DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1976/86

VEMA CRUISE 33 LEG 4 OVER THE NATURALISTE FRACTURE ZONE,
23 FEBRUARY TO 15 MARCH, 1976:

OBSERVER'S REPORT

Survey 1037

by

Peter Petkovic

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Fig. IA RV VEMA

Fig. IB THE DROPPING OF THE CORE PIPE
ABOARD RV VEMA

SUMMARY

The primary objective of leg 4 of cruise 33 of the RV *Vema* was to make a physiographic and geophysical study of the Naturaliste Fracture Zone (NFZ). Seismic, gravity, magnetic, and bathymetric data were collected along about 7000 line km of traverse, including a number of lines across and along the fracture zone. Core samples and heat flow measurements were taken at six stations and one seismic refraction probe was made.

The results indicate several important geological and topographic features in the general area of the NFZ. These include:

(a) a V-shaped graben of thick sediments where the Naturaliste and Diamantina Fracture Zones converge.

(b) a buried basement ridge along the axis of the NFZ in one area, the existence of which suggests that parts of the fracture zone have subsided.

(c) a thick transparent sedimentary sequence overlain by a horizontally bedded sequence in valleys near the intersection of the NFZ with a similar easterly-trending feature. The layered sequence is not present at depths of less than 5700 m.

(d) a large seamount near the northwest end of the NFZ. Its relation to the fracture zone is not known.

(e) a comparative lack of topographic features on the northeastern side of the NFZ, in contrast to great variety of topography on the southwestern side.

(f) block-faulting affecting both basement and sediments in one area of the northeastern side of the NFZ.

INTRODUCTION

The Lamont-Doherty Geological Observatory (L-DGO) of Columbia University, USA, operates a geophysical survey vessel, the Vema (Fig. 1). This ship, which was converted from a three-masted luxury schooner, had completed one million miles by late 1975. It has operated in all the oceans in the world, but mostly in the Atlantic. It has been the only ship in the world to collect magnetic, gravity, seismic, and core data as a matter of routine. As a consequence, L-DGO found it had a huge quantity of magnetic data to study in the light of the theory of plate tectonics which became established in the late 1960s. L-DGO geoscientists were thus among the first researchers of ocean floor magnetic lineations.

On cruise 33, Vema worked from Australian ports and L-DGO invited BMR scientists familar with the study areas to participate as observers. The activities on the first three legs are discussed by Tilbury (1976), Jongsma (1976), and Stagg (1976).

This report deals with Leg 4, which was primarily a physiographic investigation of the Naturaliste Fracture Zone (NFZ), a feature first described by Markl (1974a). Vema departed Melbourne on 23 February and arrived at Fremantle on 15 March 1976, after 21 days at sea. A total 4500 n miles was traversed (Fig. 2) and core samples and heat flow measurements were taken at six stations. The weather was generally good and did not prevent work at any time. Scientific personnel on board consisted of:

Rudi Markl	-	Chief scientist (Columbia U.)
Peter Dehlinger	-	Observer (Connecticut U.)
Peter Petkovic	-	Observer (BMR)
Bruce Herman	-	Graduate student and heat flow man (Columbia U.)
Mike Sundvik	-	Geologist and core describer (Columbia U.)
Bud Rock	-	Computer operator (Columbia U.)

2. SCIENTIFIC OBJECTIVES

Markl's program was to conduct detailed studies in selected areas of the southeast Wharton Basin where geophysical data density is low. The principal objectives were to define in reasonable detail the physiography of the NFZ, and to further define the magnetic anomalies of the Perth Sequence which is a series of northeasterly-trending Mesozoic magnetic lineations in the southeast of the Perth Abyssal Plain (Markl, 1974a & b).

