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VEMA CRUISE 33, LEG 13, IN THE BISMARCK, SOLOMON, AND CORAL SEAS, 20 DECEMBER 1976 TO 18 JANUARY 1977: OBSERVER'S REPORT

by

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SUMMARY

Marine geophysical data were collected during a co-operative survey by Lamont-Doherty Geological Observatory (LDGO) and BMR. Data from the cruise comprise gravity, magnetic, bathymetric, and reflection seismic information.

Preliminary results of magnetic and seismic profiling data indicate that the Coral Sea Basin began to form in the middle Palaeocene and the East Caroline Basin began to form in the early Oligocene.

It was concluded that LDGO's on-board computer system was inadequate for BMR's needs due mainly to the system's low sampling rate (5-10 minutes). Their program library, however, contained many programs valuable to BMR for its marine operations - in particular, the plotting programs.

1. INTRODUCTION

Marine geophysical data were collected during a survey by Lamont-Doherty Geological Observatory in which BMR co-operated. The objective of cruises V33-13 and V33-14 was to increase the understanding of the evolution of plate boundaries in the southwest Pacific since the Late Cretaceous. Leg 13 commenced on 20 December 1976 in Guam and ended on 18 January 1977 in Townsville.

As legs of LDGO's cruise 33 would cover areas proposed for future BMR work, BMR felt it would be advantageous to co-operate with LDGO on these legs.

During 1975 and 1976, BMR co-operated in legs 1, 2, 3, and 4 of cruise 33. Observer's reports by Jongsma (1976), Petkovic (1976), Stagg (1976), and Tilbury (1976) describe the geophysical equipment and procedures used aboard the VEMA.

For legs V33-13 and V33-14, BMR contributed $A10 000 towards operating costs of the VEMA and gave technical support including copies of related BMR data. In return, LDGO agreed to supply BMR with copies of all data collected during V33-13 and V33-14. The data will fill gaps in coverage obtained by BMR during the Continental Margin Survey 1970-73 and enable ties to be made between BMR lines.

In addition, G.D. Karner of BMR took part in cruise V33-13 and D. Jongsma in cruise V33-14.

<u>Scientific staff</u>: V33-13

The following scientific personnel were abroad the VEMA leg 13,

- -Dr J.K. Weissel, chief scientist
- -M. Sundvik, geologist/core describer
- -C. Gove, heat flow technician
- -V. Paisley-Smith, gravity technician
- -N. Leiser, computer programmer
- -J. Cranston) electronic technicians
- -D. Quick)
- -H. Steeves, air gun technician
- -G.D. Karner, BMR observer

All scientific personnel, excluding the chief scientist, stood 6-hour laboratory watches. The associated duties have been outlined by Stagg (1976).

2. PREVIOUS KNOWLEDGE AND INTERPRETATIONS

The present plate boundary configuration in the South Pacific was deduced from seismicity patterns and the distribution of island-arc/trench systems. Relative motions of the major plates are known from the magnetic anomaly patterns and have been inferred from earthquake focal-mechanism solutions for some of the smaller quakes (Fig. 1).

Recognisable magnetic lineations formed by seafloor spreading processes represent palaeo-accreting plate boundaries and may therefore be used to study the age, geometry, and evolution of marginal basins and their subsequent tectonic modification.

Falvey (1972), using data collected by Lamont-Doherty Geological Observatory (LDGO) in 1966 and 1967, and the Royal Australian Navy in 1967, tentatively mapped east-west magnetic lineations in the Coral Sea Basin. He attempted unsuccessfully to correlate observed magnetic anomalies with those predicted for the area using Heirtzler's standard magnetic reversal scale. More recent LDGO data not available to Falvey support the lineation trend as suggested by him, but do not indicate whether the lineation pattern is symmetric about an extinct spreading axis in the basin. Consequently, it is not known whether the Papua-Louisiade arc represents a rifted fragment of the Australian continental block, or a remnant island arc.

Magnetic lineations in the Tasman Basin indicate that there was an epidode of seafloor spreading during the Late Cretaceous and the Paleocene. This episode in the Tasman Basin may have interacted with spreading episodes in adjacent basins - in particular, the Coral Sea Basin. Basement ages in the Coral and Tasman Sea Basins are similar, suggesting that evolution of the two basins was coeval.

3. OBJECTIVES OF LEG V33-13

The leg can be divided conveniently into three sections:

i) <u>Guam and East Caroline Basin</u>

The objective of surveying the East Caroline Basin was to determine the age of basin creation based on magnetic seafloor spreading anomalies.

