DEPARTMENT OF NATIONAL RESOURCES

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RECORD 1976/84

VEMA CRUISE 33 LEG 1
OVER THE
SOUTHEAST INDIAN RIDGE,
17 NOVEMBER TO 17 DECEMBER, 1975:
OBSERVER'S REPORT

by

L.A. TILBURY

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SUMMARY

A marine geological and geophysical survey was carried out in the southeast Indian Ocean in November and December, 1975, by Lamont Doherty Geological Observatory using the research vessel Vema. The survey covered about 9000 line km and included traverses along the crest of the Southeast Indian Ridge and along Anomaly 6 on the Indian and Antarctic Plates. Rock samples were dredged from the ridge crest and heat flow and seismic refraction measurements were taken along Anomaly 6. Seismic reflection, magnetic, gravity and bathymetric data were collected routinely during the survey.

Data of particular interest to BMR are the seismic, bathymetric, gravity, and magnetic data collected while traversing the Australian margin off western Tasmania and off South Australia on the Beachport Plateau. Velocity information was collected from five sonobuoy probes on the margin. Two on the Tasmanian continental slope indicated a basement refractor of velocity 5.8 km/s which is probably The Upper Proterozoic basement surface, and three on the Beachport Plateau indicated a 'basement' refractor of velocity 4.8 km/s which is probably the top of the Lower Cretaceous Otway Group of the Otway Basin.

Ocean bottom seismometers (OBS) were used by Lamont to monitor microseismicity and deep crustal refraction shots. Each OBS contains vertical and horizontal seismometers and a hydrophone as the detector units. Seismic information and time pips are recorded on a tape recorder within the OBS. After recording for up to 12 days, the OBS is automatically released from the sea-floor and recovered at the surface. The instruments are most useful for refraction work where the offset shooting distance is greater than the transmitting range of commercially available sonobuoys. They would be particularly useful to BMR for refraction work on the marginal plateaux around Australia.

The computer system on board the R.V. Vema consists of two PDP 11 computers (16K core) coupled via a bus switch to two discpacks. Peripherals include teletypes, a visual display unit, a DECTAPE unit, and a drum plotter. The system is divided into a REAL-TIME side for on-line acquisition of data, and a BAYCH side for the batch running of navigation and interpretational programs.

1. INTRODUCTION

The southeast Indian Ocean has been systematically surveyed by the USNS Eltanin. Interpretation of data from these cruises has led to the recognition of the seafloor spreading pattern of magnetic lineations and fracture zones (Weissel & Hayes, 1972) and indicated the general sediment distribution (Houtz & Markl, 1972) and the general morphology of the region (Hayes & Conolly, 1972).

Weissel and Hays outlined the cruise proposals for Vema legs V33-01 and V33-02 in their submission to the US National Science Foundation. They proposed to collect detailed data which would test certain aspects of their interpretation which are difficult to reconcile with observations in other oceans. In particular a boomerang-shaped regional depression across both the Indian and Antarctic plates defined from 'depth anomalies' was to be investigated. A depth anomaly is the difference at a point between the observed depth to acoustic basement, corrected for the effect of isostatic adjustment under sediment loading, and a reference depth which is the average depth to acoustic basement for oceanic crust of the same age, compiled from worldwide observations. Furthermore, the nature of asymmetrically generated crust was to be investigated by making detailed traverses between Seafloor Spreading Anomalies 6 and 7.

Tracks were proposed along Anomaly 6 both north and south of the ridge, and along the ridge itself. Detailed traverses were proposed in a 2° by 2° square between anomalies 6 and 7 on both the Indian and Antarctic plates.

The following brief summary of the elements of the program and the rationale behind them has been taken from their proposal:

1) Rock dredging from the ridge crest to detect possible variations in basalt chemistry along ridge flank isochrons generated by the interaction of a mantle cold spot with an accreting plate margin.

2) Monitoring of microseismicity along the ridge crest using ocean bottom seismometers (OBS) to investigate the scale and mechanics of the accretion processes.

3) Measuring the heat flow along Anomaly 6 to investigate the relation, if any, between depth anomalies and variations in heat flux through the plate. It is predicted that depth anomalies of about 1 km caused by 'abnormal' thermal contraction of lithosphere should be associated with heat flow anomalies of about 0.5 HFU.

4) Conducting seismic refraction crustal studies along Anomaly 6 to examine the possible relation between depth anomalies and variations in the structure of the lithosphere such as changes in the thicknesses of the oceanic crustal layers.

5) Conducting detailed studies over once contiguous areas of asymmetrically generated crust to determine whether the accretionary process occurred continuously with time or by small, discrete episodes of spreading.

The BMR cooperation with Lamont-Doherty Geological Observatory entailed providing $15,000 (mainly for explosives) and 30 sonobuoys as its contribution towards the four legs sailed around Australia between November 1975 and March 1976. In return, the BMR had a representative onboard the RV Vema as a scientific observer and will receive copies of all data collected. The other three legs of cruise 33 are discussed in reports by Jongsma (1976), Petkovic (1976), and Stagg (1976).

Apart from the Magnetic Quiet Zone cruise on the southern Australian margin, the data of main interest to BMR were from the traverses across the continental margin which were surveyed while sailing to and from Lamont's survey areas. Where possible, sonobuoy probes and traverses were placed to complement traverses of BMR's Continental Margin Survey (see Fig. 2 and 3).

2. CRUISE DETAILS

Cruise summary

A schematic of the ship's track is shown in Figure 1. The Vema left Melbourne at 0500 hrs on Monday 17 November and after picking up explosives at Point Wilson began surveying at 1900 hrs. A line was run approximately due south across the Bass Basin, along the continental margin adjacent to northwestern Tasmania, southwest to Joides site 182, and thence westwards to the survey area along latitude 44°S (Figs 1 and 2). Two sonobuoy probes were successfully deployed off the Tasmanian coast. A basement refractor of 5.8 km/s, most likely to be continental basement, was detected on the first probe.

On 20 November an ocean bottom seismometer (OBS) was deployed for test purposes. A refraction line was shot in one direction using dynamite and the OBS, and then in the reverse direction using a long-range sonobuoy.