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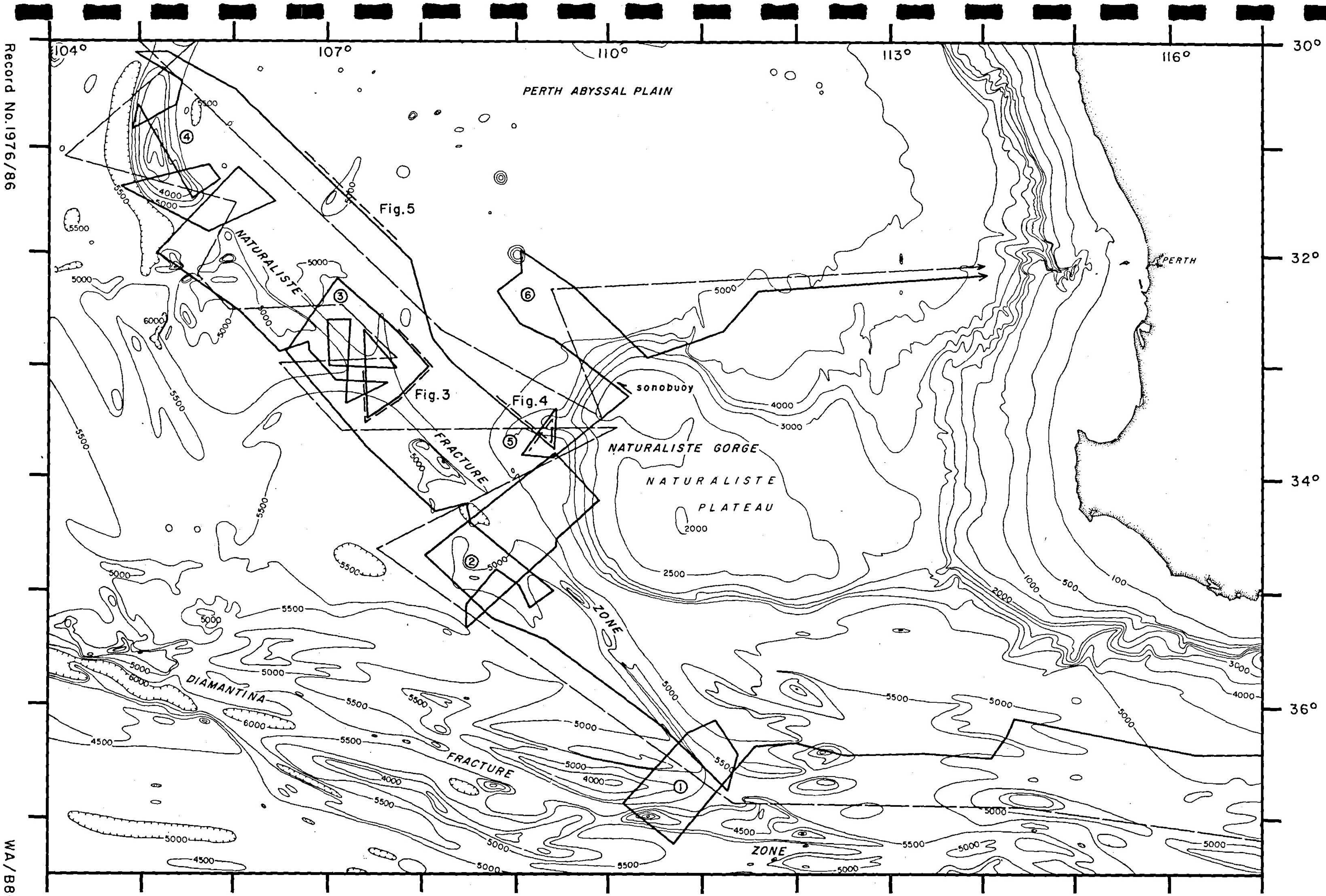


⑤ Number of area
Schematic R V Vema 33/04 track
Indicates part of traverse for which seismic profile is reproduced
Proposed track
Bathymetry after Markl (1973)
Contour interval 500 metres

Fig.2 PROPOSED AND ACTUAL TRACKS OF THE RV VEMA

WA/B8-127A

Secondary objectives were to:

a) further the exploration of the Naturaliste Gorge and its extension off the Naturaliste Plateau,

b) determine depth to basement in the northwest corner of the Naturaliste Plateau,

c) attempt an identification of bottom water currents in the vicinity of the NFZ.

3. EQUIPMENT

Routine scientific measurements on board Vema require continuous operation of the magnetometer, gravity meter, single-channel air-gun seismic equipment, precision depth recording (PDR) equipment, and satellite navigation equipment. The taking of core samples is also a routine task. Achievement of the scientific objectives for this leg required no more than this routine work. The seismic and magnetic systems were of particular importance; they functioned without breakdown.

BMR continued operation of an Ampex tape recorder and an EPC monitor recorder which had been installed on an earlier leg. Each recorder broke down once but was quickly restored to working order. The EPC record is of reasonable quality, showing the basement reflector where its reflection time is less than 8 s. The L-DGO profiler records are of excellent quality so there will be no need to playback the Ampex tape records. Markl indicated that the profiler records would be publicly available after L-DGO geoscientists had made an initial interpretation of them. He indicated that the retention period would probably not be greater than one year.

