DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

1975/105

PREVIEW REPORT ON MARINE GEOPHYSICAL SURVEY, NO. 24

(MAGNETIC) NORTHWEST CONTINENTAL SHELF, 1975

(DIVISION OF NATIONAL MAPPING, CONTRACT NO. 5)

by

R. WHITWORTH, F.W. BROWN AND J.K. GRACE

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SUMMARY

A marine magnetic survey is being made using the MV Bluff Creek in an area of the northwest continental shelf which includes the Buccaneer Archipelago and Bonaparte Archipelago. The area extends from King Sound in the south to Cape Londonderry in the north. The survey is being done on behalf of the Bureau of Mineral Resources (BMR) as part of a contract bathymetric survey by the Division of National Mapping. BMR is providing the magnetic equipment, assisting in its installation, and receiving and processing the results. A shore monitor magnetic station is being operated by BMR at Broome. Navigation will be primarily by HIFIX, operated by the contractor, but additional control will be provided by satellite Doppler equipment installed and operated by the Division of National Mapping.

The survey commenced early in June 1975. The survey will be completed within seven months if possible but no later than fifty-two weeks after commencement.

The bathymetric survey will record along traverses, striking mainly east-west, at a spacing of 1500 m. Previous BMR marine magnetic work has not been done in this area. The data from this survey will permit estimates of depth to magnetic basement and will provide a valuable contribution to knowledge of basement structure which may assist in sedimentary structure determination and greater understanding of the regional geology.

1. INTRODUCTION

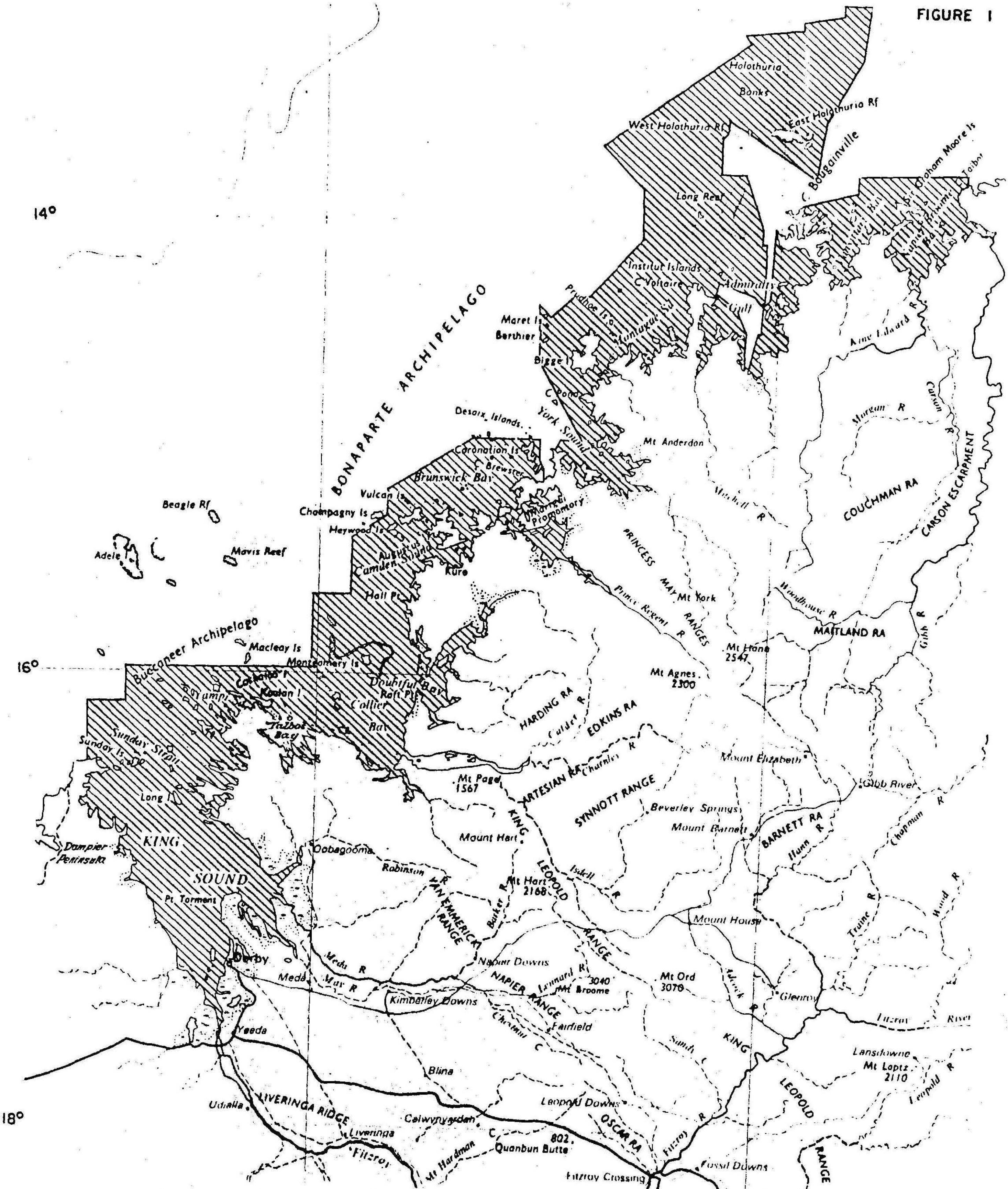
The Division of National Mapping (NATMAP) is carrying out a detailed hydrographic survey of the northwest continental shelf between King Sound and Cape Londonderry (Fig. 1). This is Contract No. 5 of the Division's program of hydrographic surveys of the Australian continental shelf. The lines are being run at a speed of 8 knots, conditions permitting, and at 1500 m spacing. They are mainly east-west and extend from water depths of 20 m to about 300 m. BMR has taken advantage of the survey by installing a Geometrics proton-precession magnetometer to obtain continuous magnetic profiles. The magnetometer is being operated and maintained by the contractor.

The shipboard magnetic installation is simple to operate. Only analogue recordings are being made, in the form of dual-channel strip chart recording at two different scales. A paper speed of 300 mm per hour has been chosen as a reasonable compromise between accuracy and the constraints of manual digitization of the recorded data. The magnetic data will be correlated with the position information through time marks supplied automatically from a clock which has been integrated by BMR with its magnetic equipment.

Navigation data should be supplied by NATMAP after the survey is completed, in a form suitable for card punching and computer processing. The BMR clock supplies hourly time marks to the magnetometer chart recorder, and a press button to give marks at navigation fix times is installed.

A magnetic diurnal monitor is established and operated by BMR at Broome. It was installed at the meteorological station before the survey started. Errors arise through measuring the diurnal at a place remote from the field observations as the diurnal phase and amplitude vary somewhat erratically from place to place. Tie-lines are used to minimize the errors

FIGURE 1



CONTRACT
BATHYMETRIC AND MAGNETOMETER SURVEY
OFF NW COAST OF W.A.
1975

SCALE
0 25 50 75 100km

Record No. 1975/105

WA/B8-95A

of observations. The intersection values can be used also for determining an average diurnal at the survey area. To obtain the best results, tie-lines should cross survey lines at right-angles. Angles of intersection less than 30° should be avoided. The greater the number of tie-lines the better, provided they are fairly regularly spaced.