FIGURE 1

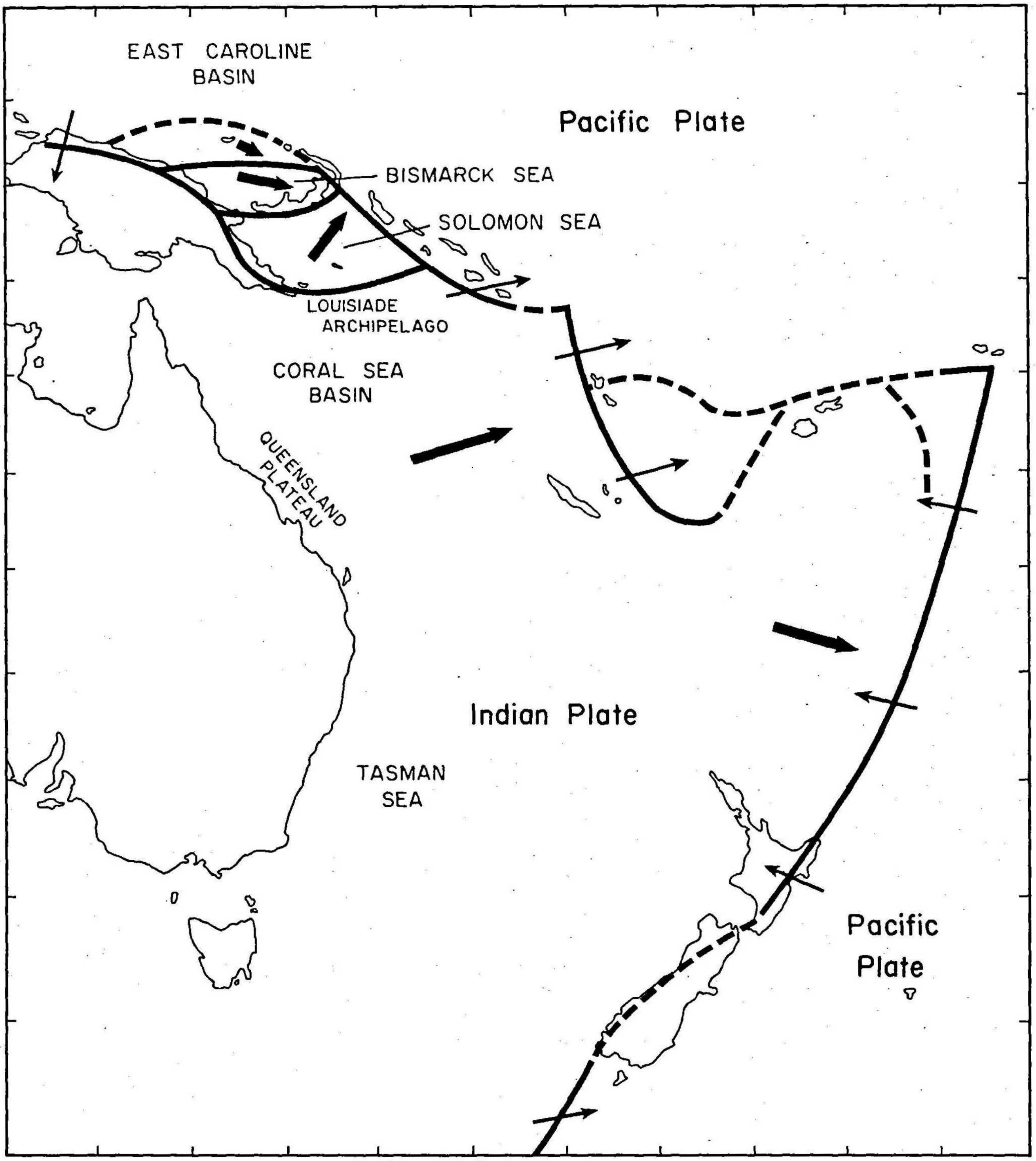


PLATE BOUNDARIES IN MELANESIA AND MAJOR PHYSIOGRAPHIC FEATURES

(MODIFIED FROM JOHNSON & MOLNAR, 1972)

Heavy arrows show the relative motion of the major plates of Melanesia determined seismically, the Pacific being held fixed. Fine arrows show local underthrusting as inferred from focal-mechanism solutions.

Record No. 1978/18 W/B8-87A

ii) Bismarck and Solomon Seas

Three objectives were considered during planning of the ship's track. They were:

a) to obtain a magnetic profile perpendicular to the fabric of the Bismarck Sea Basin as defined by Johnson & Molnar (1972);
b) to tie to all nearby lines of BMR's Continental Margin Survey in this region;
c) to investigate an offset between the Bismarck and Solomon sea plates proposed from seismological evidence.

iii) Coral Sea Basin

This was the major area of concern for V33-13.
The objectives for this basin were:

a) to determine the age of the oceanic crust underlying the Coral Sea Basin from an interpretation of the magnetic anomaly pattern;
b) to determine whether or not magnetic lineations in the Coral Sea Basin are symmetric about an extinct spreading centre;
c) to identify the mode of formation of the Papua-Louisiade arch;
d) to search for evidence suggesting interaction between the evolutions of the Coral Sea and Tasman Basins.