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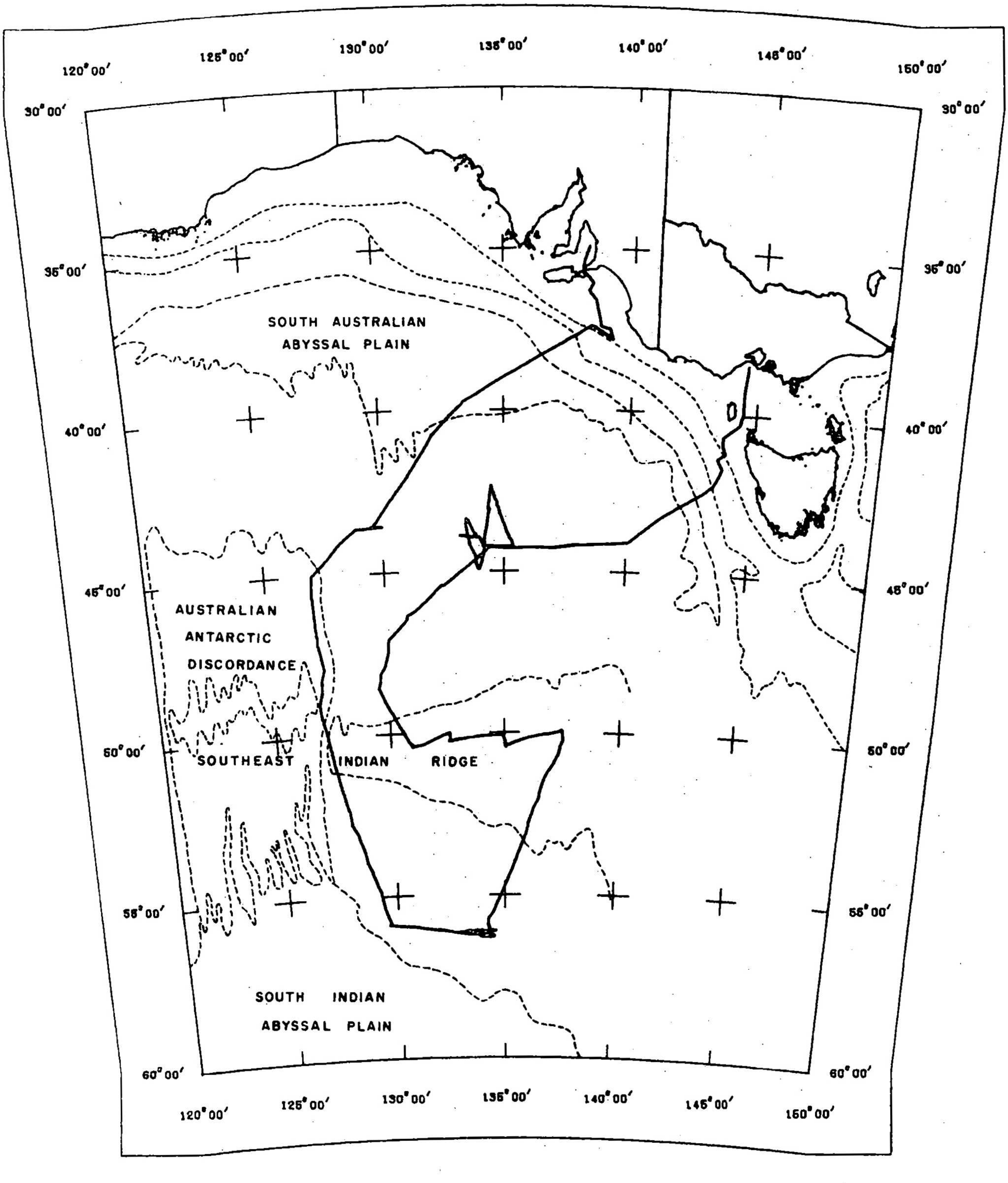