The magnetic data are being recorded in daily blocks starting at 0000 GMT. Each record is given a unique sequence number of the form SS/NNN where SS = survey number (24 in the BMR series) and NNN = sequence number. The first record obtained was 001, the next 002 and so on throughout the survey regardless of breaks in the work.

All information pertinent to the magnetic survey is annotated directly on the strip chart, as much as possible being done at the time of occurrence, e.g. hourly digital values and changes of course. Details such as lines run, sequence numbers, and start and stop times are best entered on the chart when the day's record is checked after removal from the recorder.

In this Record distances are normally given in metric units. However, ship's speed is still normally quoted in knots and corresponding distances are normally given in nautical miles, abbreviated to miles. The shipboard magnetometer recorder and shore monitor recorder use a chart printed with a millimetre scale and advance the chart in integral multiples of a millimetre. As the report is intended for use as a guide to operating practice in the field, it seems appropriate for clarity to use mixed units.

2. GEOLOGY AND PREVIOUS GEOPHYSICS

The geology of the islands of the survey area and the adjacent mainland falls into three structural divisions:

- the Kimberley Basin, in the north
- the King Leopold Mobile Zone, forming its southern border, and
- the Fitzroy-Canning Basin, in the south.

The Kimberley Basin underlies the survey area from its northern limit south to the southern shore of Collier Bay. The geology of the islands and adjacent mainland show that this is an area of stable Proterozoic sediments very largely composed of three members of the Kimberley Group. The oldest, the King Leopold Sandstone, is exposed extensively on the mainland from Cape Talbot in the north to the eastern shore of Doubtful Bay. It is found also on many of the islands from York Sound northward. Overlying this conformably is a volcanic sequence, the Carson Volcanics, found on outer islands such as Maret and Berthier in the north but appearing onshore south of York Sound and covering an extensive area from there, south to Doubtful Bay. Succeeding the volcanics conformably is another sandstone, the Warton Sandstone, which is found onshore and on most of the islands from Cape Brewster to Collier Bay. Three successively younger formations are found in a narrow belt of the coast south from Hall Point, the Buckland Point Member (of the Warton Sandstone), and Elgee Siltstone, and the Pentecost Sandstone. This sudden succession of younger formations indicates a gentle downwarp in the basin at this location. The Pentecost Sandstone developed as the iron-bearing Yampi Member in what is now the King Leopold Mobile Zone.

Thickness of these formations is not generally well established near the coast owing to extensive erosion. The range of thickness which may be anticipated is as follows:

	Max. thickness in metres		
Formation	North	Centre	South
Pentecost Sst	nil	nil	480
Elgee Siltst	nil	nil	60
Warton Sst	90; no top	300	600
Buckland Pt Member	-	600	-
Carson Vol	300; no top	700	900
King Leopold Sst	750; no base	1000; no base	1100

The Kimberley Group, in particular, is intruded extensively by sills of the Hart Dolerite. This activity evidently took place about the close of the Kimberley epoch for it intrudes all Kimberley Formations and has been given a Kimberley isotopic date of 1800 m.y. The greatest sill thickness, 1300 m, is found in the south where the basin is disrupted by the King Leopold Mobile Zone. However, sills of 80-100 m have been observed throughout the coastal parts of the basin. The islands of the Institut Group in the north and some of the Haywood Group in the central survey area are formed of Hart Dolerite. There may be unexposed occurrences elsewhere in the survey area, presumably having associated magnetic anomalies.

Marine geophysical work over the Kimberley Basin has been slight. In the north ARCO (1965) made an aeromagnetic survey which overlapped the northern margin (Figs 2, 3, 4, 5, 6, 7) near Cape Bougainville. The interpretation showed basement depths of 500 m below sea level or less, to a distance of about 100 km from the coast. It is evident from Figures 3 and 4 that the anomaly pattern is complex and tends to short, sharp anomalies in many instances smaller than the line spacing.

In the west, B.O.C. of Australia Limited (1970) carried out a marine seismic survey of a large part of the northwest continental shelf from King Sound north to Cape Voltaire, beginning generally between 30 and 100 km west of the present survey area. Traverses were oriented northwest and spaced about 25 km apart. The deepest mapped horizon, D, dips gently westward from an initial depth of about 400 m below sea level at the eastern survey limit. The interpretation refers to this as the terrace. It continues gently dipping westward for 50 to 60 km to a break which is regarded as the eastern margin of the Browse Basin at a depth of about 2000 m. There is a strong possibility that this horizon represents the Proterozoic basement surface exposed on the offshore islands.

A marine geophysical survey by BMR (Whitworth 1969) combining seismic, gravity and magnetic recordings was carried out along lines oriented east and west,

spaced 16 km apart. The eastern limit of the work was father offshore than the B.O.C. work. The magnetic variations nearest the coast were pronounced but generally gentle, suggesting the deeper area of the terrace indicated by B.O.C.

The King Leopold Mobile Zone lies in a band about 50 km wide extending southeasterly from the coast between Collier Bay and King Sound. The zone is highly disturbed at the coast and on the islands and even more disturbed inland. Folding and faulting is oriented predominantly northwest. The islands of the survey area in this zone are composed of moderately to steeply dipping normal and overturned beds comprising King Leopold Sandstone on the southwest of the zone and Pentecost Sandstone on the northeast, with only minor representation of the intervening Elgee siltstone. The Pentecost Sandstone culminates in the Yampi Member on the northeast side of the zone, still highly disturbed on the mainland and nearby islands, but settling to gentle deformation in the northeast on the islands in Collier Bay.

On the mainland there are outcrops of Carson Volcanics, Warton Sandstone, and the Hart Dolerite and also the Wotjulum Porphyry, a post-Kimberley intrusive in this area, all found close to the coast. Farther inland a number of pre-Kimberley formations are found. They form a complex of mainly acid Lower Proterozoic intrusives into the Halls Creek Group of Archaean low-grade metamorphic sediments. This complex represents the core of the mobile zone, elongated in the direction of the zone and terminating to the northwest before it reaches Talbot Bay.

The basal part of the Yampi Member contains stratiform hematite beds, deposited as detrital ironsands. They form iron ore bodies in a few places and have been mined since 1957 on Cockatoo Island and since 1964 on Koolan Island where current annual production is about 2.5 million tonnes, and total original reserves were about 60 million tonnes.

ARCO LIMITED – AAP

FIG. 2

AEROMAGNETIC SURVEY

TIMOR SEA

CONTOUR MAP

LEGEND

500 - U.T.M in Km Mo 127°00

400000 - A.T.M in Yards Mo { Zone 3 : 126°00 / Zone 4 : 131°00

REMOVED REGIONAL FIELD : East West -0,67 gamma per km.
North South -5,75 gammas per km.

