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1980 HEARD ISLAND EXPEDITION: MARINE GEOPHYSICAL OPERATIONS AND PRELIMINARY RESULTS

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CONTENTS

SUMMARY

The 1980 Heard Island Expedition was conducted between 29 February 1980 and 7 April 1980 using the M.V. Cape Pillar under charter to the Division of National Mapping. The Bureau of Mineral Resources, one of the co-operating organisations, operated a computer-based data acquisition system to collect magnetic, bathymetric, and navigational data over the Kerguelen Plateau and adjacent ocean basins. A total of 7000 n. miles of data were collected comprising about 2900 n. miles over the Kerguelen Plateau, and the remainder in the two transit lines over the Southeast Indian Ocean.

A Raytheon deep-sounding echosounder system was specially installed for the survey. Overall, records were good, and up to 200 milliseconds of sub-bottom penetration were obtained. Digital depths were generally reliable in water shallower than 1500 m, but in deeper water values were, for the most part, poor and unreliable.

Bathymetric data obtained during the expedition have further defined the morphology of the Heard-Kerguelen region. This region is the shallowest part of the Kerguelen Plateau and is defined approximately by the 1000 m isobath. The eastern margin is a steep scarp which drops from 1000 m to the seafloor at about 3500 metres water depth and is probably fault-controlled. In contrast, the western margin is not as steep, deepening gradually from the plateau edge at about 1000 m to the deep ocean floor at about 4500 m.

Magnetic anomalies over the Heard-Kerguelen region are highly disturbed overall, due to the shallow basement and abundant volcanics within this region.

The two transit lines between the Kerguelen Plateau and Fremantle filled a gap in the existing traverse network and have allowed the magnetic anomaly pattern to be better defined. The most significant result is the identification of anomaly 17 immediately adjacent to the northeast margin of the plateau. This anomaly, previously identified in the south, is now known to extend along most of the eastern margin of the Kerguelen Plateau. Several previously identified fracture zones are now known to extend southwestwards, almost to the plateau margin.

1. INTRODUCTION

The 1980 Heard Island Expedition was conducted between 29 February 1980 and 7 April 1980 using the M.V. Cape Pillar under charter to the Division of National Mapping (NATMAP). The Bureau of Mineral Resources, Geology and Geophysics (BMR) was one of the organisations which co-operated with NATMAP on the survey. The main objectives of the Expedition were: to survey the northern part of the 'Australian' sector of the Kerguelen Plateau, by carrying out NATMAP's program of bathymetric surveying of the Heard Island region, position fixing of islands and rocks within this region, and aerial photography of Heard and McDonald Islands; and, to carry out BMR's program of magnetic surveying to define the extent and possible thickness of any sedimentary basins, and to elucidate the magnetic anomaly pattern over the deep ocean basins adjacent to the Kerguelen Plateau.

Other Departments and Organisations co-operating with NATMAP included: the Antarctic Division and the Bureau of Meteorology of the Department of Science & the Environment, the Department of Transport, the Fisheries Division of the Department of Primary Industry, the Hydrographic Service of the Royal Australian Navy (RAN), Flinders Institute of Atmospheric & Marine Sciences (FIAMS), the Biology Department of the University of Melbourne, and the Geology Department of Monash University. A listing of the scientific personnel and crew members on the expedition is given in Appendix 1.

The BMR marine geophysics operation collected magnetic and bathymetric data using a computer-based data acquisition system (DAS). Data were collected continuously while the ship was underway, both over the deep ocean basins and over the Kerguelen Plateau, the large oceanic ridge on which the islands of Heard and Kerguelen are situated.

The geophysical equipment comprised a proton precession magnetometer, to measure the total intensity of the earth's magnetic field, and a deep-sounding echosounder designed to measure water depths down to 5000 metres. This special-purpose Raytheon echosounder was necessary, as the conventional echosounders on the M.V. Cape Pillar did not have sufficient range to attain the depths encountered in the deep ocean basins that accounted for over half of the total traversing surveyed.

The Heard Island Expedition provided BMR's first opportunity since 1973 to use the Raytheon bathymetric system, and it was the first time that a new array of nine transducers was used with the system. Overall, the records were good, and up to 200 milliseconds of sub-bottom penetration were obtained (See Chapter 3).

The BMR marine geophysical operation was carried out successfully and almost complete bathymetric and magnetic coverage was obtained for the 7000 n.miles traversed (Fig. 1). This comprised about 3000 n.miles over the Kerguelen Plateau and a further 4000 n.miles in the two transit lines between Fremantle and Heard Island. An additional 1000 n.miles of data were collected on the test cruise from Melbourne to Fremantle.

The proposed traverse plan over the Kerguelen Plateau was followed (Fig. 2) except that two north-south lines were deleted because of time constraints and the two southernmost east-west lines were rotated 45° because of the prevailing weather. A total distance of 2907 n.miles was surveyed over the Kerguelen Plateau. The traverses consist of six northeast-southwest crossings of the plateau. All traverses extended into deep water beyond the major increase in slope that occurs at about 1000 metres, and most reached regions with depths greater than 3000 metres. Four north-south tie lines, one of which extends to Kerguelen Island, completed the traverse network. This new network complements the existing French survey tracks, details of which were kindly supplied by R. Schlich of the Institut de Physique du Globe de Paris. Taken together the data give a fairly comprehensive magnetic and bathymetric coverage of the 'Australian region' around Heard Island.

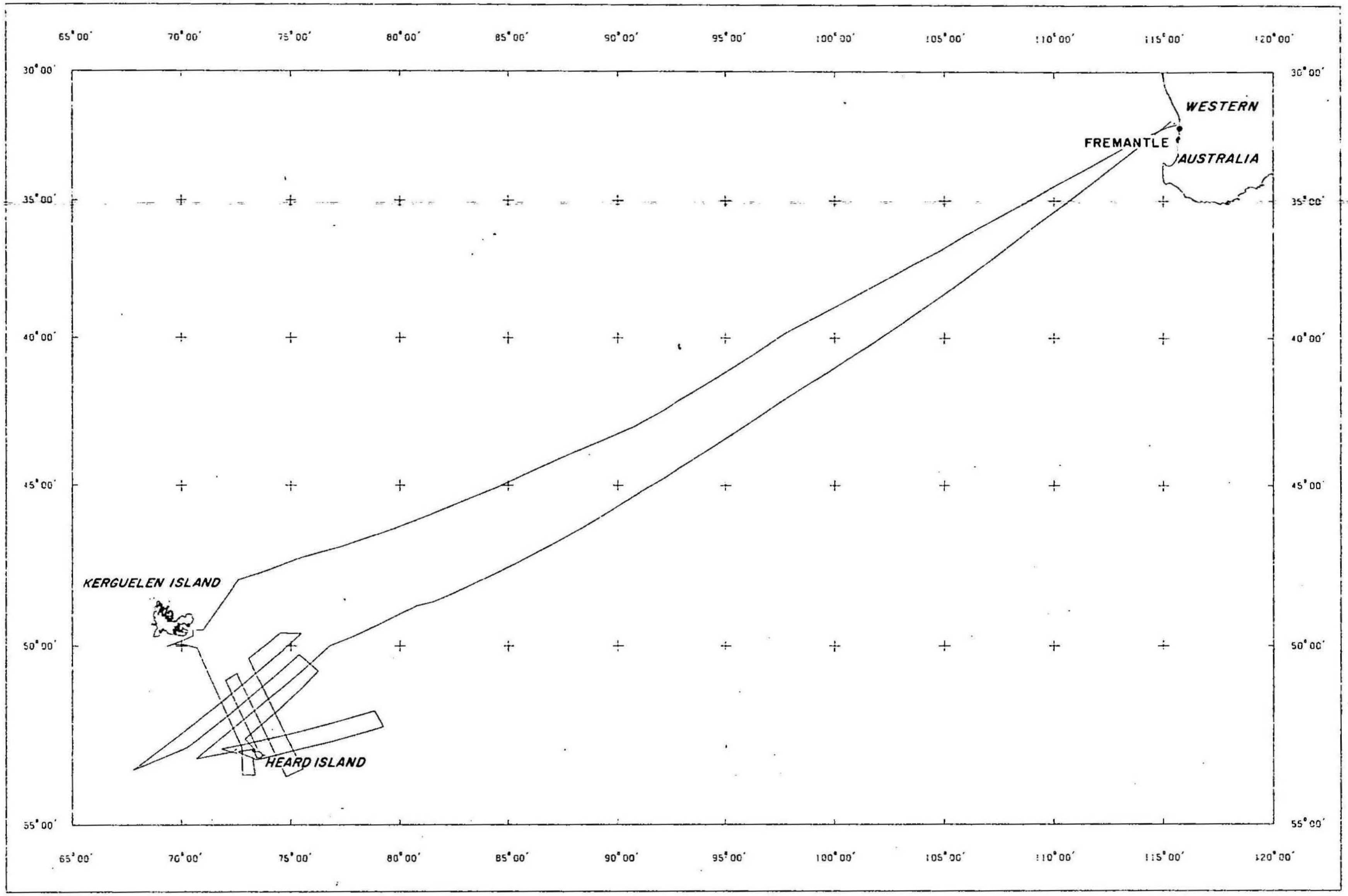
2. CRUISE SUMMARY

Installation, Melbourne, 22 January 1980 to 7 February 1980

(R. Dulski, H. Stagg).

The Raytheon and DAS equipment was installed during the outfitting of the ship for the Heard Island Expedition. For easier installation the nine transducers of the Raytheon system were mounted within the ship's double hull, in the starboard freshwater tank. The concrete lining of the tank was removed from the hull plate and the mounting brackets for the transducers welded into place. An eight metre high steel pipe was mounted in the top of the tank to provide a pressure head for the transducers. The pipe was 7.5 cm in diameter and protruded through the lower hold; its top was exposed in the tween decks for inspection and to allow for topping up to maintain the pressure head.

