of both resistivity and temperature at the same depth.

If S is the salinity, p the resistivity and T the temperature,

$$dS = -A\, dp \quad -BdT$$

where A and B are positive constants.

In sea water (approximate salinity 30,000 p.p.m.; resistivity 0.2 ohm-metre; and temperature 25°C) it was desired to detect salinity variations as small as 100 p.p.m., resistivity to 0.0005 ohm-metre, and temperature to 0.1°C . Unfortunately the commercial resistivity meters taken on the survey proved too insensitive to detect the small variations of resistivity that probably existed.

A 1000-c/s a.c. recording bridge system to indicate resistivity variations as small as 0.0003 ohm-metre was designed and tested during the short time available for experimental work. In this design, variations of cell resistance change the amount of unbalance of the bridge, operated off balance, and the unbalance voltage is processed and recorded. Unfortunately, various factors, including the presence of bubbles and detritus in the sea water, electrode corrosion, and the effect of temperature changes on the circuit elements, prevented successful operation of the system. It was not possible to eliminate all these factors in the time available.

8. MAGNETIC METHOD

It was proposed to record total magnetic field along the traverses using an 'Elsec' proton magnetometer with the detector head in a towed 'fish'. The towed 'fish' was not imported in time to reach the survey. However, some experimental work, with a detector head attached to the ship's mast, was carried out. The digital output was recorded by a three-pen 'Devar' recorder but the operating conditions gave too high a noise level and the method was discontinued.

9. TEMPERATURE

Equipment

Sea water temperature was measured with a thermistor system designed by the BMR. The circuit diagram and calibration curves are given in Plate 14. Temperature measurements were continuously recorded by a Speodomax Recorder Type G, Model S, 60,000 Series manufactured by Leeds and Northrup.

Method

For the near-surface, constant-depth temperature measurements, a thermister probe was mounted on a 1-inch diameter pipe secured to the ship and used to draw water for salinity measurements. Comparisons between the BMR thermistor system, a non-recording thermistor system belonging to C.O.G., with probe mounted beside that of the BMR, and an alcohol in glass thermometer placed in the outflow from the salinity cell, were made regularly. The depth of the thermistor probe varied from about zero to 6 ft, but was mostly about 3 ft.

Vertical temperature variations were recorded mostly at the seaward end of traverses. A second BMR thermistor probe, sinker, and electrical cable as hand line were used.

Principles

In the interpretation of the data, the following principles were used:

(a) The movement of sea-water and the interplay of currents produce a certain temperature distribution. Temperature can thus be used to deduce currents from thermal contours in much the same way as a tracer is used to observe the movement of water.

(b) When currents at different temperatures come into contact, the higher temperature water (of lower density) tends to flow above the lower temperature water (of higher density).

(c) Assuming that no other forces are interfering, currents in the sea are subject to the Coriolis force due to the Earth's rotation (Sverdrup, Johnson, and Fleming, 1961, p. 433).

(d) Assuming the correctness of principles (a), (b), and (c), it is possible to deduce qualitatively the near-surface current pattern from near-surface temperature contours. When a tongue of water is present in a cooler environment, in the southern hemisphere, the current tends to follow the contours counterclockwise. With a water tongue in a warmer environment, the current direction is clockwise along the contours (Sverdrup et al, p. 503)

(e) The temperature pattern did not vary greatly during the period of the survey.

(f) The average near-surface temperature of a traverse, at the time when in mid-traverse, equals the average of the measured near-surface temperatures, e.g. for OM49:

$$T_{OM\,49} = \sum_{i=1}^{N} t_i / N$$

where t_i is the measured temperature at regular intervals along OM49, and N the number of such measurements.

(g) The average near-surface temperatures of all traverses perpendicular to the coast are equal at a particular instant, viz.

$$T_{OM1} = T_{OM2} = \ldots\ldots = T_{OM49} = T$$

Corrections

In the time variations of near-surface temperatures on normal days, the absorption of solar radiation is probably the dominant factor.

In detail, the near-surface temperatures are influenced by wind, humidity, water turbulence, and the hours of sunshine at different periods of the day. Estimating or measuring these various influences separately is a major task, outside the scope of this investigation. Hence, a method in which these short-period influences are lumped together was devised, and a total correction to eliminate these effects was computed for any time of the day, for every day that measurements were made. After applying the total correction to the individual temperature measurements, the resulting values were plotted and contoured (Plate 10). The resulting near-surface temperature pattern represents a kind of basic pattern in which the short-period influences are eliminated, and which in our case is supposed to be characteristic of the January/February period.

To compute the total correction (T.C.), use is made of principles (f) and (g) of the previous section.

T.C. for traverse OM K becomes:

$$T.C._{OM\ K} = T - t_{OM\ K}$$

To obtain the temperature variation pattern the absolute value of T is not important. To make T.C. small and positive, T was chosen as 28°C.

<u>Example</u> from Plate 9, figure 4.

$T.C._{OM\ 49} = 28.0 - 24.8 = 3.2^{\circ}C$

$t_{OM\ 49;8500} = 24.5^{\circ}C$

Corrected temperature value at OM 49;8500 = $t'_{OM\ 49;8500}$

then $t'_{OM\ 49;8500} = t_{OM\ 49;8500} + T.C._{OM\ 49}$

$$= 24.5 + 3.2 = 27.7^{\circ}C$$

<u>Near-surface temperature results</u>

Plate 8 is an isothermal contour plan of uncorrected near-surface temperatures as measured (they are also listed in Appendix 2). Features are formed by isotherms stretched parallel to the surveyed traverses, suggesting the need for corrections of short-term temperature/time variations, to obtain an intelligible pattern. An exception is the area between the Tweed River outlet and Palm Beach, which shows high gradients with a tongue-like pattern.

The high gradients form a boundary between two water masses; the temperature records over narrow zones show sharp fluctuations, indicating turbulent mixing.

Figures 1, 2, and 3 of Plate 9 each give values of measured near-surface temperature plotted against time of day. Figure 4 gives the average near-surface temperature of individual traverses.

Plate 10 is an isothermal contour plan of near-surface temperatures after applying T.C. to Plate 8.

Plate 11 gives the average hourly and average daily measured near-surface temperatures, and their time variation. These results were not used for T.C. However, the results are interesting because they illustrate roughly the short and long-period temperature fluctuations, which could be useful in planning future temperature surveys. Figure 1 gives the average temperature of individual traverses plotted against the time of day to which the average refers. Figure 2, giving the hourly variation, is obtained by averaging, for each hourly interval, the values given in Figure 1. Figure 3 represents much the same as Figure 2 but is obtained by a best fit 'drift' type of analysis of Figure 1 data. Figures 2 and 3 show that during the day the temperature time variation (near-surface) is small between 1300 and 1600 hours E.S.T., and therefore, on normal days, this period would be the most suitable in which to do near-surface temperature measurements.

Figure 4 gives the variation of daily average measured near-surface temperatures during the measuring period. The crosses give the uncorrected values for one day, obtained by averaging data from Plate 9, Figure 4. The dots represent the corrected values; before the values of one day are averaged they are corrected to what the value should be at 1400 hours by using Figure 3 of Plate 11.

The smooth line through the dots gives the approximate long-term variation. The figure clearly shows the influence of seasonal cyclones.

The aerial photograph, Tamborine Run 7, Q546-27 'National Mapping', was examined and, near the Spit and close to Surfers' Paradise, it was noted that:

1. The bearing of the ocean waves is north-east. As the waves approach the coast, the wave-front is refracted and becomes sub-parallel to it.

2. Adjacent to the beach three tongues of sediment transport are visible, apparently moving north.

3. In the top right-hand corner of the photograph, a curved line with an approximately north-west bearing marks the boundary between two currents.

From the near-surface temperature distribution (Plate 10), the following features may be noted:

At the Nerang River outlet cool river water flows eastward (along traverse OM 46) and south-eastward (following the 25.0^{o}C contour line). The two currents are separated by warm ocean water moving westward (OM 41;12000 and 14000). Adjacent to the Spit, a cool water mass is located. Most likely, cool water has filtered from the Nerang River through the dunes.

On the abovementioned serial photograph (Tamborine Run 7, Q546-27) three sediment flows moving north were noticed within the cold water zone.

Further south, near OM 31;5000, a large eddy with warmer water in the centre has developed. A smaller eddy but with cooler water in the centre is located east from Tallebudgera Creek outlet.

Away from the coast, between OM 11;10000 and OM 22;12000, tongues of ocean water invade the cooler coastal water.

North-west and south-east from Point Danger is a cold water zone, which can possibly be explained as seepage water. Alternatively it could be cold oceanic well water. The boundary with warmer water is marked by a step-like temperature change.

East from the Tweed River a tongue of cool water represents the outflow of river water. The presence of up-welling cool oceanic water is indicated between OM 1;11000 and OM 3;12000.

Vertical temperature variation

Nine successful measurements of vertical temperature variation were made and their location (mostly at the seaward end of traverses) is shown in Plate 10. This part of the survey is considered as a preliminary investigation to check the existence of vertical temperature stratification near the coast.

Although weighted, the temperature probe and cable were usually deflected from the vertical by currents and ship's drift. Also, it was sometimes difficult to know when the probe had reached the bottom. Hence, the depth scale of the vertical temperature profiles (Plates 12 and 13) is not very reliable although accurate water depth measurements were made with the ship's echo-sounder.

On the original temperature records (Plate 13), 1-inch deflection corresponds to 8°C. Plate 12 shows the processed data plotted to show depth on a linear scale. The individual temperature/depth profiles are tied to the uncorrected near-surface temperature on the same day. It may be expected that short-period fluctuations in temperature are restricted to shallow depth.

The vertical temperature profiles show warm water overlying cooler water. It will be assumed that temperature reversals with depth do not occur in this area.

The influence of atmospheric conditions seems to be restricted to the top 20 feet, as may be observed at probes OM 6, OM 45 and OM 47. The probes may be grouped as follows:

(a) Probes OM 6 and OM 7: water of 24°C at 170 feet, and of 23°C at 190 feet, viz: cold water near the bottom.

(b) OM 18, OM 20, and OM 21: relatively warmer water of 25 to 26°C at depths of about 150 and 170 feet near the bottom. A fairly large temperature decrease with depth of about 1.5° occurs between 110 and 150 feet.

(c) Probes OM 43, OM 45, and OM 47: cold water of 23°C at depths of 160 to 180 feet, near the bottom.

Near-surface and vertical temperature variations combined

At OM 7; 15000 and OM 6; 15000, water of 24°C is at 170 feet depth but comes close to the surface at OM 3; 12000. Therefore, the boundary between cooler and warmer water must be dipping steeply in a northerly direction.

North-east from Point Danger, at OM 22; 6000, cold water comes to the surface, but at OM 18; 12000, OM 20; 13000, and OM 21; 13000 the water is relatively warm from surface to bottom (although there is a fairly large temperature decrease between 110 and 150 feet).

Hence, the somewhat incomplete pattern suggests that a mass of warm ocean water is pushing against, and is partly on top of, the colder coastal water. The surface boundary (water depth less than 20 feet) of this warmer water mass passes through OM 22; 13000, OM 21; 8000, OM 13; 4000, OM 7; 12000, and OM 4; 14000.

A similar situation may exist northwards but the vertical temperature variation data are too scarce for any definite conclusions to be drawn.

According to Leipper (1955), eddy currents and upwelling of cold water occur in places where current velocities vary within short distances. Particularly important in this respect are tidal currents in which the maximum current velocities vary with distance and water depth according to the formula

$$Vm = \frac{2\pi a}{b} \cdot \frac{x}{h}$$

where a = tidal amplitude

b = tidal period

x = distance from the coast

h = water depth

Vm = maximum water velocity

For the Gold Coast in January and February, the formula is approximately:

$$Vm = 1.7\ x/h\ \text{ft/hr}$$

For variations parallel to the coast:

$$Vm1 = 1.7\ (x/h^2).\ dh\ \text{ft/hr}$$

where dh is the waterdepth variation

For variations along the depth contour line:

$$Vm2 = (1.7/h)\ dx\ \text{ft/hr}$$

where dx is the variation of distance from the coast.

If the depth contour lines are regular and parallel to the coast, dh and dx = 0, and hence Vm=0. However, if the contour lines are irregular because of valleys or hills in the sea-bottom, Vm1 and Vm2 could have appreciable values, resulting in eddy currents and upwelling water. Well water, which is presumably colder water, is associated with negative dh.

With the above theory the location of eddy currents and cold well water can be predicted.

Plate 15 shows the main eddy currents and well-water features of Plate 10 superimposed on a sea-bottom topography plan. The locations are approximately places where the depth contours show irregularities which could cause the formation of eddy currents and well water. This confirms that the method of processing the data and theory used in interpretation is at least qualitatively correct.

A good example is located northeast and southeast from Point Danger (Plate 10) where the depth contours in the zone adjacent to the beach converge around the cape. Following Leipper's arguments, this is also an area where eddy currents with well water can be formed; hence this could be the explanation for the cold water zone adjacent to the beach, stirred upwards from a lower level.

This temperature survey was not meant to be complete and was carried out during a 'Sonar Boomer' survey without additional cost, to test the practical value of the method in the area. For a more complete study, the observations should be extended over longer periods, more temperature/depth profiles should be measured, and the observations should be combined with studies of currents, including tidal currents.