CRUISE SUMMARY

Cruise 33 leg 13 of the VEMA began at Guam on Monday 20 December 1976 and ended at Townsville on Tuesday 18 January 1977. Magnetic, gravity, bathymetric, and seismic data were collected along 10 000 n miles of ship's track.

(i) Guam and East Caroline Basin

Surveying began at 1400 hrs on 20 December after safety drills had been performed in Apra Harbour, Guam. The VEMA crossed the Marianas Trench between 0200 and 0800 on 21 December and entered the East Caroline Basin at 1900 hrs on 22 December. As this basin is relatively unexplored, the bathymetric data revealed numerous previously unknown bathymetric features. All geophysical equipment functioned correctly though the magnetometer had difficulty in holding weak signals. Sub-bottom seismic penetration was only 0.5 seconds 2-way time, probably because the sea-floor is highly reflective.

The ship's course was set perpendicular to the predominant magnetic trend of the basin as defined by Bracy (1975). Heat flow was measured successfully at only one of four stations. The successful measurement was made in the East Caroline Basin at $5^{o}10'N$, $146^{o}30'E$, and gave a value of 2.7 HFU. The other stations were: further south in this basin, and in the Bismarck and Solomon Seas. Eventually it was realised that the problem was caused by failure of the lithium cell batteries in the heat probe.

(ii) Bismarck and Solomon Seas

The VEMA entered the Bismarck Sea at 2200 hrs on 25 December and surveyed along the track shown in Figure 2. The geophysical equipment continued to function well and difficulties in detecting weak magnetic signals were no longer experienced. Seismic penetration ranged from 1.0 to 1.5 s, compared with 0.5 s in the East Caroline Basin. Data of excellent quality were obtained in the Bismarck Sea. South of the Bismarck Sea plate boundary, however, the magnetic field is complicated by the effects of numerous seamounts, and the profile contained anomalies which could not be recognised as part of the standard seafloor spreading anomaly sequence.

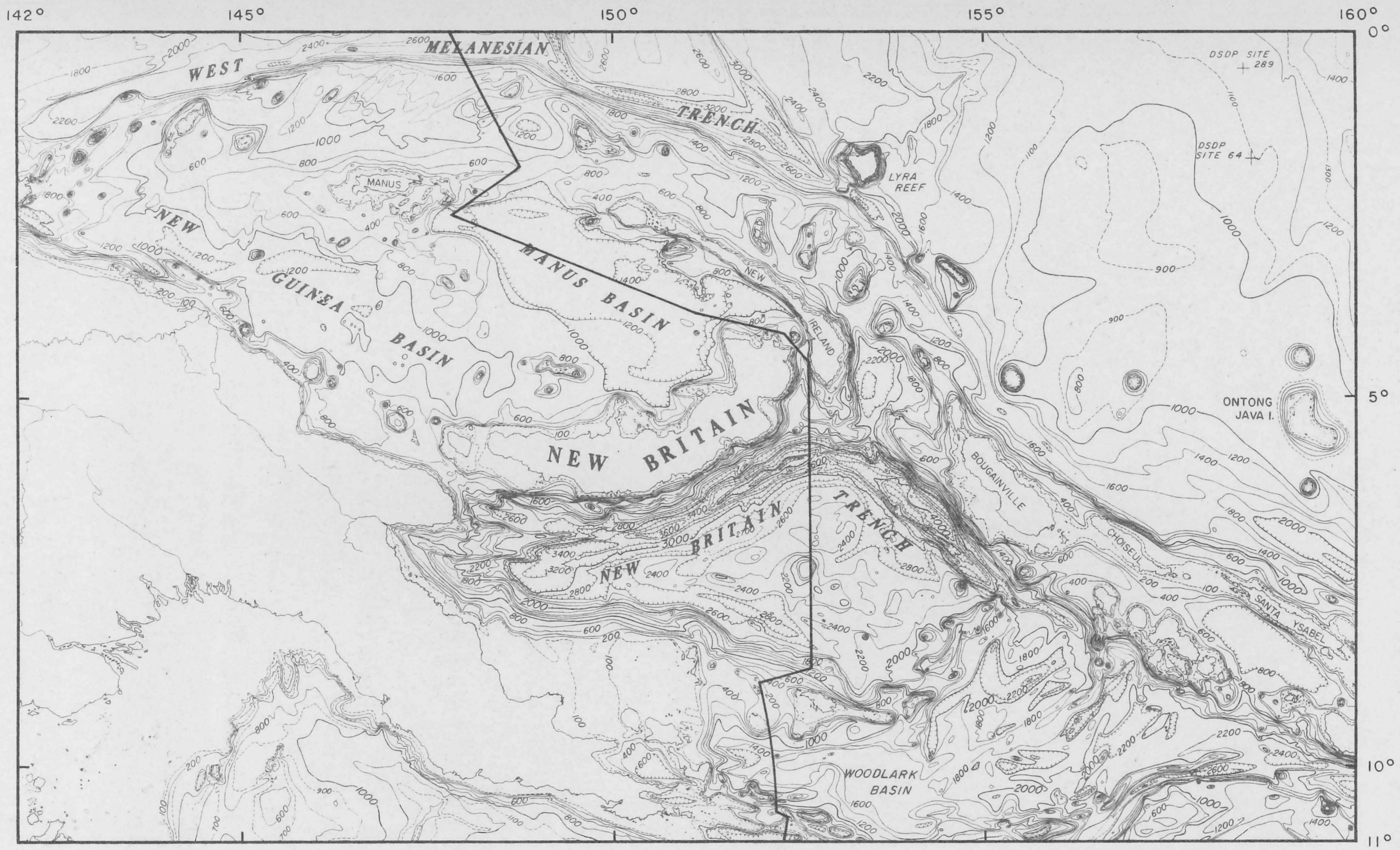
The VEMA entered the Solomon Sea at 1500 hrs on 27 December. As in the southern Bismarck Sea, the magnetic field is dominated by the effects of seamounts, and again, the magnetic profile contained anomalies unrecognisable in terms of the standard seafloor spreading anomaly sequence.