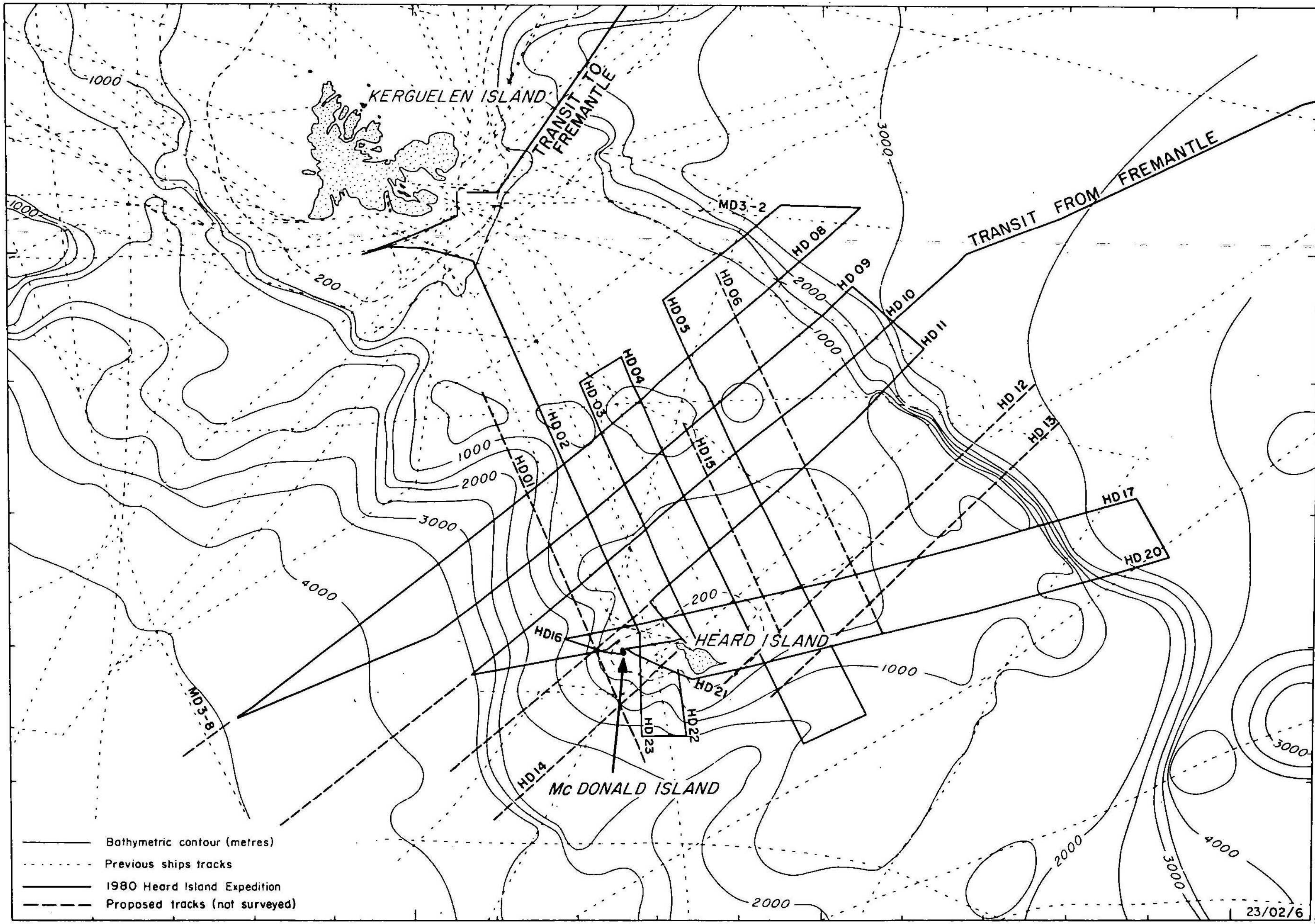
The DAS equipment was installed in three racks in the VIP cabin on the bridge deck. The racks were reinforced and braced laterally to the bulkhead (this extra reinforcing of the equipment racks proved to be a wise precaution as extremely heavy seas were encountered during the survey). An updated version of



Record 1981/16

W/B8-167A

Fig.1 1980 HEARD ISLAND EXPEDITION
TRACK MAP



Record 1981/16

FIG. 2 PROPOSED AND ACTUAL TRACKS OVER THE KERGUELEN PLATEAU the DAS computer program was tested during the installation period to verify that data were acquired correctly, as there would be no means of correcting deficiencies during the operation of the survey.

Installation, Melbourne, 19 February 1980 to 21 February 1980
(R Dulski, L. Tilbury).

Final preparations for the survey were carried out. The remaining DAS equipment was installed, and the equipment and the DAS program tested. A new magnetometer cable, with a sensor attached, was wound onto the magnetometer winch.

Test Cruise, Melbourne to Perth, 21 February 1980 to 26 February 1980.

The transit from Melbourne to Perth was used to test the DAS and Raytheon equipment under operational conditions, and some 1000 n.miles of data were collected between Cape Otway, Victoria and Albany, Western Australia. Surveying was then suspended as the ship's a.c. power supply system required modifications. In the Great Australian Bight about 20 hours of data (about 200 n.miles), were not recorded as the DAS computer (Hewlett-Packard HP2108 mini computer) was being used in tests involving the Magnavox satellite navigation system.

During the test cruise, several problems were encountered. The noise level on magnetic records using the new magnetometer sensor was higher than normal, with peak-to-peak values of 3-4 nT (nanoteslas). The fluid in the sensor was replaced but the high noise level remained. A check of the system revealed that the output signal from the sensor was only about 30 percent of the expected signal, and this probably contributed to the relatively high noise level encountered on this survey.

The magnetometer winch motor was found to have insufficient starting torque to commence rewinding the magnetometer cable, and three seamen were required to pull on the cable to enable the winch to get started. The problem was solved in Fremantle by electrical contractors who rewired the starting mechanism for the winch motor.

The Raytheon system was tested at sea to determine the optimum operating settings. It was found that full power output could not be obtained on the rapid firing rates of one and two seconds as the overload light on the transceiver (PTR) came on. Therefore, a compromise was made between the maximum frequency of firing and the power output. In most cases, the system required the maximum power output in order to obtain consistent water depths. During the initial testing, the system was working as a conventional pulse-mode echo sounder, until a fault in the signal correlator unit (CESP) was located and repaired on 24 February 1980. The system then worked correctly using the correlated signal.

The digital water depth from the Raytheon system is greater than the true water depth by an amount equal to the width of the transmission pulse (64 milliseconds or 46.4 metres). Rather than use the delay facility in the CESP/PTR to compensate for the transmission pulse width, all depth values are recorded unadjusted. In addition, no corrections are made for the draught of the ship. This approach was carried out to ensure that digital values were consistent with the depths displayed on the EPC graphic recorder which used the start of the transmitted pulse as the zero mark. Such an approach avoided recording depth data in different forms with inconsistent datums, which would lead to problems during later editing of the bathymetric data.

True water depths are computed using the formula:

TRUE DEPTH = PDD READING - 46.4m + DRAUGHT

where PDD READING is the digital value from the Precision Depth Digitiser (PDD).

Transit to McDonald Island, 29 February 1980 to 11 March 1980.

This transit line was positioned approximately midway between the existing Eltanin 47 and Conrad 08-02 lines extending from the Australian margin to the Kerguelen Plateau. The transit line continued across the Plateau as line HD10 (Fig. 2), and then backtracked to McDonald Island. The transit line was 2005 n.miles in length, with a further 370 n.miles surveyed over the Plateau.

The sea states were low for the first three days, but then the weather deteriorated rapidly until the wind reached Beaufort Scale Force 9 (BS 9). Large swells developed, and the ship's speed was reduced to 5.2 knots, compared with a normal cruising speed of 12 knots. In the heavy weather, the Doppler sonar would not work in the automatic water-track mode. On 2 March 1980 it was placed in the manual mode and remained in this mode for most of the survey.

The noise level on the magnetic data was highly dependent on the sea state, a high noise level correlating with rough weather. At its worst, the noise envelope was 10 nT with spikes to 20 nT.

On 4 March 1980, the first sign of 'bit problems' in the digital recording appeared. The BCD output card in the magnetometer was replaced and the CPU/Multiplexer cable checked. The problem appeared to have been corrected.

The Raytheon system worked well in low sea states, but in rough weather the sea bottom was barely evident in the noise on the EPC record. The record became particularly noisy when the ship was pitching into high seas. In addition, the return echo was weakened in rough seas, and consequently the digital tracking of the water bottom tended to fail. The first example of good sub-bottom penetration by the system was obtained on 7 March 1980 (Fig. 4(b)).

Problems were encountered owing to the inadequacy of the ships a.c. power supply. Three failures of the DAS computer, and six failures of the Magnavox system were caused by the inconsistent power supply.

At anchor, McDonald Island, 11 March 1980 to 12 March 1980.

The scientific party of the Australian National Antarctic Research Expedition (ANARE) and the NATMAP shore party were landed by helicopter and amphibious vehicle on McDonald Island - the LARC amphibious vehicle landing was the first recorded boat landing on McDonald Island.

Aerial photographs were taken by NATMAP using the helicopter. The photography was unfinished at the end of the first day and the ship remained overnight so that the photography could be completed. However, the weather closed in next day, and the rest of the photography had to be abandoned.

The ship sailed, leaving the land party ashore to complete their observations.

McDonald Island to McDonald Island, 12 March 1980 to 14 March 1980.

The ship sailed northwest on line HD 16, with the intention of running the north-south lines, HD01 and HD02. However, rough seas, high winds (BS 6-8), and a large swell prevented this, as the seas would have been on the ship's beam. Instead, lines HD17 to HD21 were surveyed. A total of 574 n.miles of data were collected on these lines.

The noise level on the magnetic data reached a high of 10 nT peak-to-peak when the ship was pitching into heavy seas on line HD16, but reduced dramatically to 2-3 nT peak-to-peak as the ship ran with the seas on line HD17. An intermittent problem occurred again with the 2-bit of the hundreds digit on the digital output, but the problem disappeared after a thorough check of the magnetometer.

The freshwater tank containing the Raytheon transducers began to leak towards the end of the transit voyage and the pressure head on the transducers could not be maintained. The system could only be run at reduced power output (half normal power) for this portion of the survey but good digital depth recordings were still obtained as the water depths were mostly shallow. However, no sub-bottom penetration was observed because of the reduced power output.

A minor problem arose with the GED clock when it was found that the digital output from the clock was different to that shown on the clock face. The problem was not critical because it only affected the tens digit of the day number display, and data acquisition was continued without interruption. The day number was easily adjusted during later processing.

At anchor, McDonald Island, 14 March 1980 to 15 March 1980.

The land party on McDonald Island was to be collected by the LARC, but the beach, where the original landing was made four days earlier, was awash; all personnel and equipment had to be transferred to the ship by helicopter. The aerial photographic work was not completed because of the overcast weather.

McDonald Island to Heard Island, 15 March 1980 to 15 March 1980.

After leaving McDonald Island, the ship sailed north to establish the position of Meyer Rock, the northernmost island in the McDonald Group. The position of Meyer Rock was determined using several satellite passes, the range and bearing of the rock being obtained at the satellite fix time. A line was then surveyed to Heard Island, but only bathymetric and navigation data were recorded.

At anchor, Atlas Cove, Heard Island, 15 March 1980 to 18 March 1980.

The NATMAP and ANARE land party was disembarked by LARC and helicopter, and a base camp was established on Heard Island using the huts from the 1971 French expedition.

An automatic weather station, supplied by Antarctic Division, was installed during the three days at anchor.

A hydrographic survey of Atlas Cove, the main anchorage at Heard Island, was carried out by NATMAP, using the small Sea Eel boat and a miniranger navigation system.

During the stopover, the water tank housing the Raytheon transducers was repaired. The fresh water was transferred from this tank to another and replaced by sea water. This was done as a precaution in case the fresh water was required on the return voyage.

Heard Island to Heard Island, 18 March 1980 to 25 March 1980.

Before commencing normal surveying, the ship sailed north to determine the positions of Shag Island, Sail Rock, and Drury Rock. These rock outcrops are located some 10 km north of Heard Island.