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OMEGA TRAVERSES

MARK	1	2	3	4	5	6	7	8	9	10	12	13	14	15	16	17	18	19	20	21	22	MARK
100																						100
200																						200
300										-											-	300
400										-								-			-	400
500								-		62								-			-	500
600								-		73								60			-	600
700								87		87								65			-	700
800								88		96								76		-	-	800
900	-							-		105								78		54?	-	900
1000	-	-						105		111								80		58?	-	1000
1100	-	R						107		-		-						89		62?	-	1100
1200	-	R						107		-		-						88		71?	-	1200
1300	78?	R						115		-		-						88		-	-	1300
1400	76?	R	44					133		124		-						90		80	-	1400
1500	81?	R	54					133?		133		-						94		82	93	1500
1600	-	R	-					133?		129		-	55					97		86	95	1600
1700	-	R	67					134?		128		-	60					99	-	89	99	1700
1800	R	R	77					135?		129		-	-					101	-	93	102	1800
1900	R	-	82					136?		129		84	65					103	-	93	108	1900
2000	R	-	95					142		130		85	66					103	-	95	-	2000
2100	R	-	101?					144		-		85	68					103	91?	97	-	2100
2200	R	-	100?					145		142	-	84	73					109	93	98	-	2200
2300	R	-	102					145		143	75	85	81					117	-	100	-	2300
2400	R	-	-					145		144	80	89	95	-				117	-	102	-	2400
2500	R	-	107		-			146		146	82	101	93	-				-	-	104	-	2500
2600	R	-	106	-	-			146		148	92	107	99	64				123	-	110	-	2600
2700	R	-	-	-	-	-		145	-	152	-	108	102	66				127	-	113	-	2700
2800	R	-	105?	-	70	-	-	147	-	153	100	113	104	96				129	104	114	117?	2800
2900	R	-	91?	-	75	80	-	152	-	-	102	115	108	100				131	107	115	115?	2900
3000	R	-	94?	-	90	86	-	150	-	155	105	122	110	109				-	116	117	114	3000
3100	R	-	105?	68?	104	92	-	151	-	-	108	120	114	113				-	117	118	116	3100
3200	R	-	106?	81?	107	98	-	153	-	151	116	-	113	118				138	118	119	119	3200
3300	R	117	102	90?	108	102	-	156	-	150	-	-	113	114	-			142	119	121?	119	3300
3400	R	-	100	-	110	113	-	-	-	149	115	-	119	120	77			145	-	123	122	3400
3500	R	-	103	-	110	123	-	157	-	150	124	128	116	120	91			146	-	119?	127	3500
3600	R	-	111	-	112	130	-	158	-	152	136	129	123	121	90			148	122	121	-	3600
3700	R	116	117	-	114	127	-	160	-	154	139	133	-	122	-			149	123	125	-	3700
3800	R	116	117	-	117	129	-	166	-	155	140	139	130	-	110			-	124	125	125	3800
3900	R	116	118	112?	120	126	141?	-	-	156	137	-	132	-	114			152	127	126	127?	3900
4000	R	116	117	102?	126	136	146?	172	-	157	139	-	136	-	-	-		153	130	128	129?	4000
4100	R	115	-	108?	129	145?	146?	169	-	157	141	-	138	121	-	-		155	132	131	130?	4100
4200	R	118	-	112	130	-	146?	169	-	161	141	-	139	125	-	-		156	133	135	-	4200
4300	R	116	124	114	132	-	143?	171	-	162	141	-	142	127	-	-		157	-	138	-	4300
4400	R	121	125	115	135	-	144?	168	-	164	150	151	144	132	-	-		157	142	141	-	4400
4500	R	132	125	118	138	-	146?	-	-	164	155	152	140	133	126	-		157	146	142	144?	4500
4600	R	137?	-	125	140	-	143?	170	-	-	156	151	142	134	129	-		158	147	144	145	4600
4700	R	140?	122?	130	140	-	144	170	-	-	158	156	143	137	132	-		159	-	144	146	4700
4800	138	-	-	-	138	-	147	165	-	165	158	160	144	140	135	-		160	150	146	149	4800
4900	140	127?	-	-	138	-	147	164	-	168	158	158	147	141	137?	-		160	151	148	150	4900
5000	140	129	-	-	138	-	150?	165	-	-	158	-	149	143	142	-	-	166	153	148	150	5000
5100	140	130	122	-	135	-	148?	166	-	-	156	-	152	146	146	-	-	168	155	147	150	5100
5200	138	130	R	-	134	-	144?	169	-	177	156	-	156	147	147	-	102	-	157	148	150	5200
5300	131	134	R	-	136	-	142	169	-	178	158	-	157	148	149	-	112	-	157	149	148	5300
5400	127	136	R	-	135	-	142	170	-	-	161	-	160	151	150?	131?	117	-	158	150	149	5400
5500	126?	138	R	-	137	-	141	170	-	-	160	-	161	154	149	136?	123	-	158	152	148	5500
5600	-	139	R	-	139	-	141	172	-	180	157	-	163	156	150	-	128	-	-	151	R	5600
5700	117	138	R	-	140	-	143	175		180	153	-	164	158	152	-	129	-	160	150	R	5700
5800	122	-	R	119?	143	-	144	177		181	150	-	165	160	153	-	129	-	160	149	R	5800
5900	127	128?	R	124?	144	-	145	180		-	147	-	166	162	155	-	131	-	161	150	R	5900
6000	135	-	R	127?	145	-	146	180		178	150	-	167	163	158	140	131	-	160	151	R	6000
6100	141	-	131	-	144	-	147	180		179	152	-	166	165	158	155	132	-	-	154	R	6100
6200	143	-	136	-	143	-	148	179		-	156	170?	167	165	158	151	-	169	162	157	R	6200
6300	145	-	138	-	143	-	152	181		-	160	-	167	166	159	154	-	167	164	158	-	6300
6400	148?	136	141	-	145	-	153	179		185	165	-	164	168	160	153	-	164	164	160	163?	6400
6500	152	135	-	-	148	-	154	182		-	168	-	163	170	160	154	-	167	164	161	164	6500
6600	154	-	146	-	147	-	155	-		180	170	-	164	170	159	152	-	167	-	162	164	6600
6700	157	136?	147	-	150?	-	156	186		179	174	-	165	171	159	157	-	168	168	163	165	6700
6800	160	145?	150	-	-	-	158	184		-	173	-	166	172	161	161	-	171	168	168	166	6800
6900	161	146	150	-	152	-	159	186		-	168	-	168	173	-	159	-	174	169	169	168	6900
7000	161	156	150	146	154	-	160	184?		-	174	-	165	174	165	156	-	174	170	170	-	7000
7100	164	162	161	154	150	-	162	188		-	177	-	165	174	-	161	-	174	170	171	-	7100
7200	166	167	164	149	149	-	165	188		-	175	-	172	176	-	163	-	176	170	-	170	7200
7300	169	167	167	148	150	-	166	188		-	175	-	-	177	172	163	-	175	172	-	170	7300
7400	174	174	-	146	155	-	166	185		-	175	-	178	178	173	163	-	177	174	-	170	7400
7500	176	182	174	R	145	-	165	184		-	174	-	181	177	174	165	-	175	172	-	169	7500
7600	179	-	175	R	137	170	166	180		-	175	-	181	177	176	169	-	178	170	169	166	7600
7700	180	-	176	R	140	170	166	180		-	176	-	182	178	-	175	-	176	170	170	166	7700
7800	184	177	-	R	142	171	166	174		-	178	-	183	178	175	176	-	177	172	171	-	7800
7900	184	181	-	R	148	172	167	179		-	178	-	185	178	176	178	-	176	-	172	-	7900
8000	187	183	178	R	150	172	167	181		169?	178	-	188	177	178	180	160	168?	172	174	173	8000
8100	192?	187	182	149	155	172	169	183		173?	179	-	183	179	178	181	162	176	173	176	173	8100
8200	191	190	184	153	160	167	175	185		188	-	-	183	182	-	-	162	170	174	177	174	8200
8300	197	192	188	158	160	170	178	186		179	181	-	184	184	180	180	163	180	179	179	176	8300
8400	-	192	190	160	164	172	183	184		180	181	-	185	184	-	-	162	181	178	181	175	8400
8500	-	192	191	160	167	170	180	185		-	183	-	186	185	182	178	-	183	178	179	174	8500
8600	-	191	191	159	169	171	178	190		-	185	-	186	185	-	179	165	184	178	177	176	8600
8700	-	191	191	160	170	173	179	192		186	182	-	187	185	181	180	165	185	174	177	179	8700
8800	-	194	191	160	171	172	177	195		-	183	-	188	186	184	181	-	186	180	179	180	8800
8900	-	194	196	163	175	170	175	201		191	184	197	189	188	185	182	-	186	179	180	181	8900
9000	209?	192	198	165	175	169	175	205		192	188	196	190	188	-	182	171	187	178	180	181	9000
9100	209	202	202	171	176	172	175	207		195	190	198	190	189	185	183	172	187	180	180	181	9100
9200	210	202	204	173	178	166	175	206		198	189	197	190	190	185	183	172	187	181	181	183	9200
9300	210	207	206	173	181	168	173	204		201	182	199	189	191	185	177	173	187	181	181	184	9300
9400	210	208	207	175	185	169	171?	206		203	181	201	192	191	184	178	174	187	182	-	185	9400
9500	213?	208	209	179	187	172	164?	210		207	188	202	194	192	185	182	175	188	182	181	-	9500
9600	215	212	212	180	188	176	R	211		212	189	203	194	193	187	183	176	188	183	182	-	9600
9700	216	214	212	181	189	174	-	219		216	188	204	195	194	188	183	178	189	184	182	-	9700
9800	219	216	213	186	189	176	-	220		220	206	205	197	194	188	184	179	189	185	183	-	9800
9900	224	-	213	187	189	184	-	220		225	202	202	198	191	191	186	180	189	185	185	-	9900
10000	225	221	215	188	190	181	-	223		225	202	200	201	190	192	189	-	189	185	187	-	10000
10100	226	222	217	188	191	180	-	225		227	191	200	203	190	193	190	181	-	186	188	-	10100
10200	229	223	218	190	195	181	-	229		226	192	201	203	191	194	191	180	-	186	190	-	10200
10300	229	225	226	191	193	183	-	230		227	193	203	204	195	194	191	-	-	187	190	-	10300
10400	230	-	226	193	193	188	-	232		230	193	204	207	197	197	192	-	-	187	191	-	10400
10500	233	-	226	200	201	193	-	239		232	198	207	204	199	197	193	180?	-	187	191	183?	10500
10600	-	237	229	201	205	193	-	241		234	201	213	205	200	201	193	-	-	188	191	184	10600
10700	231	238	229	202	207	196	-	240		233	203	208	205	201	199?	193	-	-	189	192	186	10700
10800	233	237	231	202	208	201	-	247		234	204	211	208	203	198?	193	180?	-	189	192	187	10800
10900	230	236	230	205	201	201	-	245		234	205	211	207	204	194	194	180?	-	190	192	187	10900
11000	231	238	-	208	201	200	192	246		235	208	214	215	207	198	194	181?	-	193	195	185	11000
11100	235	228?	240?	203	206	205	-	245		237	-	216	213	209	199	196	-	-	194	197	184	11100
11200	236	225	245?	205	209	207	-	245		-	214	218	217	210	200	200	183?	-	196	198	184	11200
11300	238	225	243?	206	209	211	-	248		241	214	218	216	210	204	201	185?	-	198	198	185	11300
11400	237	226	-	206	210	211	-	257		246	210	218	215	211	205	202	-	-	198	198	186	11400
11500	236	227	-	208	221	-	205	261		-	214	220	215	211	207	202	-	207	198	198	188	11500
11600	236	229	-	213	224	216	-	264		241	217	223	214	212	207	201	-	207	197	197	188	11600
11700	236	230	-	220	225	219	-	265		244	218	224	216	213	207	200	-	207	199	196	188	11700
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11900	235	230	-	225	228	220	-	267		246	217	220	-	-	210	199	191	-	202	200	188	11900
12000	234	230	-	225	231	222	216?	267		247	215	220	214	-	212	204	191	-	202	200	187	12000
12100	238?	231	-	226	232	223	218	267		-	216	222	212	-	214	208	192	215	202	200	187	12100
12200	238?	232	R	226	233	226	218?	268		-	217	223	216	-	216	211	192	219	202	200	187	12200
12300	235	233	-	228	234	227	224	269		-	217	223	216	-	216	214	192	-	203	200	189	12300
12400	235	-	-	227	235	230	226	-		-	218	224	216	-	217	216	194	-	204	200	190	12400
12500	235	235	-	230	243	227	227	-		-	218	226	-	-	217	216	195	216	205	200	192	12500
12600	240	235	-	232	244	233	230			252	218	227	219	-	217	215	197	-	205	200	192	12600
12700	242	235	-	235	246	238	232			255	218	225	222	-	218	215	198	-		200	192	12700
12800	240	-	-	240	248	242	234			258	218	224	226	-	221	215	198	-		200	194	12800
12900	239	236	-	243	247	246	235			264	222	228	223	-	220	216	-	-		198	195	12900
13000	244	236		247	249	248	235			249	222	229	221	219	220	217	204			198	196	13000
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13200				246	253	248	-						226	218	220	219	209					13200
13300				247	253	249	-								221	220	210					13300
13400				250	252	247	-									221	-					13400
13500				252?	250	247	-									225	210					13500
13600				252	251	247	-										211					13600
13700				252	252	248	-										216					13700
13800				252	251	250	-															13800
13900				251	250	249	-															13900
14000				253	250	252	-															14000
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14200				257	246?	252	-															14200
14300				253	249	251	-															14300
14400				255	253	252																14400
14500				-	255	254	-															14500
14600				-	259	256	-															14600
14700				-		257	-															14700
14800				-		257	-															14800
14900				-		258	-															14900
15000				-		259	-															15000
15100				-		257																15100
15200						257																15200
15300						257																15300
15400																						15400

TO ACCOMPANY RECORD No. 1968/18

APPENDIX I Sheet 1 of 3

DEPTH TO BEDROCK

H56/B5-25

MARK	23	24	25	26	29	30	31	32	33	34	36	37	38	39	41	42	43	45	46	47	48	MARK
100																						100
200																						200
300													-									300
400													-									400
500													-									500
600					-				-				-									600
700					60?				-				-									700
800					-			-	-				-									800
900					57?			-	-				-	-								900
1000					59			-	74	-		-	-	-								1000
1100	57				64	-		-	75	-		-	-	-								1100
1200	61				64	-		-	77	-		-	-	-								1200
1300	63				78	-		-	78	-		-	-	-								1300
1400	67				78	-		-	81	-	-	-	-	-								1400
1500	68				86	81		83?	84	-	-	-	-	-								1500
1600	66				85	86		-	86	-	-	-	-	-								1600
1700	63				91?	90		92	88	-	-	-	-	-								1700
1800	62				86	92	-	-	94	-	-	-	-	-								1800
1900	R				93	95	60?	113	101	-	-	-	-	-	-							1900
2000	79	-			96	98	67?	114	108	-	-	-	-	-	53?	-						2000
2100	82	-			98	100	81?	106	-	-	-	-	-	-	54?	-						2100
2200	77	-			99	102	73?	104	-	-	-	-	-	-	60?	-						2200
2300	R	-			100?	104	84?	104	-	-	-	-	-	-	62?	-						2300
2400	-	-			100?	106	-	107	-	-	-	-	-	-	65?	-	-					2400
2500	-	86			106?	106	85?	106	115?	-	-	-	-	-	68?	-	-					2500
2600	83	93			106?	107	-	107	115	-	-	-	-	-	72	-	-					2600
2700	88	92			107	107	100?	109	116	-	-	-	-	-	77	-	-					2700
2800	89	97	-		108	106	-	109	117	-	-	-	-	-	84	-	-					2800
2900	93	100	-		110	107	105?	-	120	-	-	-	-	-	88	-	-					2900
3000	98	100	-		111	108	-	109	-	-	-	-	-	-	90	-	-					3000
3100	105	-	-		112	108	-	113	121	-	-	-	111?	-	94	-	-					3100
3200	109	101	81		116	107	102?	119	121	-	-	-	112?	-	96	-	-					3200
3300	112	101	95		122	108	106?	117	121	-	-	-	113?	-	-	-	-					3300
3400	112	104	100		123	110	-	120	122	-	-	-	-	-	-	-	-					3400
3500	112	107	105		125	113	104	118	123	-	-	-	-	-	-	-	-					3500
3600	112	108	108	-	127	114	114	118	125	-	-	-	-	-	107	-	-					3600
3700	112	110	111	-	128	119	123	120	127	-	-	-	-	-	110	-	-					3700
3800	111	111	112	97?	130	121	131	121	131	-	-	-	129?	-	110	-	-					3800
3900	110	114	114	103	-	123	132	123	133	-	-	-	129?	-	112	-	R					3900
4000	109	117	116	110	-	125	133	125	137	-	-	125?	130?	-	111	-	R	-				4000
4100	108	120	116	114	-	127	-	125	139	120?	-	-	130?	-	111	-	-	-				4100
4200	109	122	118	119	-	127	130	126	142	125	-	127?	-	-	113	R	-	-				4200
4300	112	124	120	123	135	129	130	126	143	127	-	-	-	-	113	-	-	-				4300
4400	116	126	121	125	135	130	126	127	145	127	-	130?	-	-	114	-	R	-				4400
4500	121	124	123	128	135	131	129?	128	147	130	-	-	-	-	115	-	R	-				4500
4600	124	126	123	130	136	131	122	131	149	129	-	135?	-	-	116	-	R	-				4600
4700	124	127	124	130	136	132	124	133	150	129	-	-	-	-	115	-	-	-	-			4700
4800	128	128	125	132	137	132	127	134	153	-	-	136?	-	-	113	-	-	-	-			4800
4900	136	130	126	134	140	132	128	136	154	-	-	-	-	-	R	-	-	98?	-			4900
5000	134	130	128	135	144	134	128	138	154	129	-	138?	-	-	-	-	-	105?	-			5000
5100	134	132	129	135	147	138	129	140	-	130	-	-	-	-	-	-	-	-	74?			5100
5200	137	137	131	135	148	141	132	143	156	-	-	139?	-	-	-	-	-	115?	88			5200
5300	140	138	134	137	150	147	135	142	157	-	-	-	-	-	-	-	R	-	90			5300
5400	146	-	135	138	152	150	138	144	157	-	-	139?	-	-	-	-	R	-	95	-		5400
5500	147	-	136	138	156	150	146	152	160	-	-	-	-	-	-	-	R	-	97	-		5500
5600	148	142	136	140	155	148	147	153	156	-	-	140?	-	-	-	-	-	105	98	70		5600
5700	150	144	136	141	155	145	150	156	-	146	-	-	-	-	-	-	R	110	99	76		5700
5800	151	145	140	143	157	153	148	158	155	147	-	142?	-	-	-	-	-	113	100	90		5800
5900	153	148	142	144	159	153	147	157	154	147	-	-	-	-	-	-	-	110	102?	87	-	5900
6000	155	150	145	143	159	153	143	158	155	153	-	140?	-	-	R	-	-	R	-	97	-	6000
6100	156	147	148	144	160	154	144	158	155	151	-	-	-	-	R	R	-	R	-	100	68	6100
6200	155	145	150	144	160	155	151	160	155	153	-	138?	R	-	-	-	R	R	-	103	83	6200
6300	153	144	155	143	162	161	152	162	158	154	-	-	R	-	-	-	R	R	-	110	89	6300
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6500	153	147	157	146	165	165	154	165	156	-	-	-	-	-	142	-	R	R	107	120	102	6500
6600	160	149	154	146	165	166	158	166	156	-	-	140?	-	-	148	-	-	R	109	119	98	6600
6700	161	151	154	150	165	167	160	168	157	154	-	-	-	-	145	-	-	R	109	123	97	6700
6800	163	154	154	150	169	170	160	168	162	154	-	145?	-	-	141	-	-	R	107	120	109	6800
6900	164	159	154	150	170	173	160	168	165	156	-	-	-	-	141	-	-	R	133	123	112	6900
7000	166	161	160	151	170	171	163	168	170?	-	-	148?	-	-	140	-	-	R	116	126	112	7000
7100	166	163	162	152	170	173	165	167	178	-	-	-	-	-	143	-	-	R	118	129	114	7100
7200	166	161	163	153	169	173	167	167	-	150	-	150?	-	-	144	-	-	-	120	134	115	7200
7300	166	165	166	154	169	174	168	166	175	R	-	-	-	-	145	-	-	-	123	137	118	7300
7400	166	165	169	156	170	174	170	-	173	R	-	155	-	-	148	-	R	-	124	138	124	7400
7500	166	164	167	159	170	175	170	-	173	145	-	-	-	-	151	R	-	-	125	140	127	7500
7600	168	166	169?	161	162	175	171	167	171	150	-	R	-	-	153		-	R	129	141	136	7600
7700	167	169	-	162	167?	176	171	167	172	-	-	R	-	-	155	-	-	R	133	145	137	7700
7800	161	170	-	-	173	177	164	167	170	157	-	R	-	-	156	R	-	R	134	146	146	7800
7900	168	171	-	-	177	-	164	168	171	-	-	-	-	-	157	-	-	-	133	147	146	7900
8000	172	170	-	161	177	-	164	168	172	-	-	-	R	-	157	-	-	-	133	146	140	8000
8100	171	172	-	165	179	176	-	168	173	-		-	R	-	157	R	R	R	R	150	138	8100
8200	161	172	-	165	182	175	-	168	176	-			R	-	-	-	R	R	140	149	140	8200
8300	150	173	-	167	181	173	156?	168	179	-			-	-	-	R	-	-	140	148	144	8300
8400	149	174	-	167	178	173	157?	168	179	-			-	R	-	-	-	-	143	146	148	8400
8500	145	172	-	166	175	173	161	169	180	-			-	-	-	-	-	-	146	142	148	8500
8600	149	173	-	166	175	-	-	170	179	-			-	-	R	R	-	R	145	140	148	8600
8700	158	177	-	167	175	172	171	170	180	-			-	-	-	R	-	R	R	R	146	8700
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9000	172	179	-	169	176	172	178	169	-	175?			171?	R	R	R	R	-	148	147	145	9000
9100	175	180	-	170	179	172	176	165	181	175?			172?	-	R	R	R	-	150	148	148	9100
9200	173	180	-	170	176	171	177	R	176	-			-	-	R	R	R	R	153	149	150	9200
9300	175	178	-	170	175	-	177	R	170	-			-	-	R	R	R	R	155	149	152	9300
9400	176	177	-	170	177	172	177	168	-	-			172	-	R	R	R	-	157	152	157	9400
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9600	176	178	168	168	179	175	178	169	R	-			173	R	R	-	R	-	153	158	164	9600
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9900	179	179	172	167	183	174	178	173	179	180			177	-	R	R	R	R	153	162	167	9900
10000	179	180	173	169	180	176	179	173	179	181			176	-	R	R	-	R	R	162	-	10000
10100	179	180	174	171	177	178	177	172	180	-			175	-	R	R	-	R	R	162	-	10100
10200	178	180	174	172	176	180	177	171	179	-			-	-	R	R	-	-	R	162	-	10200
10300	179	179	175	172	175	180	177	172	180	-			-	-	R	R	R	R	R	161	-	10300
10400	178	179	176	171	176	179	177	175	181	181			-	-	R	R	-	R	R	159	-	10400
10500	178	180	176	171	176	180	178	175	181	181			-	-	155?	-	R	R	R	R	-	10500
10600	180	180	177	172	176	179	173	-	182	182			177	-	161?	-	-	R	R	R	161	10600
10700	178	180	176	172	178	178	173	178	182	182			187	-	166	-	-	R	R	160	167	10700
10800	178	178	178	173	183	181	175	180	182	183			187	-	170	-	-	R	R	165	169	10800
10900	181	179	177	175	179	178	176	184	183	183			186	-	-	-	-	R	165	165	173	10900
11000	181	177	177	177	180	178	177	187	183	186			-	-	-	-	-	-	163	167	178	11000
11100	181	179	178	177	183	179	179	190	187	187			183	-	-	R	-	176?	166	168	169	11100
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11400	183	175	179	177	182	187	186	192	189	193			198	-	178	179	172	178?	171	161	162	11400
11500	182	175	180	176	184	189	186	193	191	194			200	-	181	182	175?	178?	172	R	157	11500
11600	182	175	181	177	185	190	187	195	193	197			202	-	184	182	175	179?	R	-	158	11600
11700	182	175	180	178	-	190	189?	197	194	196			203	-	183	180	173	-	165	177	171	11700
11800	184	176	178	178	187	191	190	201	197	-			207	-	183	-	173	-	174	178	171	11800
11900	184	178	178	178	185	193	190	203	200	201			205	-	180	178	173	R	175	180	167	11900
12000	177	178	179	178	189	195	192	205	200	202			204	-	182	181	173	-	166	180	166	12000
12100	178	178	180	179	192	196	197	205	200	204			206	-	182	182	178	-	R	181	168	12100
12200	179	178	180	179	194	197	197	206	201	206			210	-	182	182	183	-	R	183	172	12200
12300	-	179	180	179	196	198	198	200	202	208			210	-	184	-	182	R	R	183	176	12300
12400	-	180	180	178	198	201	199	210	202	208			212	-	185	-	182	R	R	183	176	12400
12500	185	184	180	177	198	203	200?	210	203	208			216	-	187	-	180	-	R	184	177	12500
12600	187	185	182	178	202	206	200	210	203	212			219	-	188	186	183	183	R	185	177	12600
12700	190	185	182	177	203	208	200	213	203?	212			222	-	189	186	189	195	R	182	178	12700
12800	193			179	204	211	202	213	203?	210			225	-	191	184	188	183	R	180	177	12800
12900				179	207	214	207	214	204?	213			224	-	190	-	191	R	R	179	179	12900
13000				178	209	214	212		204?	214			224	-	189	189	193	-	R	175	179	13000
13100				178			214						229?	-	194	191	192	R	175	174	180	13100
13200				178			216						-	-	198	192	191	-	181	176	177	13200
13300				179											198	192	191	-	180	177	178	13300
13400				-											196	196	190	-	184	178	176	13400
13500				-											194	197	189	-	185	177	172	13500
13600				-											197	199	195	-	184	180	174	13600
13700				-											199	198	202	-	185	184	175	13700
13800				-											203	196	199	197?	186	187	178	13800
13900				-											207	200	196	202	187	187	182	13900
14000				-											208	205	198	207	189	186	184	14000
14100				-											210	209	199	201	187	186	187	14100
14200				-											213	209	201	202	188	190	187	14200
14300				-											214	213	204	202	196	193	187	14300
14400															214	219	209	201	201	192	190	14400
14500															215		212	199	197	193	195	14500
14600																	217	196	197	194	196	14600
14700																	-	203	197	196	197	14700
14800																	215	211	199	195	196	14800
14900																	217	211	200	195	197	14900
15000																	215	211	200	195	197	15000
15100																			200	195	198	15100
15200																				195	200	15200
15300																				197	203	15300
15400																					203	15400
15500																					203	15500
15600																					205	15600