(iii) Coral Sea Basin

The VEMA entered the Coral Sea Basin at 0900 hrs on the 29 December and surveyed along the track shown in Figure 3. Crossings of the basin were made perpendicular to the predominant magnetic trend. The work extended regional magnetic and gravimetric coverage considerably and resulted in the discovery of an (?)extinct spreading centre. Most of the LDGO tracks intersect BMR Continental Margin Survey tracks on the Queensland Plateau.

Record No. 1978/18 PNG/B8-95A

FIGURE 2



BATHYMETRY AND TRACK CHART,

BISMARCK AND SOLOMON SEAS

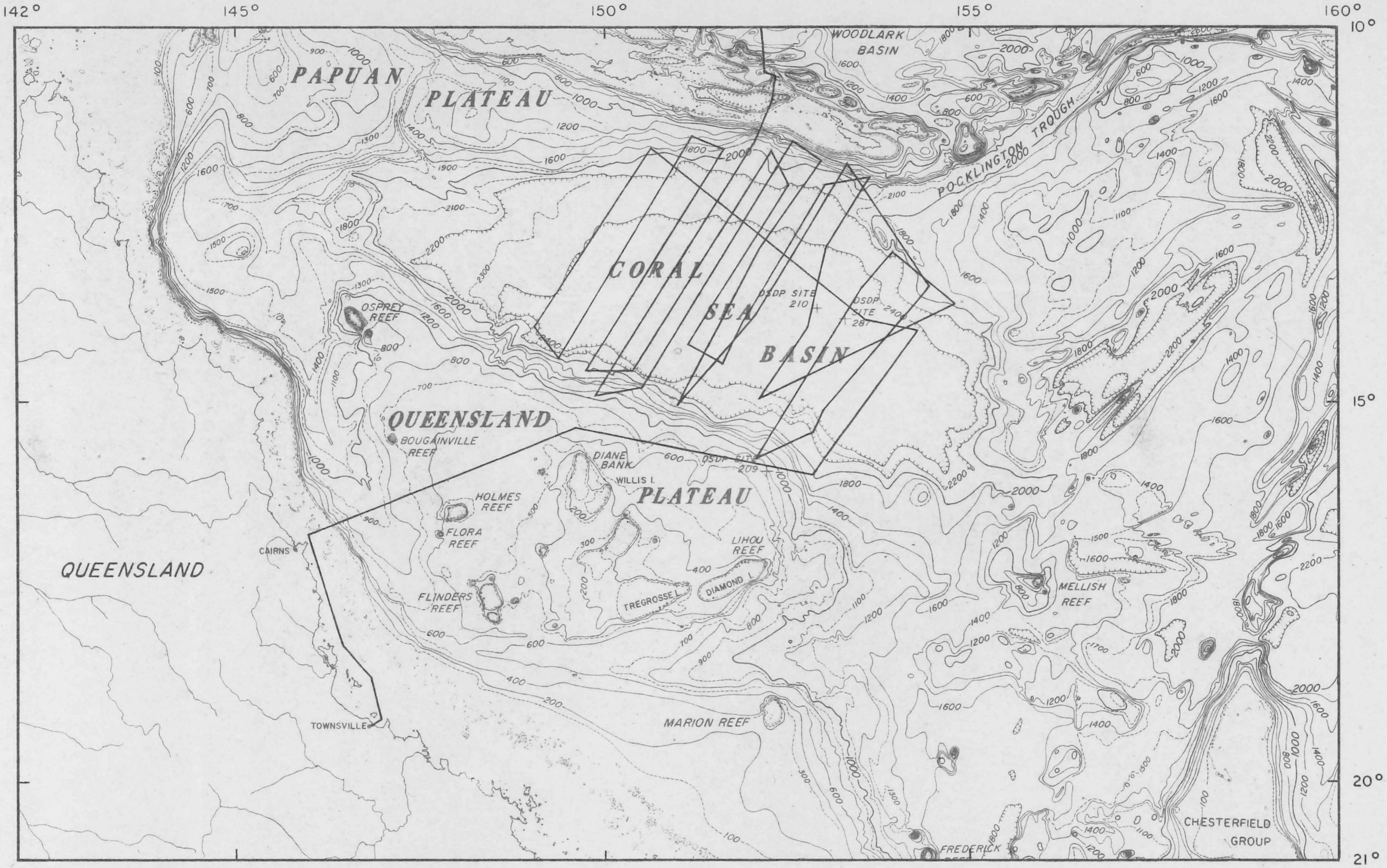


FIGURE 3

BATHYMETRY AND TRACK CHART,

CORAL SEA

Record No. 1978/18

A/B8-188A

Good-quality magnetic and gravimetric data were recorded but the quality of the seismic data was affected by severe towing noise for about three days. After the oil in the tail section was replaced with water and pre-amplifiers were inserted along the streamer, the towing noise was greatly reduced. Penetration in this basin was typically 1-2 seconds.

5. EQUIPMENT PERFORMANCE

All geophysical equipment operated satisfactorily except for minor intermittent problems with the seismic system. The computer system, however, was out of service for the entire cruise. Interpretation peripherals normally attached to central processor unit one (CPU-1), such as the Tektronix video display unit and Calcomp plotter, could not be operated. As a result, on-line data display was greatly impeded and all plotting had to be done by hand. CPU-2 was used for simple tasks such as the creation of geophysical and navigation data files and the processing of satellite fixes. Arrangements were made for technicians in Townsville to repair the computer system before leg 14 of the cruise.

6. ON-BOARD COMPUTER SYSTEM

As BMR is presently developing its own data acquisition system for use in marine surveys, the LDGO on-board computer system was carefully studied to see if features of that system were applicable to the BMR system.