Fig. 1 VEMA V33-01 TRACK IN SOUTHEAST INDIAN OCEAN

1:2500000 TASMANIA

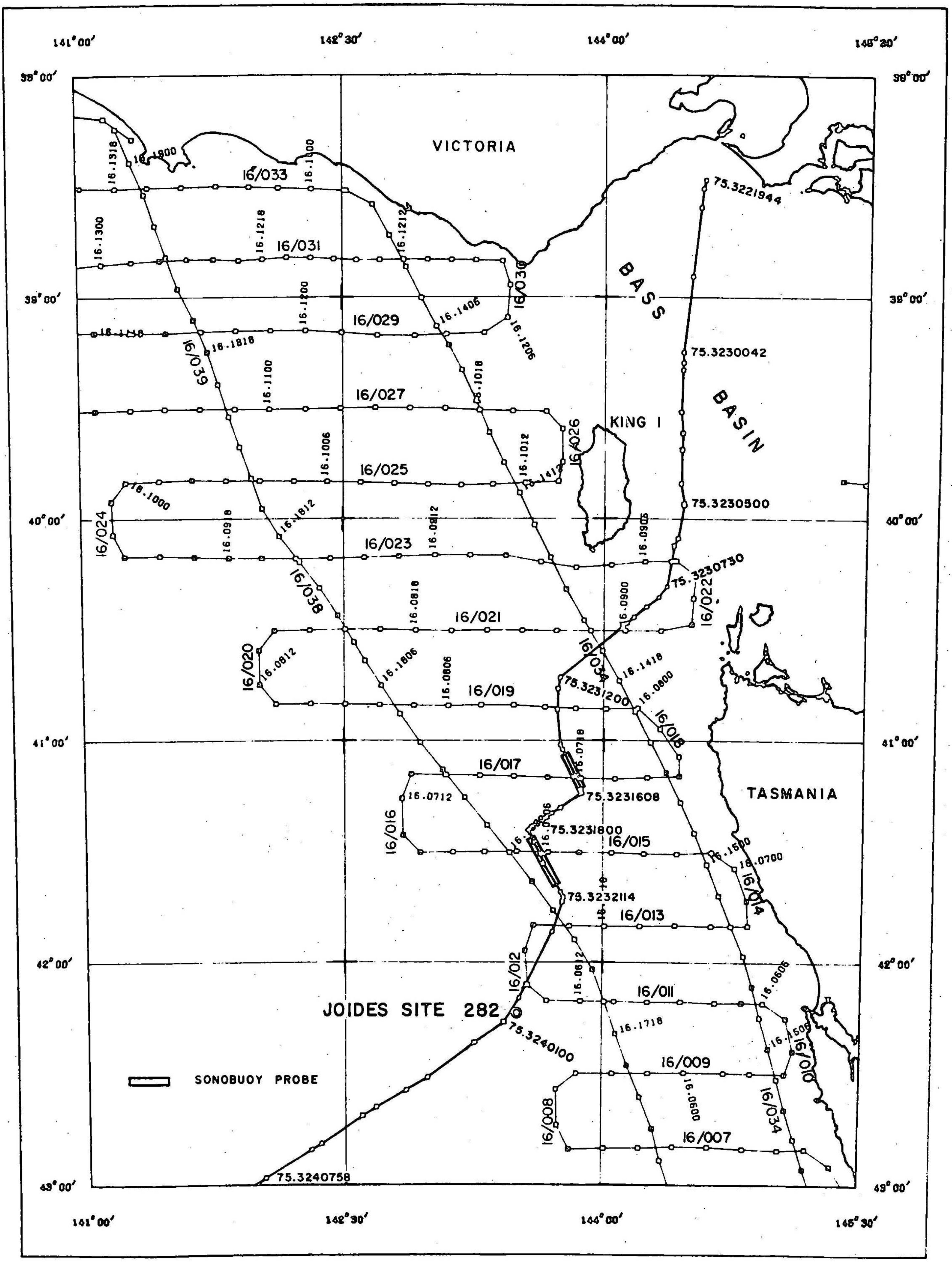

Fig. 2 VEMA V33-01 TRACK AND SONOBUOY LOCATIONS ON TASMANIAN MARGIN

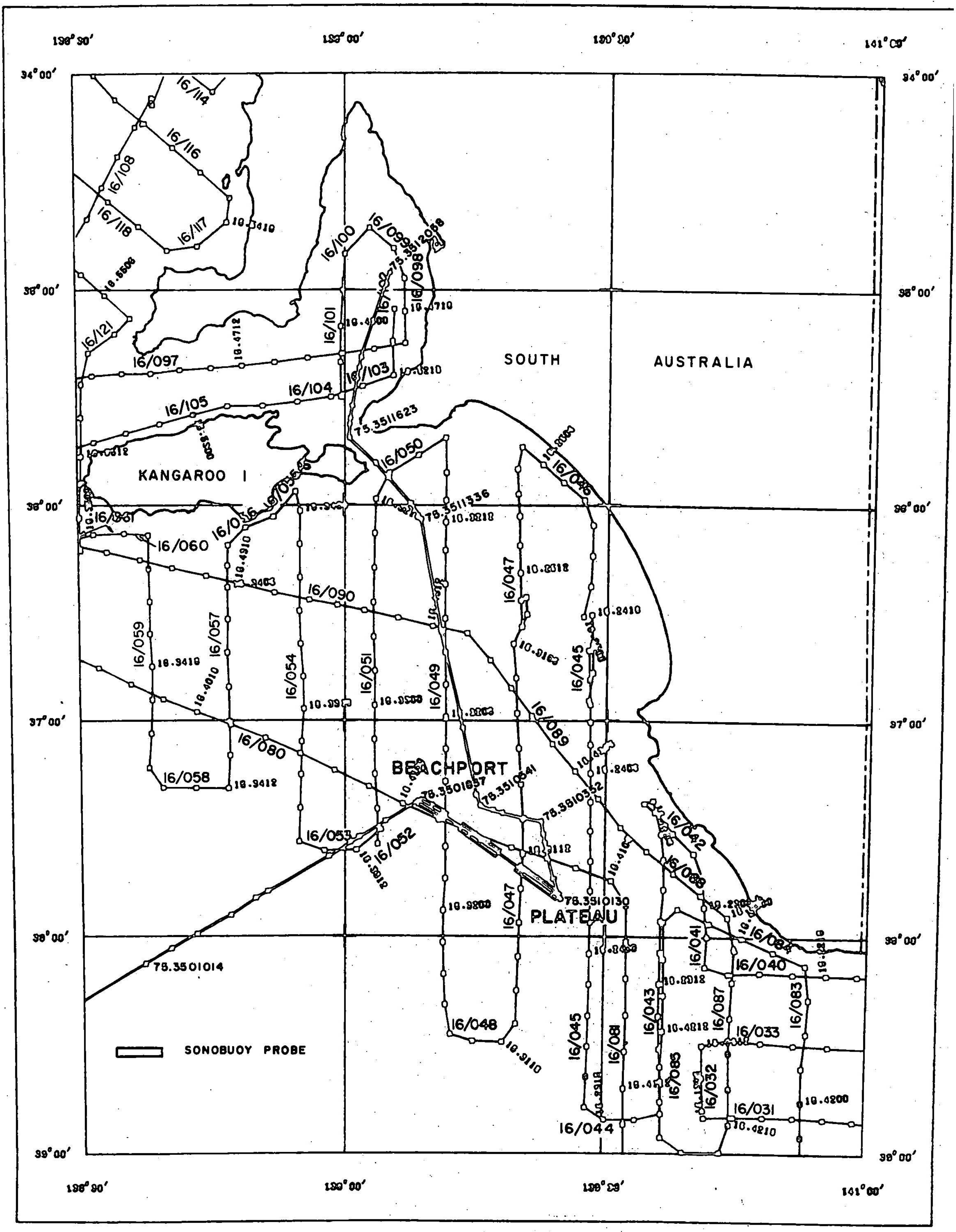

Fig.3 VEMA V33-01 TRACK AND SONOBUOY LOCATIONS ON SOUTH AUSTRALIAN MARGIN

Between 22 and 27 November, survey work was carried out in the 2° by 2° square between Anomalies 6 and 7. Owing to adverse weather conditions, only two north-south lines, a deep crustal refraction probe using three OBS spaced 20 n miles apart, and two core samplings with T-grad sensors attached (Appendix) were successfully carried out. For most of this time the gravity meter had to be clamped.

From 27 to 30 November a survey line was run southwest from the 2° x 2° square to the Southeast Indian Ridge crest. Only magnetic, bathymetric, and seismic reflection measurements were made along this line. The gravity meter was put out of service for the remainder of the cruise by several severe rolls of up to 45°.

Four dredge sites were occupied along the ridge crest between 30 November and 2 December. All dredge hauls were successful with between 30 and 250 lb of fresh basalt being dredged at each site. The dredge stations were sited on a narrow magnetic anomaly superimposed on the main central magnetic anomaly (Anomaly 1). This small anomaly is supposedly caused by highly magnetized oceanic crust which is the youngest crust on the ridge. The anomaly is associated with a topographic high in most places but in one area, in the Australian-Antarctic discordance (Weissel & Hayes, 1972), is associated with a rift valley.

A survey line was then run south-southwest to the southern 2° x 2° square. Only a multigrad probe (Appendix), core and T-grad probe, and OBS refraction work were carried out. An OBS was not recovered and two survey days were lost searching for it.

On 8 December the Vema sailed westwards along Anomaly 6 of the Antarctic Plate. Two cores and T-grad probes were taken before the ship headed northwards for Adelaide on 9 December.