TO ACCOMPANY RECORD No. 1968/18

APPENDIX I Sheet 2 of 3

DEPTH TO BEDROCK

H56/B5-26

APPENDIX I Sheet 3 of 3

DEPTHS IN FEET

78? = DOUBTFUL VALUE

R = REEF

MARK	SEISMIC 1	SEISMIC 2	SEISMIC 3
0			
100	-		
200	-	-	
300	-	35?	
400	-	51	
500	-	42	-
600	-	59	-
700	-	70	-
800	-	76	68
900	-	82	69
1000	-	94	80
1100	-	100	90
1200	-	104	94
1300	-	107	98
1400	-	110	101
1500	-	115	101
1600	-	114	103
1700	-	122	109
1800	-	125	109
1900	-	127	111
2000	-	134	113
2100	-	135	117
2200	-	136	116
2300	-	133	117
2400	-	139	117
2500	-	142	118
2600	-	143	120
2700	-	144	119
2800	-	145	119
2900	-	146	119
3000	-	147	126
3100	-	149	127
3200	-	151	127
3300	-	154	128
3400	-	154	128
3500	-	155	128
3600	-	156	130
3700	-	158	131
3800	-	159	132
3900	-	160	132
4000	-	162	134
4100	-	164	136
4200	-	165	138
4300	-	166	138
4400	-	167	137
4500	-	167	137
4600	-	-	139
4700	-	167	140
4800	-	171	145
4900	-	170?	147
5000	-	171	147
5100	-	171	149
5200	-	172	149
5300	-	172	150
5400	-	173	151
5500	-	173	150
5600	-	174	151
5700	-	173	151
5800	-	174	152
5900	-	175	152

MARK	OMEGA 49	SEISMIC 1	SEISMIC 2	SEISMIC 3	SEISMIC 4
6000		-	175	152	
6100		-	173?	153	
6200		-	172	153	
6300		-	173	153	
6400		-	173	153	
6500		-	174	152	
6600	-	-	176	152	
6700	-	-	177	152	
6800	-	-	178	152	
6900	-	-	180	151	
7000	-	-	180	150	
7100	-	-	180	150	
7200	-	-	180	149	
7300	104	-	180	149	
7400	104	-	181	149	
7500	108	-	182	149	
7600	113	-	183	-	
7700	112	-	183	-	
7800	118	-	183	-	
7900	123	-	182	-	
8000	125	-	182	142	
8100	118	-	184	142	
8200	121	-	184	-	-
8300	127	-	184	-	-
8400	128	-	184	-	-
8500	124	-	182	-	-
8600	137	-	183	-	-
8700	143	-	182	140	-
8800	147	-	182	139	-
8900	151	-	181	139	-
9000	157	-	183	139	-
9100	159	-	182	139	-
9200	160	-	183	139	-
9300	161	-	183	139	-
9400	160	-	184	141	-
9500	156	-	184	141	-
9600	155	-	184	141	-
9700	154	-	185	142	-
9800	155	-	185	141	-
9900	156	-	184	141	-
10000	160	-	184	140	-
10100	161	-	185	140	-
10200	169	-	185	139	-
10300	171	-	185	139	-
10400	171	-	185	138	-
10500	169	-	186	131	-
10600	169	-	186	135	-
10700	172	-	187	135	-
10800	171	-	187	135	-
10900	173	-	187	135	-
11000	173	-	189	136	-
11100	173	-	188	134	-
11200	176	-	189	132	-
11300	178	-	189	136	-
11400	180	-	189	136	-
11500	178	-	189	137	-
11600	177	-	189	136	-
11700	177	-	189	136	-
11800	174	-	189	135	-
11900	176	-	189	134	-

MARK	OMEGA 49	SEISMIC 1	SEISMIC 2	SEISMIC 3	SEISMIC 4
12000	179	-	189	134	-
12100	179	-	190	134	-
12200	179	-	190	134	-
12300	180	-	190	133	-
12400	180	-	191	-	-
12500	181	-	192	134	-
12600	182	-	190	134	-
12700	181	-	190	137	-
12800	182	-	190	139	-
12900	183	-	190	139	-
13000	184	-	190	139	-
13100	182	-	189	139	-
13200	181	-	189	140	-
13300	180	-	189	139	-
13400	181	-	188	141	-
13500	182	-	188	138	-
13600	182	-	188	139	-
13700	182		190	139	-
13800	185		190	139	-
13900	186		190	139	-
14000	188		188	137	-
14100	191		185	140	-
14200	192		188	140	-
14300	191		188	139	-
14400	190		187	139	-
14500	190		186	139	-
14600	190		185	138	-
14700	190		187	138	-
14800	190		187	138	-
14900	190			136	-
15000	190			130	-
15100	190			133	-
15200	181			135	-
15300	190			136	-
15400	190			130?	-
15500	190			128	-
15600	192			127	-
15700	192			128	-
15800	193			127	-
15900	192			126	-
16000	192			128	-
16100				123	-
16200				120	-
16300				123	-
16400				125	-
16500				124	-
16600				120	-
16700				119	-
16800				118	-
16900				118	-
17000				-	-
17100				118	-
17200				117	-
17300				118?	-
17400				123	-
17500				121	-
17600				121	-
17700				123	-
17800				-	-
17900				-	-

MARK	SEISMIC 3	SEISMIC 4
18000	123	-
18100	123	-
18200	123	-
18300	123	-
18400	123	-
18500	123	-
18600	121	-
18700	120	-
18800	-	-
18900	-	-
19000	-	-
19100	-	-
19200	-	-
19300	-	-
19400	-	
19500	-	
19600	-	
19700	-	
19800	-	
19900	-	
20000	-	
20100	-	
20200	-	
20300	-	
20400	-	
20500	-	
20600	-	
20700	-	
20800	-	
20900	-	
21000	-	
21100	-	
21200	-	
21300	-	
21400	-	
21500	-	
21600	-	
21700	-	
21800	-	
21900	-	
22000	-	

TO ACCOMPANY RECORD No. 1968/18

H56/B5-27

APPENDIX 2 Sheet 1 of 3

TEMPERATURE VALUES (°C)

(UNCORRECTED NEAR-SURFACE)

TRAVERSES

MARK	1 in	2 out	2 in	3 in	4 out	5 in	6 in	6 out	6 in	7 out	8 out	9 out	10 in	12 out	13 in	14 out	15 in	16 out	17 in	18 out	19 in	MARK
100																						100
200																						200
300													25.7									300
400													"								25.6	400
500											25.6		25.6									500
600											"		25.5								25.2	600
700											"		"									700
800											"		25.6									800
900											"		"									900
1000	25.3		25.1								"		"								25.3	1000
1100	25.2	25.8	"								"		"									1100
1200	25.3	25.8	"								25.7		"		21.3							1200
1300	25.5	25.9	"	26.5							"		"									1300
1400	25.6	25.8	"	26.8							"		25.5		21.5							1400
1500	25.7	25.7	25.0								"		"									1500
1600	"	"	"								"		"			21.4						1600
1700	"	"	24.9	26.3							"		"									1700
1800	"	"	"	26.6							"		"									1800
1900	25.8	25.8	"	"							"		"		22.0							1900
2000	25.9	"	"	26.0							"		"			21.8					25.2	2000
2100	25.8	"	"								"		25.6								"	2100
2200	25.9	25.9	"								"		"	21.6		22.0					"	2200
2300	"	"	25.0								"		"	"	22.1						"	2300
2400	"	"	"								"		25.5	21.5		22.2					"	2400
2500	26.0	25.8	25.2			25.4					"		"	21.4		"					"	2500
2600	"	"	"		24.8	25.5					"		"	21.5		"					"	2600
2700	"	"	"	26.5	"	"	25.5	25.7			"	24.9	"	"		22.4					"	2700
2800	"	"	25.3		25.0	"	"	"			"	"	"	21.6		22.7					"	2800
2900	"	"	"	26.0	"	25.6	"	25.8			"	"	25.6	21.8		"	23.3				"	2900
3000	"	"	"		"	"	"	"			"	"	"	22.0	22.8	"	23.5				25.1	3000
3100	26.1	"	"		25.1	25.8	"	25.9			"	"	"	22.1								3100
3200	"	"	"	26.3	25.2	"	25.6	"			"	"	25.5	"		23.0	23.8				25.4	3200
3300	"	"	25.4		25.3	"	"	"			"	"	25.6	"			24.1	23.5				3300
3400	"	"	25.5		25.4	"	"	25.8			25.6	25.0	"	22.2			"	23.7				3400
3500	26.0	"	25.6		25.5	"	"	"			"	"	"	"		23.4	24.2	"				3500
3600	"	"	25.8		"	"	"	25.9			"	"	"	22.3			24.3	"				3600
3700	"	25.9	26.0		"	"	"	26.0			"	"	"	22.4			"	"				3700
3800	26.1	"	26.1		"	"	"	"		25.5	"	"	"	22.5			"	"				3800
3900	26.0	25.8	"		"	"	"	"			"	"	"	"			"	"				3900
4000	26.1	"	26.2		"	"	"	"	26.1		"	"	"	22.6	23.6	23.6	24.4	"			25.5	4000
4100	"	"	"	26.6	25.4	"	25.7	"	"		"	"	"	22.7			"	"	24.1			4100
4200	"	"	"		"	"	25.6	"	"		"	"	"	"		23.7	"	"				4200
4300	"	"	"		"	"	"	26.1	"		"	"	"	22.8		"	"					4300
4400	26.2	"	"		"	"	25.7	"	"		"	"	"	22.9		"	"	24.2				4400
4500	"	25.9	"		25.3	"	"	"	"	25.6	"	"	"	23.0		23.8	24.5		24.4			4500
4600	26.1	25.8	"	26.0	"	"	25.8	"	"	"	"	"	25.7	"		24.0	"					4600
4700	"	"	"		"	25.9	"	"	"	"	"	"	25.6	23.1		"	"					4700
4800	"	"	26.1		25.2	26.1	"	"	"	"	"	"	25.7	"		"	24.7					4800
4900	"	"	"		25.3	25.8	"	26.2	"	"	25.7	"	"	23.2			24.6					4900
5000	"	"	"		25.5	"	"	"	"	"	"	"	"	"	24.1	24.2	24.7			24.0		5000
5100	"	"	"		25.6	25.9	"	"	"	"	"	"	"	23.3		24.3	"				25.4	5100
5200	"	"	"		"	"	"	26.1	"	"	"	"	"	23.5		"	"					5200
5300	26.0	"	"		"	"	"	"	"	"	"	"	"			"	"			24.2		5300
5400	"	"	"		"	"	"	26.2	"	"	"	"	"			"	"			24.3		5400
5500	"	"	26.2		"	"	"	26.1	"	"	"	"	"			"	"	24.6	24.2 24.9	24.2		5500
5600	"	"	"		"	"	"	26.2	"	"	"	"	"			"	"					5600
5700	"	"	"		"	"	"	"	"	"	25.8	"	25.8	23.8		"	24.8					5700
5800	"	25.9	"		25.5	"	"	"	"	"	"		"			24.4	"			24.1		5800
5900	"	"	"		"	"	"	"	"	"	"		"			"	"					5900
6000	"	"	"		"	"	"	"	"	"	"		25.7	23.9		"	"			24.2		6000
6100	"	"	"		"	26.1	"	"	"	"	"		25.8			24.5	24.7			24.8		6100
6200	"	25.8	"		"	"	"	26.3	"	"	"		"			"	"				25.6	6200
6300	"	"	"		"	"	"	"		"	"		"			"	"					6300
6400	25.9	"	"	26.6	"	"	"	"		"	"		"			"	"					6400
6500	"	25.9	"		"	25.9	"	26.2		"	"		"			"	"					6500
6600	"	"	"		"	"	"	"		"	"		"			"	"					6600
6700	"	"	"		"	26.0	"	"		"	"		"			"	"					6700
6800	25.8	"	"		25.6	"	"	"		"	"		"			"	"					6800
6900	"	"	"		"	"	"	"		"	"		"			"	"					6900
7000	"	25.8	"		"	"	"	"	26.2	"	"		25.9		24.4	"	"			25.1		7000
7100	"	25.9	"		"	"	"	26.3		"	"		25.8		"	"	"		25.0			7100
7200	"	25.8	26.1	26.0	"	25.9	"	"		"	"		"		"	"	"					7200
7300	"	"	"		"	"	"	"		"	"		"		"	"	"					7300
7400	"	"	"		"	25.8	25.7	"		"	"		"		"	"	"	24.7			25.7	7400
7500	"	"	"		"	"	25.8	26.2		"	"		25.9		"	"	"				"	7500
7600	25.7	25.7	"		"	"	25.7	26.3		"	25.9		"		"	"	"				"	7600
7700	"	"	"		"	"	"	26.2		"	"		"		"	"					"	7700
7800	"	"	"		"	"	"	"		"	"		"		"	"					"	7800
7900	"	"	"		"	"	"	26.3		"	"		"		"	"					"	7900
8000	"	"	"		"	25.9	25.6	"	26.3	"	26.0		"		"	"				25.2	"	8000
8100	25.6	"	"		"	"	25.5	"	26.4		25.9		"			"					"	8100
8200	"	"	"		"	26.0	"	"	"		"		"			"	24.9				"	8200
8300	"	"	"		"	"	"	26.4	"		"		"			"	"				"	8300
8400	"	"	"		"	25.9	"	"	"		"		"			"	"	24.8			"	8400
8500	25.5	"	"		"	"	"	26.5	"		"		"	24.2		"	"					8500
8600	"	"	"		"	"	"	26.4	"		26.0		"			"	"					8600
8700	25.4	"	"		"	"	"	"	"		"		"			"	"					8700
8800	25.3	"	"		"	"	25.6	"	26.3		"		"		24.2	"	"					8800
8900	"	"	"		25.5	"	"	26.5	"		"		"			"	"					8900
9000	"	25.6	"		"	"	"	26.4	26.2		26.1		"			"	"			25.3		9000
9100	"	25.7	"		"	"	"	"	"	25.1	26.0		"			"	"				25.6	9100
9200	25.2	"	"		"	"	"	"	"		"		"			"	"					9200
9300	"	"	"		"	"	"	"	"		25.9		25.8			"	"					9300
9400	25.1	25.6	"		"	"	"	26.5	"		"		"			"	"					9400
9500	"	25.5	"		"	"	"	26.4	"		"		"			"	"					9500
9600	25.0	"	"		"	"	25.5	"	26.1		"		25.7			"	"				25.7	9600
9700	"	25.4	"		"	25.8	25.6	"	"		"		"			"	"				"	9700
9800	24.9	"	"	25.5	"	"	"	"	"		"		"			"	"				"	9800
9900	"	25.3	"		"	"	"	26.3	26.2		"		"			"	24.8				"	9900
10000	24.8	"	"		"	"	"	"	26.1		"		25.6		24.1	"	"				"	10000
10100	"	25.2	"		"	"	"	26.4	"		25.8		"				"				"	10100
10200	"	25.3	"		25.6	"	"	"	"		25.7		"	24.3			"				"	10200
10300	24.7	25.1	"		"	"	"	"	26.2		"		"				"				"	10300
10400	24.6	25.0	"		"	"	"	"	"		"		"				"				"	10400
10500	"	24.9	"		"	"	"	"	"		"		"			24.6	"				"	10500
10600	"	25.0	"		"	"	"	26.5	26.1		"		"				"				"	10600
10700	"	"	"	25.2	"	"	25.7	26.4	"		"		"				"		25.1	25.4	"	10700
10800	"	"	"		"	"	25.6	26.5	"		"		"				"			"	"	10800
10900	24.4	25.1	"		"	"	25.7	26.4	26.2		25.6		"			24.5	"			"	"	10900
11000	24.3	25.0	26.0		"	"	"	26.5	26.1		"		"				"			"	"	11000
11100	24.2	24.7	"		"	"	"	"	26.2		"		25.7				"			"	"	11100
11200	"	24.6	"		"	"	"	"	"		"		"				"			"	"	11200
11300	"	24.5	"	24.3	"	"	"	"	"		25.7		"				"			"	"	11300
11400	"	"	"		"	25.9	"	26.3	26.1		"		"				"			"	"	11400
11500	"	"	"		25.7	25.8	"	"	26.2		"		"							"	"	11500
11600	24.4	24.7	"		"	"	"	26.5	"	25.5	"		"							"	"	11600
11700	24.5	24.8	"		"	25.9	25.6	26.4	"		"		"		24.0					"	"	11700
11800	24.6	24.9	"		"	"	"	26.5	"	25.4	"		25.5							"	"	11800
11900	"	"	"		"	25.8	"	26.4	26.3		"		"			24.6				"	"	11900
12000	24.9	25.0	26.1	24.8	"	25.9	"	26.5	26.2		"		"							"	"	12000
12100	25.1	25.1	26.0		"	25.8	25.7	"	"		"		"							"	"	12100
12200	"	25.3	"		"	"	"	"	"		"		25.4					24.7		"	"	12200
12300	"	25.5	"		"	"	"	26.6	"		"		"				24.7	"		"	"	12300
12400	"	"	"		"	"	"	"	"		25.5		25.3			24.7		"		"	"	12400
12500	"	25.6	"	25.7	"	"	"	"	"		"		25.4					"		"	"	12500
12600	"	"	26.1		"	"	"	"	"		"		"					"		"	"	12600
12700	"	"	"		"	"	25.6	"	"		"		"	24.0				"		"	"	12700
12800	"	"		25.6	"	"	"	26.5	26.3		"		"			24.6	25.5	"		"		12800
12900	"	25.7			"	25.9	25.7	"	"		"		"		23.9			"		"	25.6	12900
13000	25.1	25.8			"	25.8	"	"	"		25.6					25.4		"		"		13000
13100					"	"	"	"	"								25.6	"		"		13100
13200					"	"	"	"	"							25.7		"		"		13200
13300					"	"	"	"	"									"		"		13300
13400					"	"	"	"	"	25.6										"		13400
13500					"	"	"	26.6	26.2											"		13500
13600					"	"	"	26.5	"											"		13600
13700					"	"	"	"	"											"		13700
13800					"	25.7	"	"	"											"		13800
13900					"	25.8	"	26.6	"													13900
14000					"	"	"	26.7	"													14000
14100					"	"	"	26.6														14100
14200					"	"	"	"														14200
14300					"	25.7	"	26.5		25.7												14300
14400					"	"	"	26.7														14400
14500					"	"	"	"														14500
14600					"		"	"														14600
14700					"		"	"														14700
14800					"		"	"														14800
14900							"	"														14900
15000							"	"														15000