The principal objective of LDGO's computer system is to reduce marine geophysical data from their raw form and combine them with the ship's navigation information to obtain reduced values of geophysical parameters and the positions at which the values were obtained. The most important function of the system is its ability to store large amounts of geophysical data on random-access discs and retrieve them quickly and efficiently. The system is controlled by two PDP11 computers of medium size and speed. Medium-speed computers are used in preference to high-speed computers. A high-speed computer operates much faster than the display peripherals and would therefore be on standby for long periods while, for example, plotting was being completed. As most of the programs on the VEMA produce graphical plots, the benefits of high-speed computers would not justify the greater cost of hardware.

Reiterating: LDGO's on-board computer system has two main functions:

(i) to acquire, validate, process, and store input geophysical and navigational data;

(ii) to act as a link between the random-acess discs and newly created files, and the plotter.

Input data are hand digitised from analogue records, usually at 6-minute intervals. The plotter output is used to check for errors in input and during data processing and to define editing requirements. LDGO's system comprises two central processor units. CPU-1 is dedicated to interpretation and plotting programs. CPU-2 is dedicated to data acquisition and on-line processing. During this cruise, CPU-1 was out of action and CPU-2 did the basic satellite navigation processing and geophysical file creation. A schematic diagram of the LDGO dual system is shown in Figure 4 (after Tilbury, 1976). Tilbury's report reviews LDGO's hardware system.