Another dredge haul was taken on the ridge crest, and a long-range sonobuoy and multigrad probe along latitude 44°S. Three sonobuoy probes and extra traversing were carried out on the Beachport Plateau to complement BMR survey work (Fig. 3). A survey line across the South Australian continental shelf was done before the ship docked at Adelaide on 17 December.

BMR seismic recording

Onboard the RV Vema, the BMR had a 14-track FM AMPEX tape recorder for permanent storage of seismic information and an EPC electrostatic recorder for an on-line monitor. A spare AMPEX and a spare EPC were onboard as backup.

Seismic information was not recorded on BMR equipment until 18 November at 1545 hrs, after most of the line off the Tasmanian coast had been run. Several problems arose when trying to couple the BMR tape recorder with the Lamont seismic system. The signal from the Lamont cable was very weak and a spare amplifier had to be found and used to solve the problem. The amplifier proved to be excessively noisy. In addition, the shot instant trigger was very noisy. This problem was partly remedied by building a Shmidt trigger unit, but the EPC recorder was still occasionally triggered from spurious noise in the shot instant signal.

The trigger was then taken from Lamont recorders. This was more successful but data were lost whenever the Lamont recorders stopped or malfunctioned. Paper changes every 3 hours and radio transmissions once or twice a day caused data losses of up to half an hour or more each time.

The seismic information was recorded on 2 tracks of 14 track tapes, using an AMPEX tape recorder. Eight tapes were produced during this cruise, each tape holding up to 63 hours of data. The seismic data appear from the monitor records to be of reasonable quality, but as the EPC monitor was on an 8-s sweep with no extra filtering of input, the quality is difficult to judge.

Sonobuoys

The four BMR 'Select' buoys supplied to Lamont were deployed unsuccessfully. RF signals from the first two, which were deployed off the west Tasmanian coast, were not received owing to a problem in the Aquatronics receiver. Signals from the third buoy, on the Beachport Plateau, were of no value because the sonobuoy failed to release its hydrophones. Reflection hyperbola were discernible in the record but the noise was too high and recording was abandoned. In all cases of failure of the BMR sonobuoys, Lamont buoys were used instead and good refractions were obtained. The fourth buoy was placed in a bucket of water to check if the hydrophones were released. They did not, although the buoy transmitted for over 10 hours.

To ensure the hydrophones are released the Select buoys must be manually deployed. It is best to deploy the buoys in a bucket of seawater to check if the audio electronics and firing pin are activated. This also allows the sonobuoy receiver to be tuned before launching the buoy. If the hydrophones are not released they must be manually deployed. This involves cutting the two wires to the firing pin and removing the U-bolt and firing pin. The bottom portion of the buoy then falls away releasing the hydrophones.

3. OCEAN BOTTOM SEISMOMETERS (OBS)

Ocean bottom seismometers have been developed and used by several scientific institutions. Papers have been published by scientists at Lamont-Doherty Geological Observatory (Carmichael et al., 1973), the Institute of Geological Sciences, England (Francis et al., 1975) and the University of Washington (Lister & Lewis, 1976). The instruments were originally designed for monitoring microseismicity on the mid-ocean ridges. However, they are increasingly being used for deep crustal refraction probes. A line drawing of the OBS used by Lamont is shown in Figure 4.

On RV *Vema* leg V33-01, three OBS were used for refraction probes in three areas. In a typical instance, they were deployed in an east-west line about 20 n miles apart. Refraction shooting was then done along the line using dynamite charges ranging between 4 and 100 lb. This configuration resulted in two reversed profiles between the buoys and a single profile at each end. The complete refraction probe from positioning the first OBS to recovering the last OBS usually took about 28 hours. The time taken to do the OBS refraction work is about the same as the time taken to do similar work with long-range sonobuoys. If reversed profiles are required a sonobuoy experiment would take about 24 hours.

Description

The OBS contains vertical and horizontal seismometers and a hydrophone as the detector units. The main function of the hydrophone is to detect the D-wave. Signals from the detectors and time pips from a master clock are amplified and recorded in FM form on a modified SONY 4-track tape recorder. Recording continues for 10-12 days. Circuitry is powered by about 12 lithium cells, each with a rated life of 10 ampere hours. Preset delay switches incorporated into the circuitry are used to control the OBS functions. Delays include those for time on bottom, time before main circuitry switches on, time for backup release to activate, etc. A schematic diagram of the OBS record unit is shown in Figure 5.

Sequence of events in OBS

1) Prelaunch procedures

The preset delay switches in the OBS are set to the required times and the pressure cylinder is sealed and evacuated to check for leaks. The OBS is weighted down with an extra 100 lb of lead. This is sufficient for the OBS to reach the sea bottom in about two hours in water depths of 5000 m. Immediately before the OBS is launched, the preset delay switch is zeroed to start delays and turn on the master clock and pinger. The OBS is then launched using an overhead crane and its progress is monitored on the PDR recorder.

2) After reaching bottom

After the first delay time, the pinger is switched off and the system electronics are turned on. The delay unit provides a 'gimbal unlock' function to permit self-levelling of the seismometers. After levelling, the gimbals are relocked to give rigid coupling between seismometer and main frame. Fifty minutes later, the delay unit calibrates the seismometers by generating sweeps of various frequencies at various amplitudes. This frequency domain calibration consists of four sweeps of frequencies varying between 100 and 0.8 Hz with the amplitude level of each sweep 10 dB below the preceeding sweep. Every 24 hours a 'time domain' calibration occurs.

3) OBS active

After the calibration, the OBS is in its normal recording mode and can be used for recording refraction shots or monitoring microseismicity.

4) After active period

About two hours before the end of the active period, the pinger is turned on. This is useful for locating the OBS on the sea-bottom because once the ship is within 6 n miles of the OBS station, the pinger signal is received on the PDR. The trace of the pinger signal increases on the PDR as the ship steams towards the site (Fig. 6b), and when it is a maximum, the OBS lies below or to one side of the ship. The exact position can be determined by turning the ship 90^{o} and finding another maximum. The ship is then positioned above the OBS to await its ascent to the surface.