TO ACCOMPANY RECORD No. 1968/18

H56/B5-23

TEMPERATURE VALUES (°C)
(UNCORRECTED NEAR-SURFACE)

TO ACCOMPANY RECORD No. 1968/18

MARK	OMEGA TRAVERSES																					MARK
	20 in	21 out	22 out	22 out	23 in	24 out	25 out	26 in	29 out	30 in	31 out	32 in	33 out	34 in	36 out	37 in	38 out	41 out	42 in	43 out	45 out	
100																						100
200																						200
300			27.3														23.4					300
400				25.3																		400
500			27.2																			500
600			27.4						24.5													600
700			27.2	25.1									25.8									700
800		24.6																				800
900		24.7	26.8						24.5			25.7				25.5						900
1000			27.1	25.1	25.3					25.0		25.6	25.7			"						1000
1100		24.9										25.7		25.6		"						1100
1200		24.7			25.0					25.1		25.8				"						1200
1300		24.8	27.2	25.1	24.7							25.7		25.5		"						1300
1400			27.1		24.6					25.4		25.9		25.8		"						1400
1500		24.7			"					"		"	25.8			25.4						1500
1600		"	27.2		"					"		25.8	25.9				24.5					1600
1700	24.8	"			24.4					"		25.9										1700
1800	25.0	"	27.3						24.8	"		"		25.6		25.5						1800
1900	24.8					25.1						"	25.8			25.4						1900
2000	25.0	24.8	27.1			25.6				25.6	25.3	"		25.7		25.5	24.8					2000
2100		24.9	"		24.6	25.1				"						"			23.9			2100
2200	24.8		"		"					"		26.0	25.9			"		23.7	24.1			2200
2300		25.1			"					"		"	"	25.5		"						2300
2400				25.6	"	24.7				"		"	"	"		"	25.0					2400
2500	25.0	25.6	27.2		"	"				"	25.5	"	"	"		25.4				23.8		2500
2600					"	"				"			"	"		"			24.2			2600
2700	25.7	25.7			"	"				"		25.9	"	"		"						2700
2800				25.8	"		26.5			"		25.8	"	"		"			24.4			2800
2900		25.6	26.8	"	"				25.0	"				"		"	24.9	23.9		24.1		2900
3000			26.3	"	"				"	"	25.6		25.8	"	25.0	"						3000
3100			26.5	"	"				"	"	"	25.9	"	"		"						3100
3200	25.7			"	"				"	"	"		"			"						3200
3300	"			"		24.8			"		"		"			"				24.0		3300
3400	"					"			"		"	25.7	"			"						3400
3500	"				24.7	"			"	25.5	"	25.8	25.9	25.6		"			24.2	24.5		3500
3600	"	25.7				"		26.7	"	"	"					"			24.7			3600
3700	"					"			"	"	"					"		23.8				3700
3800	"		26.7			"		26.8	"	"	"			25.5	25.1	"						3800
3900	"		27.0			"		27.0	"	"	"				25.2	"			24.8	24.6	25.7	3900
4000	"	25.7	26.8			"	26.7	26.9	"	"	"				"	"					25.8	4000
4100	"					"	26.8		"	"	"				"							4100
4200	"				24.8		27.1		"	"	"			25.6	"		25.0			24.9	25.7	4200
4300	"				"				"	"					"		24.9	24.3			"	4300
4400	"			25.3	"				"			25.7	25.8	25.7	"			24.4			"	4400
4500	"		26.9		"			26.8	"												25.8	4500
4600	"				"				"			25.8			25.0						"	4600
4700	"		27.0	25.1	"				"			"									"	4700
4800	"	25.6			"				"			"		25.6		25.5		24.5		25.1	"	4800
4900	"		27.3		"				"			"		"		"					"	4900
5000	"		27.4		24.9	25.3	26.9	27.0	"			"	26.0	"		25.4	25.0				"	5000
5100	"		27.2			25.4	"	"	"	25.4	25.5	"		"		"					"	5100
5200	"	25.7				"	"	"	"	"		"		"		25.3					"	5200
5300	"	26.0				"	"	"	"	"	25.6	"		"						25.2	"	5300
5400	"				25.0	"	"	"	"	"	25.5	"		"		25.4				"	"	5400
5500	"	25.9	27.4	24.8		"	"	"	"	"	"	"		"	25.2	25.5				"	"	5500
5600	"						"	"	"	"	"	"		"						"	"	5600
5700	"	25.8					"	"	"	"	"	"		25.7			25.2			"	"	5700
5800	"	25.9					"	"	"	"	"	"								"	"	5800
5900	"	"		24.4			"	"	"	"	"	"		25.5						"	"	5900
6000	"	"	27.5		24.9	25.5	"	"	"	"	"	"		"	25.3	25.2			25.1	"	"	6000
6100	"	"				"	"		"		"		25.9	"	25.2	"				"	"	6100
6200	"	"		24.3		"	"		"		"			"	"	"				"	"	6200
6300	"		27.3			"	"		"		"				"	"				"	"	6300
6400	"	25.6				"	"		24.9		"				"	"		24.9		"	"	6400
6500	"					"	"	26.5	25.0		"				"	"	25.3			"	"	6500
6600	"						"				"			25.6	"	"	"				"	6600
6700	"						"	26.7			"		25.8	"		"	"				"	6700
6800	"	25.7					"	26.3			"			"		"	"	25.0			"	6800
6900	"						"	"			"			"		"	"				"	6900
7000	"	25.6	27.1		24.8	25.4	"	"			"				25.1	"	"				"	7000
7100	"										"	25.7		25.8	"	"			25.4		"	7100
7200	"							26.5			"			"	"	25.0				25.3	"	7200
7300	"	25.7						"			"			"	"	"					"	7300
7400	"	25.7					26.6	"			"		26.0	"	"	"					"	7400
7500	"							"	24.9		"		"	"	"	"					"	7500
7600	"		26.9		24.6			"		25.2	"		"	"	"	"					25.9	7600
7700	"						26.7	"		"	"		"	"	"	"	25.4					7700
7800	"									"	"			"	"	"						7800
7900	"		27.0					26.4	25.0	"	"			"	"	"					26.0	7900
8000	"		26.9	24.6			26.6			"	"	25.9	26.1	"	"	"		25.2			25.8	8000
8100	"						26.5			"	"											8100
8200	"						26.6	26.5		"	25.6											8200
8300	"	26.0			24.9	25.3				"		25.8										8300
8400	"							26.4		"			26.2								25.9	8400
8500	"									"			"								26.0	8500
8600	"		27.0			25.2				"			"	25.7							"	8600
8700	"	26.2			24.6	"				"			"							25.2	"	8700
8800	"				"	"	26.7		25.0	"	25.5	26.0	"								"	8800
8900	"				"	"	"			"			"				25.5				"	8900
9000	"				"		"			"			"	26.0							"	9000
9100	"			25.0			"						"	"								9100
9200	"				24.7		"							"								9200
9300	"						"							"					25.3			9300
9400	"						"			25.3	25.6	26.1		"							25.9	9400
9500	"			24.8			"	26.5		"			26.3	"								9500
9600	"						"			"	25.7		"	"			25.6	25.3				9600
9700	"				25.0				25.2	"			"	"								9700
9800	"							26.8		"			"	"								9800
9900	"				25.1		26.4			"			"	"			25.5					9900
10000	"									"			"	"							25.8	10000
10100	"			25.2						"		26.0	"	"							25.9	10100
10200	"				25.0					"		26.1	26.2	"							"	10200
10300	"									"			"	"							"	10300
10400	"							26.6		"		26.2	"	"			25.6				"	10400
10500	"			25.0		25.1	26.7		25.3	"	25.8	"		"			25.5				"	10500
10600	"			"			"		"	"	"	"		"				25.2			"	10600
10700	"			"	25.2		"		"	"	"	"		"							"	10700
10800	"			"			"		"	"	"	"	26.3	"						25.1	"	10800
10900	"			"			"		"	"	"	"	"	"			25.6				"	10900
11000	"			"	25.0		"		"	"	"	"	26.2	"							"	11000
11100	"			"		25.3	"		"	"	"	"									"	11100
11200	"			"			"		"	"	"	"									"	11200
11300	"			"			"		"	"	"	"							25.1		"	11300
11400	"			"			26.6	26.8	"	"	"	"						25.1			"	11400
11500	"			"					"	"	"	"	26.1								"	11500
11600	"			"					"	"	"	"	26.0								"	11600
11700	"			"					"	"	"	"	"							25.0	"	11700
11800	"			"		25.2			"	"	"	"	"							25.3	"	11800
11900	"	26.4		"					"	"	"		"							25.2	"	11900
12000	"			"	25.1	25.0	26.8	26.7	"	"	"		"	25.9						25.4		12000
12100	"			"		24.9	"	"	"		"		"									12100
12200	"			"		25.0	"	"	"		"											12200
12300	"			"	25.0	"	"	"	"		"											12300
12400	"			"		"	"	"	"		"											12400
12500	"			"		"	"	"			"											12500
12600	25.6			"		"	"	"			"									25.4	26.1	12600
12700		26.3		"		"	"				"									"	"	12700
12800				"	25.1						"										"	12800
12900				"					25.2		"	26.1	25.9								"	12900
13000										25.1	"			25.8				25.0				13000
13100											"							"				13100
13200											"						25.7	"			26.0	13200
13300																		"			"	13300
13400								26.5										"			"	13400
13500																		"		25.5		13500
13600								26.7										"		25.6		13600
13700								"										"				13700
13800								"										"				13800
13900								"										"	24.8	25.7		13900
14000								"										"	25.0		26.2	14000
14100								"										"	"			14100
14200								"										"	"	25.6		14200
14300								"										"	"			14300
14400																			"			14400
14500																		25.1				14500
14600																				25.7		14600
14700																						14700
14800																					25.9	14800
14900																				25.6		14900
15000																				25.8	26.0	15000

TEMPERATURE VALUES (°C)

(UNCORRECTED NEAR-SURFACE)

	OMEGA TRAVERSES				SEISMIC TRAVERSES			
MARK	46 in	47 out	48 in	49 out	1 in	2 in	3 out	4 out
100								
200						24.5		
300								
400						24.6		
500						24.9	24.5	
600					26.0		24.3	
700					"			
800					"			
900					"		24.7	
1000					"	25.0	"	
1100							"	
1200								
1300							25.0	
1400								
1500								
1600								
1700								
1800								
1900								
2000					26.1			
2100					"	25.1		
2200					"			
2300					"			
2400					"			
2500					"			
2600					"			
2700					"			
2800					"			
2900					"			
3000					"	25.2	25.1	
3100					"	"	"	
3200					"	"	"	
3300					"	"	"	
3400					"	"	"	
3500					"	"	"	
3600					"	"	"	
3700					"	"	"	
3800					"	"	"	
3900					"	"	"	
4000					"	"	"	
4100						"	"	
4200						"	"	
4300						"	"	
4400						"	"	
4500						"	"	
4600						"	"	
4700						"	"	
4800	25.7					"	"	
4900	25.8					"	"	
5000					26.0	"	"	
5100	25.6				"	25.4		
5200	25.7				"			
5300	25.6	25.3			"			
5400	25.7	25.5			"			
5500	"	25.4			"			
5600	25.6	"			"			
5700	25.5	"			"			
5800	"	"			"			
5900	"	"	25.4		"			
6000	"	"	"		"	25.5		
6100	"	"	"		"	"		
6200	"	"	"		"	"		
6300		"	"		"	"		
6400	25.7	"	25.3		"	"		
6500	"	"	25.4		"	"		
6600	"	"	"		"	"		
6700	"	"	"		"	"		
6800	"		"	24.4	"	"		
6900	"		"	"	"	"		
7000	"			24.5	"	"	25.0	
7100	"	25.5		24.4	"		"	
7200	25.6		25.2		"		"	
7300	"	25.6	"	24.3	"		"	
7400	25.7		"	24.4	"		"	
7500	"			"	"		"	
7600	"		25.4	"	"		"	
7700	"			"	"		"	
7800	"			"	"		"	
7900	"			"	"		"	
8000	"		25.3	"	"	25.4	"	
8100	"	25.7		"	"		"	
8200	25.8			"	"		"	
8300				"	"		"	
8400					"		"	
8500				24.5	"		"	
8600	25.7	25.8		"	"		"	
8700			25.4	"	"		"	
8800		25.7		"	"		"	
8900		25.8		"	"		"	
9000				"	"	25.3	"	
9100		25.9			"		"	
9200					"		"	
9300	25.9	26.0	25.7	24.8	"		"	
9400	25.8			25.0	"		"	
9500				"	"		"	
9600	25.9	25.9		"	"		"	
9700	25.8			"	"		"	25.5
9800	"			"	"		"	
9900	"			"	"		"	
10000	"			"	"		"	
10100	"	26.0		"	"		"	
10200	"	26.1		"	"		"	25.4
10300	"	26.0		"	"		"	
10400	"				"		"	
10500	"		25.6	25.1	"		"	
10600					"		"	
10700	25.9				"		"	
10800					"		"	25.3
10900					"		"	
11000	26.0				"	25.2	"	25.4
11100	"			25.0		"	"	"
11200	"					"	"	"
11300	"			25.1		"	"	"
11400	"	26.1				"	"	"
11500	"	26.0				"	"	"
11600	"					"	"	"
11700	"	26.1				"	"	"
11800	"					"	"	"
11900	"					"	"	"
12000	"	26.0			25.8	"	"	"
12100	"	"		25.0		"		"
12200	"	"		"		"		
12300	"	"		"		"		
12400		"		"		"		
12500		"		"		"		
12600		"	25.4	"		"		25.2
12700		"	"	"		"		25.3
12800		"	"	"		"		"
12900		"	"	"		"		
13000	25.9	"	"	"	25.9	"		
13100	"		"	"		"		
13200	"		"	"		"		25.1
13300	"		"	"		"		
13400	"	26.1	"			"		
13500	"		"			"		25.2
13600	"		"			"	24.9	
13700	"	26.0	"			"	"	
13800	"		"			"	"	
13900	"		"	25.1		"	"	
14000	"		"			"	"	25.3
14100			"			"	"	"
14200			"			"	"	"
14300		26.1	"			"	"	"
14400			"			"	"	"
14500		26.0	"	25.0		"	"	25.2
14600	25.7			"		"	"	"
14700				"		"		"
14800				"		"		"
14900				"				"
15000	25.8			"			24.8	"

	OMEGA TRAVERSES		SEISMIC TRAVERSES			
MARK	48 in	49 out	1 in	2 in	3 out	4 out
15100		25.0			24.8	25.2
15200		"			"	"
15300		"			"	"
15400	25.2	"			"	"
15500		"			"	"
15600		"			"	25.1
15700		"			"	"
15800		"			"	"
15900		"			"	"
16000		"			"	"
16100					"	"
16200					"	"
16300					"	"
16400					"	"
16500					"	"
16600					"	"
16700					"	"
16800					"	"
16900					"	"
17000					"	"
17100					"	"
17200					"	"
17300					"	"
17400					"	"
17500					"	"
17600					"	"
17700					"	"
17800					"	"
17900					"	"
18000					"	"
18100						"
18200						"
18300						"
18400						"
18500						"
18600						"
18700						"
18800						"
18900						"
19000						"
19100						"
19200						"
19300						"
19400						
19500						
19600						
19700					24.7	
19800						
19900						
20000						
20100						
20200						
20300						
20400					24.6	
20500						
20600						
20700						
20800						
20900					24.5	
21000						
21100						
21200					24.6	
21300						
21400					24.5	
21500					"	
21600					"	
21700					"	
21800					"	
21900					"	
22000					"	
22100						

NOTE: (1) *Temperature gradients, for the zones between values given, are constant.*

(2) *The date/time on which the traverse was surveyed can be found in Plate 2. Times of individual temperature readings may be found by interpolation.*

TO ACCOMPANY RECORD No. 1968/18

H56/B5-22

APPENDIX 3

Results of seismic refraction traverses at sea

Traverse Seismic 1 (inshore)

Shot No.		2	4	5	6
Direction		In	Out	In	Out
Spread Location (metres)		2030 2113	1970 1887	2090 2173	1902 1822
Depth (ft)	Shot Water	103 103	103 103	103 103	103 103
First Refractor	Velocity (ft/s)	5500	5700	5600	5000
	Depth (ft)	103	103	103	103
Second Refractor	Velocity (ft/s)	-	-	19,500	6300
	Depth (ft)	-	-	159	135
Third Refractor	Velocity (ft/s)	-	-	-	17,000
	Depth (ft)	-	-	-	185
Shot Distance (ft)		50	50	185	250

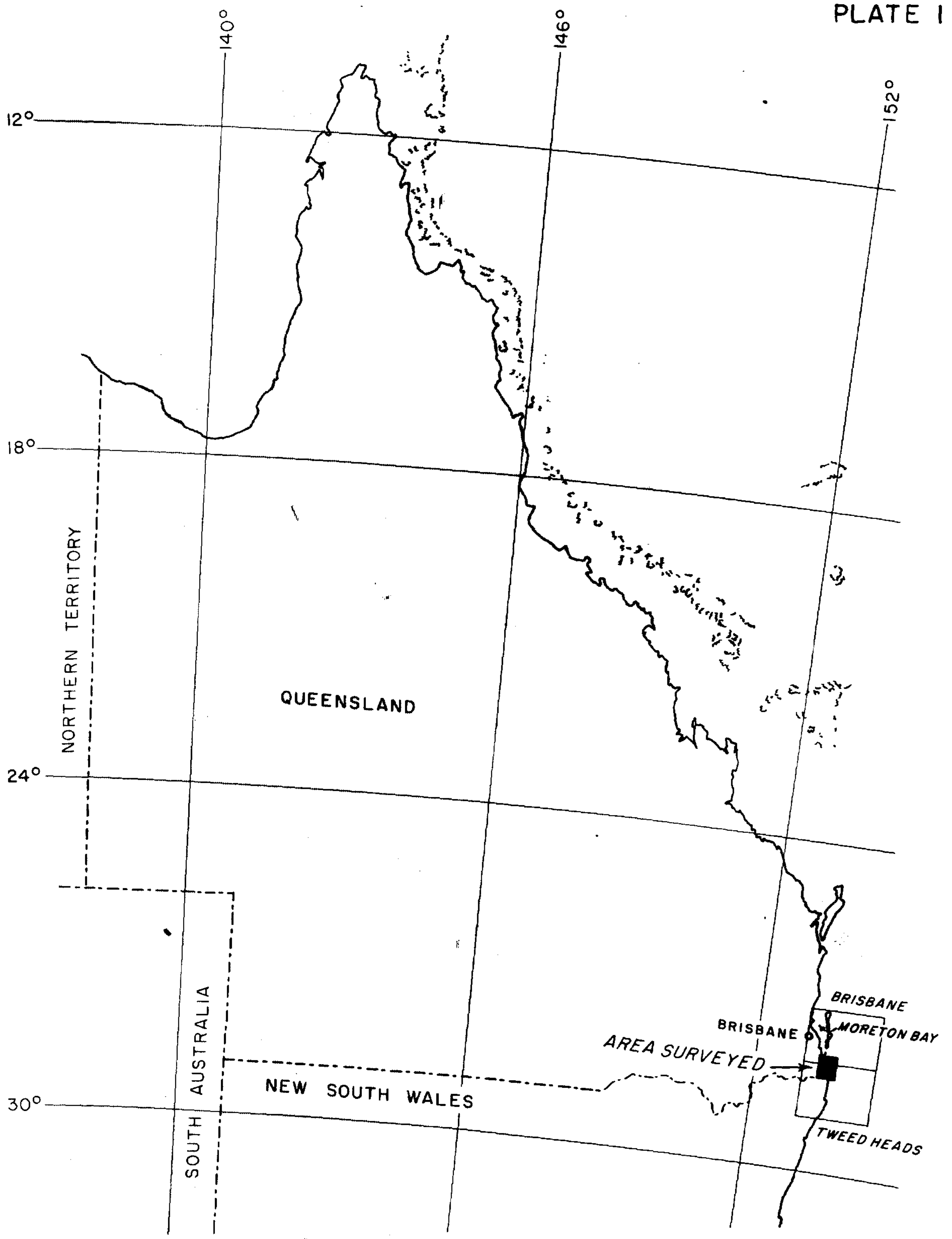
APPENDIX 3

Traverse Seismic 1 (at sea)