File structuring

There are two basic file structures used by the LDGO computer system. They are:

(i) a Navigation or N-file, and

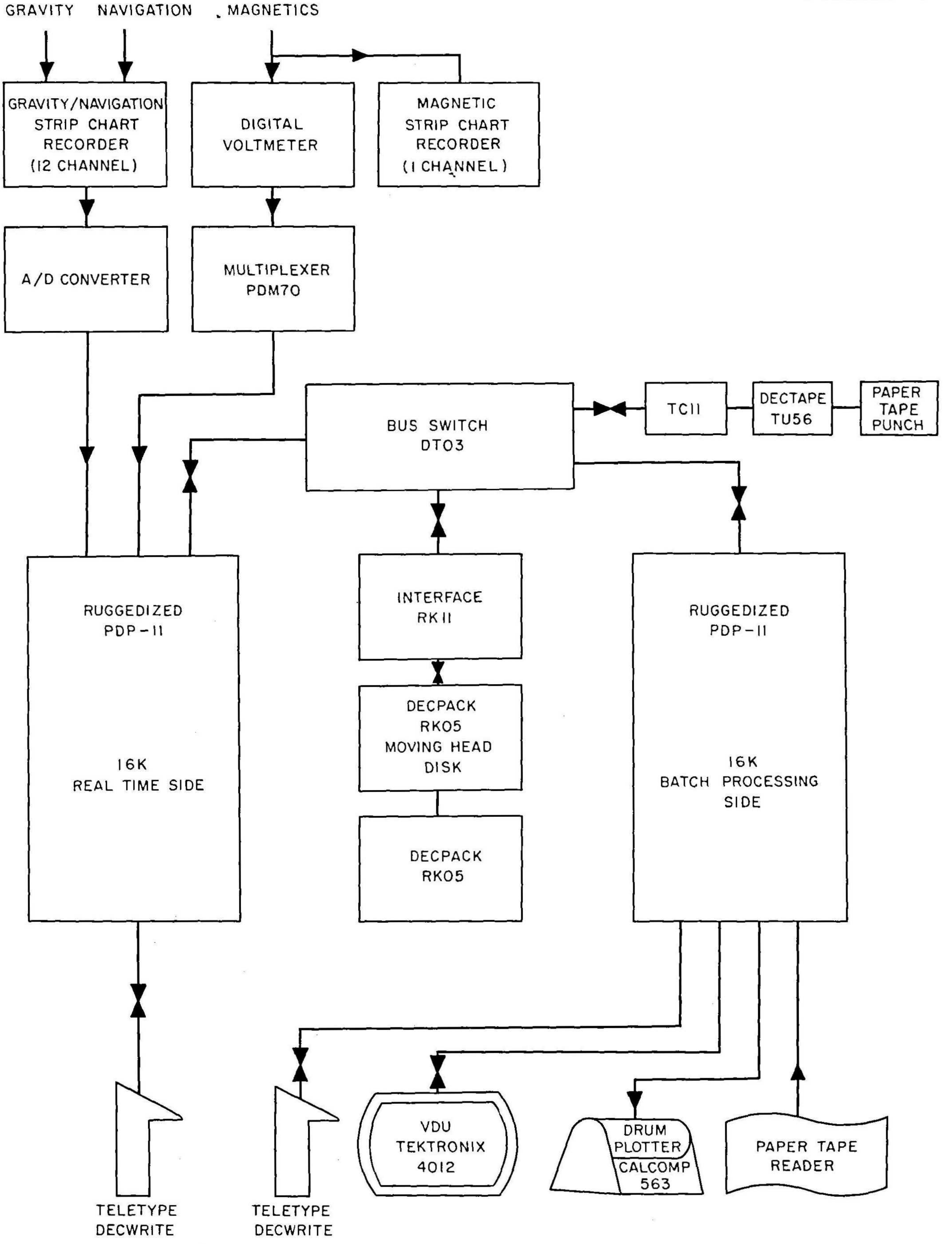
(ii) a Geophysical file comprising a gravity of G-file, a Magnetic or M-file, and a bathmetry or T-file (T= Topography).

The data are stored in two time sequences: one sequence consists of data on the ship's position at navigation points; the other contains the value of the geophysical parameter in raw form for each station, together with the constants necessary to produce the reduced value of the geophysical parameter. (see Geophysical file definitions later).

Navigation file

Common to most of the on-line programs used on the VEMA are the navigational data represented by navigation points. Navigation points are points in time when a change is made to the ship's velocity or when a navigation fix (by satellite) is taken. Regular time points can be calculated by linear interpolation between the navigation points. The N-file is the

FIGURE 4



SCHEMATIC DIAGRAM OF COMPUTER SYSTEM ON BOARD R.V. VEMA most important of the data files because all the geophysical data files use the navigation points to obtain the location of the sampling stations. The times and positions of navigation points are hand-digitised and input to the program DSKNV, which updates the navigation file daily. Once the N-file has been updated, a suite of related files are produced to be used with the geophysical programs. For example, program MGNAV, using the N-file, determines the value of the regional magnetic field (after Cain et al., 1964) at each navigation point and stores it on the disc file. From these values, the regional field at each magnetic data point is calculated by interpolation.