The sea was remarkably calm for the next three days and the north-south lines, HD03 to HD05, were run without incident. The weather began to deteriorate during the sailing of line HD08 to the southwest, the longest proposed line across the Kerguelen Plateau, planned to tie to the French lines Marion Dufresne MD3-2 and MD3-8. A tie was made to MD3-2 in the east, but due to loss of time caused by the heavy seas, the line HD08 was cut short and did not tie to MD3-8 in the west. Lines HD09 and HD11 across the Ridge were then surveyed, but line HD11 was terminated prematurely to return to Heard Island to embark the land party. A total of 1665 n.miles were traversed over the Kerguelen Plateau during this part of the survey.

The noise level on the magnetic record was again closely correlated with the sea state. The level was mostly 2-3 nT peak-to-peak, but increased to 10 nT peak-to-peak when the boat was pitching into heavy seas on line HD08. Again, when the ship turned to run with the seas on line HD09, the noise levels reduced dramatically. Intermittent BCD errors occurred with the digital recording of the magnetics. The problem was finally solved on 21 March 1980 when it was found to stem from a loose connection in the magnetometer-to-multiplexer cable.

The Raytheon system worked reasonably well when sea states were low, and some very good examples of 'sub-bottom penetration' were observed (Figure 4(a)). Problems arose with the digital tracking when the underlying reflectors had similar amplitudes to the seabed signal. At these times the digital tracking jumped back and forth at random (Fig. 6).

The water bottom was barely visible on the record when the ship was pitching into heavy seas (BS 7-8) on line HD08; the digital tracking was also bad at this time.

Several system crashes occurred, each time resulting in the loss of the DAS program from the computer memory. A large power surge blew the computer fuse and damaged the tube of the storage CRO used to monitor the Raytheon signal. Two further system crashes occurred during severe rolling of the ship, and may possibly have been caused by a loose connector on the power lead or by power surges.

The ship had to stop twice because of engine trouble; once on line 0508 and again on line HD08. Only a few hours were lost, and the lines were tied back to the original lines to provide continuity of data.

At anchor, Atlas Cove, Heard Island, 25 March 1980 to 27 March 1980.

The land party was embarked by LARC. Antarctic Division's weather station was completed and tested to check that the data were being transmitted correctly. A second, smaller weather station, belonging to the Bureau of Meteorology, was installed and calibrated.

The remains of an old, Walrus survey-aircraft, were salvaged. This aeroplane had been used for aerial photography, but was wrecked during the first expedition to Heard Island.

Heard Island to Kerguelen Island, 27 March 1980 to 29 March 1980.

Some 460 n.miles were traversed, including a loop to the southwest of Heard Island (lines HD22 and HD23), and a northerly line (HD02) along the strike of the Kerguelen Plateau extending from Heard Island to the island of Kerguelen. Sea states were low.

The first major problems with the Magnavox satellite navigation system were encountered during this section of surveying and line HD22 had to be restarted. Following this restart, there was no satellite update for $6\frac{1}{2}$ hours;

satellite fixes generally were taken every hour or so during the survey, but on this day, a bad configuration of satellite passes (most at low elevations) meant that no satellite fixes were obtained.

A further problem occurred which resulted in no positions being recorded by the DAS for the last 16 hours before reaching Kerguelen Island (however positional information at 5 minute intervals was available from the Magnavox printout for later incorporation during data reduction). The problem arose because the Magnavox computer would not load and start the small BMR program which is used to extract key navigational data for input to the DAS computer. No explanation was found for this problem. After leaving Kerguelen Island, the Magnavox system loaded properly, including the small BMR program. The problem disappeared and did not recur.

The first signs of a major problem with the Raytheon system also came to light during this period. Poor records and poor digital tracking were observed, even though the ship was pitching only slightly in the relatively low sea states. The decrease in draught caused by the lightening of the ship through fuel consumption as the cruise progressed, may have led to an increase in aeration beneath the hull resulting in a loss in efficiency of the Raytheon output pulse.

At anchor, Kerguelen Island, 29 March 1980 to 30 March 1980.

The expedition visited the French base on Kerguelen Island to obtain medical treatment for 3 crew men. The French welcomed the expedition party and treated all to their hospitality.

Transit to Fremantle 30 March 1980 to 7 April 1980.

This transit line subparalleled Eltanin line 47-1 and was located about 60 n.miles to the north of it. A total of 2300 n.miles was traversed.

The noise level on the magnetic data was low, about 2-3 nT, as the sea states were mostly low and the ship was running with the seas. The only problem involving the magnetometer system was with the paper speed mechanism of the strip chart recorder, which malfunctioned intermittently, resulting in a disjointed magnetic trace.

The Raytheon system worked well for the first 3 to 4 days after leaving Kerguelen and good EPC monitor records and reasonable digital tracking down to 3400 metres were obtained. The quality of the records then deteriorated over a day or so until not even the seabed trace was visible on the charts. No electronic fault could be found, and the power output from the transducers was constant. A reduction in the speed of the ship to 10 knots had little effect. The poor quality of the records appears to have been caused by an increase in aeration beneath the hull of the ship; during the first three to four days the ship had sailed with a large swell which probably gave sufficient push to keep the bow of the ship down slightly. The degree of aeration beneath the hull would have been reduced, hence enabling good Raytheon records to be obtained. A decrease in the size of the swell and a slight change in course of about 7° coincided with the deterioration in the chart records.

As the water depths began to shallow near the Australian margin the Raytheon record improved and reasonable records and digital depths were once again obtained.

Three hours of surveying were lost when further problems occurred with the ship's engine. However, the continuity of data was maintained because each time the ship returned to tie into the previously surveyed line.

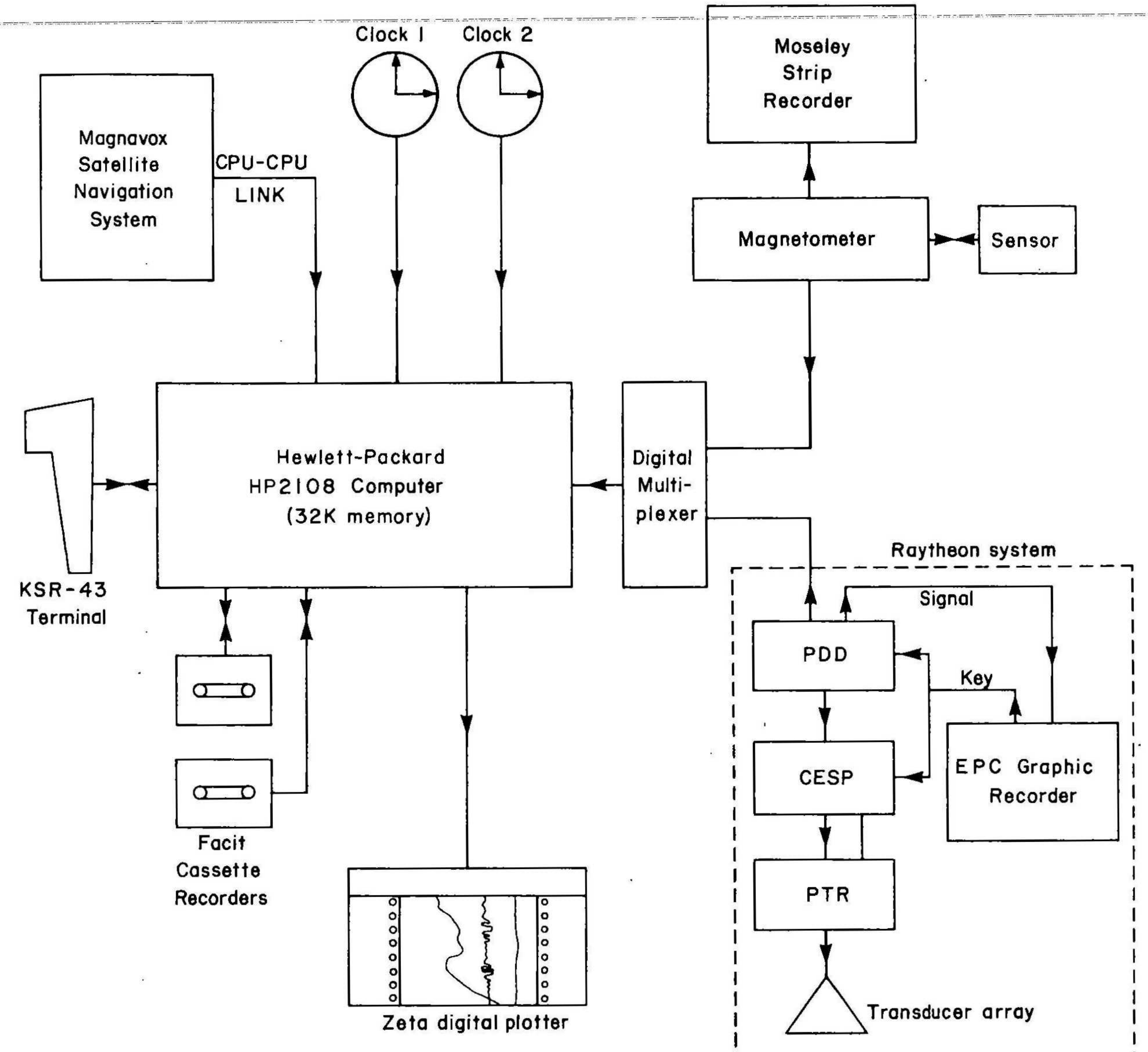
3. EQUIPMENT PERFORMANCE

3.1 Data Acquisition System (DAS).

The computer-based DAS (Fig. 3) was configured for this survey to acquire bathymetric, magnetic, and navigational data at a 10-second sample rate. The data was recorded on cassette tape and plotted in both raw and reduced form on a Zeta digital plotter. A dump of the data at 5 minute intervals, as well as error reports and system messages, were output to a printer terminal.

Little down-time occurred with the DAS equipment because most of the individual components had back up units within the overall system. The acquisition program functioned well and, apart from a few minor modifications required from a user's point of view to speed up the initialisation process and remove some aesthetic problems, the DAS program was fully operational.

Power failures or instability (power surges) of the ship's a.c. power supply, accounted for eight out of thirteen of the system crashes and may have been a contributing factor in two of the remaining crashes. They were also the direct cause of five out of nine crashes of the Magnavox satellite navigation system at times when the DAS was still operating.



Record 1981/16

W/B8-168A

Fig.3 SCHEMATIC OF DATA ACQUISITION SYSTEM ON M.V. CAPE PILLAR (MARCH 1980)

Because of the power supply problems the strip chart recorder was disconnected from the digital-to-analogue output of the computer, and was used to record the magnetic data directly from the analogue output of the magnetometer. This kept the loss of data during power failures to a minimum as the magnetometer was functional immediately power was restored, whereas the DAS required program loading and initialisation involving a delay of 10 to 30 minutes. Power surges occasionally disabled the DAS computer program without affecting any of the sensing equipment. In these cases, data was recovered completely; recovery of bathymetric data from the EPC graphic recorder used to drive the Raytheon system, magnetic data from the strip chart recorder and navigational information from the Magnavox printout, was possible.