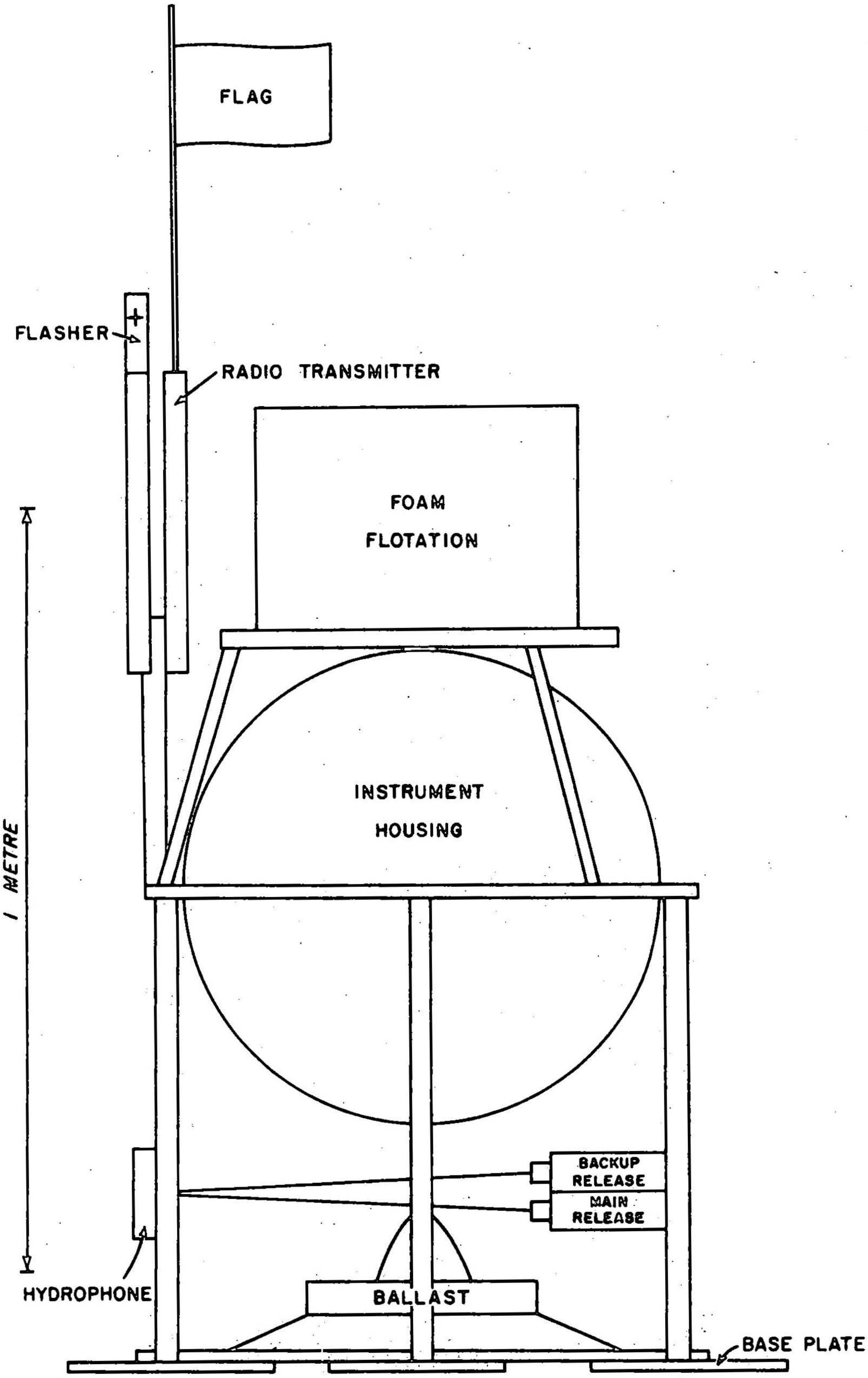

Fig. 4 LINE DRAWING OF OCEAN BOTTOM SEISMOMETER

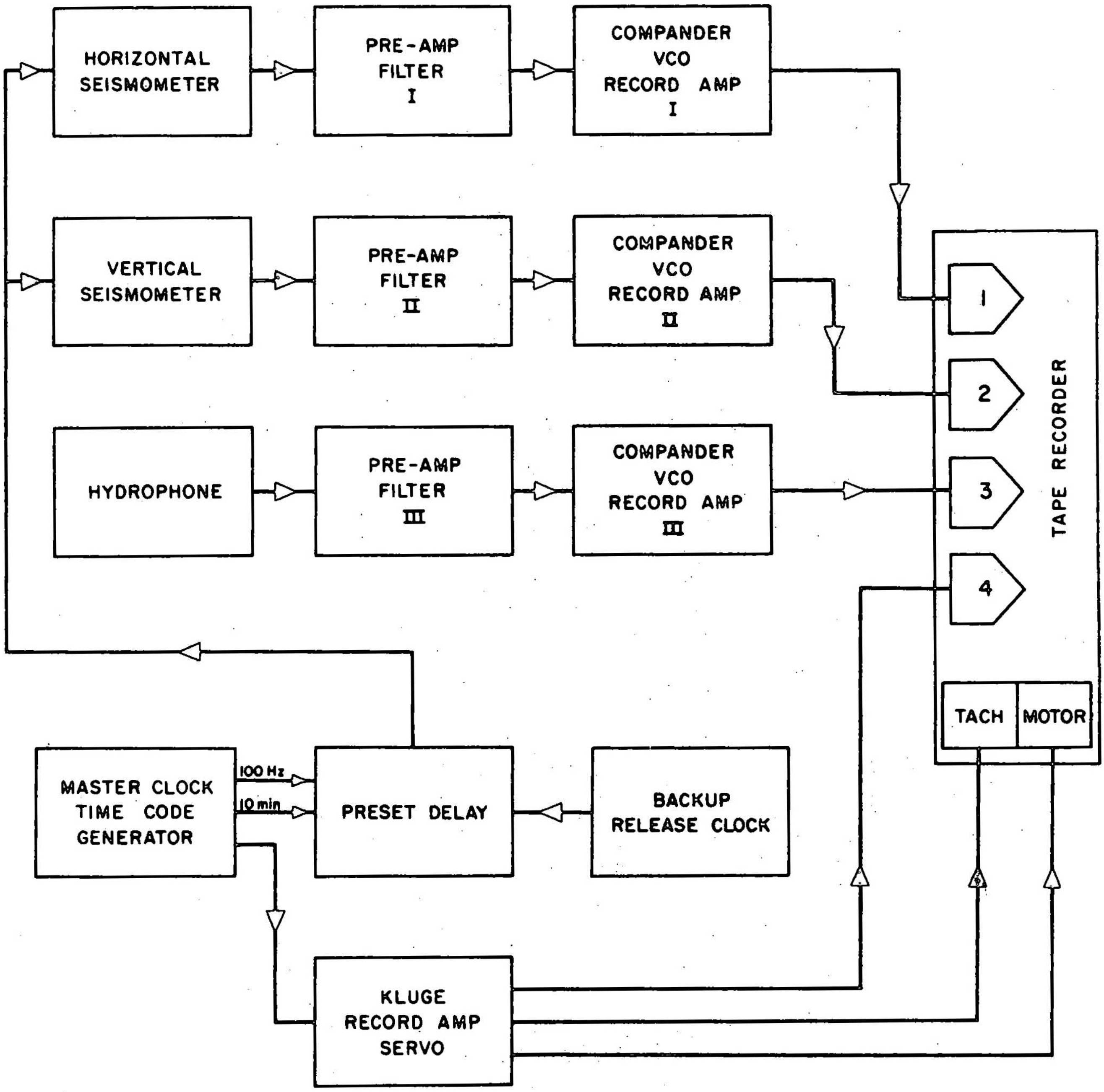

Fig. 5 SCHEMATIC DIAGRAM OF OCEAN BOTTOM SEISMOMETER RECORD UNIT

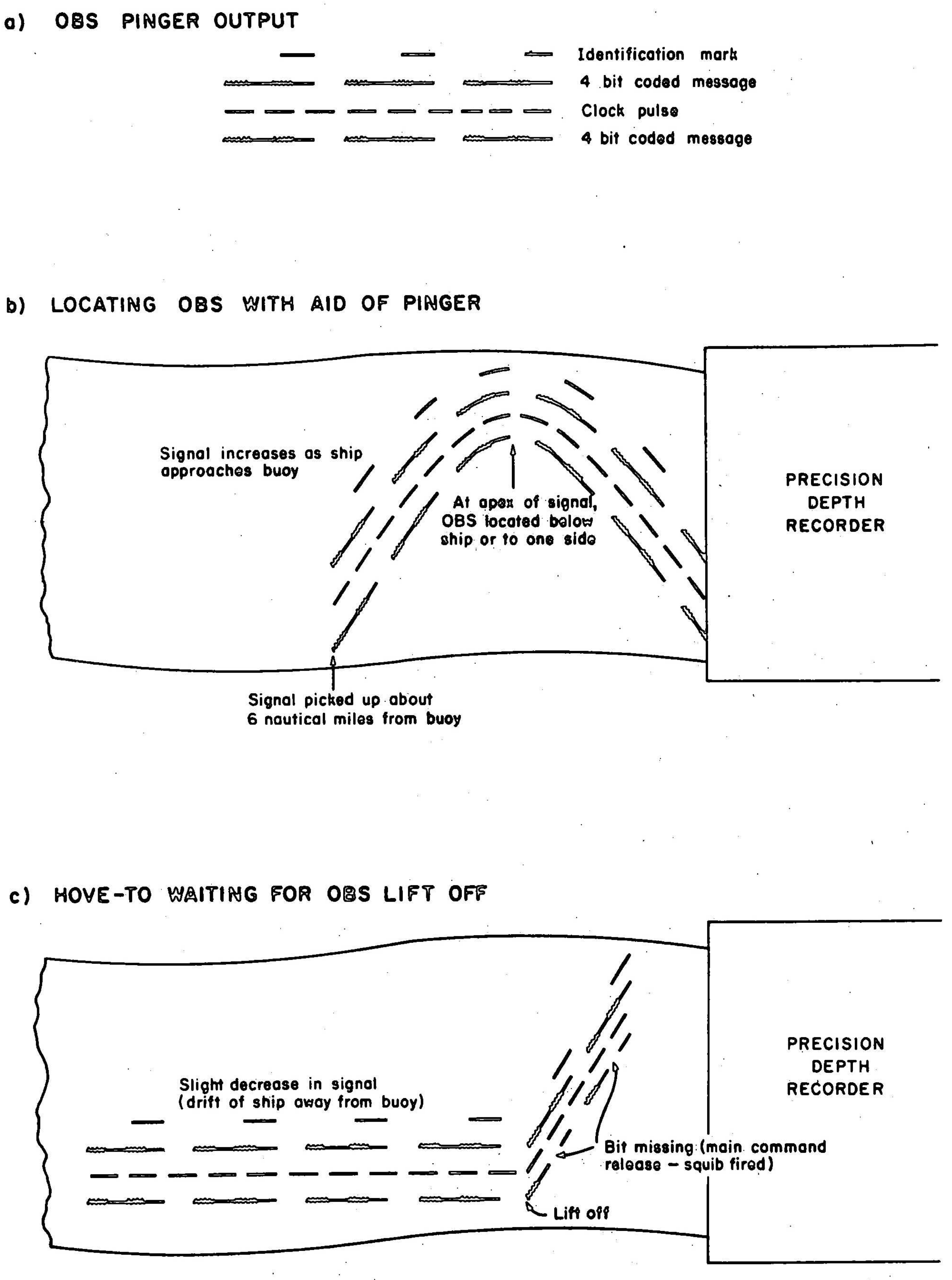

Fig. 6 OCEAN BOTTOM SEISMOMETER (OBS) PINGER OUTPUT AS DISPLAYED ON PRECISION DEPTH RECORDER

At the main release time a squib is fired which releases the lead weight and base plate causing the OBS to rise to the surface under its own buoyancy. A backup release squib is fired after a set interval, usually about an hour. The back-up release time is deliberately set well after the main release time to allow for time slop in the second oscillator.

The status of the OBS is indicated by the coded messages in the pinger signal (Fig. 6a). A bit drops out for each function performed. For instance, Figure 6c illustrates how a bit is deleted from the signal when the main release squib is fired.

5) Retrieval

The OBS has flashing lights, coloured flags, radio transmitter, and radar reflector so that it can be located on the surface. At night it is easily found as the lights can be seen many miles away. During the day a RDF (Radio Direction Finder) is used to guide the ship towards the buoy and lookouts are posted to search for it. Once the buoy is located, the ship manoeuvres to allow it to be hooked and lifted aboard ship by an overhead crane.

Advantages of using ocean bottom seismometers

a) Noise sources on ocean bottom are insignificant compared to those on the surface, so the signal/noise value is high.

b) Using them saves the cost of having a second ship as the receiver station.

c) They can be deployed in arrays to give a 3-D profile.

d) Unlike sonobuoy signals, OBS signals are not transmitted and recording is therefore unaffected by ship-detector separation.

e) Their operation is not affected by water depth, whereas the performance of sonobuoys deteriorates as the depth of water increases.

f) They can operate in any sea state whereas sonobuoys cannot be used in moderate or rough seas.