Shot No.		7	8
Direction		In	Out
Spread Location (metres)		10090 10173	9910 9827
Depth (ft)	Shot Water	75 185-190	75 185-190
First Refraction	Velocity (ft/s) Depth (ft)	5300 185-190	5000 185-190
Shot distance (ft)		297	250

Traverse Omega 37

Shot No.		1	3	4
Direction		Out	Out	In
Spread Location (Metres)		2213 2130	2200 2117	2392 2475
Depth (ft)	Shot Water	82 82	82 82	82 82
First Refractor	Velocity (ft/s) Depth (ft)	5500 82	5500 82	6700 82
Second Refractor	Velocity (ft/s) Depth (ft)	12,500 163	11,000 173	12,500 160
Shot Distance (ft)		250	-	-



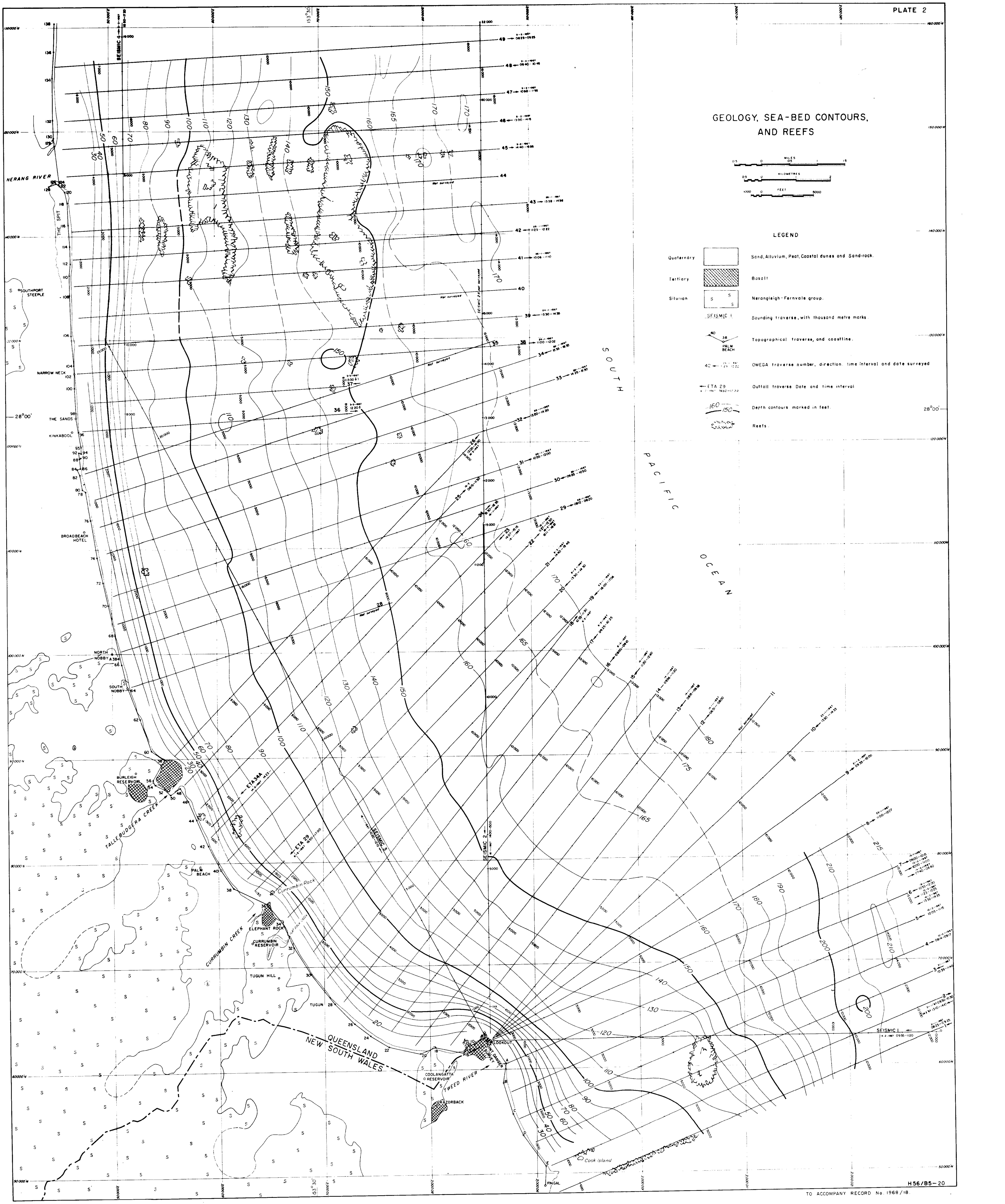
REFERENCE TO AUSTRALIA STANDARD 1:250,000 MAP SERIES : BRISBANE
TWEED HEADS

GOLD COAST, QUEENSLAND, 1967
COASTAL EROSION SURVEY
LOCALITY MAP

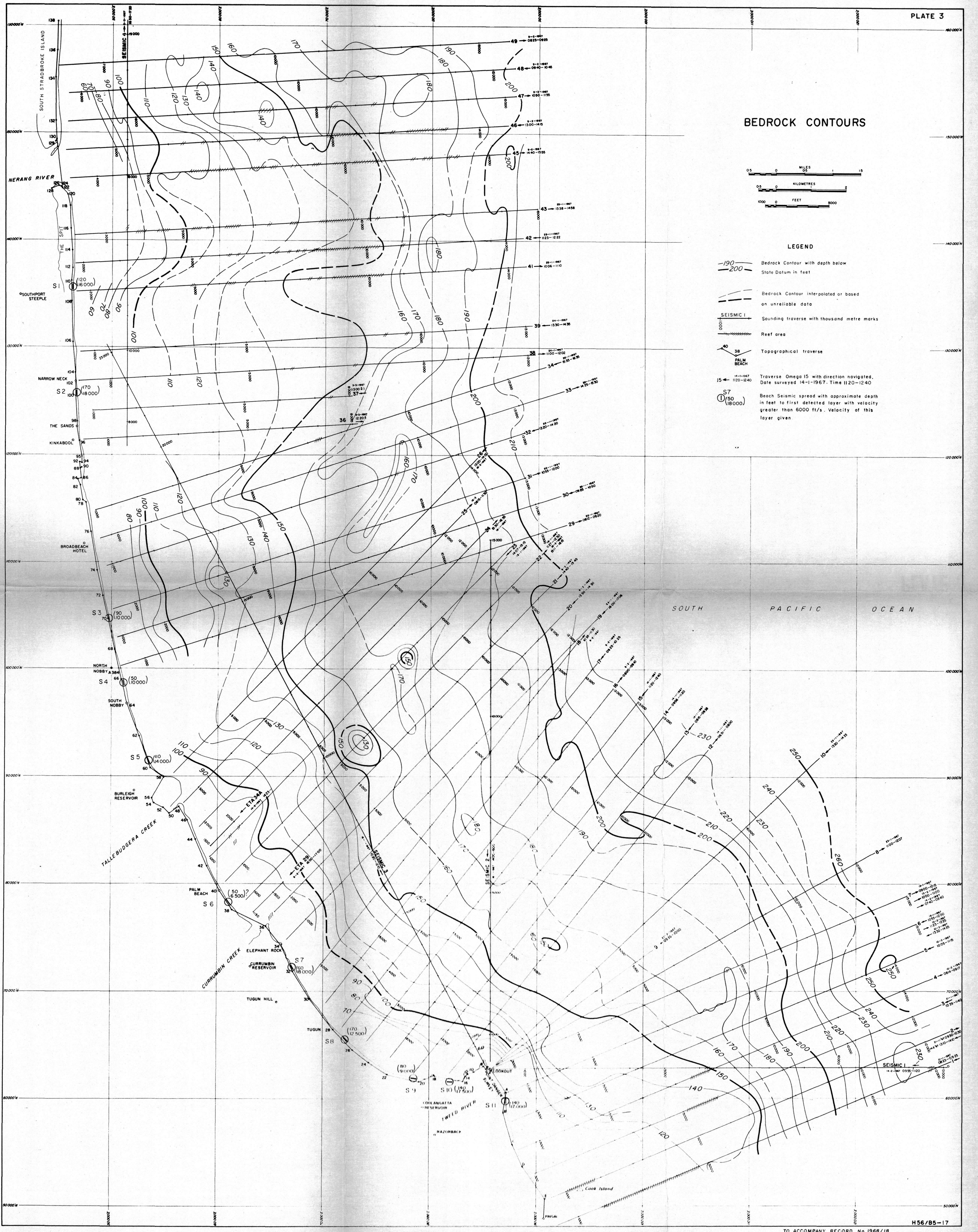
MILES
200 0 200 400

H56/B5-14

TO ACCOMPANY RECORD No. 1968/18



Coastal Erosion Survey QLD 1967



COASTAL EROSION SURVEY QUEENSLAND 1967

TO ACCOMPANY RECORD No 1968/18

PLATE 4

FIG. 1 SOME MULTIPLE REFLECTIONS

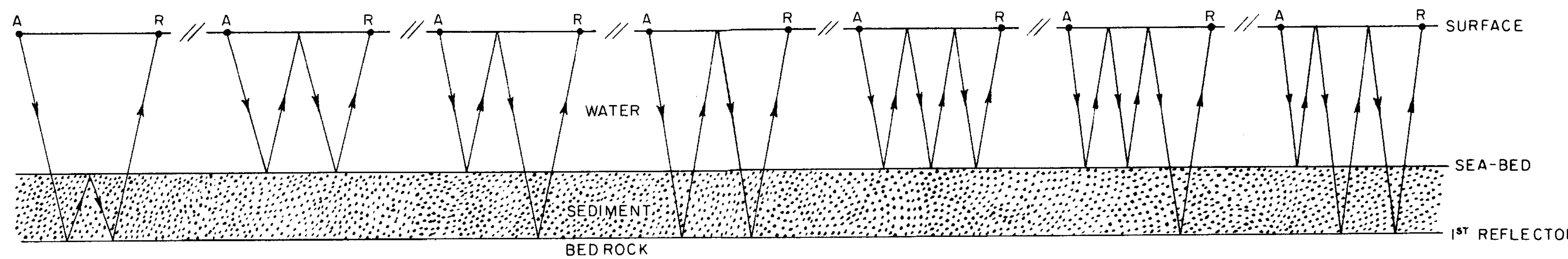


FIG. 2 NOMOGRAM FOR COMPUTING TRAVEL TIMES OF BOTTOM REFLECTIONS

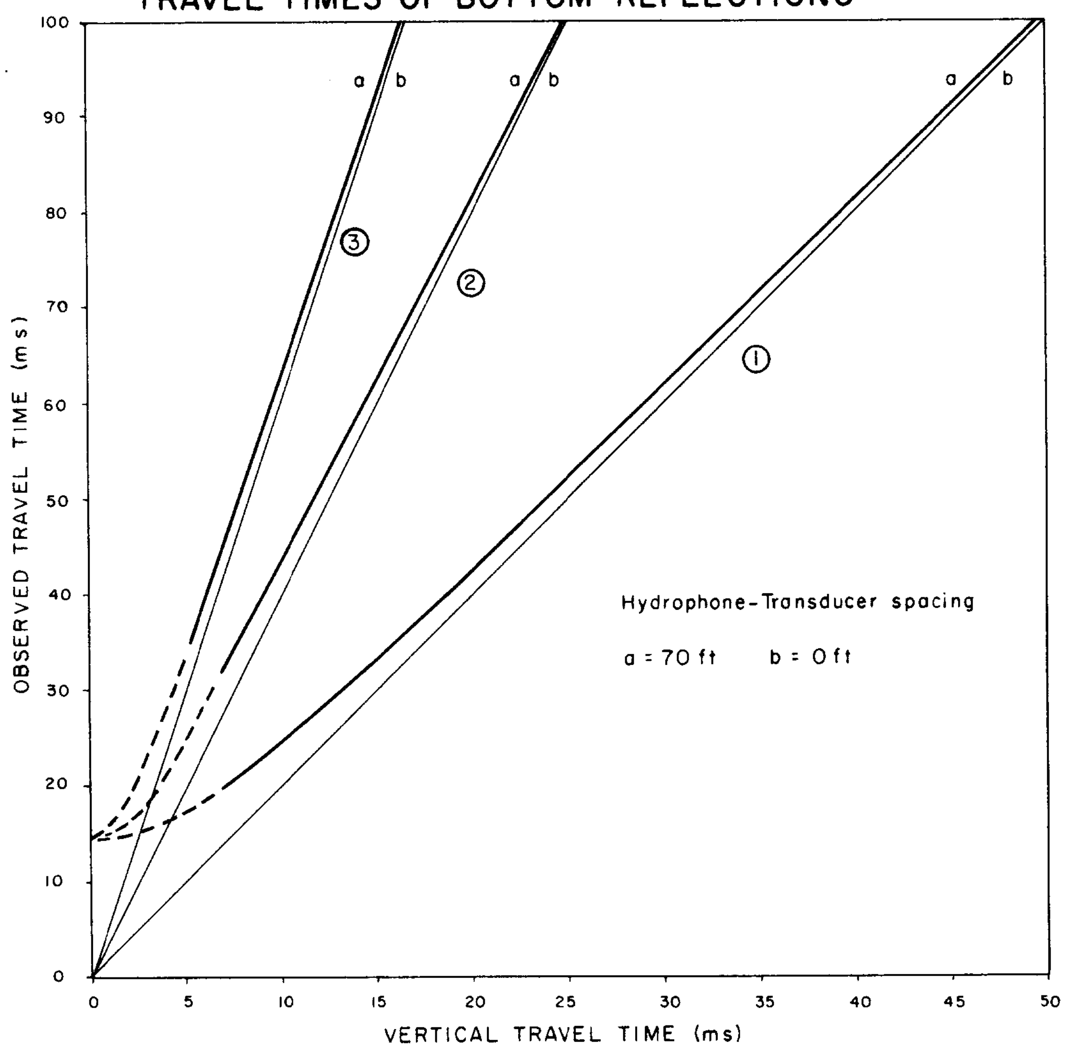


FIG.3 TRAVEL TIMES

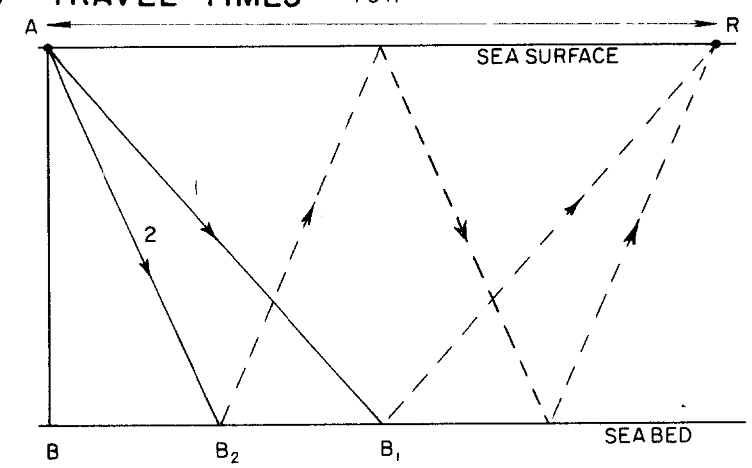
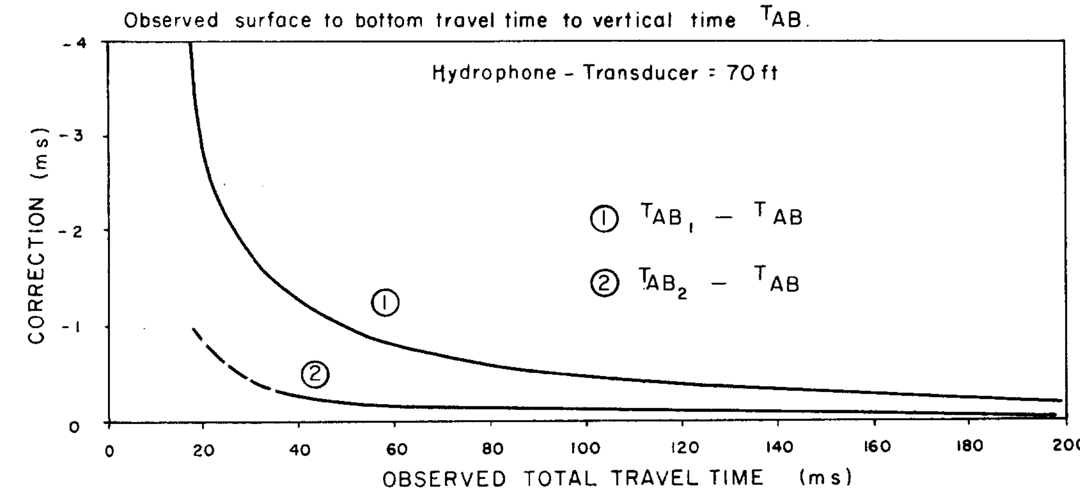


FIG. 4 GEOMETRICAL CORRECTION

Observed surface to bottom travel time to vertical time TAB.