3.2 Magnetometer.

The magnetometer sensor was streamed at every opportunity after the ship departed from Fremantle on 29 February 1980. The quality of the data varied from good to poor depending on the sea state. In good weather the noise level on the magnetic trace was about 2-3 nT peak-to-peak, but increased to over 10 nT peak-to-peak when the ship was pitching into heavy seas. The signal output of the magnetometer sensor was low and may have been a factor in the higher-than-normal noise levels recorded in good weather. It should be noted that the sea was so rough during these periods of high noise level that operations would normally have been suspended; however, because of the rigid time constraints and the rough weather prevailing in the Heard Island region, operations were continued.

The digital recording was free of errors, except for several days when the 2-bit of the hundreds digit locked-on intermittently. The magnetometer and the cabling were checked, the BCD card and the multiplexer slots changed. Each time the configuration was checked or changed, the problem would disappear, only to reappear a day or so later. Eventually the fault was traced to a loose connection in the magnetometer/multiplexer cable at the rear of the magnetometer; once this fault was corrected no further problems occurred. Isolated BCD errors occurred in the units digit of the magnetic value. An illegal units number would appear on the magnetometer front panel, followed immediately by a BCD error printed out on the DAS terminal.

3.3 Raytheon Bathymetric System:

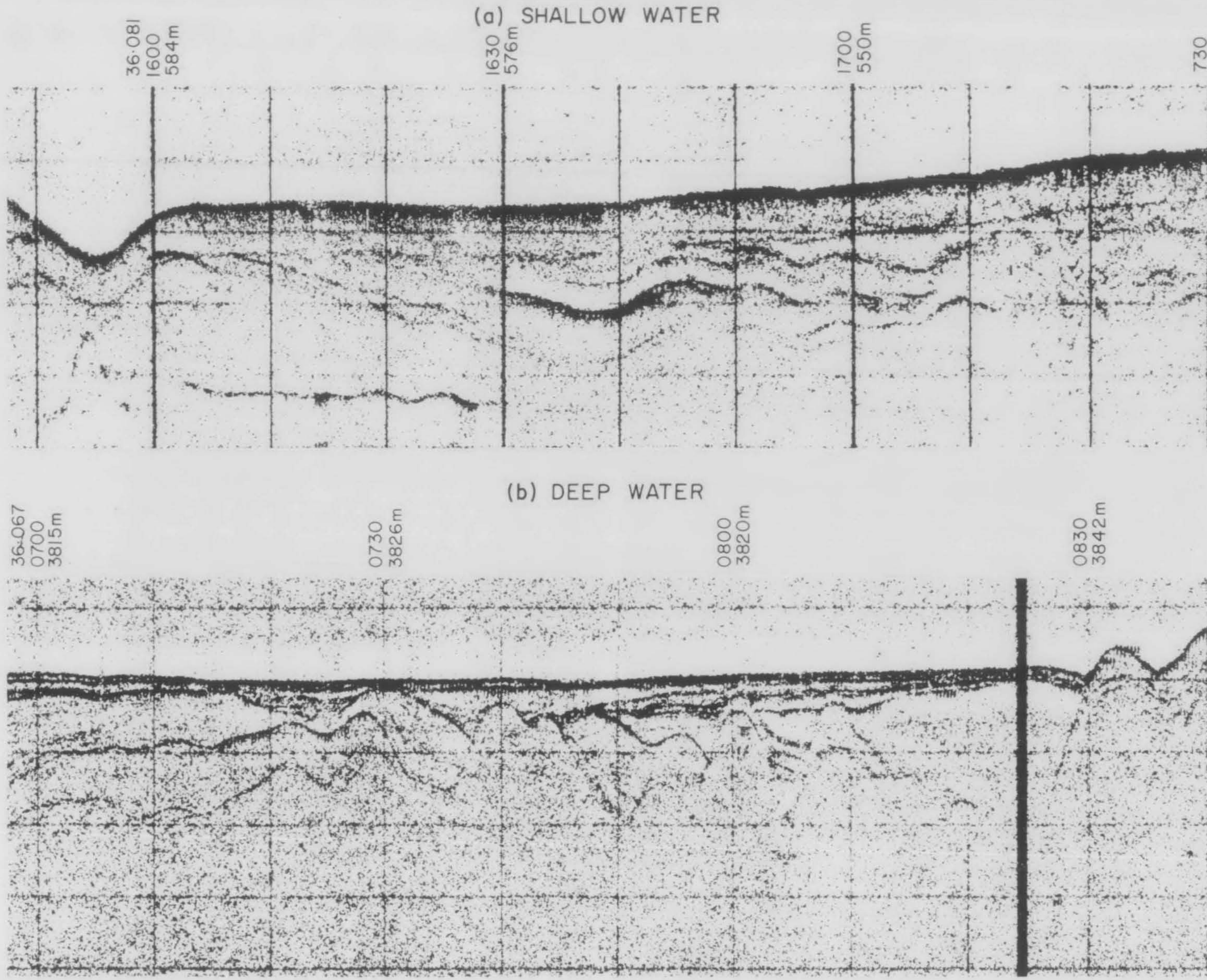
The Raytheon system has two prime outputs; an analogue signal connected to an EPC graphic recorder, which displays the seabed event and any underlying reflectors, and a digital depth reading transmitted to the DAS computer.

The analogue display varied from extremely good, with up to 200 milliseconds 'sub-bottom penetration' (Fig. 4), to extremely poor (not even the water bottom visible on the record). High sea states and large swells were not conducive to collecting high quality data. The Raytheon system was particularly sensitive to the angle of attack of the sea, and poor quality records were obtained whenever the ship was pitching. Presumably the pitching caused aeration beneath the hull which dissipated the energy output. Even though the quality of the records was poor at times, the system overall worked well to a depth of 2000 metres, and complete coverage of the Heard-Kerguelen Region was obtained.

Digital depths were generally reliable in water depths less than 1500 metres but, in deeper water, the digital values were mostly poor and unreliable. An example of good digital tracking of the seabed is shown in Figure 5.

In rough weather, the seabed return echo was usually hidden within the noise envelope, and it was only the consistency of the trace on the EPC record which defined the seabed. In these cases, digital tracking was poor as many echoes were missed, and spurious noise triggered the digitiser, causing inconsistent digital depths to be recorded.

A problem arose when trying to maximise the 'sub-bottom penetration' facility of the Raytheon system. The deeper reflecting horizons sometimes had similar amplitude return echoes to the seabed which caused the digital tracking to jump from one to another at random. An example of this phenomenon is given in Figure 6 where the analogue display is shown on the Raytheon record, and the digital water depths is shown on the Zeta plotter record - the analogue display appears reasonable, but the digital depths are randomly distributed between the seabed and underlying reflectors. To counteract this problem, the FIRST mode option was used. This option locks onto the first pulse which is within the gate and above the threshold. However, in this mode, the system tended to track upwards away from the water bottom, presumably because the signal-to-noise ratio was low.



Record 1981/16

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FIG. 4 RAYTHEON BATHYMETRIC SYSTEM – EXAMPLES OF 'PENETRATION'

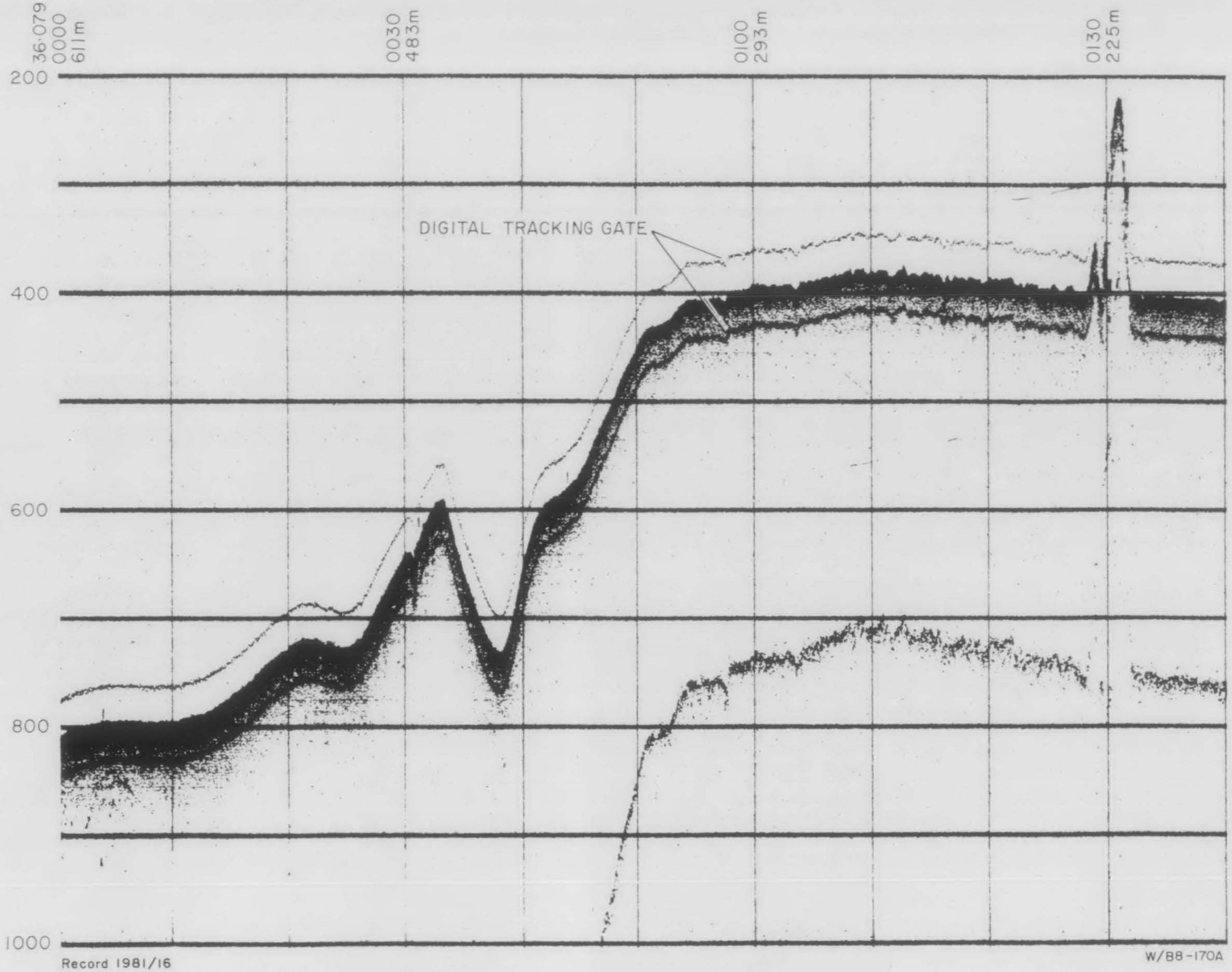
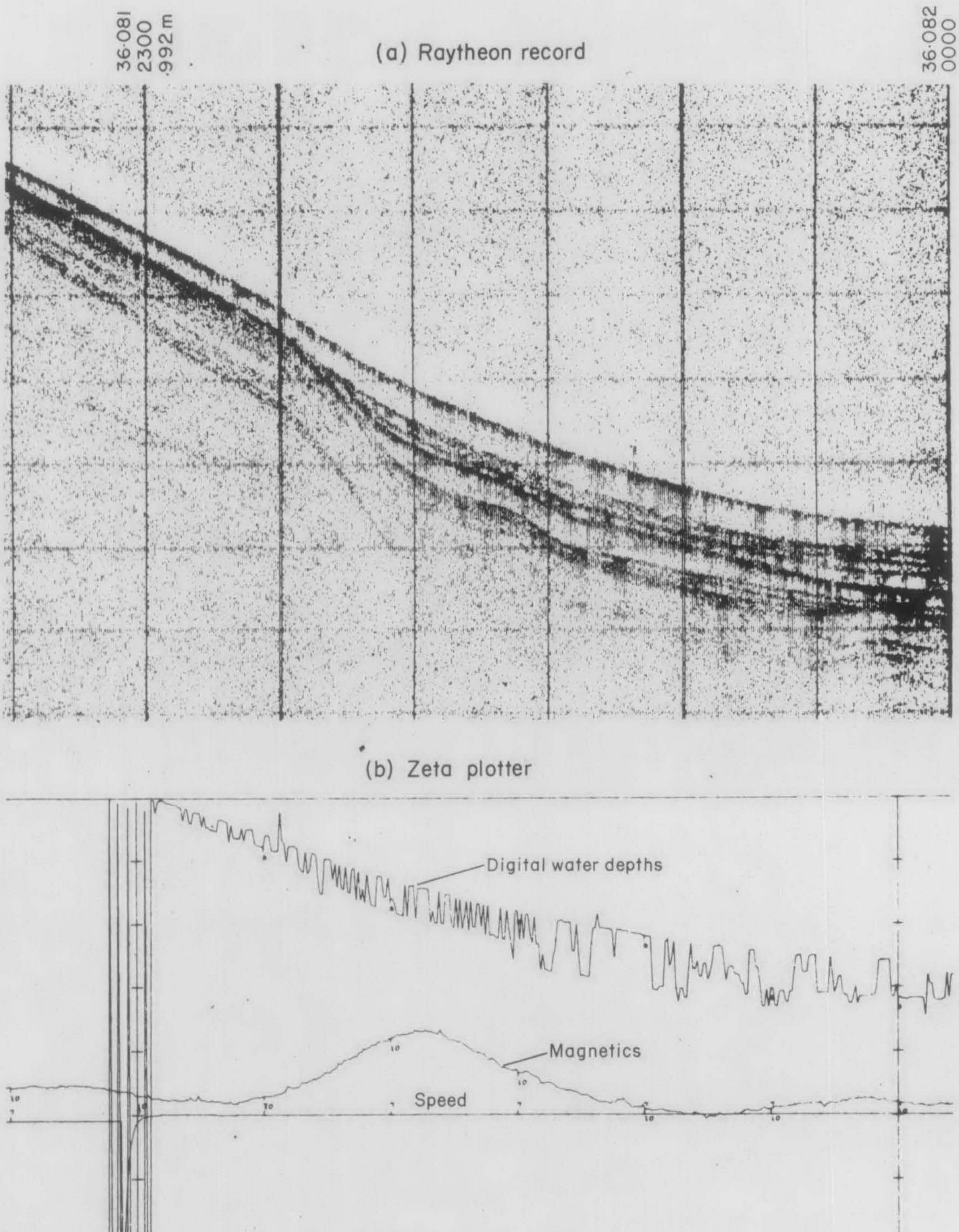