The N-file structure is shown in Figure 5. The first two records do not contain information concerning the navigation points but contain flags indicating what stage the data processing has reached, and file identification labels.

Geophysical data files

(i) Storage of data. The geophysical files are used to store only raw geophysical data. Processed or reduced data are not stored. This decision results in keeping only a minimum number of files, for, if data were kept also in reduced form, two sets (raw and reduced) would need to be saved. The amount of machine time used for data reduction is trivial, so no appreciable time is lost in recomputing the reduced data each time it is required.

(ii) Geophysical file structure. The gravity, magnetic, and topographic files are organised as follows (Fig. 5). There are 16 words of storage reserved for each record. The data values are described by information on two kinds of data records - header records and data records. Each header record contains information concerning day, month, year, time zone, the number of geophysical parameter records, the number of points on the last record, and constants needed to convert the raw data to reduced data. (JDAY, MONTH, JYR, TZ, LB, LC). Each data record contains space for eight data values and their respective times. (JTIME, JVAL). With the exception of the time zone parameter, all numbers in both records are in integer mode and hence must lie within the integer range of the particular computer used - for the PDP11: ± 32767 or $2^{15}-1$. The use of integer mode is a space-saving technique as geophysical data values can be stored in a modified, compressed format.

(iii) Geophysical file definitions. Some geophysical quantities do not change rapidly, so LDGO have adopted "day cards" to record the data. Each geophysical parameter has its own day - there are topographic, gravimetric, and magnetic days. A day for a parameter is defined as the period during which the numerical values of constants used to construct the geophysical parameter remain within limits specified according to the accuracy of the geophysical meter. A new day starts when the limits are exceeded by any one constant. In a data file for a geophysical day, the day card is followed by records containing information in packed format. (time and parameter value). For example, program MGRAD stores gravity data in the above file format. The data point time series consists of time (hr, min.) and strip chart readings. Constants JDIAL, DRR, CF, GZ are needed to convert the strip chart reading JG(i) to a gravity value GRAV by the formula:

GRAV = GZ + (JDIAL = JG(I) * DRR) * CF * 0.001

The constants are used for Graf-Askania data reductions, and are stored as part of the "gravity day" card data.

(iv) Program library. Listed below are the types of programs used at sea for the on-line processing of data.

(a) Gravity, magnetic, and topographic reduction programs.
(b) Posting of gravity, magnetic, or topographic values on mercator charts.
(c) Plotting of gravity, magnetic, or topographic profiles along ship's track on mercator charts.
(d) Obtaining profiles of gravity, magnetic, or topographic values projected onto a selected lime.
(e) Obtaining and plotting average free-air gravity and Bouguer values.
(f) Navigation processing and navigation file creation programs.

7. SCIENTIFIC OBSERVATIONS AND RESULTS

The leg was scientifically very successful. It produced enough data to fulfil the objectives of the leg.

NAVIGATION FILE

record	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15 word
1	DISA		NUM		DMAX		JBSYR	MAGFL	NSTFL	NMZFL					
2	KPRTS														
3	TNAV		XLAT		XLONG		DIST		STDRF		TZ		IRES	NSTA	NMZ
4	"		"		"		"		"		"		"	"	"
⋮															

GEOPHYSICAL DATA FILE

record	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 word
1	JDAY	MONTH	JYR	TZ		LB	LC	(NMZ)								
2	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL
⋮																
LB^{th}	JTIME	JVAL	··· to LC^{th}:		JTIME	JVAL										
LB +1	JDAY	MONTH	JYR	TZ		LB	LC	(NMZ)								
LB +2	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL	JTIME	JVAL
⋮																

SCHEMATIC REPRESENTATION OF DATA AS STORED ON DISC (FROM TALWANI, 1969)

FIGURE 5

(i) East Caroline Basin

A graben-like structure, 15 kilometres wide, which was traversed at $3^{o}54'$N, $146^{o}54'$E, appears to be an extinct spreading centre. The structure was not known to Bracy (1975), who suggested that the Caroline Basin spreading axis had been consumed at the Caroline Ridge subduction zone. Magnetic anomalies of high amplitude and approximate easterly strike have been identified to the north and south of the spreading axis. They appear to be symmetric about the axis and have been identified as magnetic anomalies 9 to 11 (28-31 m.y.) in the north and 9 to 12 (28-32 m.y.) in the south. An age of early to mid-Oligocene is inferred for this basin based on the magnetic anomalies; this age is consistent with estimates based on results from nearby DSDP holes.