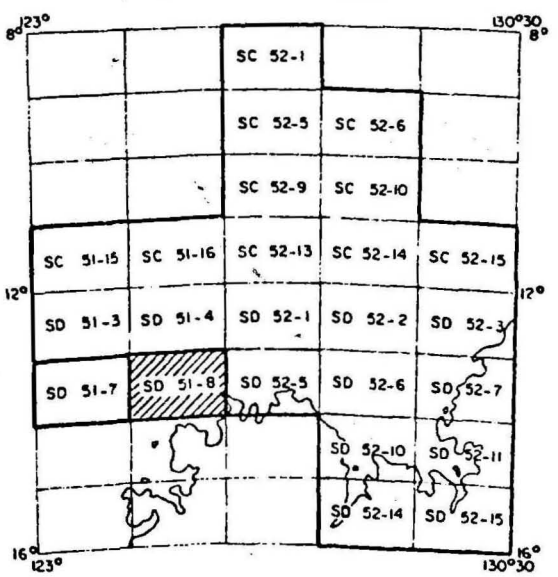
CONTOURS SPACING : I GAMMA

50 & 100

5 & 10

I GAMMA

LOCATION DIAGRAM



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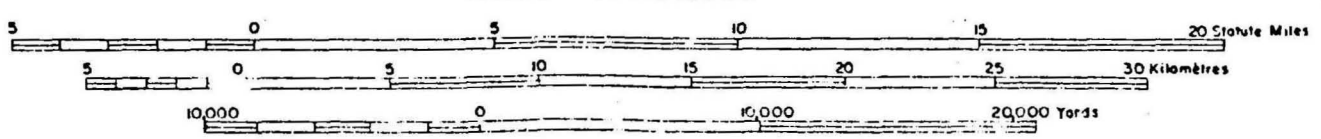


Survey and compilation carried out by:

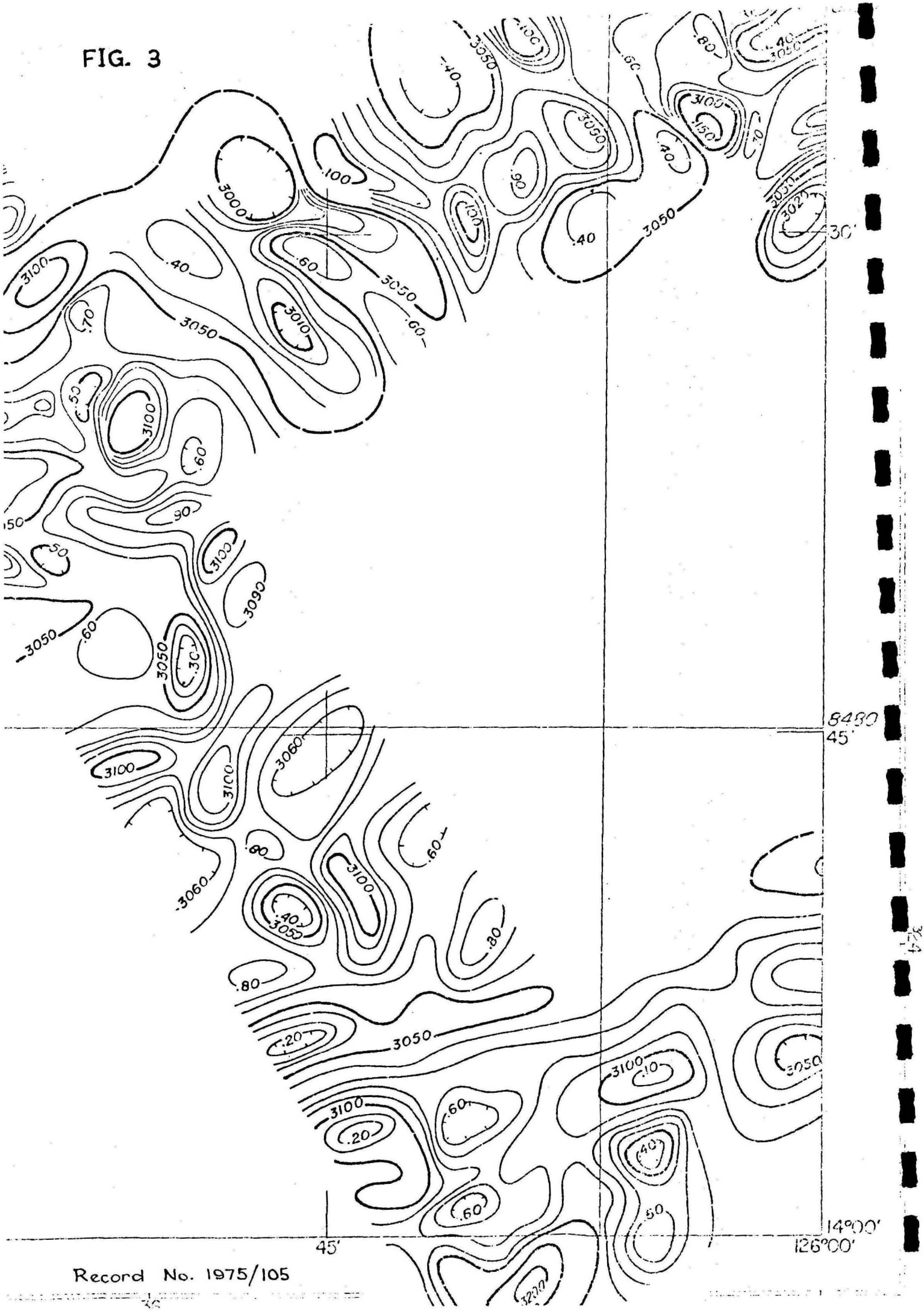
JUNE - NOV. 1965

COMPAGNIE GENERALE DE GEOPHYSIQUE

50 rue Fabert - PARIS VII

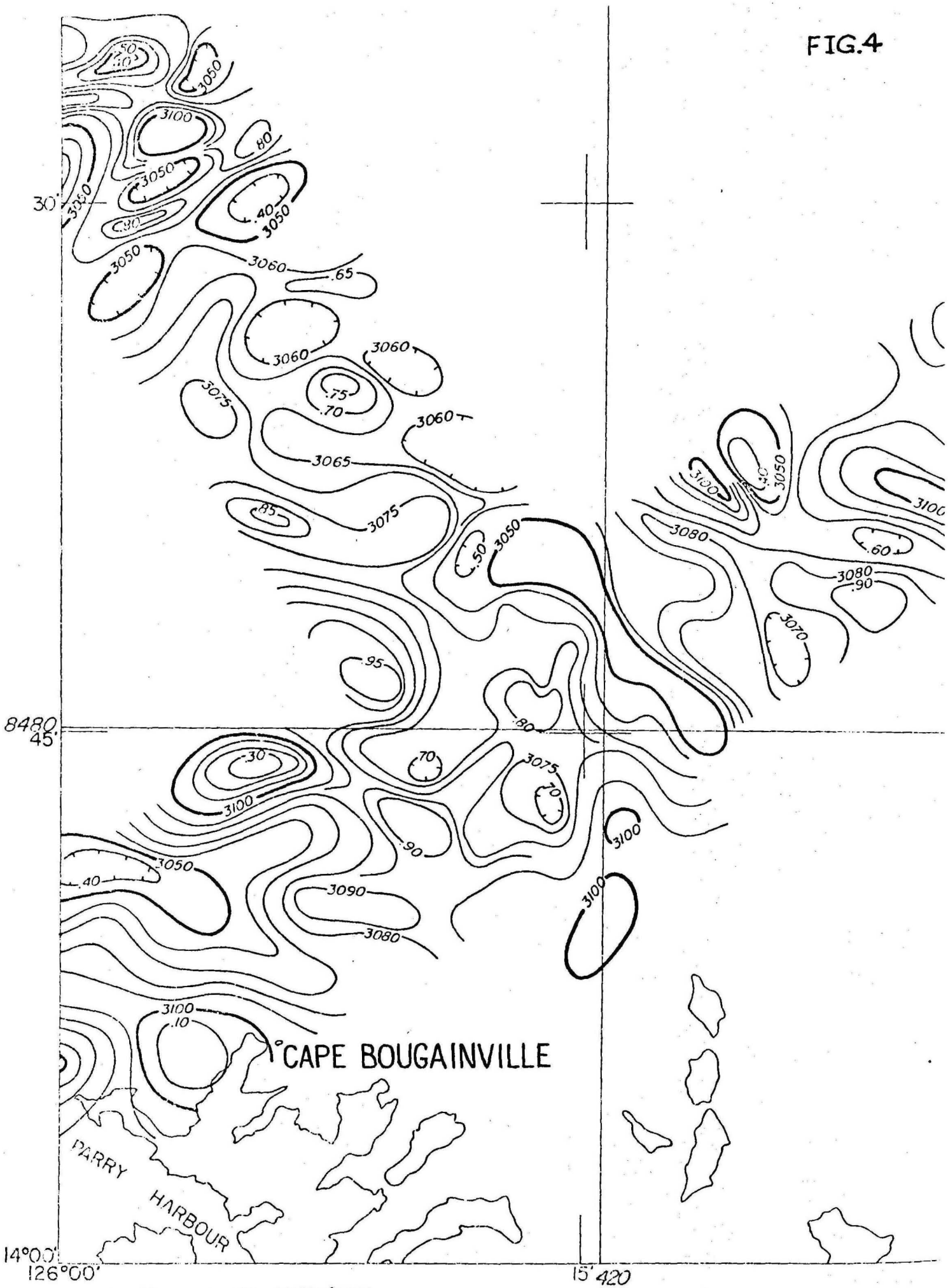
Record No. 1975/105

FIG. 3



Record No. 1975/105

FIG.4



Record No. 1975/105

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FIG. 5

AEROMAGNETIC SURVEY

TIMOR SEA

INTERPRETATION MAP

ALL DEPTHS IN THOUSAND OF METERS BELOW SEA-LEVEL

MAGNETIC BASEMENT DEPTHS

		sure	probable	dubious
Hypothesis	Compartment extending to infinite depth	-5.6	-5.6	-5.6?
	Thin plate	-2.3 tp	-2.3 tp	-2.3? tp

INTRASEDIMENTARY CONTRASTS DEPTHS

Hypothesis	Compartment extending to infinite depth	-1.2	-1.2	-1.2?
	Thin plate	-0.9 tp	-0.9 tp	-0.9? tp

Main anomalies axis

Anticlinal trend

Synclinal trend

Fault

500 U.T.M. in Km Mo 127°00

400000 A.T.M. in yards Mo { Zone 3 : 126°00 / Zone 4 : 131°00

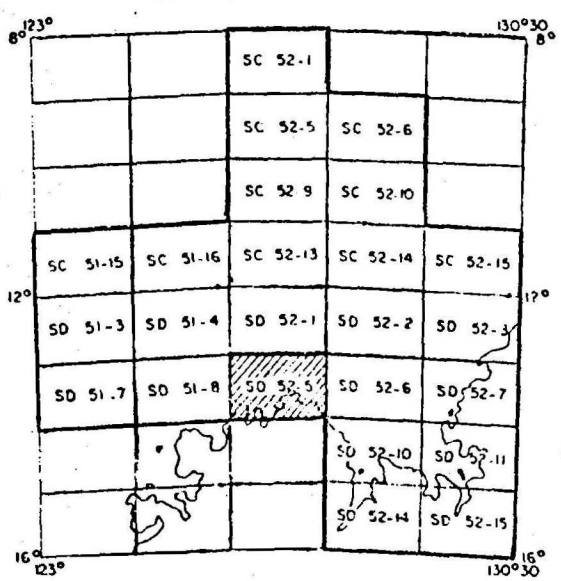
ISOBATHS

Basement isobaths -4 C

Intrasedimentary layer isobaths -1 C

Well (Td = Total depth) Td=3.000

LOCATION DIAGRAM



Scale 1 : 250,000

5 0 5 10 15 20 Statute Miles

5 0 5 10 15 20 25 30 Kilomètres

10,000 0 10,000 20,000 Yards

Survey and compilation carried out by:

JUNE - NOV. 1965

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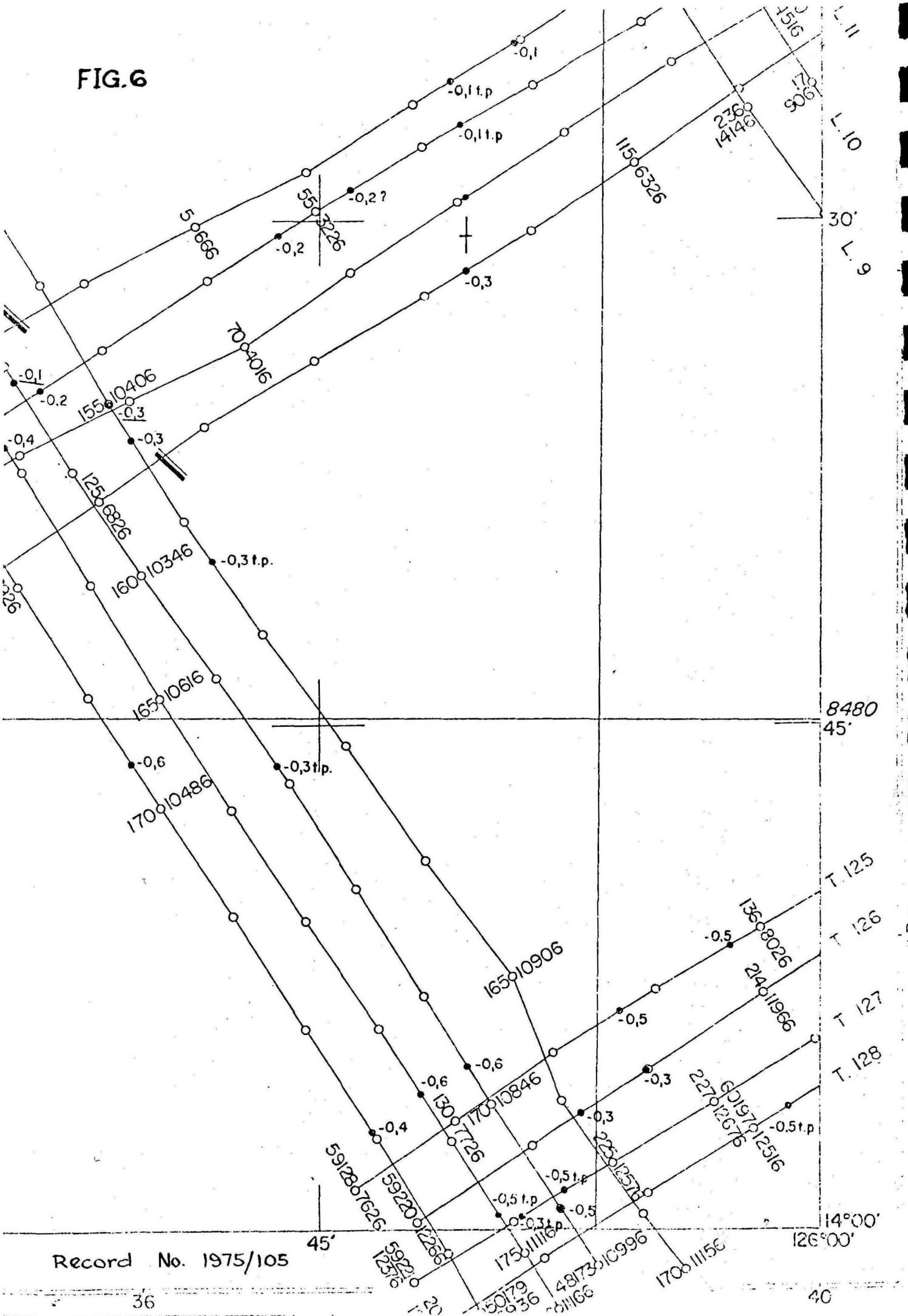
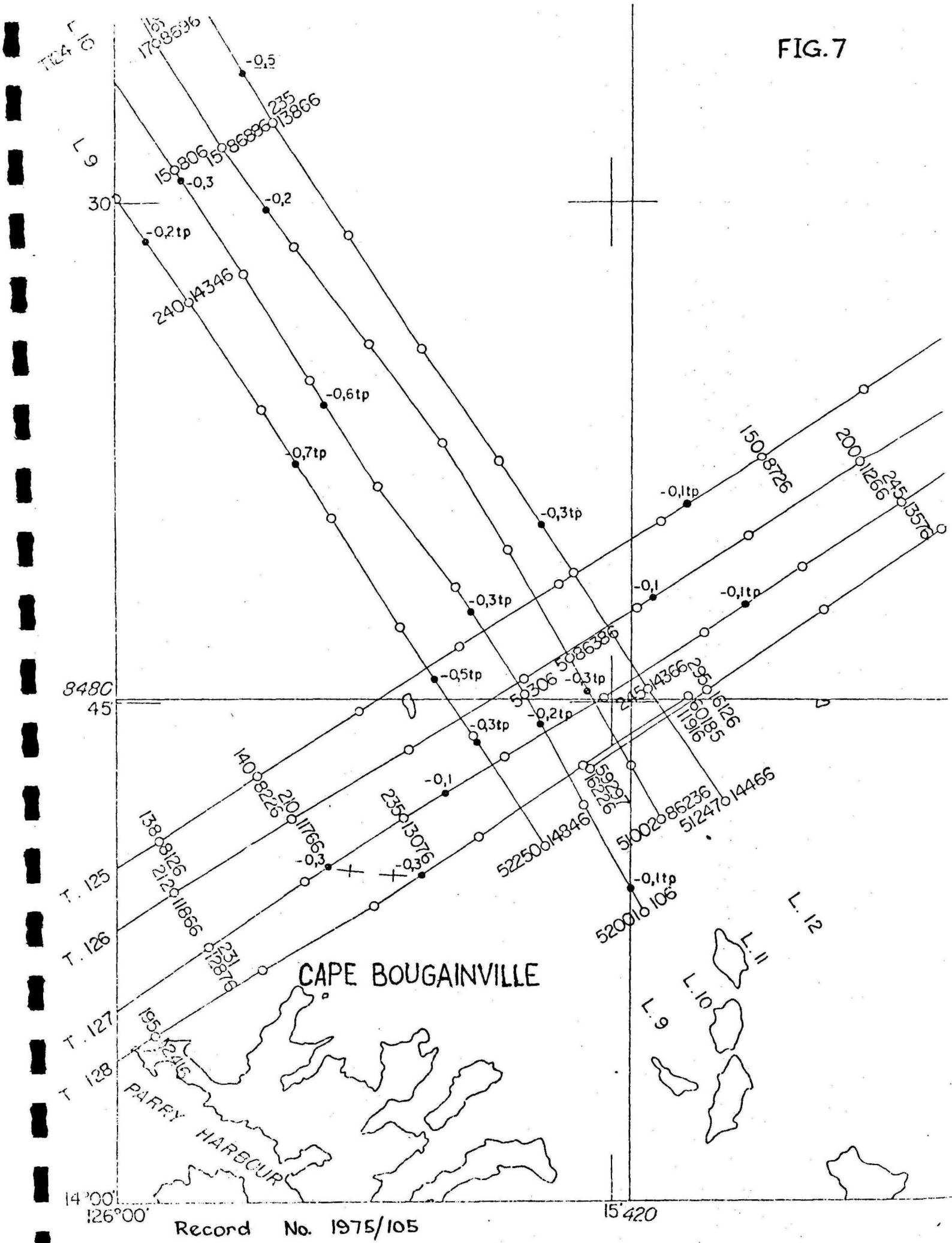
FIG.6



Record No. 1975/105

FIG. 7



Record No. 1975/105

The Fitzroy - Canning Basin lies on the southwest side of the King Leopold Mobile Zone and extends about 450 km to the southwest. Only the north flank of the Fitzroy Trough is involved in the survey area and it is a gentle down warp in the flank which is expressed in King Sound. The contact with the mobile zone passes across the mouth of the Sound west of Long Island and the Sunday Island Group but is not exposed on the mainland of Dampier Peninsula. A seismic survey by WAPET (1970) comprising a traverse down the western shore and one crossing the middle of the Sound showed sedimentary section at least 5000 m thick in the south but thinning steadily towards the Proterozoic exposures in the north. An aeromagnetic survey had been conducted previously by WAPET (1966) over King Sound and some of the adjacent land area, particularly in the sedimentary basin. Traverses were oriented about northeast and spaced about 3 km apart. The present survey should provide additional delineation of some very sharp anomalies revealed by the WAPET survey which are particularly evident over shallow Proterozoic basement. Interpretation of the WAPET magnetic survey conforms to the seismic result in showing great basement depth in the south, decreasing to the northeast.

3. OBJECTIVES

The opportunity to carry out the magnetic survey is provided by the bathymetric survey of the area being carried out as a contract operation for the Division of National Mapping. The primary objective of the field activity is, therefore, to map the sea-bottom surface. The magnetic recording is provided as an additional contractual service under the general control and direction of the Division of National Mapping. BMR provided technical assistance in installation of the BMR magnetic equipment, instructions on its use, and recommendations for survey procedures, especially related to the magnetic recording.

The objective of the magnetic survey itself is to obtain the more detailed magnetic coverage of this area permitted by the closely spaced traverses of the bathymetric survey. This will provide a 1500 m grid of magnetic data plus continuous profiles in the direction of traversing. The greater detail will permit better analysis and interpretation of the magnetic field in terms of magnetic basement depth and rock types, which may be of use in resolving basement and sedimentary structure as well as in consideration of regional crustal structure.

In addition, the efficiency and effectiveness of the operation will be considered with a view to future improvements.