LEGEND

A	Transmitter (Transducer)
R	Receiver (Hydrophone)
T_{AB}	Vertical travel time
T_{AB_1}	Surface to bottom travel time, bottom reflection
T_{AB_2}	Surface to bottom travel time, first bottom multiple
①	Single bottom reflection
②	Double bottom reflection (1st bottom multiple)
③	Triple bottom reflection (2nd bottom multiple)

MULTIPLE REFLECTIONS AND GEOMETRICAL CORRECTIONS

COASTAL EROSION SURVEY QUEENSLAND 1967

H56/B5-21

TO ACCOMPANY RECORD No. 1968/18

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

COASTAL EROSION SURVEY, QUEENSLAND 1967

SAMPLE SONAR BOOMER RECORDING

240FT DEPTH SCALE

TRAVERSE OMEGA 13

SHIP: *MV "SI BON"* DATE: *14/1/67*

EQUIPMENT

Energy source	*EGG 1000 Watt-sec system*
Transducer	*EGG Transducer Model 236*
Hydrophone	*Model 262-G*
Recorder	*EGG Model 254*

RECORDING INFORMATION

Source output	*1 kWs*
Firing interval	*1·2 seconds*
Source–receiver distance	*65 feet*
Source depth	*3–6 feet*
Receiver depth	*3 feet*
Gain (recorder)	*180 x 100 approx*
Passband	*200 c/s – 20 kc/s*
Print mode	*Negative*
Boat speed 1. Engine revs	*1000 rev/min*
Boat speed 2. Approx. speed	*6–8 m.p.h.*

HORIZONTAL SCALE *1 inch = 180 metres (approx)*

REMARKS *Recording from (OM 13; 11100) to (OM 13; 10000)*

(1) Firing instant
(2) Direct arrivals
(3) Sea bottom reflection
(4) Bedrock reflection

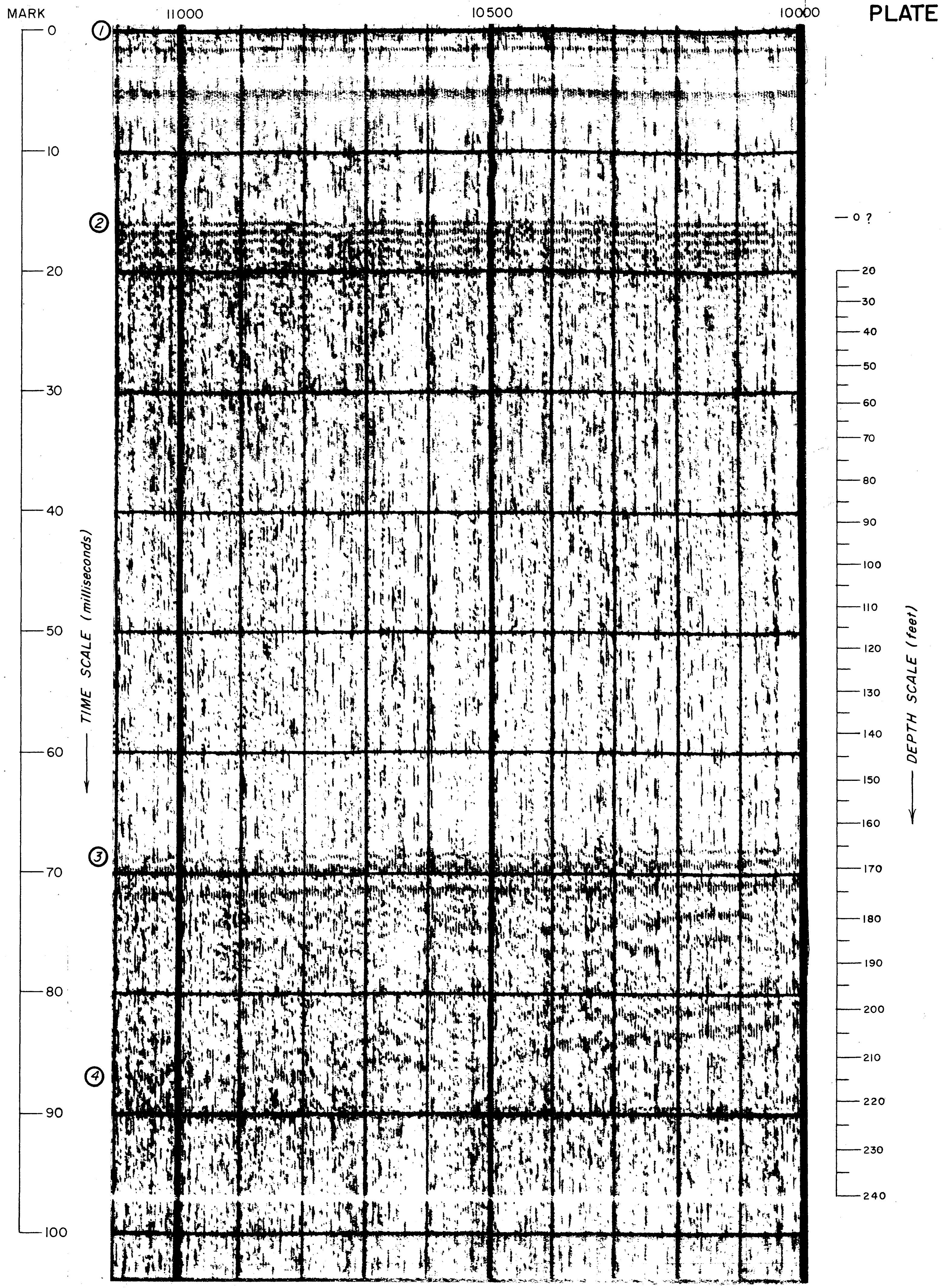


PLATE 5

TO ACCOMPANY RECORD No. 1968/18

H56/B5-28

PLATE 6

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

COASTAL EROSION SURVEY, QUEENSLAND 1967

SAMPLE SONAR BOOMER RECORDING

600FT DEPTH SCALE

TRAVERSE OMEGA 16

SHIP: *MV "SI BON"* DATE: *8/2/67*

EQUIPMENT

Energy source	*EGG 1000 Watt-sec system*
Transducer	*EGG Transducer Model 236*
Hydrophone	*Model 262-G*
Recorder	*EGG Model 254*

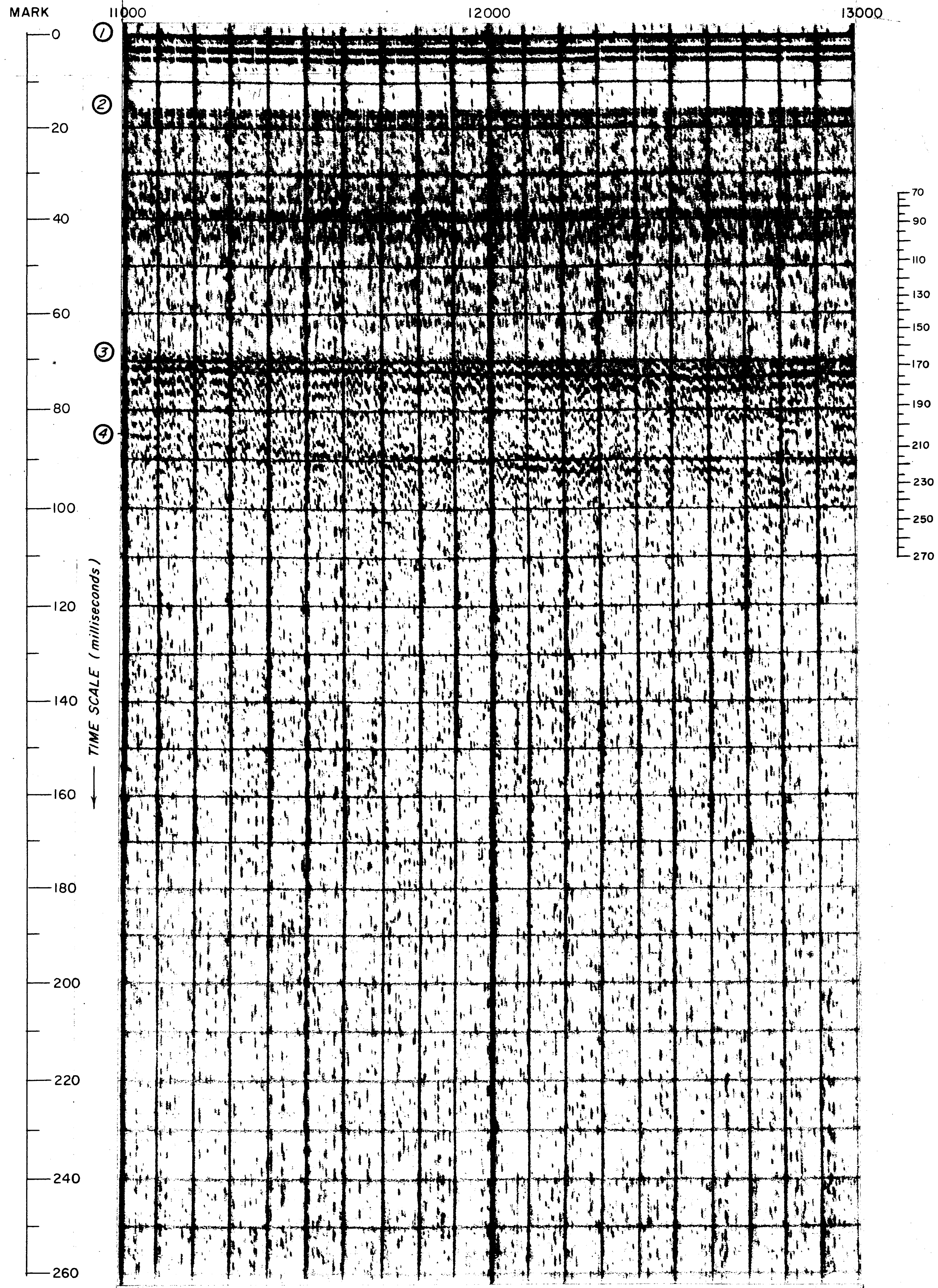
RECORDING INFORMATION

Source output		*1 kWs*
Firing interval		*1·2 seconds*
Source-receiver distance		*65 feet*
Source depth		*3-6 feet*
Receiver depth		*3 feet*
Gain (recorder)		*180 x 100 approx*
Passband		*200 c/s - 20 kc/s*
Print mode		*Negative*
Boat speed	1. Engine revs	*1000 rev/min*
	2. Approx. speed	*6-8 m.p.h.*

HORIZONTAL SCALE *1 inch = 330 metres (approx)*

REMARKS *Recording from (OM 16; 11000) to (OM 16; 13000)*

(1) Firing instant
(2) Direct arrivals
(3) Sea bottom reflection
(4) Bedrock reflection



TO ACCOMPANY RECORD No. 1968/18

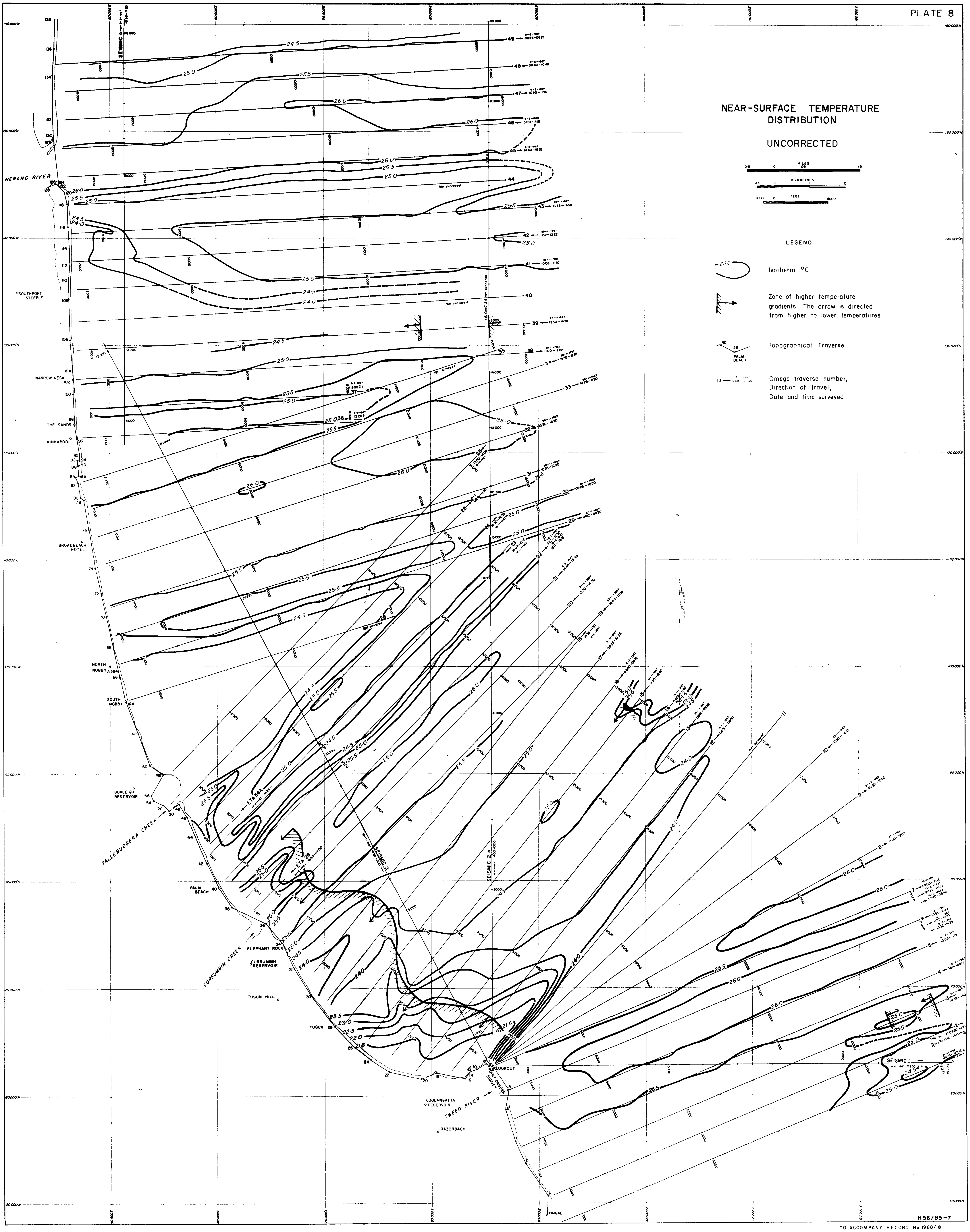
H56/B5-29

PLATE 7

H56/B5—6

TO ACCOMPANY RECORD No. 1968/18

COASTAL EROSION SURVEY QUEENSLAND 1967



TO ACCOMPANY RECORD No 1968/18

HEATING EFFECT AND TRAVERSE AVERAGE NEAR-SURFACE TEMPERATURES

N-S. = Near-surface
Times shown are Eastern Standard

Fig.1 N-S. TEMPERATURE vs. TIME (20 JAN 1967)

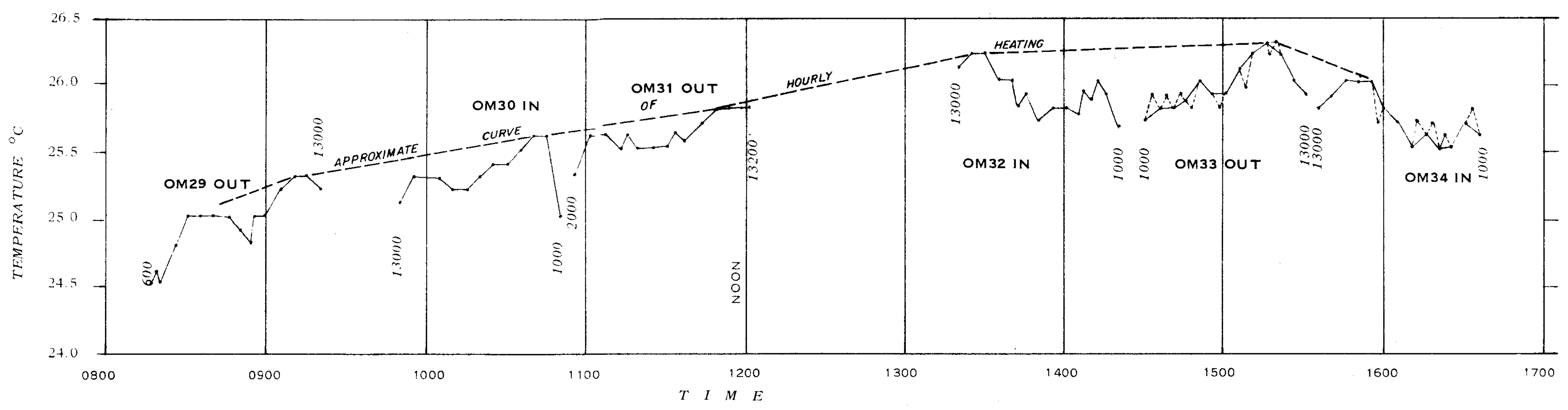


Fig.2 N-S. TEMPERATURE vs. TIME (25 JAN 1967)

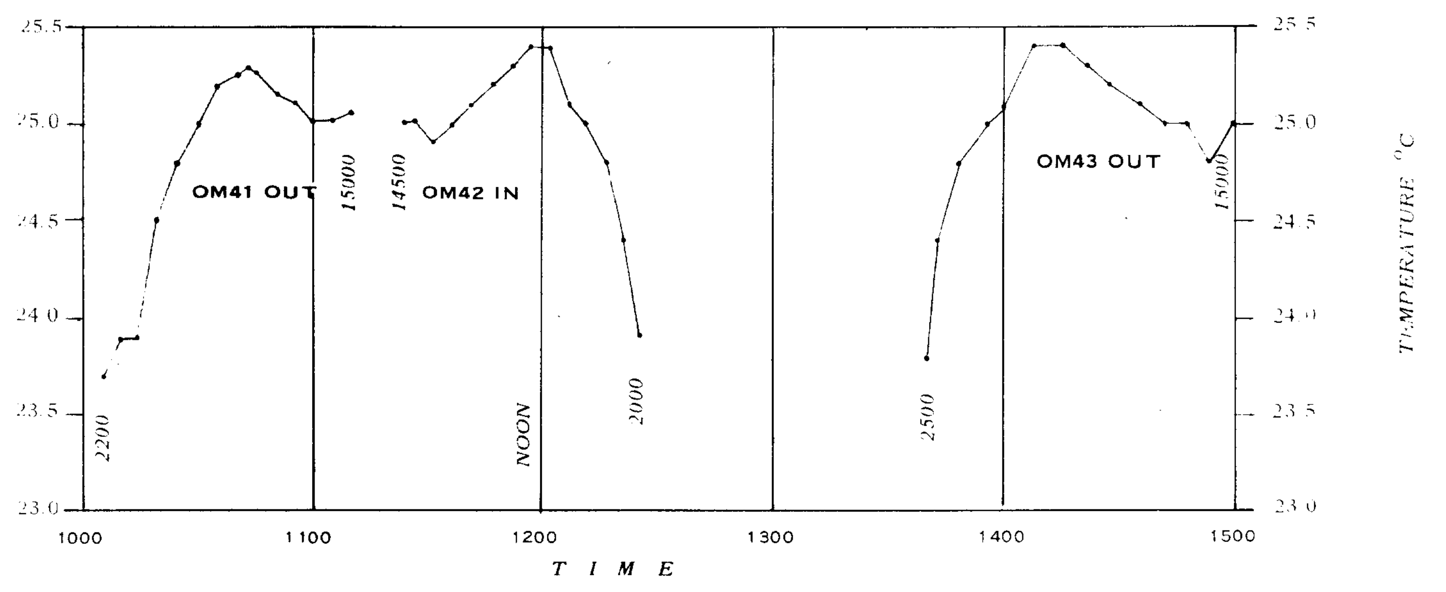


Fig.3 N-S. TEMPERATURE vs. TIME (9 FEB 1967)