FIG.5 RAYTHEON BATHYMETRIC SYSTEM - EXAMPLE OF GOOD DIGITAL TRACKING



Record 1981/16

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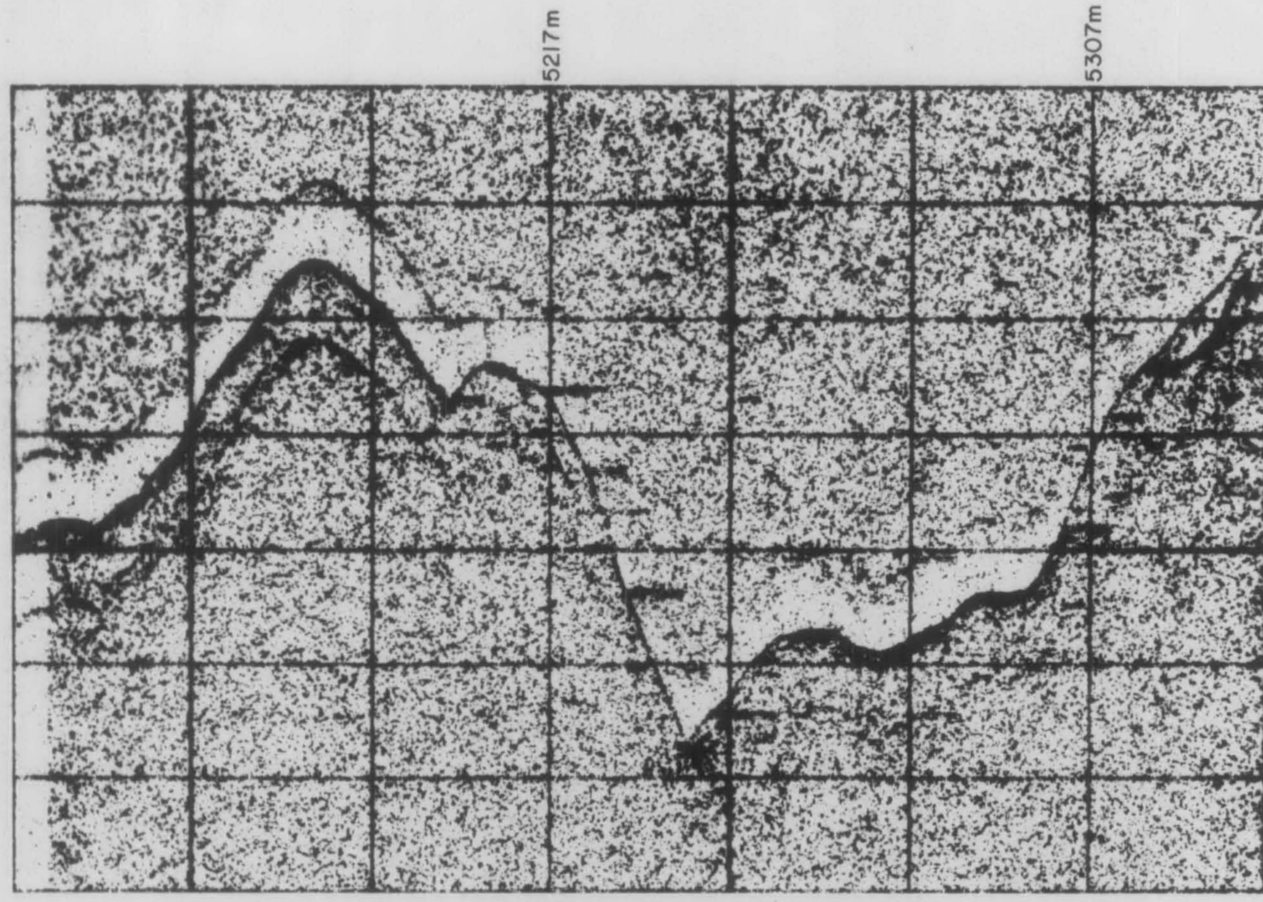
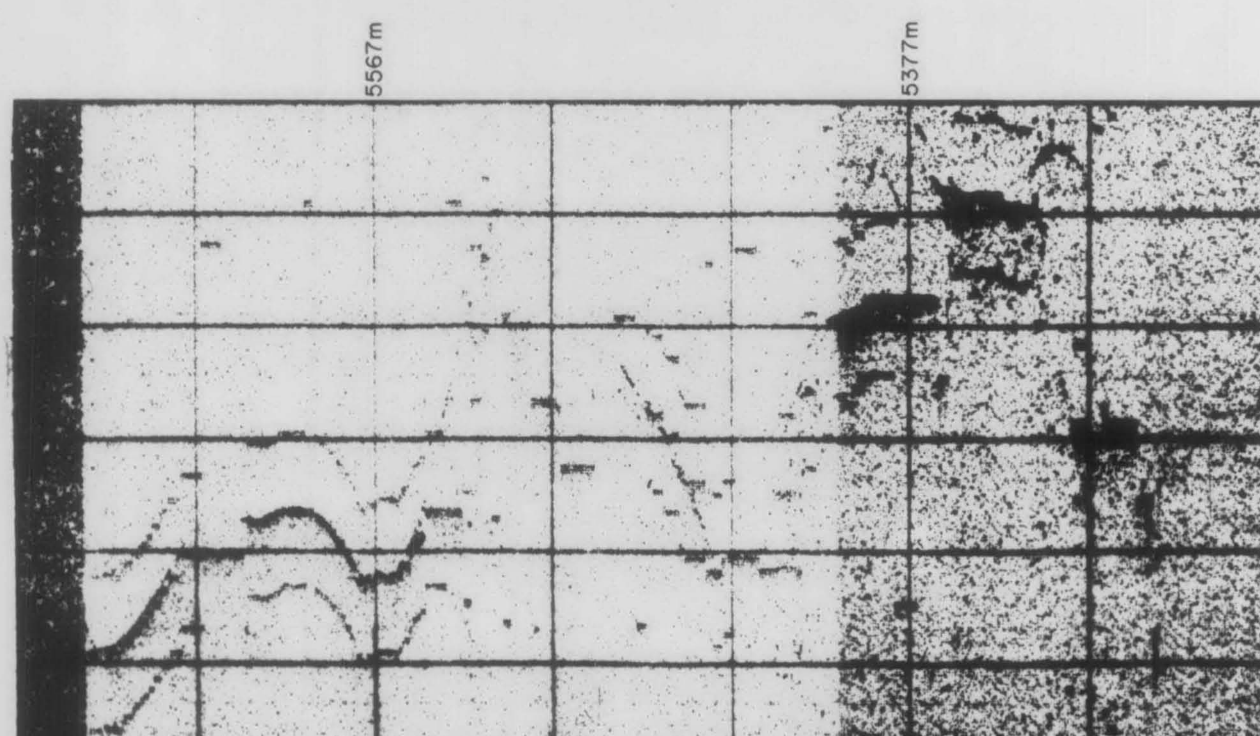
FIG.6 RAYTHEON BATHYMETRIC SYSTEM - EXAMPLE OF POOR DIGITAL TRACKING



a) CESP Threshold set at 5-6 (optimum)



b) CESP Threshold set at 8 (high)

Record 1981/16 23/02/7

FIG.7 RAYTHEON BATHYMETRIC SYSTEM - COMPARISON OF CESP THRESHOLDS

A further complication which was not fully understood, occurred on the transit line from Kerguelen to Fremantle. For the first three days out of Kerguelen the system was working well, tracking a rough bottom topography down to about 4000 metres, with the ship running with the swell at speeds up to 12 knots. The record then started to deteriorate and, after a day or so, even the water bottom was not visible on the record. The only changes in the conditions during this time were a slight change of course (about 7°), a decrease in the swell to almost a calm sea, and a resultant slight increase in ship's speed to 13 knots. A check of the electronics showed that the power output and sensitivity of the system were identical to previous observations. The ship speed was reduced to ten knots to check the effect of ship speed, but this gave no improvement to the record. Once the ship was in shallower water of about 3000 metres over the Naturaliste Plateau, the Raytheon system began tracking normally. The ship was drawing less water because of the lightening resulting from fuel consumption during the long duration of the cruise (later in Fremantle, it was found that the bow was riding about one metre higher than usual); this could have lead to an increase in aeration beneath the hull, attenuating the Raytheon's output pulse sufficiently to lose track of the water bottom in deep water.