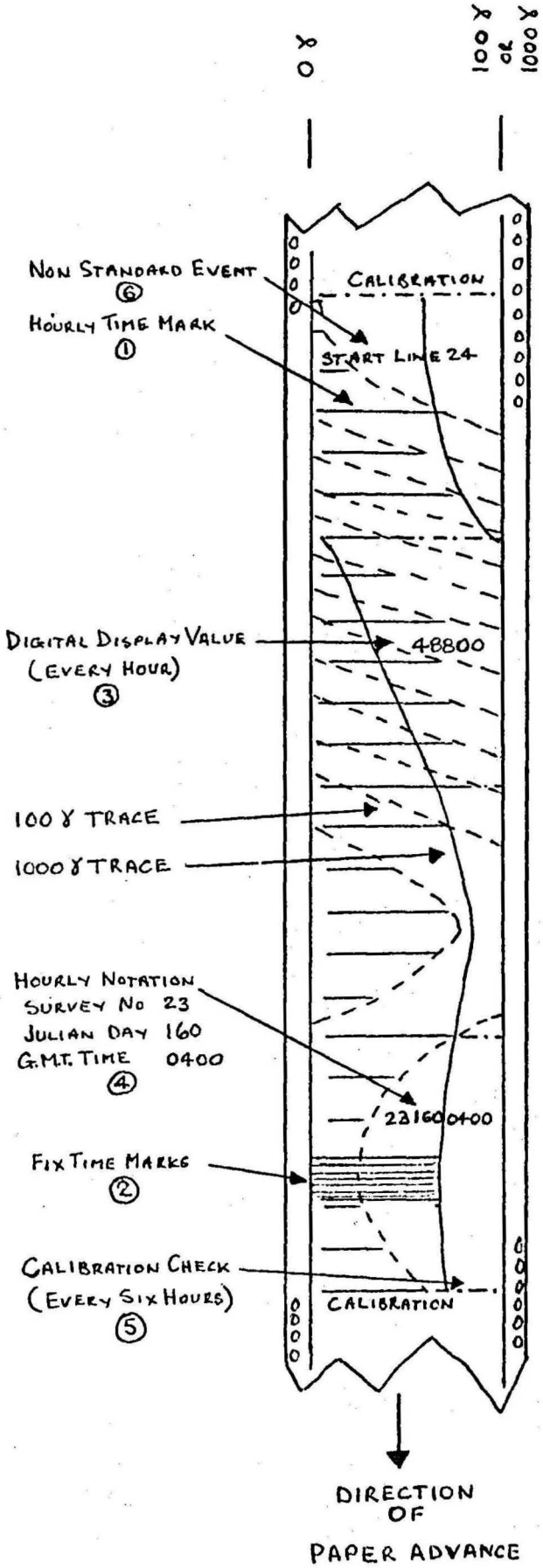
4. NAVIGATION REQUIREMENTS

Position fixing on this survey is essentially an on-line process carried out by the contractor using HIFIX. Ranges to two transmitters are plotted on a range line chart, and the position co-ordinates are arrived at indirectly from the chart. For computation of the magnetic survey, the navigational data must be prepared in digital form and integrated with the digitized magnetic data on magnetic tape before the results can be processed through the computer. It would be unacceptable to obtain the navigational data in digital form by digitizing the positions plotted on the NATMAP track charts because the accuracy would be too low.

However, the original range values displayed by the HIFIX equipment for each fix will be logged. These values will be used to obtain adequate positional accuracy for use in post-processing. An accuracy of $\pm$0.02 n. miles is desired; therefore time must be known to $\pm$5 seconds and HIFIX range to better than $\pm$0.01 n. miles.

Time is the prime variable as it is the only reference to the magnetic recordings. A precision clock is being provided to give hourly time-marks automatically on the magnetic strip. The time of each navigation fix will be recorded on the magnetic record. Control of clock time is described in Section 8 and Appendices 1 and 2.

FIG. 8



NOTES

① HOURLY TIME MARKS ON 100 γ TRACE

② FIX TIME MARKS ON 1000 γ TRACE

③ DIGITAL DISPLAY VALUE NOTED HOURLY

④ HOURLY CHART NOTATION –
SURVEY NUMBER
JULIAN DAY
HOURS G.M.T.

⑤ RECORDER CALIBRATION CHECK
(SIX HOURLY INTERVALS)

⑥ NON-STANDARD EVENTS
e.g. START OF LINE
END OF LINE

MAGNETOMETER RECORD SCHEMATIC

Record No. 1975/105

It is desirable to record distance values also at times of non-standard events such as course and speed changes. Intermediate positions can then be calculated with acceptable accuracy by linear interpolation between recorded positions.

Further advantage can be obtained by logging data on forms oriented to key-punching. The data sheets may then be punched readily with little editing. All that is required is coding marks on existing forms similar to the marks on standard ADP coding forms.

Accurate timing is essential to permit best use of the data. The hourly time marks and navigation fix time marks are recorded on the two recording traces, 100-gamma and 1000-gamma respectively. The spacing of hourly time-marks should be checked for regularity from time to time to ensure that there are no paper feed problems. Time-marks will be provided at the times of satellite fixes, and these should be marked accordingly.

5. SHIPBOARD MAGNETIC OBSERVATIONS

The Geometrics magnetometer model G801 (serial No. 1150) will be the main instrument used throughout the survey. All magnetic data will be recorded by this instrument in analogue form on strip charts. It is essential that the strip chart recording and annotated information be adequate for later processing requirement. All relevant data as well as the magnetic values should be annotated on the strip chart, so minimizing extra paper work. All non-standard events should be clearly marked on the record at the time at which they occur. These would include start and end of lines, all intermediate changes in course and speed, instrument problems and modifications, calibrations, changes in tuning, and satellite passes (Fig. 8).

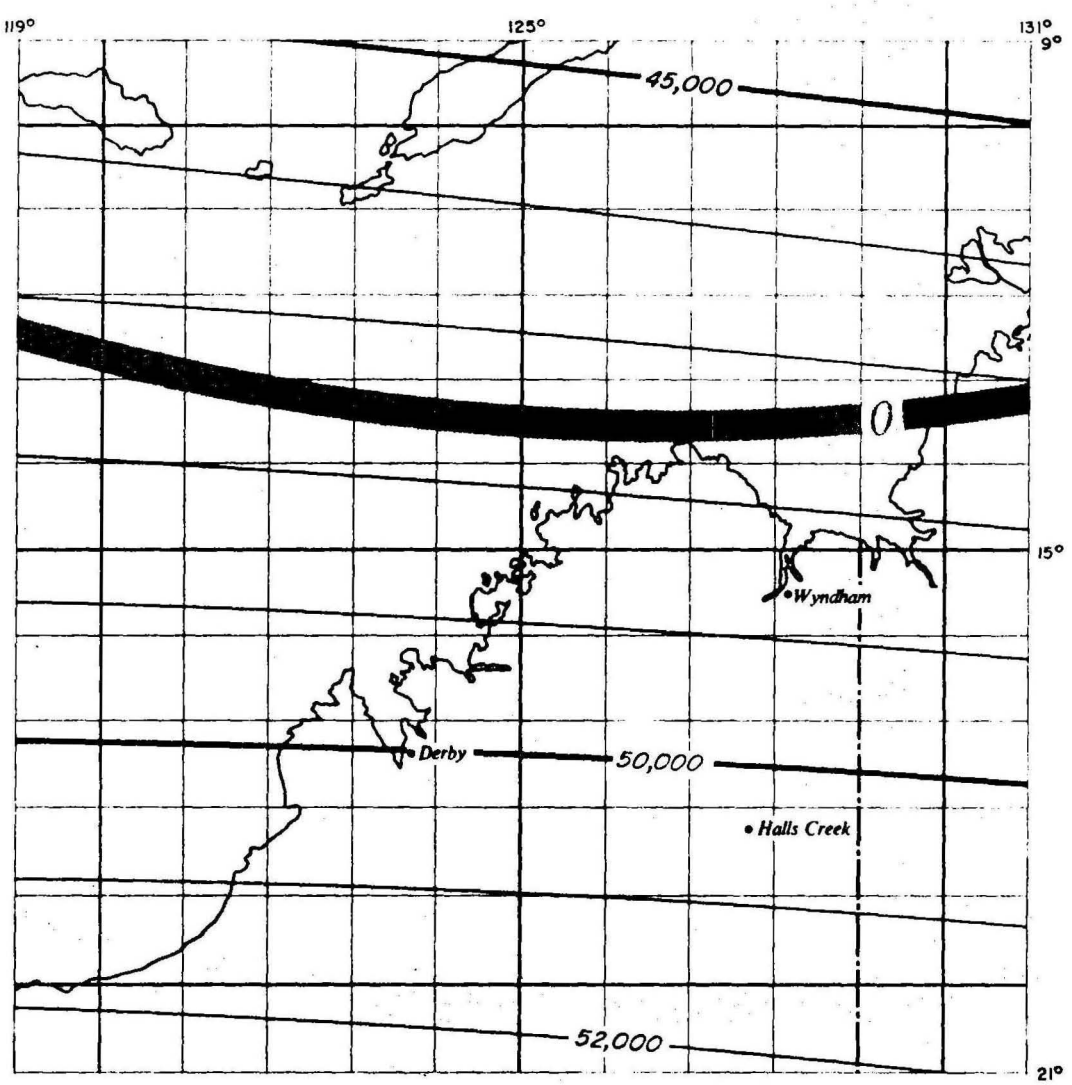
Time entries should correspond with the GMT day. During continuous recording each record should run from 0000 to 2400 GMT, regardless of the lines being run. The only exceptions should be when the cruise begins and ends or when there is a major break in observations at sea. To provide a