(ii) Bismarck and Solomon Seas

The magnetic profile obtained over the Bismarck Sea shows anomalies 2', 2, 1, and 0 (3 m.y.-present) where the 0 or central anomaly coincides with a sediment-free area at $3^{o}30'$S, $150^{o}00'$E. No anomalies could be identified to the south of the sediment-free area nor in the Solomon Sea since the magnetic field is dominated by the effects of numerous seamounts.

(iii) Coral Sea Basin

The most important result of work in this basin is the verification that magnetic anomalies are symmetric about an extinct spreading centre. Basically, the magnetic pattern consists of a broad positive anomaly near the centre of the basin flanked by one or more narrower positive anomalies. The anomalies are offset near $153^{o}24'$E. The magnetic anomalies are highly skewed, as defined by Schouten & McCamy (1972), but appear to be similar in character to anomalies 24 to 26 (50-60 m.y.) on either side of an extinct spreading centre as in the Tasman Sea. Assuming that the anomalies have the same ages as anomalies 24 to 26, the age of the Coral Sea Basin is deduced to be Middle Paleocene; this age is consistent with that inferred from DSDP data. The amplitudes of the anomalies decrease significantly towards the northwest, probably reflecting an increase in sediment cover and hence, alteration increase, towards the Papuan shelf. Both the Queensland Plateau and the Louisiade Archipelago show strong magnetic anomaly 'edge effects'.

A pronounced quiet zone along the seaward side of the Queensland Plateau is similar in character to the magnetic quiet zone to the south of Australia.

In summary, the Coral Sea Basin exhibits symmetric magnetic anomalies about an extinct spreading centre. The basin is deduced to be of Middle Paleocene age from studies of both the magnetic anomaly pattern and DSDP data. The geometry of the Coral Sea Basin as revealed by the magnetic anomaly pattern suggests that the Papuan-Louisiade arch is a remnant island arc. The East Caroline Basin also exhibits symmetric magnetic anomalies about an extinct spreading centre. The new data indicate that its age is early to middle Oligocene.

8. RECOMMENDATIONS

The LDGO on-board computer system is inadequate for BMR's needs because of its low sampling rate. However, the acquisition of data in integer form is an interesting feature of the system, and is worth considering for application to BMR's data acquisition system. Output magnetic tapes containing integer data are compatible with any computer system; hence data format conversion is accomplished via the operating system of the computer rather than by specific conversion programs.

The use of random-access discs is also an interesting feature of LDGO's system. Use of such discs in our own acquisition system would aid data retrieval for on-line data display and optimise input/output operations.

It is highly recommended that our data acquisition system include a plotter to produce on-line graphical plots of ship's track, gravity, magnetic and bathymetry profiles, etc. To complement the plotter, the types of programs outlined in the section on "program library" should be included in our own repertoire of on-line data display programs.

9. REFERENCES

BRACY D.R., 1975 - Reconnaissance geophysical survey of the Caroline Basin. Bulletin of the Geological Society of America, 86, pp. 775-784.

CAIN J.C., DANIELS, W.W., 1964 - NASA report X-612-65-72.

FALVEY D.A., 1972 - On the origin of marginal plateaux. Ph. D. thesis, University of New South Wales, Australia. (unpublished).

JOHNSON T. & MOLNAR P., 1972 - Focal mechanisms and plate tectonics of the southwest Pacific. Journal of Geophysical Research, 77, pp. 5000-5032.

JONGSMA D., 1976 - VEMA Cruise 33, leg 2 in the southeast Indian Ocean, 21 December 1975 to 17 January, 1976: Observer's Report. Bureau of Mineral Resources, Australia, Record 1976/85 (unpublished).

PETKOVIC, P., 1976 - VEMA Cruise 33, leg 4 over the Naturaliste Fracture Zone, 23 February to 15 March 1976: Observer's Report. Bureau of Mineral Resources, Australia, Record 1976/86 (unpublished).

SCHOUTEN H., & McCAMY K., 1972 - Filtering marine magnetic anomalies. Journal of Geophysical Research, 77, p. 7089.

STAGG H.M.J., 1976 - VEMA Cruise 33, leg 3 over the magnetic quiet zone south of Australia, 20 January to 19 February 1976: Observer's Report. Bureau of Mineral Resources, Australia, Record 1976/87 (unpublished).

TALWANI M., 1969 - A computer system for the reduction, storage and display of underway data acquired at Sea. Lamont Doherty Geological Observatory, Technical Report No. 1.

TILBURY, L., 1976 - VEMA Cruise 33, leg 1 over the southeast Indian Ridge, 17 November to 17 December 1975: Observer's Report. Bureau of Mineral Resources, Australia, Record 1976/84 (unpublished).

WATTS, A., & WEISSEL, J., 1976 - Evolution of plate boundaries in Melanesia, research proposal to National Science Foundation. Bureau of Mineral Resources, Australia. File 1976/895.