The EPC sweep rate, the key to trigger the Raytheon system, was set to three seconds in the normal operating mode on this cruise. At this firing rate the system could be used at full power output. At a one or two second firing rate using full power, the excess duty light indicated an over-load, and the power output had to be lowered. In shallow water the system would track well using a one or two second firing rate at half power output, but no sub-bottom 'penetration' was obtained.

The precision depth digitiser unit (PDD) was set with a zero threshold and was used normally in the PEAK mode, the largest echo within the gate being selected as water bottom.

The most critical of all the settings in the Raytheon system is the THRESHOLD control on the signal correlator unit (CESP). This control is designed such that only signal amplitudes greater than the threshold value are used in the correlator, and consequantly only this portion of the signal is provided as the correlated output signal for the EPC graphics recorder and the PDD. Using the minimum threshold (0) will result in all of the return signal (echo) being transmitted, while the maximum threshold (10) will transmit almost no signal through the correlator.

In general the threshold on the CESP was set to about 4 to 5. If low settings (0 to 3) were used, the return echo tended to become masked within the background noise, and an almost black (uniform) record was obtained. If high settings (7 to 10) were used, only large pulses such as the sea bottom echo were transmitted, and weaker pulses, such as those from sub-bottom events, were effectively filtered out. On the high setting the tracking capability of the PDD improved as the correlated signal was essentially noise-free. However, as conditions deteriorated, such as in regions of rugged sub-surface topography or during rough weather, the sea-bottom echo became weaker until finally no digital depth was obtained; no seabed event could then be seen on the analogue record as all low-level signals were filtered out by the correlator (CESP).

A comparison of high-versus-medium settings for the CESP threshold is given in Figure 7; the examples shown were recorded in water depths of about 5300 m, within 2 hours of each other. The sea bottom is virtually continuous on the medium setting, but is lost completely on the higher settings.

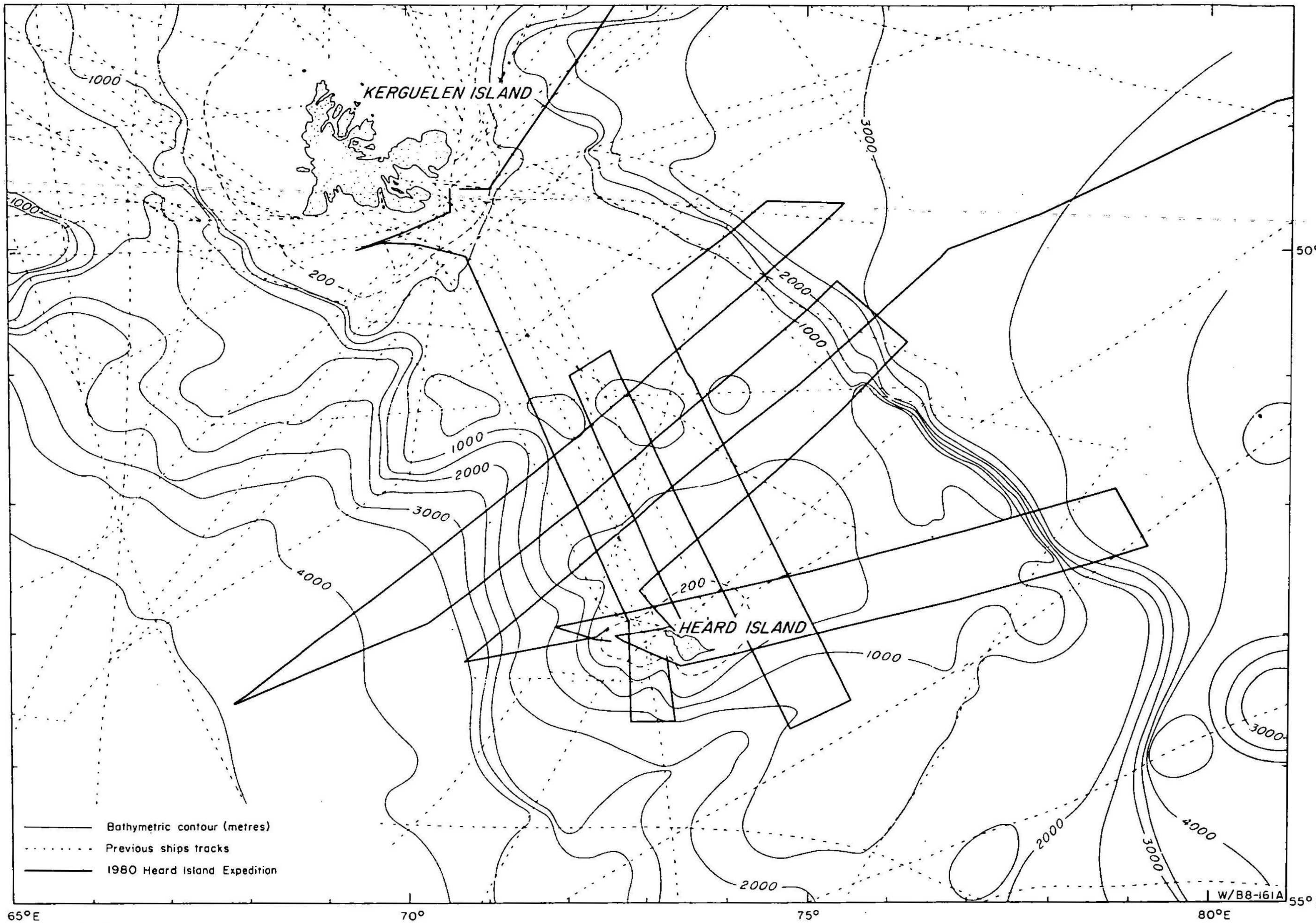
The most important aspect of using the Raytheon system is to produce an acceptable analogue record regardless of the quality of the digital depths. The analogue record can be manually digitised at a later stage for those regions where the digital depths are suspect.

4. PRELIMINARY RESULTS AND DISCUSSION

The preliminary results of the 1980 Heard Island expedition are based on monitor sections produced on board the ship, and preliminary one-minute values extracted from data files that have been only partly cleaned and reduced. Minor errors are present in the line profiles as the navigation data have not been adjusted.

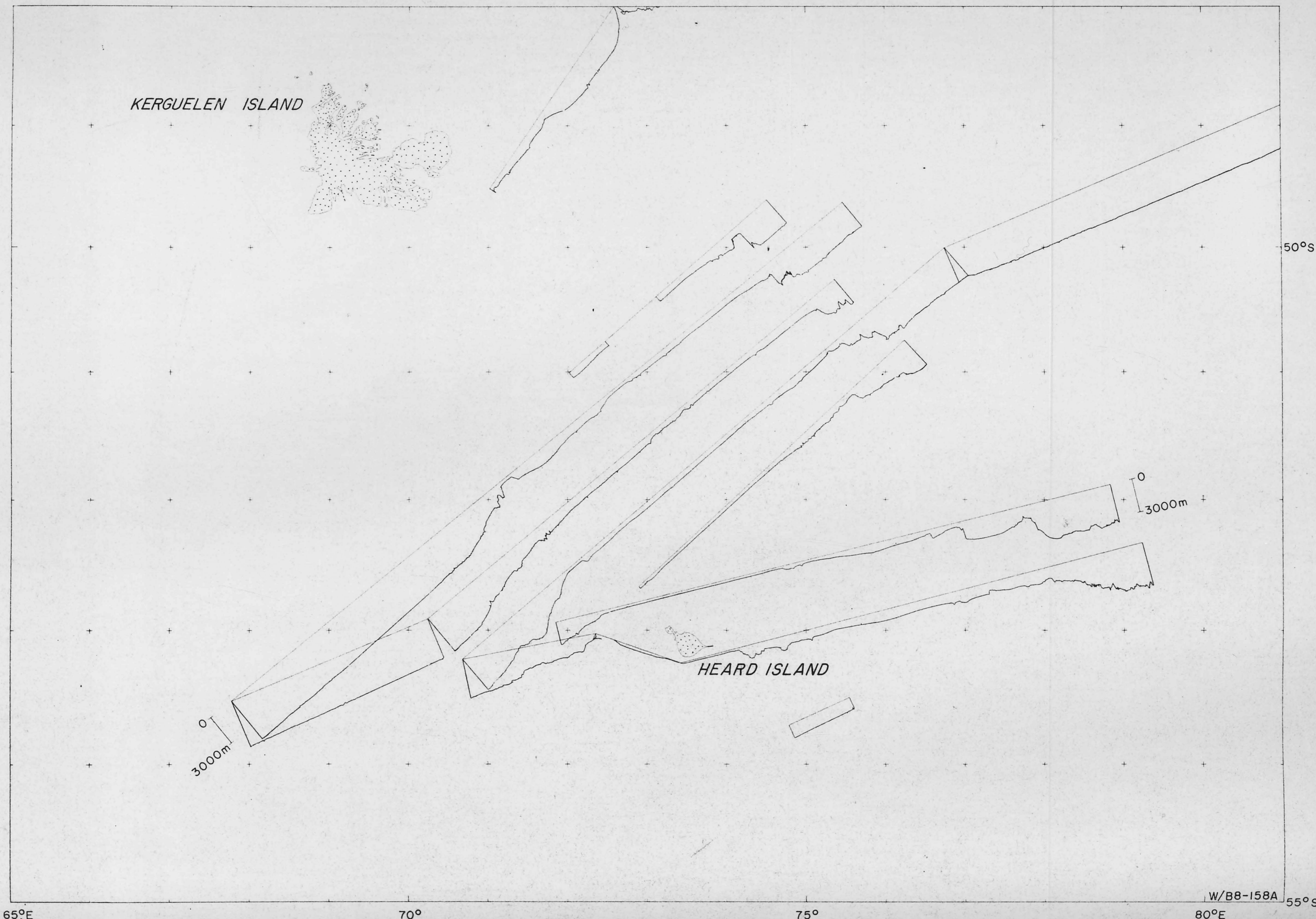
Kerguelen Plateau.

The Kerguelen Plateau is a broad topographic high situated in the south-central Indian Ocean. It is about 2000 km in length, beginning about 300 km north of Kerguelen Island and extending more than 1000 km southeast of Heard Island to within 200 km of the Australian Antarctic Territory. Studies by Houtz and others (1977) have shown that much of the Kerguelen plateau appears to be covered by a veneer of sediments up to 1 km thick. Localised accumulations of sediment at least 2-3 km thick have been recognised and are of particular economic interest.