ready reference each record should be labelled at beginning and end with the GMT date, Julian day number, start time, record sequence number, and at the end with the stop time and identification of the lines or parts of lines run. A separate index list should be kept of this information.

The chosen paper speed is 300 mm per hour, which must be maintained for all magnetic recording. Variable chart speed is unacceptable for both operational and data processing reasons. In particular the digitizer to be used has an accuracy of $\pm$0.1 mm; this is equivalent to $\pm$0.005 km ($\pm$0.003 n.m.) assuming a paper speed of 300 mm per hour and a ship's speed of 8 knots; also, it represents about 1 second in magnetic record time and about 0.3 gamma difference in magnetic record intensity assuming 1000 gammas full-scale on a chart paper width of 250 mm. The advantage of this high digitizing accuracy will be lost if chart speed varies irregularly or marks and annotations are inaccurate.

Two pens are used to record simultaneously at 100 gammas and 1000 gammas full scale. The sensitivity of this instrument is 1 gamma for both pens. An earlier model Geometrics magnetometer model G803 (serial No. 59) has a sensitivity of 1 gamma on the 100-gamma full-scale trace and 10 gammas on the 1000-gamma trace. It will be used if the model G801 breaks down. Normally only the 100-gamma trace will be digitized, but in magnetically disturbed areas it may be too complicated to follow and the 1000-gamma trace will be used instead.

In addition to the pen record on the strip chart, the instrument displays the current value of magnetic field on a digital readout on the front panel of the instrument. To recover the total magnetic field value the digital readout must be noted on the chart at regular intervals. Hourly intervals are proposed for this annotation not only to provide ample control most of the time, but also to allow a continual check on the recorder calibration.



TOTAL MAGNETIC INTENSITY

EPOCH 1970·0

45,000 — Magnetic Contours (gammas)

0 Annual change of TMI (gammas)

Regular calibration of the recorder is essential to obtain data consistent to ±1 gamma and to ensure continuity of digitized values between the 100-gamma and 1000-gamma traces in disturbed areas. Digitizing complications will be reduced if the recorder is recalibrated only at the start of each day's recording, but checked at regular intervals. A six-hourly checking interval is considered adequate, but should the calibration shift by more than 2 mm, recalibration must be carried out and a more frequent checking interval adopted.

When the magnetometer is functioning properly, the noise level is generally within 2 gammas peak-to-peak (±1 gamma), occasionally 3 gammas peak-to-peak. Noise of this amplitude is readily observed on the 100-gamma trace when the magnetometer polarization cycle is of 5 seconds duration, which it should be at all times. Higher noise level can arise from a variety of causes. It will pay to start checking for the simplest possible causes, working to the more complex. The most useful steps when investigating excessive noise are:

- Check that the tuning is properly set for the magnetic field being measured, and cross-check against the expected field value (Fig. 9);
- Vary the tuning and inspect the result on the oscilloscope; the amplitude of the precession signal should reach a maximum and should be clearest when the equipment is properly tuned, and the signal should last for a reasonable length of time;
- Check the oscillator and any other electronic parts easy to get at: fuses, polarization current and period of polarization, cycle rate etc;
- Check all electrical plugs carefully, particularly at the winch and sensor; clean as necessary;
- Inspect the cable and sensor for damage such as broken wiring, broken shielding, and earthing.

The daily routine to be following by the contractor's observers relative to the magnetic survey is set out in Appendix 1. The procedure to be following in launching themagnetometer sensor and initiating recording is set out in Appendix 2.

6. SHORE MONITOR AT BROOME

Magnetic observations are disturbed by time variation in the total field. For simplicity this disturbance can be split into components of two types:

- Long-period - daily cycle or diurnal, reaching an amplitude of about 100 gammas.
- Short-period - generally one hour or less, which may reach an amplitude of 1000 gammas or even more in extreme cases but are commonly within 100 gammas. They are generally worldwide and simultaneous in their effect, but the amplitude varies from point to point.

It is important to remove these temporal disturbances from the record to permit reasonable analysis and interpretation of the spatial disturbances of the Earth's magnetic field which arise from geological causes.

The long-period disturbances can be determined from the field record, although with degraded accuracy, provided there are sufficient line intersections to detect the total amplitude of the diurnal change in field strength. However, the short-period disturbances cannot be detected in this way. With the vessel travelling at 8 knots they will be indistinguishable from the record of many ordinary spatial field changes, which are used in calculating depth to magnetic basement. For these reasons a separate stationary monitor recorder is required, operating in the vicinity of the survey area, to provide a continuous record of the short-period disturbances.

Correlation between the ship and monitor data permits effective removal of such events from the field record,as well as the diurnal effect.

7. SHORE MONITOR REQUIREMENTS

A shore magnetometer station will be operated at Broome throughout the survey to provide diurnal and short period information for correction of the magnetic data being collected on board the Bluff Creek.

For the shore station to be established and operated effectively the following action was required.

Accommodation

Accommodation was arranged to house the magnetometer and recording equipment, storage space for charts, inks, and spare parts and working space for the shore station operator. The magnetometer station was sited at Broome Meteorological Station. A suitable alternative site would have been a house, garage, or shed, but it is essential that the chosen site be free from strong, frequent magnetic disturbances. Mains electricity is required.

Equipment required

Geometrics Magnetometer mod. G806

Chart recorder

Power supply

Sensor head and stand

Instruction manuals

Operations instructions

Spare parts kit for all equipment

Clock

Radio (for time signals)

Tool kit

Log sheets

Stationery

Personnel

The shore monitor will be operated in off-duty time by an officer from the Broome Meteorological Station who has been instructed in the operation of the equipment and the daily routine required by the BMR.