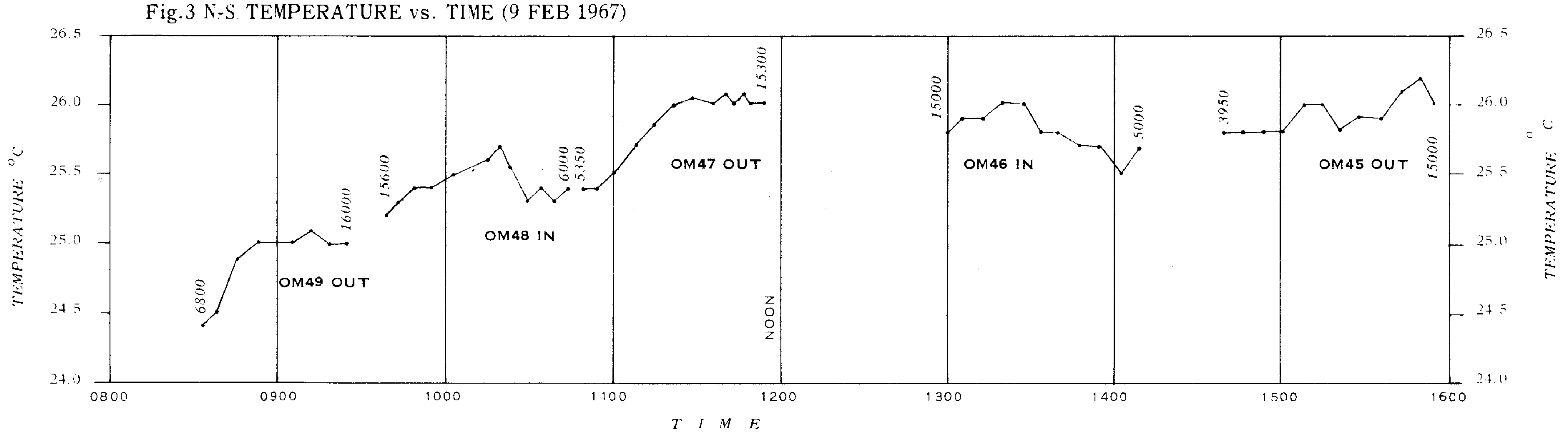
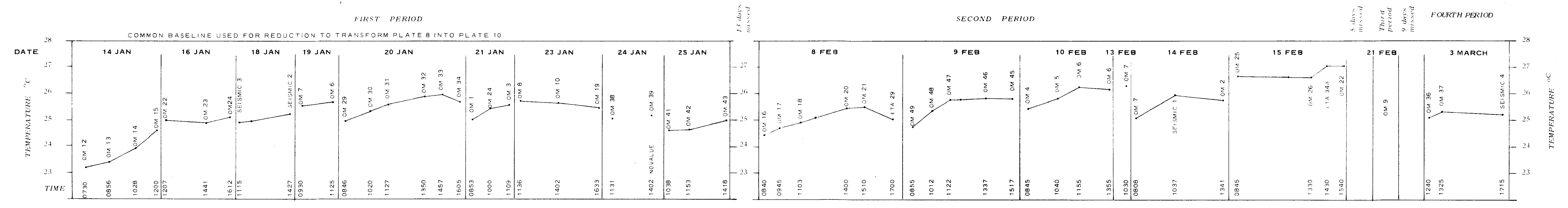
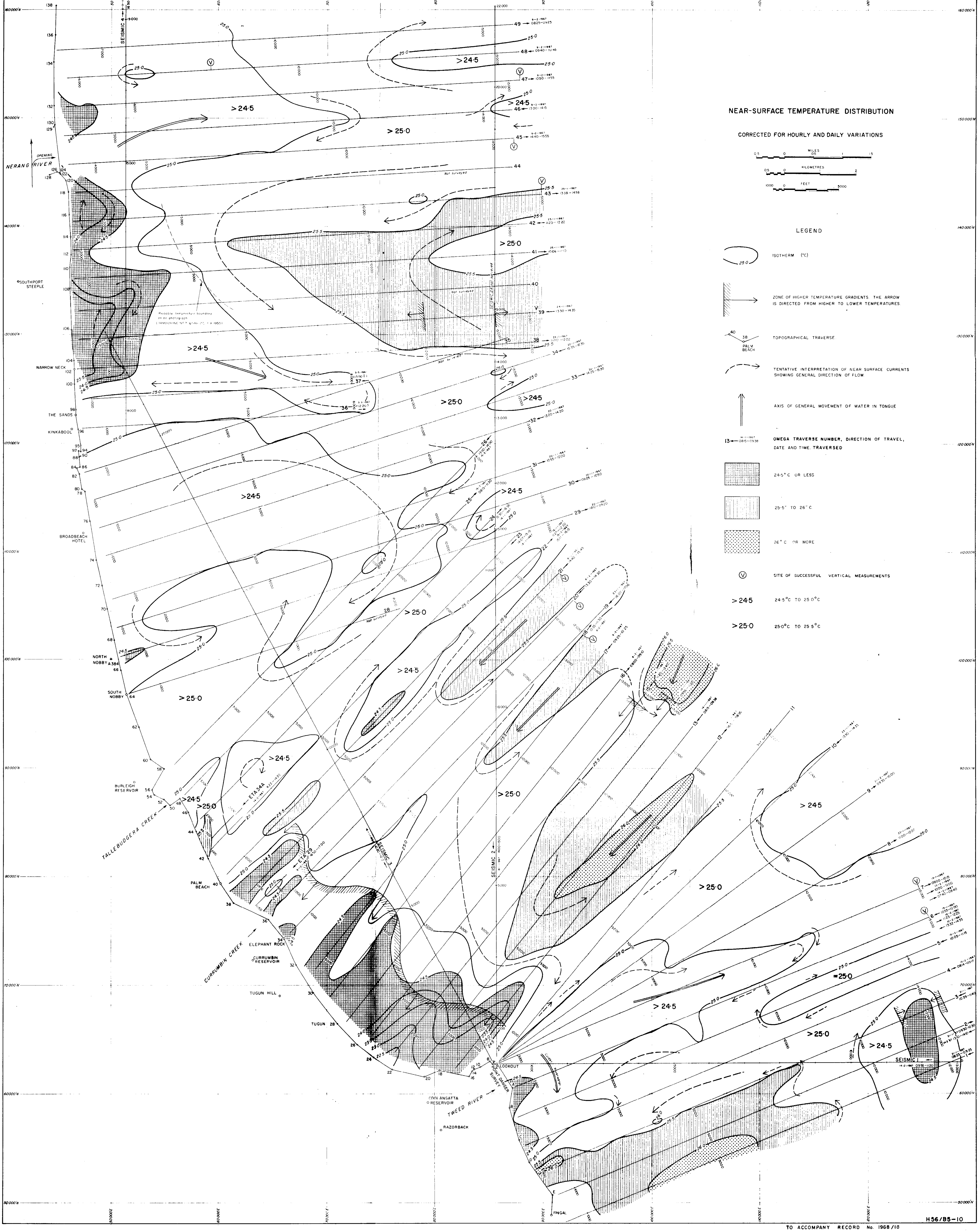


Fig.4 ~~N-S~~ UNCORRECTED TRAVERSE AVERAGE OF N-S TEMPERATURES




NEAR-SURFACE TEMPERATURE DISTRIBUTION
CORRECTED FOR HOURLY AND DAILY VARIATIONS
MILES
KILOMETRES
FEET
LEGEND
ISOTHERM (°C)
ZONE OF HIGHER TEMPERATURE GRADIENTS. THE ARROW IS DIRECTED FROM HIGHER TO LOWER TEMPERATURES.
TOPOGRAPHICAL TRAVERSE
PALM BEACH
TENTATIVE INTERPRETATION OF NEAR SURFACE CURRENTS SHOWING GENERAL DIRECTION OF FLOW.
AXIS OF GENERAL MOVEMENT OF WATER IN TONGUE
OMEGA TRAVERSE NUMBER, DIRECTION OF TRAVEL, DATE AND TIME TRAVERSED
24·5°C OR LESS
25·5° TO 26°C
26°C OR MORE
SITE OF SUCCESSFUL VERTICAL MEASUREMENTS
>24·5 24·5°C TO 25·0°C
>25·0 25·0°C TO 25·5°C
NERANG RIVER
OPENING
SOUTHPORT STEEPLE
NARROW NECK
THE SANDS
KINKABOOL
BROADBEACH HOTEL
NORTH NOBBY
SOUTH NOBBY
BURLEIGH RESERVOIR
TALLEBUDGERA CREEK
PALM BEACH
CURRUMBIN CREEK
ELEPHANT ROCK
CURRUMBIN RESERVOIR
TUGUN HILL
TUGUN
LOOKOUT
POINT DANGER
COOLANGATTA RESERVOIR
TWEED RIVER
RAZORBACK
FINGAL
SEISMIC 1
SEISMIC 2
SEISMIC 3
SEISMIC 4
Not surveyed

H56/B5-10

FIG 1 AVERAGE N.-S. TEMPERATURES OF TRAVERSES

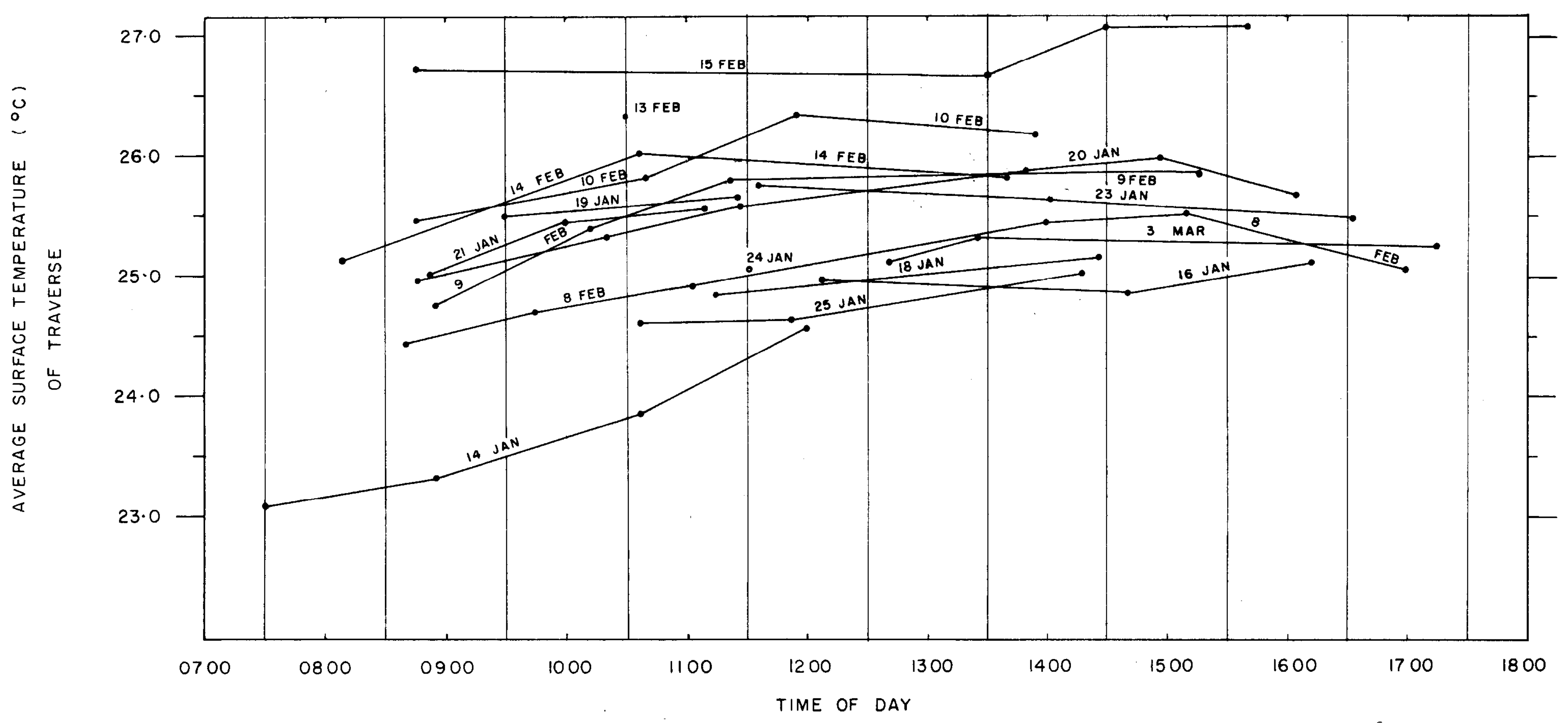


FIG 2 MEAN HOURLY N-S TEMPERATURES (Derived from FIG I)

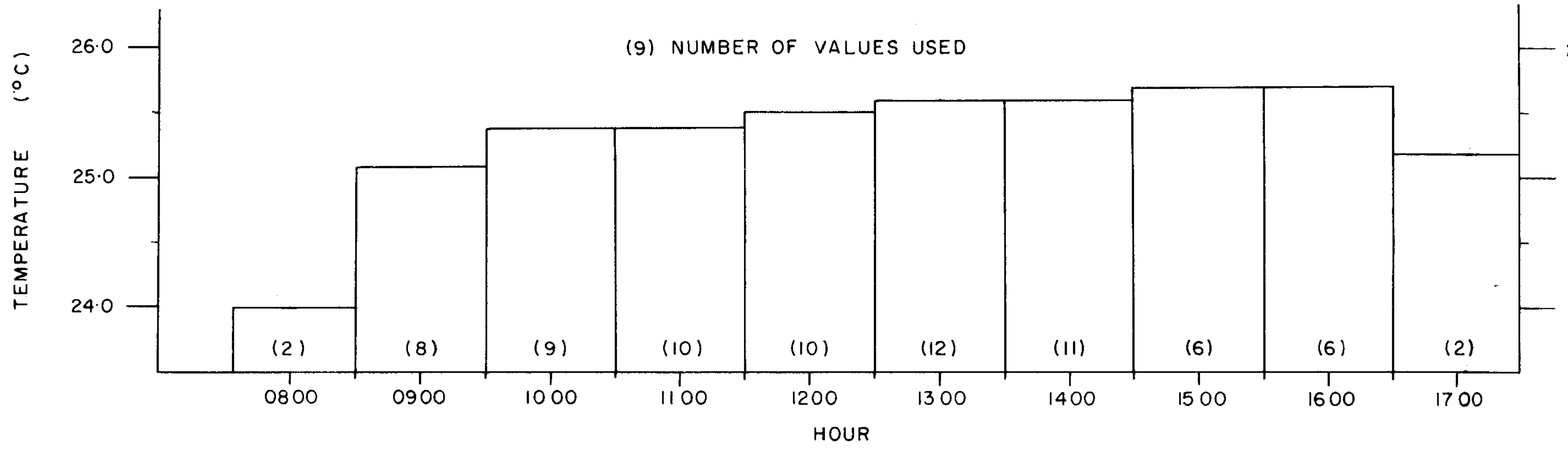
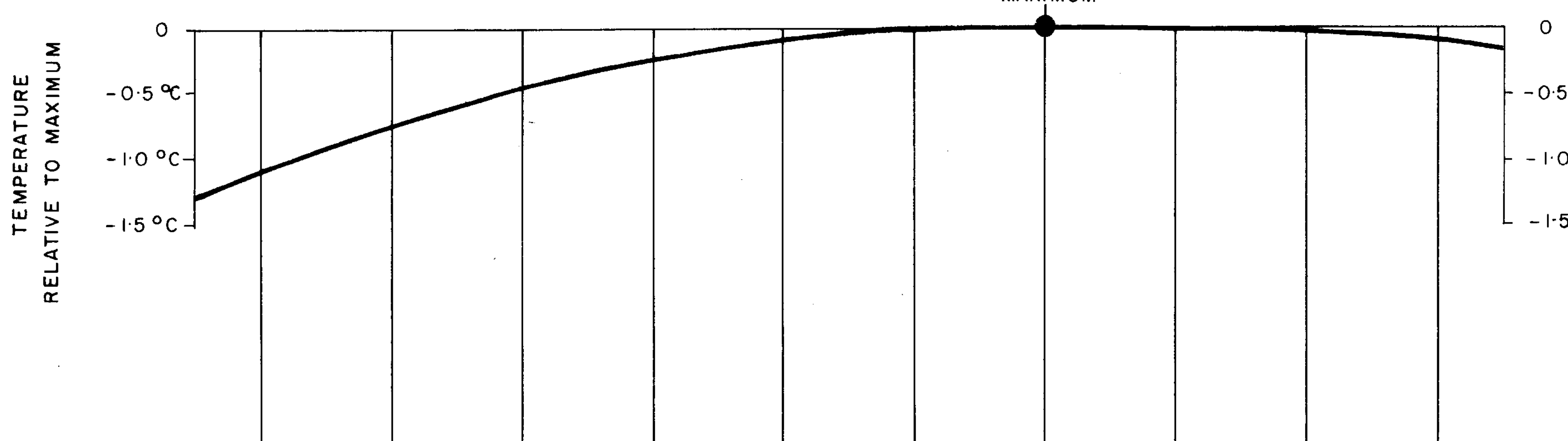


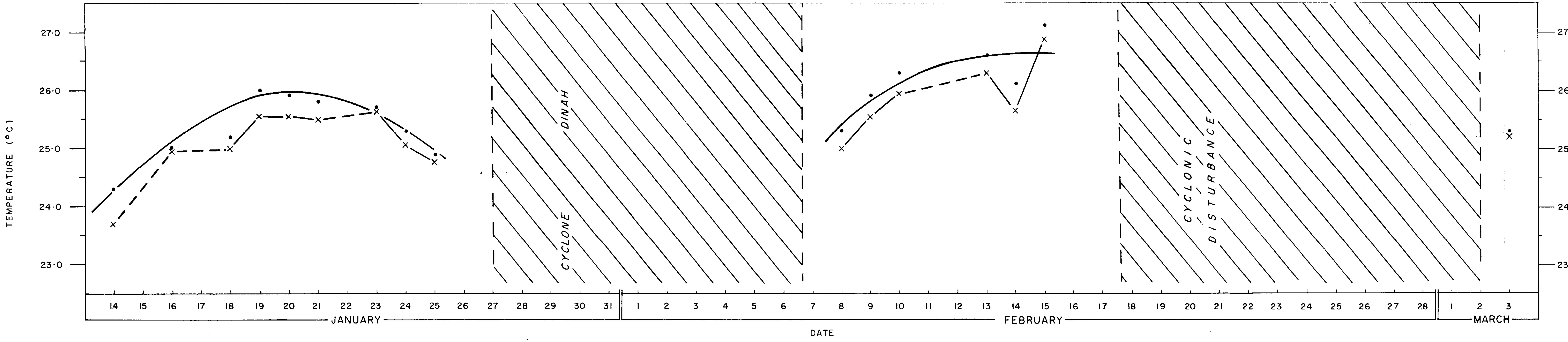
FIG 3 MEAN DIURNAL N.-S. TEMPERATURE VARIATION
(Drift analysis of FIG I data)



TIME OF DAY	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700
CORRECTION	1·1	0·7	0·4	0·2	0·1	0	0	0	0	0·1
(°C)	1·3 0·9	0·6	0·3	0·2	0	0	0	0	0·1	0·2

CORRECTION RELATED TO 1400

FIG 4 DAILY AVERAGE N.-S. TEMPERATURES x = Uncorrected • = Corrected for diurnal variation from FIG 3