Disadvantages

a) Probably the biggest disadvantage of using OBS is the risk of losing them - they cost about $25 000. However, costs are decreasing as more are being built and Lamont are now working on an ocean bottom hydrophone (OBH) which will cost only about $5000.

b) OBS signals are not monitored onboard ship, so preliminary results are not available to assist decision-making in a continuing refraction program. A consequence is that excessive amounts of explosives must be used in refraction shots to ensure that sufficient energy is available.

c) It is difficult to obtain the status of the OBS while shooting, so it is not known if it is recording properly. If a sonobuoy fails, another buoy with different channel frequency can be immediately deployed, and the refraction program continued with minimum loss of time.

d) Considerable ship time is lost in deploying and recovering the OBS, causing interruptions in the normal seismic reflection surveying. However, if a comprehensive refraction program including several reversed profiles is undertaken, the time difference between using OBS and long-range sonobuoys is minimal.

4. COMPUTER SYSTEM

The computer system onboard the RV Vema was established primarily to reduce data on-line as an aid to preliminary interpretation. As such the system does not have the data acquisition and assessment aspect that BMR requires and it is this which is the main shortcoming of the Lamont system.

The system consists of two PDP 11 computers coupled via a bus switch to two discpacks. Each computer is a digital, ruggedized model with 16K of core. Discpacks are the cartridge type and have a capacity of 1.2 million words each. Peripherals include two teletypes, a visual display unit (VDU), a paper tape reader/punch, a small magnetic tape recorder (DECTAPE unit), and a drum plotter. A schematic of the system is given in Figure 7.

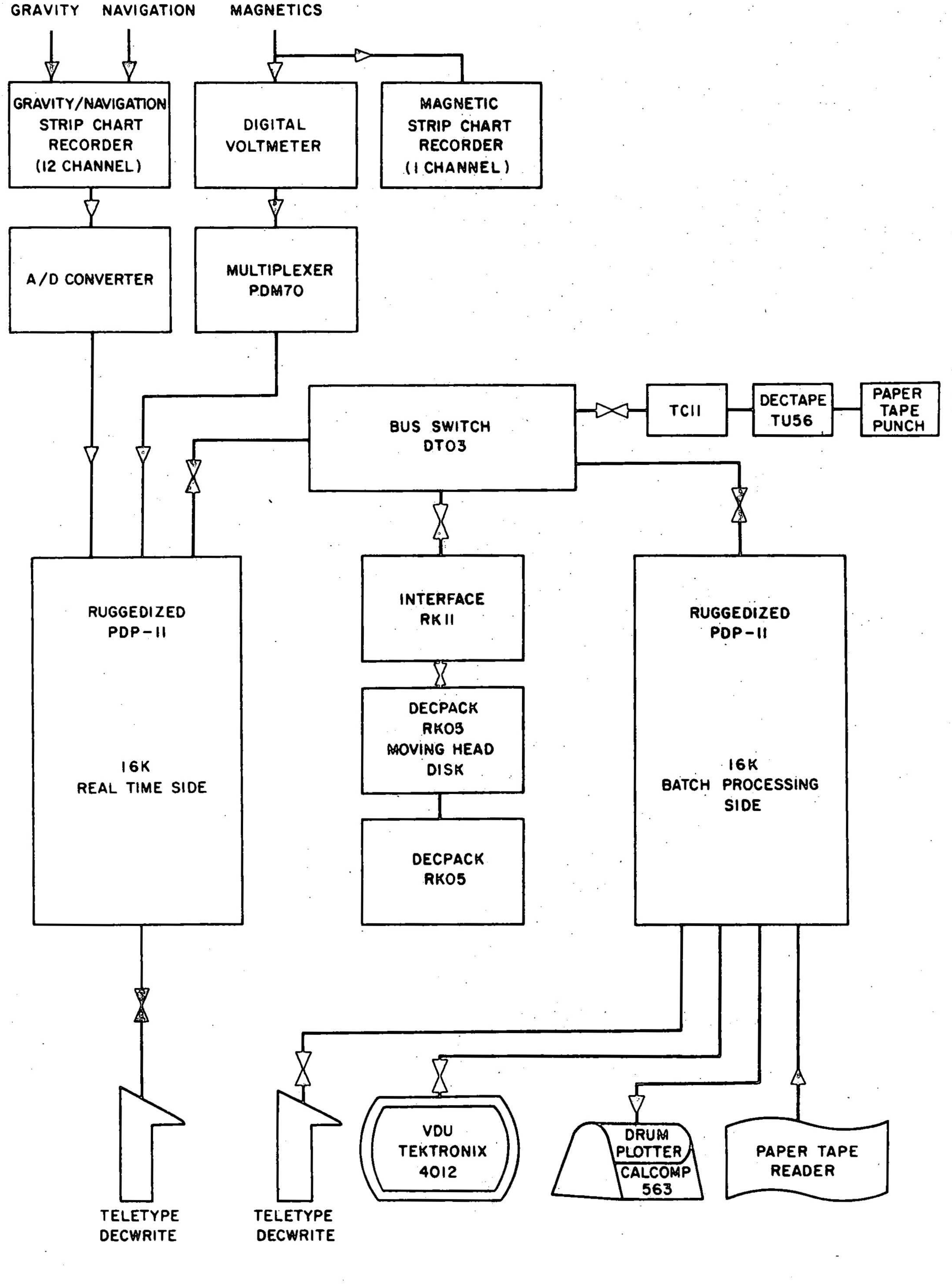

Fig. 7 SCHEMATIC DIAGRAM OF COMPUTER SYSTEM ONBOARD RV VEMA

The system is divided into a REAL-TIME side and a BATCH processing side with one computer allocated to each task.

Real time side

Ideally the magnetics, gravity and navigation data are saved at 6-minute intervals on disc. Water depth data are manually digitized and input through a teletype (or VDU) to be merged with the real time data. Approximately 3 cruises of data can be saved on one disc. If post-processing is required the disc can be removed and returned to Lamont where it can be read on an identical computer system.

Normally this data file is accessed by the BATCH side and programs are run to reduce and plot the data in profile or map form.

However, there are still problems with the acquisition of data and thus the real-time side has not been very successful. On Leg V33-01 it was not working at all owing to hardware faults in the computer system.

Batch side

The batch side is for the batch running of programs and is used for basic data reduction and display. The NAVIGATION suite of programs is most commonly used during normal operations. Satellite fixes are calculated about every hour from data on paper tape output by a US Navy Satellite system. Each day a satellite alert program is run to give a listing of alerts. Other programs are used to merge the satellite fix data and ship's log data, to produce a file of corrected dead-reckoned positions, course, speed, and current. This file can be used to produce a plot of the ship's track.