Record 1981/16

FIG. 8 BATHYMETRIC CONTOURS AND TRACKS OVER THE KERGUELEN PLATEAU



Record 1981/16

FIG.9 BATHYMETRIC PROFILES ACROSS KERGUELEN PLATEAU

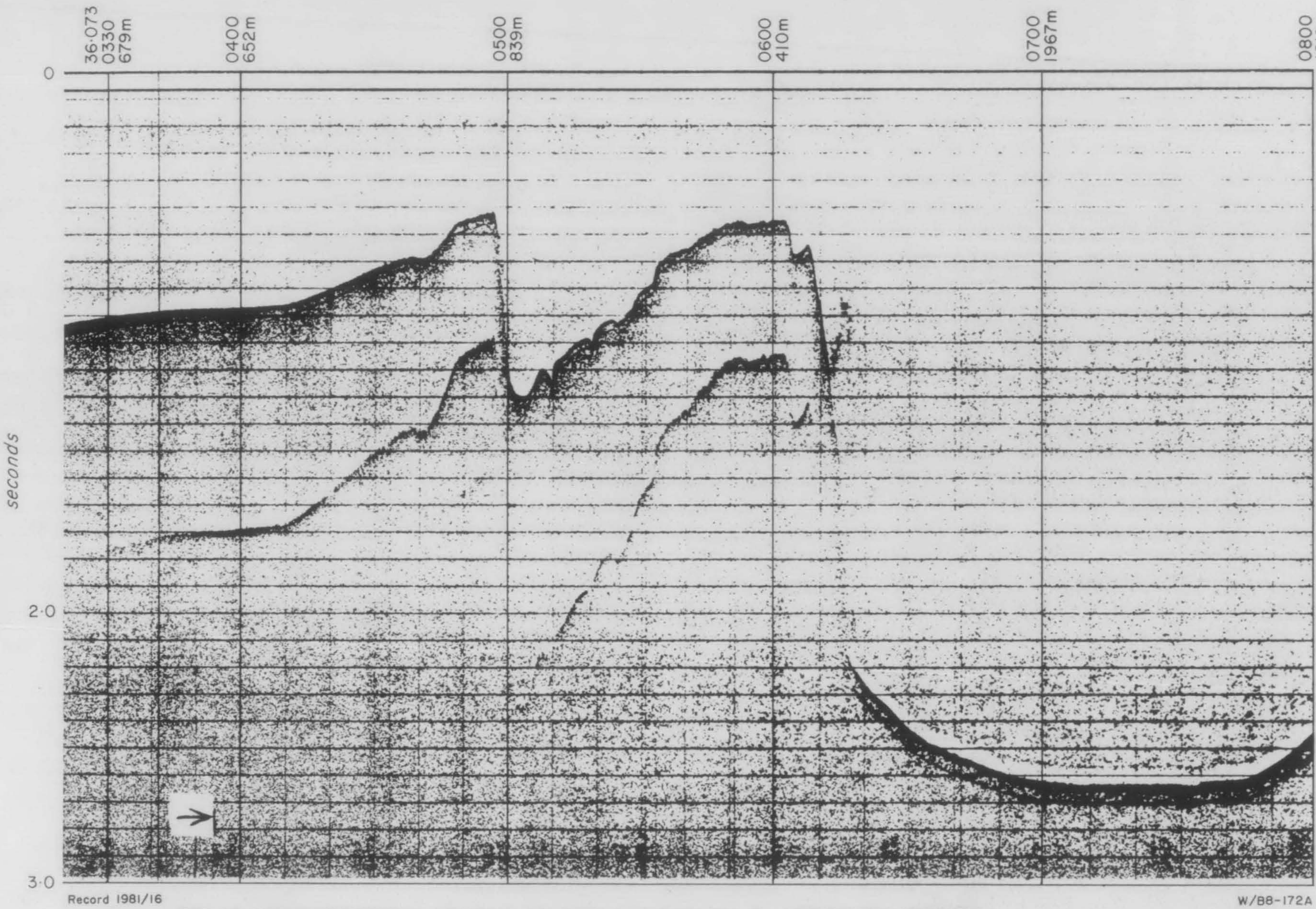
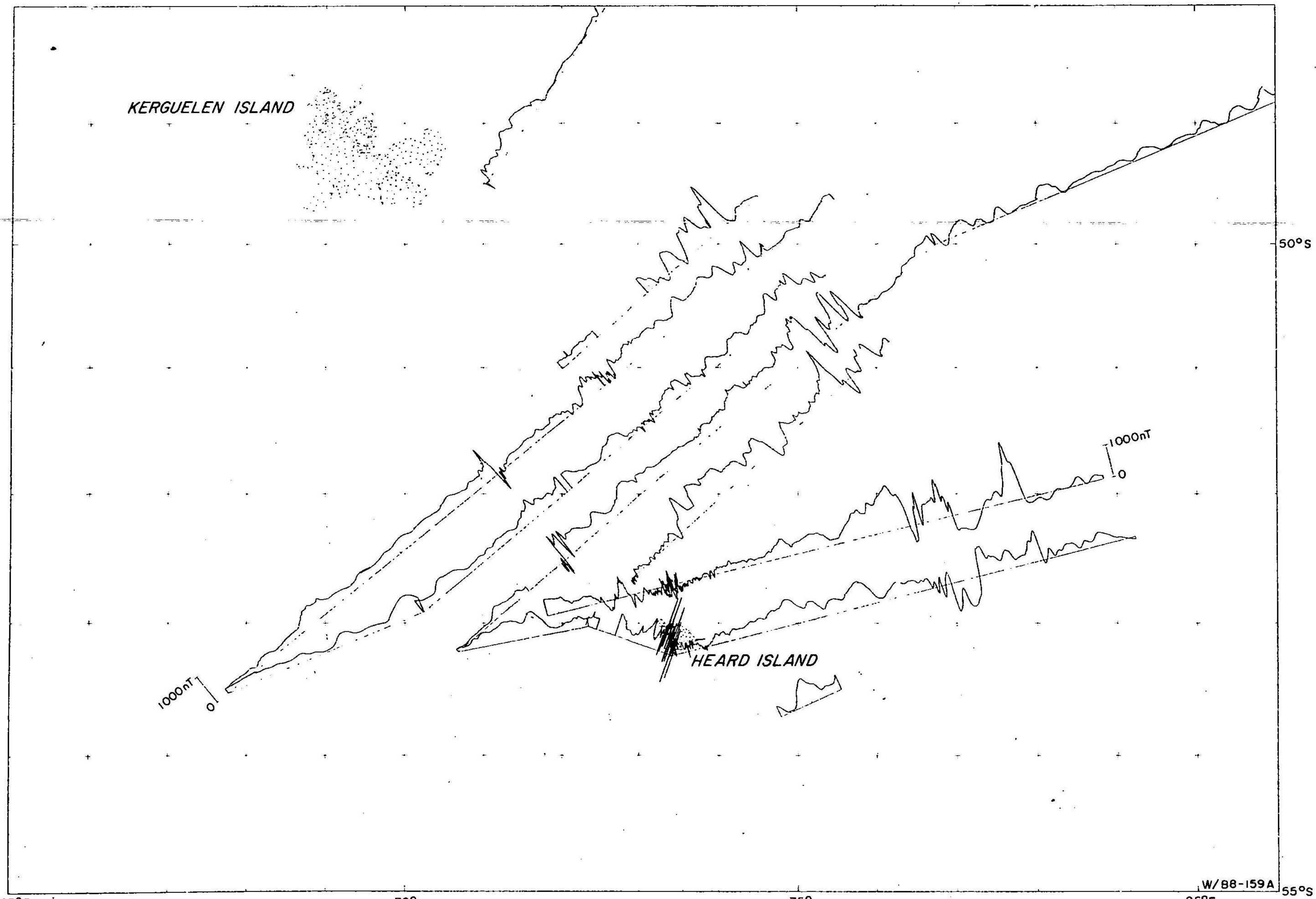


FIG.10 NORTHEASTERN MARGIN OF THE KERGUELEN PLATEAU AS SHOWN ON THE RAYTHEON ECHOSOUNDER RECORD



Record 1981/16

FIG.11 MAGNETIC PROFILES ACROSS KERGUELEN PLATEAU

SOUTHEAST INDIAN OCEAN

SCALE 1:10000000

EDITION OF 1980/09/08

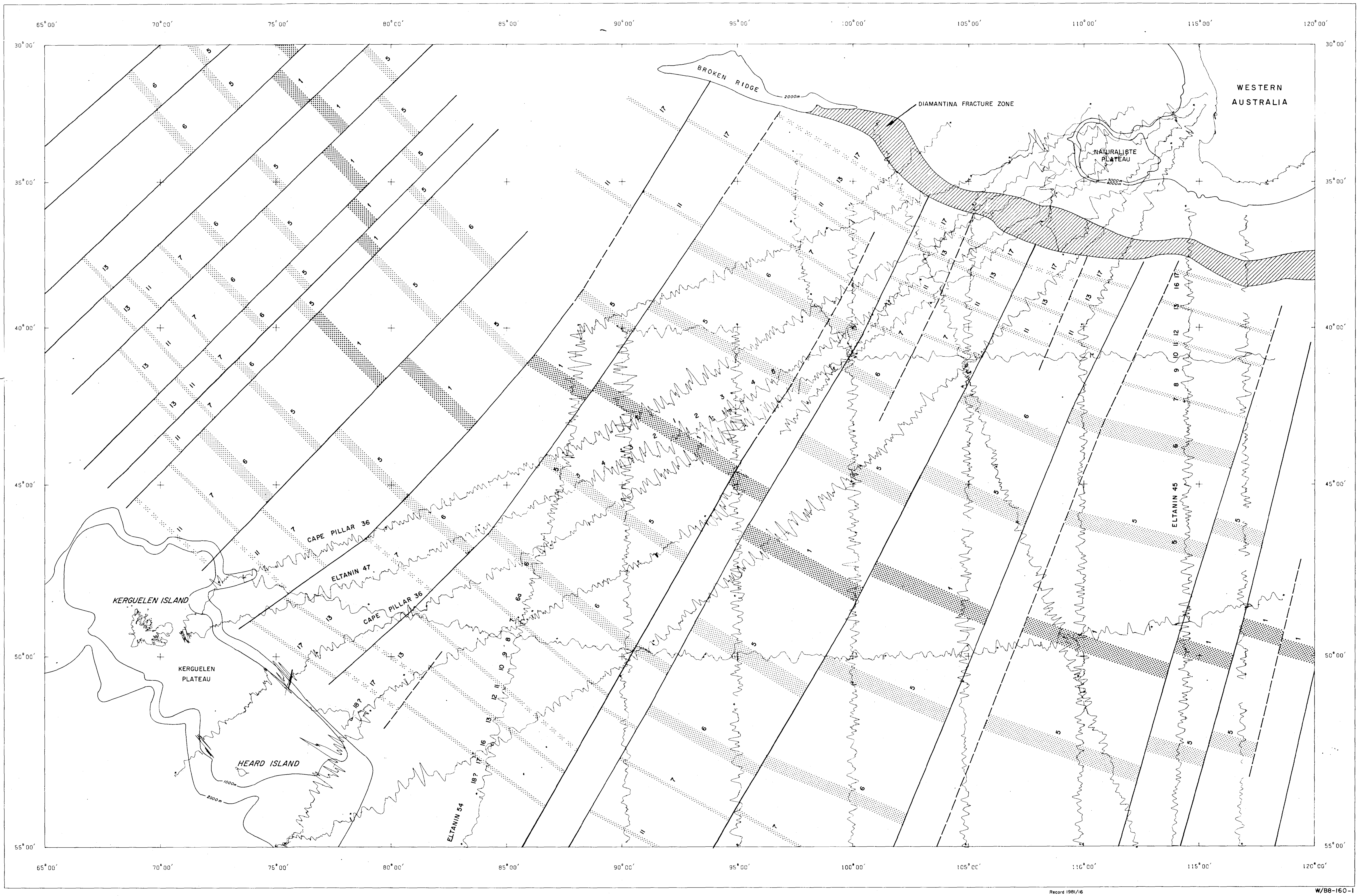


FIG.12 MAGNETIC PROFILES ACROSS THE SOUTHEAST INDIAN OCEAN

A.P.L. SPHEROID
STANDARD MERCATOR PROJECTION
WITH NATURAL SCALE CORRECT
AT LATITUDE 0°00′

PROFILE SCALE: 1 cm = 1000 nT
PROFILE BASELINE VALUE: 0 nT
• positive direction of profile, generally to north and west