HOURLY AND DAILY NEAR-SURFACE TEMPERATURE VARIATIONS

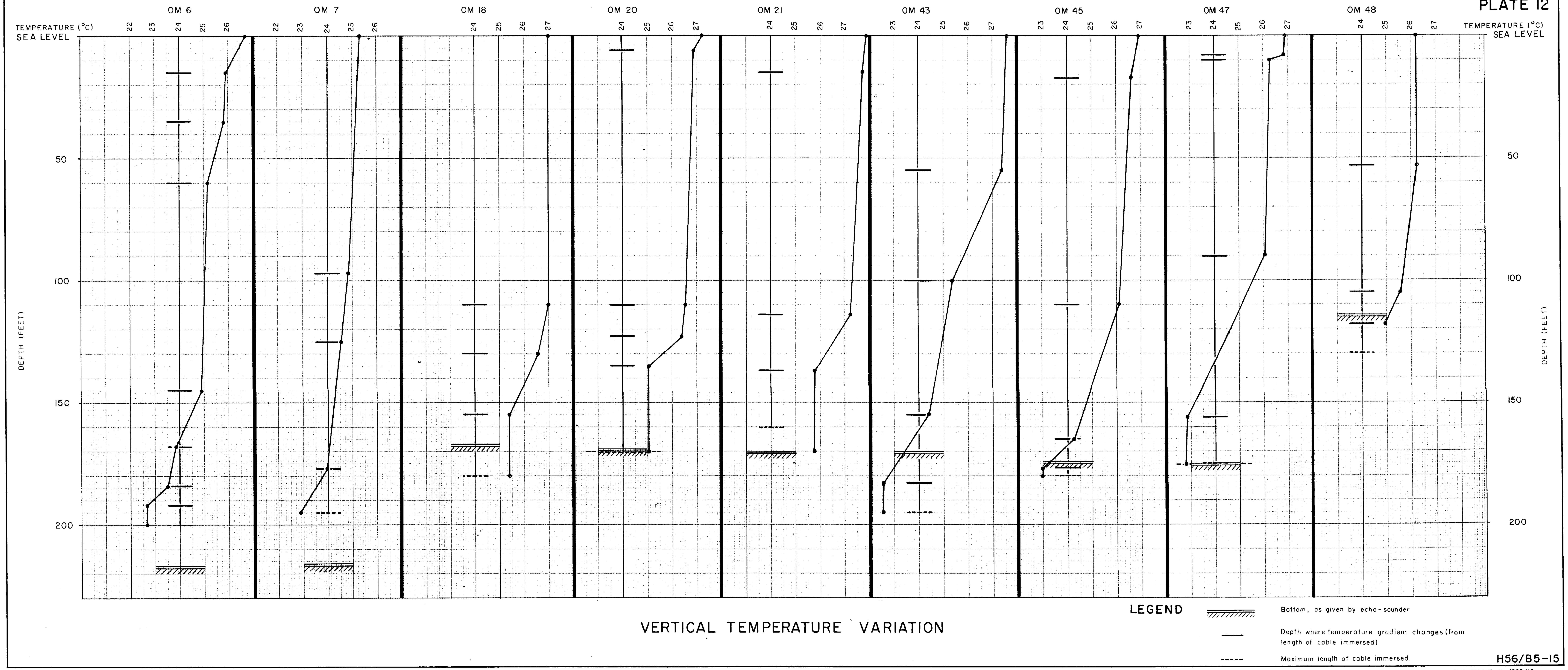
(N.-S.= NEAR SURFACE)

COASTAL EROSION SURVEY
GOLD COAST QUEENSLAND, 1967

H56/B5-11

TO ACCOMPANY RECORD No. 1968/18

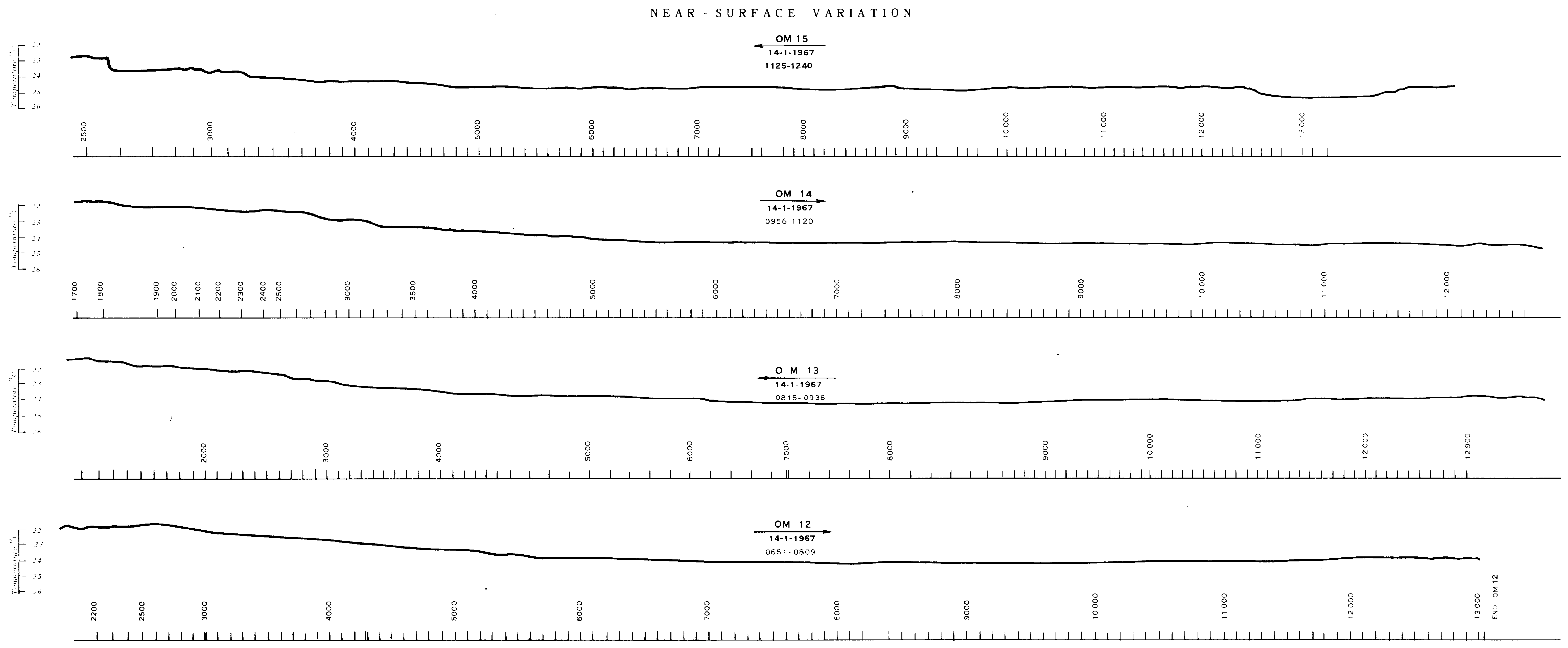
PLATE 12

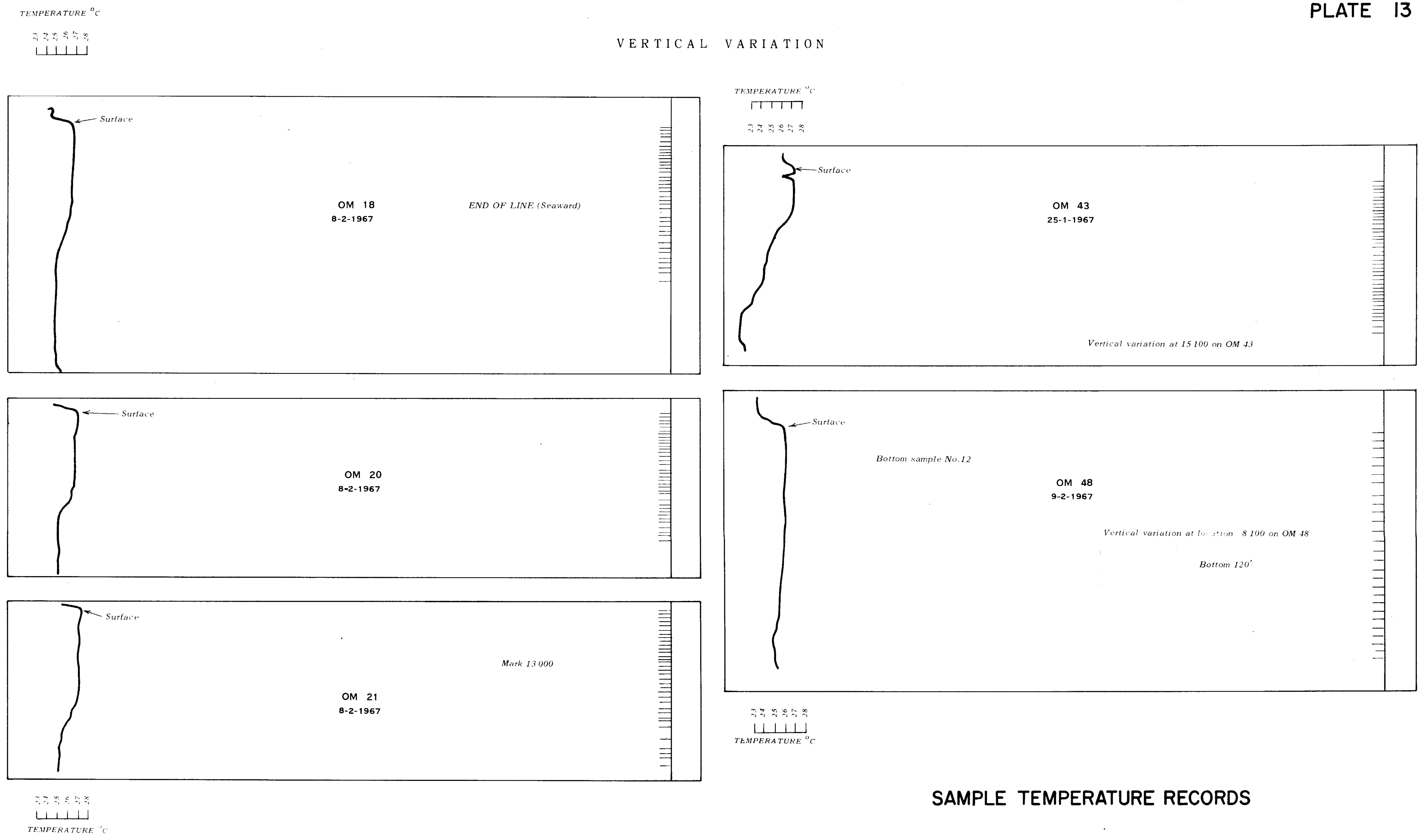


VERTICAL TEMPERATURE VARIATION

H56/B5-15

TO ACCOMPANY RECORD No. 1968/18





SAMPLE TEMPERATURE RECORDS

The fiducial marks on the right hand side of the vertical temperature variation records are time intervals corresponding to each additional 5 feet of hand cable immersed.

FIG 1 TEMPERATURE PROBE CALIBRATION CURVES

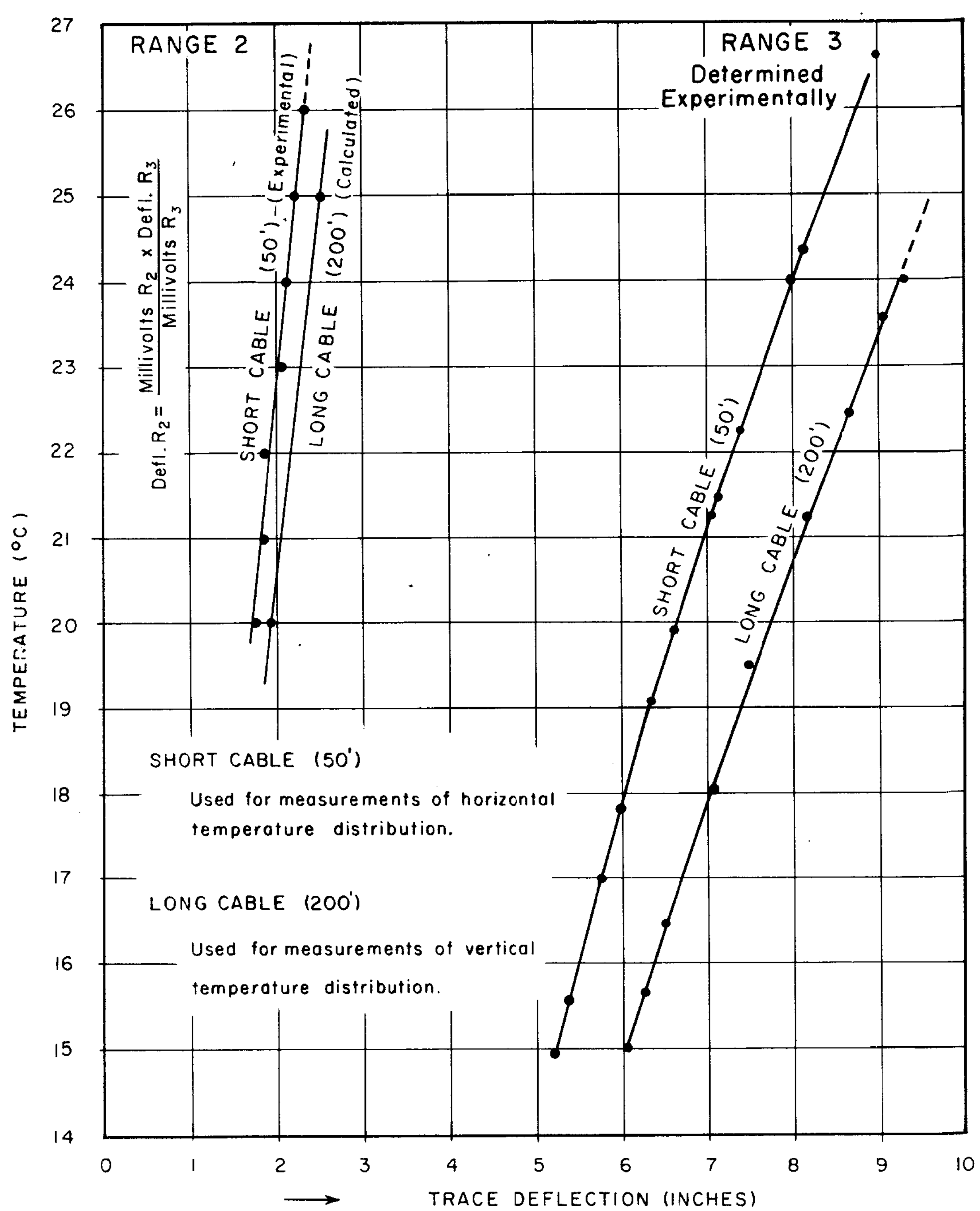


FIG 2 THERMISTOR SYSTEM TTP1 CALIBRATION CURVES

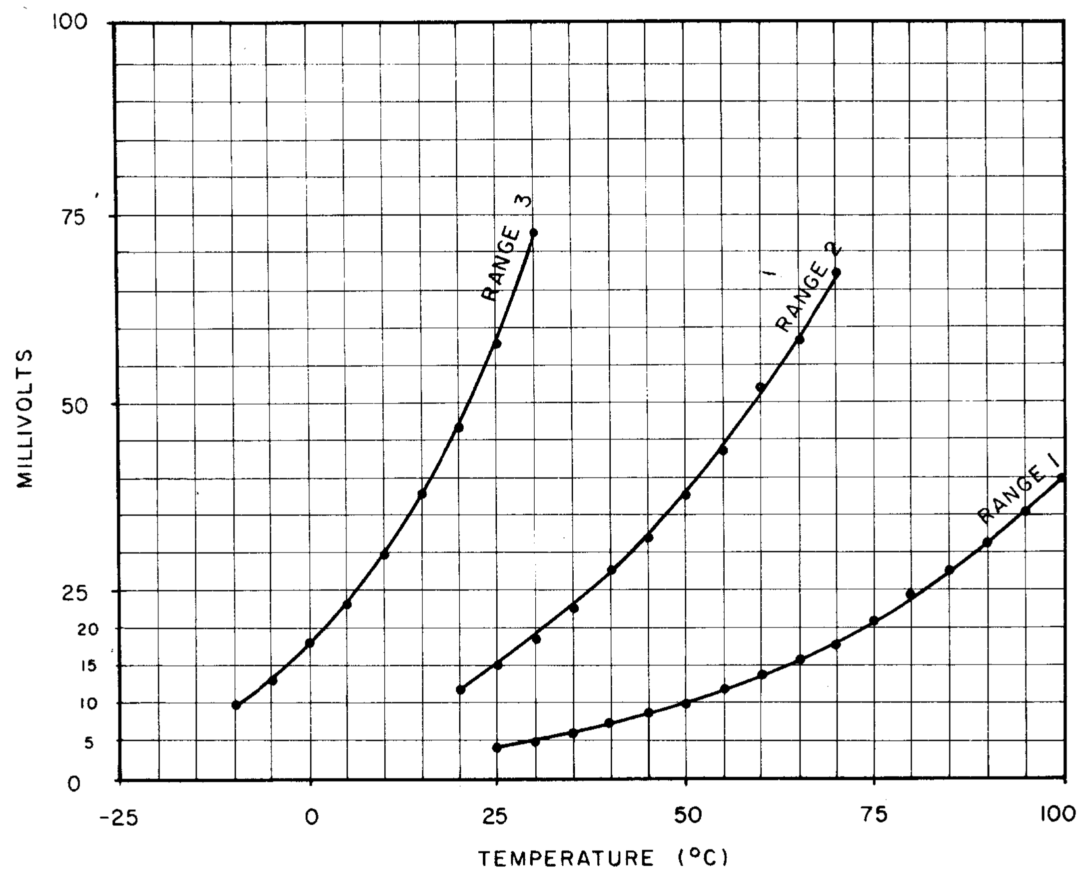
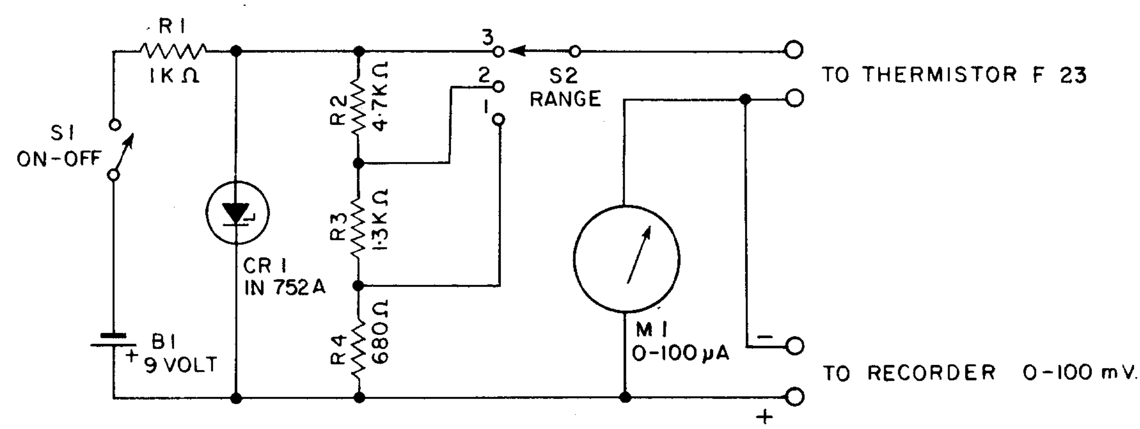


FIG. 3 CIRCUIT DIAGRAM



THERMISTOR SYSTEM TTP 1 CIRCUIT DIAGRAM AND CALIBRATION CURVES

COASTAL EROSION SURVEY, QUEENSLAND 1967

COLD UPWELLED WATER AND EDDY CURRENTS RELATED TO SEA-BED CONTOURS

MILES

H56/B5-16

COASTAL EROSION SURVEY, QUEENSLAND 1967

TO ACCOMPANY RECORD No.1968/18