A large suite of GEOPHYSICAL programs is also available. These include programs to reduce the gravity, magnetic, and bathymetric data and to list or plot the data in profile form. Further programs can be used to plot anomaly profiles along the ship's track or projected onto a straight line of a chosen orientation.

Relevant points to note from the Lamont system

a) Lamont have successfully used moving head discs at sea. BMR had no end of trouble with a fixed head disc during the Continental Margins Survey.

b) The DECTAPE unit, a small magnetic tape recorder attached to computer system, provides a useful backup system for program loading which may be preferable to the normal BMR practice of using paper tape.

c) Programs are written in FORTRAN and therefore can be easily modified by the scientific personnel onboard.

d) An identical computer system is kept at Lamont. This has several advantages:

- data returned to Lamont on disc can be easily processed because of the compatibility between the ship and shore systems,
- programs can be developed or modified at Lamont and then sent to the ship,
- problems with the shipborne system can be investigated at Lamont as well as on the ship, and any advice relayed to the ship.

5. CONCLUSIONS AND RECOMMENDATIONS

Valuable geophysical information along 9000 km of traversing has been obtained from RV <u>Vema</u> cruise V33-01 in the southeast Indian Ocean. About 1000 km of this surveying was done on the Australian Continental Margin and included traverses off the west coast of northern Tasmania, and over the Beachport Plateau off South Australia (Fig. 1).

The data of particular interest to BMR are the seismic, bathymetric, gravity, and magnetic ties to the BMR Continental Margins Survey, five sonobuoy refraction probes, and data from a survey line near Tasmania which ties the BMR traverses to Joides site 182 in the nearby abyssal plain.

Two sonobuoy probes were made on the Tasmanian continental slope, where BMR data indicate over 1 km of sediment. These were on the upper slope at 1390 m water depth and on the lower slope at 3316 m. Preliminary interpretation indicates a basement refractor of velocity 5.8 km/s. No allowance for dip was made, so the velocity is over-estimated. The refractor is probably Upper Proterozoic rocks which crop out in western Tasmania.

On the Beachport Plateau extra traversing was run to complement BMR coverage (Fig. 3). Three sonobuoy probes were made across the centre of the plateau where the water depth is about 700 m, and the sediment thickness ranges from about 0.3 to over 1 second of two-way reflection time. A rather low 'basement' refraction velocity of about 4.8 km/s was measured. The refractor is probably the Lower Cretaceous Otway Group which unconformably underlies younger sediments on the plateau.

Perhaps the main techniques that BMR can learn from Lamont's geophysical activities are their refraction methods:

a) Long-range sonobuoys

These seem to be much better than the normal short-range buoys used on previous BMR surveys. When dynamite charges are used, they have a transmitting range of about 50 km, compared to 25 km for the short-range buoys. Using the air-gun, both buoys have a useful range of 10-15 km. The most valuable refraction information is normally recorded beyond a range of about 20 km, which indicates the advantage of long-range buoys over short-range buoys.

The long-range buoys cost about $600 compared to $300 for the short-range buoys.

b) Ocean bottom seismometers (or hydrophone)

These instruments could be used for refraction work over areas such as the Exmouth and Queensland Plateaux. BMR should consider acquiring or developing a retrievable OBS, as it would be very useful for deep crustal refraction work on the continental margin. In deep ocean basins the long-range sonobuoys have sufficient range to obtain mantle refractions and would be more cost-effective for work in these regions. An alternative to developing an OBS would be to arrange a co-operative survey with Lamont and use their OBSs.

Co-operative surveys are a way of complementing and extending the data obtained by BMR marine surveys. The running costs of Lamont's ships are low (about $100 000 per 30-day cruise) and if a proposal is of benefit to both BMR and Lamont, a co-operative survey could be arranged. The RV Vema lacks a high-powered seismic system, but scientists on the RV Conrad are now experimenting with a ?12-channel digital seismic system. Apart from seismic reflection data, much useful information could still be gained, especially refraction, gravity, dredging, and coring information, from co-operative surveys.

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APPENDIX : SUMMARY OF SYSTEMS ONBOARD

1. MAGNETOMETER

Lamont model towed 200 m behind ship. Analogue output to single-pen continuous recorder.

2. GRAVITY METER

Graf Askania GSS2 mounted on a Aeroflex gyro-stabilized platform. A cross-coupling computer independent of the meter is used to correct meter output. Data are output onto both a gravity recorder, which is a two-pen continuous recorder monitoring instananeous beam and corrected trace; and navigation recorder, which is a 12-channel dot recorder which plots Beam, Cross-Coupling, Course, Ramp (distance travelled vs time), Speed, Sum (gravity), Pitch, and Roll.

3. SEISMIC REFLECTION

Source : air-gun, 50 in^3. capacity, fired every 11-15 s.

Cable : Single-channel Lamont cable - active section 20 m long (40 hydrophones_ offset 150 m.

Profilers : Two electrostatic drum profiles. Each has own amplifier and filter banks and is capable of monitoring two channels. Sweep rate is 10 s. Approximately 3 hours data can be recorded before paper changed.

4. SEISMIC REFRACTION

Sonobuoy system : Aquatronics and Lamont receivers. Output to profilers or SIE amplifier and paper camera recorder.

5. BATHYMETRY

Two PDR recorders - 12 and 3.5 kHz. No digital output.

6. NAVIGATION

US Navy satellite system, ships log, and gyrocompass.

7. COMPUTER SYSTEM

Two 16K digital PDP 11 computers coupled to 2 disc-packs (1.2 million words capacity each). Peripherals include 2 teletypes, VDU, 36" drum plotter, paper tape reader and punch, dectape unit.

Twin system; REAL TIME SIDE and BATCH SIDE. Real time side samples gravity, magnetic and navigation data at 6-minute intervals on a real time basis. Problems have arisen and Lamont have not got this working properly yet. Batch side contains user programs such as the satellite fix program to compute positions, alert program, programs to plot magnetic, gravity and bathymetry profiles along track, programs to plot corrected ships track, etc.

8. OBS SYSTEM

Ocean bottom seismometers - used for microseismicity and deep crustal refraction work. This system is probably one of the newest innovations on the geophysical scene and appears to be extremely successful.

9. HEAT FLOW

Two systems onboard;

a) T-grad single-probe system used in conjunction with core-pipe. Thermistors placed at constant intervals along pipe.

b) Multi-grad - single probe with 3 thermistors which can be repeatedly extracted and inserted into sediments to give multiple readings at one station. Also takes both temperature gradient and conductivity measurements at one time.

10. CORING

Ewing piston corer.

11. DREDGING

Normal type drag dredge.