CENTRAL ANOMALY

MAGNETIC ANOMALIES WITH ANOMALY NUMBER

MAGNETIC PROFILE WITH BASELINE AND DIRECTION OF POSITIVE ANOMALY

FRACTURE ZONE

The Heard-Kerguelen region of the Kerguelen Plateau is shown in Figure 8. This figure shows the bathymetric contours of Goslin and others (1978) and the tracks of this survey and previous surveys. The area is the shallowest part of the Kerguelen Plateau and is defined approximately by the 1000 m isobath. Several culminations rise to less than 500 m water depth. Two major exposures are Kerguelen Island, and the Heard-McDonald Island Group but only a small area around these island groups have depths less than 200 m.

The north-eastern margin of the plateau is a steep scarp which drops from 1000 m to the deep ocean floor at about 3500 metres water depth. Bathymetric profiles in Figure 9 show this scarp in detail and support the conclusions of Houtz and others (1977) that this margin is fault controlled. A section of the Raytheon bathymetric record across the eastern margin of the plateau illustrates the faulted nature of this margin (Fig. 10). Associated with the margin is a rugged bottom topography presumably caused by numerous volcanic extrusions. The steep scarp is broken by a small terrace that occurs midway down the slope on the southern profiles.

In contrast, the western margin is not as steep, deepening gradually from the plateau edge at 1000 m to the ocean floor at about 4500 m. This ocean basin is significantly deeper than the southeast Indian Ocean basin adjoining the eastern margin, leading to the speculation that it is much older. Several block structures trend northwesterly along the inner edge of the plateau.

South of Heard Island there is an easterly-trending scarp, with relief of about 500 m, which forms a topographic boundary between the northern and southern portions of the Kerguelen Plateau. The scarp may also be an expression of a structural boundary. Eltanin profiles reproduced in Houtz and others (1977) show a distinct change in basement from a volcanic/igneous intrusive complex in the north to a more subdued basement topography in the south. The southern portion, defined approximately by the 2000 m isobath, is much deeper than its northern counterpart and contains no island groups.

Magnetic anomalies across the Heard-Kerguelen region (Fig. 11) are highly disturbed overall, due to the shallow basement or abundant volcanics within the region. A zone of high amplitude, short wave length anomalies along the eastern margin of the Plateau is probably related to the volcanic/igneous complex shown in the Eltanin seismic data (line 4C in Houtz and others, 1977). The anomalies within this zone have amplitudes up to 2000 nT. The amplitude and frequency of the magnetics decreases westwards, reflecting the change to a more subdued basement topography.

Near Heard and McDonald islands, short wavelength (less than 0.5 km) anomalies of about 500 nT in amplitude reflect the shallow volcanic basement existing around these islands. In fact, the rugged seafloor topography apparent on the echosounder records suggests that the magnetic anomalies arise from sources within the seafloor or very close to it.

The block structures along the western margin all have large, high frequency magnetic anomalies associated with them, and are probably volcanic/igneous rocks formed as upthrown fault blocks or emplaced by normal extrusive processes. As several of these structures are flat-topped and lie at consistent water depths of about 260 metres, they have probably been subjected to subaerial erosion in the recent geological past. The Raytheon echosounding system, which normally gave 100-200 milliseconds penetration in sedimentary areas, gave no penetration over these block structures and very little penetration in the Heard-McDonald area in general.

Southeast Indian Ocean.

The two transit lines across the Southeast Indian Ocean were run subparallel to, and about sixty nautical miles north and south of, an Eltanin 47 line, a great circle line from Fremantle to Kerguelen Island. These lines have filled a gap in the existing traverse network and have allowed the magnetic anomaly pattern adjacent to the northeastern margin of the Kerguelen Plateau to be better defined.

The magnetic profiles from these transit lines are shown in Figure 12, together with existing data from Eltanin and Umitaka-Maru cruises. Fracture zones and anomaly identifications in the northwest have been taken from Patriat and others (1978), however major fracture zones in the east of the area, shown in Weissel & Hayes (1972) have been modified slightly. Selected bathymetric contours have been used to define the adjacent plateaus. The Diamantina Fracture Zone, a morphologic feature consisting of basement ridges and troughs, is also outlined in Figure 12.

Oceanic spreading anomalies, identified and labelled according to the system of Heirtzler and others (1968), have been correlated by using two key lines that for most of their length are apparently undisturbed by fracture zones, and therefore contain almost complete anomaly sequences. These key lines are an Eltanin 54 line running NNE along approximately longitude 85°E containing anomalies 5 to 18 on the southern limb of the spreading centre, and an Eltanin

45 line along approximately longitude 115° containing anomalies 5 to 17 on the northern limb. Anomalies 1 through 5 are readily identified on most lines, as for example Eltanin 47 (see Fig. 12).

On the Cape Pillar lines, anomalies 1 through 5 on both sides of the spreading ridge form a continous sequence with no offsets caused by fracture zones. Adjacent to the Kerguelen Plateau, the oldest anomaly encountered on the southern line is 17, while on the northern line the oldest anomaly is probably 11. These results are consistent with Schlich and others (1971) who found that anomaly 11 was the oldest anomaly north of Kerguelen, and Houtz and others (1977) who found that anomaly 17, and possibly anomaly 18 were the oldest anomalies east of Heard Island. These anomalies represent a continuous sequence progressively offset in a southwesterly direction by fracture zones. Two major fracture zones on the southern spreading limb apparently cross the Cape Pillar lines. On the northern line one fracture zone causes a repeated sequence near anomaly 6a, and the other zone causes a large offset of anomaly 6 and cuts the southern line in the vicinity of anomaly 11.

On the northern limb of the spreading centre, anomaly 17, and possibly anomaly 18, can be identified on both of the Cape Pillar lines immediately adjacent to the Diamantina Fracture Zone. One major fracture zone is also apparent, offsetting the anomaly pattern at anomaly 6 on the southern line, and at anomaly 9 on the northern line. Other minor fracture zones show little or no expression in the anomaly pattern.

Although the age of the ocean floor adjacent to the eastern margin of the Kerguelen Plateau varies from anomaly 18 (45 million years ago) to anomaly 11 (33 million years ago), the isobaths in the main are parallel to the isochrons and thus the northeast margin is not time transgressive in the sense of truncating the anomaly pattern. The Kerguelen Plateau can be reconstructed against Broken Ridge and the Diamantina Fracture Zone at about the time of anomaly 17 (or possibly anomaly 18), 43-45 million years ago.

The plateau north of Kerguelen appears to be the only region where major overlap may occur. Houtz and others (1977) have explained this overlap by the accretion of younger material to the northern portion of the plateau. As Kerguelen Island is still thermally active, they believe that the locus of a hypothetical mantle hot spot may be inferred to be moving slowly northward, gradually extending the plateau to the north.

In the ocean basin northeast of the region where overlap may occur, there are two large ridge offsets which have offset the spreading ridge by about 300 km to the southwest. As the distance between Broken Ridge and the Kerguelen

Plateau is approximately constant, these large offsets would require additional crust on the Broken Ridge side to maintain the observed configuration.

An alternative explanation is that a small ridge jump may have occurred at about anomaly 11 time, and that the missing anomaly sequence is attached to the northern limb southwest of Broken Ridge. This process would not need the accretion of extra crust, and would explain the large offsets found in the present Southeast Indian Ridge.

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APPENDIX 1: SCIENTIFIC PERSONNEL AND CREW MEMBERS OF THE HEARD ISLAND SCIENTIFIC EXPEDITION

SCIENTIFIC PERSONNEL.

Cornelius	VEENSTRA	NATMAP	Expedition Leader. Chief Surveyor.
Barry	OBST		S-i-C Bathymetry.
John	MANNING		S-i-C Onshore Surveys.
Rodney	STREETER		Surveyor.
Edward	GRAHAM		STO (Photography).
Kenneth	BROWN		STO
Jack	PITTAR		STO (Eng).
Michael	SPELLACY		TO.
Larry	TILBURY	BMR	Leader. Geophysicist.
Ronald	DULSKI		TO (Eng).
Gavin	JOHNSTONE	ANARE	Leader. Zoologist (Dr).
Richard	WILLIAMS		Marine Biologist.
John	JENKIN		Botonist (Dr), Melbourne University.
Ian	CLARKE		Geologist, Monash University.
Des	ROSS	Helo.	Pilot. Central Australian Helicopters, Alice Springs.
Roy	RAYNOR		Mechanic.

CREW OF M.V. CAPE PILLAR

Gordon	MAXWELL	Master.
Richard	IRELAND	Chief Officer.
Andrew	CODRINGTON	2nd. Officer.
Peter	VERHEYDEN	3rd. Officer.
Robert	McMANAMON	Marine Radio Officer.
Vernon	OSBORN	Boatswain.
Terry	MERSON	Shipwright.
Etham	ORMAN	Able Seaman
David	CLEGHORN	"
Warren	ROTHACKER	"
Charles	BRIDGE	"
Karl	BALLING	"
Alan	SCOTT	"
Noel	COBB	"
John	HATFIELD	"
Ronald	McNEILL	"
Ronald	DAVIDSON	Chief Engineer.
Peter	STOKES	2nd. Engineer.
Peter	PITTIGLIO	3rd. Engineer.
John	VINTER	4th. Engineer.
Peter	JIEAR	Electrical Engineer.
Peter	BIRCH	Wiper.
Maurice	FLOOD	"
Robert	LIDSTER	"
Perry	GARDNER	Chief Steward.
Patrick	HUTCHINS	Steward.
Alfred	AQUILLINA	"
Stephen	STOKOE	"
Timothy	ROXBY	Junior Steward.
Brian	FOWLER	Chief Cook.
Thomas	SPENCE	Cook.
Brian	MULLIGAN	Sculleryman.
Mervin	TRELOAR	Crew Attendant