Magnetometer and electronic equipment

The magnetometer, chart recorder, and power supply were checked and tested in Canberra by a technical officer of the marine group (R. Dulski). The equipment was sent by air freight to Broome for installation at the meteorological station.

Daily routine

The daily routine to be followed by the shore monitor operator is set out in Appendix 3.

8. CLOCK CONTROL

A crystal controlled clock is installed as part of the BMR equipment on the ship and an electronic clock is installed at the magnetometer monitor station. The setting of the shipboard clock is initiated and checked by reference to the A.P.O. radio time signals and checked also against time signals received by the satellite Doppler navigation system when it is operating. The setting of the shore monitor clock is also initiated and checked against A.P.O. radio time signals. Time signals generated by the A.P.O. standard are within about 100 microseconds of the international standard of Co-ordinated Universal Time as determined by the Bureau International de l'Heure. As received, the signals may exhibit jitter of the order of 1 millisecond r.m.s. owing to ionospheric effects.

Both clocks have 1 second reading precision and can be set within 1 second of the radio time signals. Their specified drift rates are 1 in 10^7 and 1 in 10^5 for ship and shore clocks, respectively. Therefore time keeping of the clock on the ship will not change normally during operational periods of this survey and that of the clock ashore by less than 1 second a day. As

both the ship and shore magnetometers operate at a cycling rate of 6 seconds, drift in either clock up to ±3 seconds would not affect the accuracy of the data but might indicate abnormal operation requiring close attention.

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APPENDIX 1: DAILY SHIPBOARD ROUTINE

1. Remove record each day at 0000 GMT and check that there is sufficient paper for the next 24 hours' operation.

2. Pull paper forward 0.5 m and label with date, Julian day number, and chart sequence number.

3. Reset zero and full-scale deflections on recorder at the start of each days record, marking recalibration on chart.

4. Read magnetic field value from digital display at the start of recording and each hour on the hour and write it on record against the starting time and each hour mark.

5. After any power failure check the setting of the clock against A.P.O. radio time signals and adjust as necessary. The magnitude and time of all clock adjustments should be noted on the record. Check the setting of the clock against A.P.O. radio time signals each day at 0000 GMT. Record on the magnetometer chart the difference from radio time but do not adjust unless there is a change exceeding 3 seconds from the previous check. The clock should also be checked against the satellite Doppler time signals when these are received. Suspected abnormal behaviour should be reported promptly and monitored closely.

6. Label hour mark with day and hour with a pen; also mark times of all satellite and navigation fixes.

7. Check tuning of magnetometer at regular intervals using oscilloscope; mark chart with new value if tuning is changed.

8. Check zero and full-scale calibration of recorder every six hours, but do not recalibrate unless error exceeds 2 mm, mark calibration on chart; make sure that a calibration check is made shortly before 0000 GMT, i.e. at end of day's record.

9. Mark the start and end of each line with time and line number; should a big break in time be anticipated between the end of one line and the start of the next, turn off recorder and mark the break clearly with the time and reason for break, if known. Pull the chart paper forward 0.5 m before annotating for the next commencement, as in 2. For short breaks between lines, continue recording and simply annotate end of line (EOL) and start of line (SOL).

10. Note on the chart against the appropriate time-mark all course and speed changes and the times at which they occur.

11. After the record is taken off, label the end with date, Julian day number, and chart sequence number; then note start and stop times of the record and lines traversed during the day; e.g. end line 05, line 06, line 07, start line 08; mark these on both the beginning and end of the record.

APPENDIX 2: PREPARING FOR RECORDING, ROUTINE MAINTENANCE

1. Inform the ship's bridge of the intention to stream the cable and wait their acknowledgement that ship's speed has been reduced to 2 or 3 knots; use a similar procedure when picking the cable up.

2. Connect the lead from winch to power outlet and switch on.

3. At the winch - remove the canvas cover,
   - unlash the sensor,
   - unchain the reel,
   - unplug the sensor signal cable and tuck it under the elastic strap on the side of the reel,
   - switch on the winch motor,
   - lower the cable into the sea and allow the cable to reel out to the required length (3 ship's lengths),
   - stop the reel in such a position that the sensor signal cable can be reconnected without strain,
   - replace the chain through the reel,
   - connect the sensor signal cable, making sure it is pushed completely home,
   - replace the canvas cover,
   - disconnect the winch power cable at the winch, and stow it with the end wrapped in a waterproof bag.

4. At the equipment rack -
   - plug in the D.C. power supply and switch on power at the wall socket,
   - switch on the D.C. power supply,
   - adjust the output to 28 volts,
   - check all switch settings (see manual, page 3-2),
   - switch on the power switch of the magnetometer system,

- monitor the internal voltages, + 12V, -12V, + 5V,
- switch the mode switch to 'normal' and the monitor switch to 'polarization' and check the polarizing current,
- switch the monitor switch to 'signal',
- adjust tuning to give the maximum signal.

5. At the recorder -

- check that the paper supply is adequate for 24 hours' operation; change if necessary,
- check the switch settings (see manual),
- turn on the power and chart switches,
- carry out zero and calibration checks.

6. Maintenance

Winch
- keep the cover on the winch whenever the winch is not being operated,
- keep the signal cable connector greased with a non-conducting grease such as silicone,
- keep the sensor head securely lashed when it is stowed,

Recorder
- clean the pens whenever a new roll of paper is installed and at other times if necessary for clean records.

APPENDIX 3: DIURNAL MONITORING

The shore station has been set up by a technical officer of the BMR at the Broome meteorological station and will be operated by an officer of the Meteorological Bureau.

For the diurnal data collected to be of maximum reliability the shore station shall be visited regularly each day at 0000, 0600 and 1200 hours GMT.

The following procedures shall be followed:

Record labelling at the shore station

1. Remove the record each day at 0000 GMT and check that there is sufficient paper for the next 24 hours' operation. Load a new roll if it is not.

2. Pull paper forward 2 feet and label the date, Julian day number, and chart sequence number starting from 24/001.

3. Reset zero and fullscale deflections on the recorder at the start of each day's record, marking 'recalibration' on the chart.

4. Read the magnetic field value from the digital display each hour on the hour when at the station, and write the value on the record against the hour mark.

5. Check zero and full-scale calibration of the recorder at every visit but do not recalibrate unless error is greater than 2 mm; mark 'calibration' on the chart; make sure a calibration is made shortly before or after 0000 GMT i.e. at the end of each day record.

6. Check the setting of the clock against the A.P.O. radio time signals daily at or near 0000 GMT. The difference from radio time should be noted on the record and daily log sheet.

7. Label the end of the record taken off with date, Julian day number, and chart sequence number, then note the start and stop time of the recording at both the beginning and the end of the record.

8. At weekly intervals mail the magnetometer records and the daily log sheets to BMR Canberra.

Daily Log Sheets - Note at the time of occurrence or observation:

(Use a new sheet for each day)

1. All instrument adjustments, scale changes, calibration tests.

2. Any equipment faults or reasons for interruption in recording.

3. Any disturbances of the sensor head.

4. Times of visits to the station.

5. Any occurrence which causes unusual or irregular events on the record.

6. Start and stop times of chart.