4. OPERATION AT SEA

The system of command onboard Vema begins with the captain, who has direct responsibility for both ship's crew and scientific personnel. The crew maintains the ship's normal operation and the chief scientist directs scientific operations and plans traverses as required, subject to agreement with the captain.

A chief scientist normally uses Vema in this fashion for one leg (cruise from port to port), after which another takes over. The work load on Vema personnel varies, depending upon scientific requirements. On one leg the emphasis may be on cores and heat flow measurement (Jongsma, 1976), and on another, seismic refraction (Stagg, 1976). Gravity, magnetic, and seismic data are recorded on all cruises.

All monitoring equipment and many other scientific instruments are located in one laboratory area, the 'upper lab', which is also the most favoured social centre aboard the Vema. The chief scientist normally works in the upper lab together with other scientific personnel on duty. The upper lab watch changes at six-hourly intervals starting at midnight. At least two people share responsibility for the monitors. The records are automatically marked each half hour by an event-mark generator which also emits an audible buzz. Upon hearing this signal, the man on watch annotates each monitor strip chart with readings of distance travelled, time, ship's speed and course, and water depth. Event-marks are generated manually when the course or speed is changed. The times of all events and profiler paper changes are recorded in a log book, and the PDR, gravity, and magnetometer records are manually digitized at 6 min intervals.

The other major task required of personnel on duty in the upper lab is to compute the ship's position from satellite fixes. Satellite alert times are posted each day next to the receiver in the upper lab. At each alert time the man on watch attempts to tune into the satellite transmission aided by an acoustic cue. If the tuning is successful, the receiver outputs a punched paper tape which is then fed to the navigation computer in the after lab. The computed position is read to the bridge watch via the intercom.

When the ship stops to take a core sample, the trailing cables and air-gun are pulled in by any available scientific personnel. The PDR and navigation system continue operating. The core winch and pipe are handled by ship's crew with help from the core describer and heat flow man (Fig. 1). At the completion of the coring procedure, the cables are once again streamed and the ship continues surveying.

5. WORK ROUTINE AND CO-OPERATION

I participated in the scientific activities while on-board and had the 0600-1200 watch in the upper lab. During the afternoons and evenings I had frequent discussions with the chief scientist on planning of the ship's track. Markl was receptive to my comments and suggestions, and indicated that he was very satisfied with this sort of co-operation. The other L-DGO people were equally willing to explain their work, and to give me assistance when this was required. I made gravity ties to the Australian National Gravity Network while the Vema was berthed in Melbourne and Fremantle.

I initiated the exchange of data by giving Markl a copy of all BMR seismic sections over the Naturaliste Plateau from the Continental Margins Survey and a track plan of the area showing BMR (MV Lady Christine) and Shell (MV Petrel) lines. I also gave him a copy of the preliminary 1:2 500 000 gravity, magnetic, and bathymetric contour maps for the southwest margins, and indicated our willingness to provide him with any other data he may wish to use.

I was given a track plan without positions (Fig. 2), a copy of Markl's Ph.D. thesis and several copies of a bathymetric map of the Wharton Basin.

6. SCIENTIFIC RESULTS

The principal objective on this leg was to make a detailed study of the Naturaliste Fracture Zone (NFZ). This is a newly discovered and poorly defined feature, possibly a transform fault, trending approximately northwest from 36°30'S, 110°E, where it diverges from the Diamantina Fracture Zone (DFZ). On previous crossings of the area it was observed that a ridge on the southwest side of the NFZ and the ridges in the DFZ bound a V-shaped area of thick sediments, thinning to the northwest. Therefore, a related objective was to discover the source of these sediments.

Markl's thesis concerning the plate tectonics of the southeast Wharton Basin concludes that spreading occurred in the Perth Abyssal Plain from a spreading centre trending northeast. Thus the proposed direction of spreading is parallel to the NFZ. The source of the above mentioned sediments is, according to Markl's ideas, the Naturaliste Gorge. The questions to be answered on this leg were as follows:

a) what is the physiography of the sea-floor where the NFZ and DFZ converge?

b) how was sediment transported from the Naturaliste Plateau, across the NFZ bounding ridge, and into the V of the NFZ-DFZ convergence?

c) what is the magnitude and sense of strike slip movement along the NFZ?

d) does the NFZ cut through the large seamount located at $31^{O}S$, $105^{O}E$?

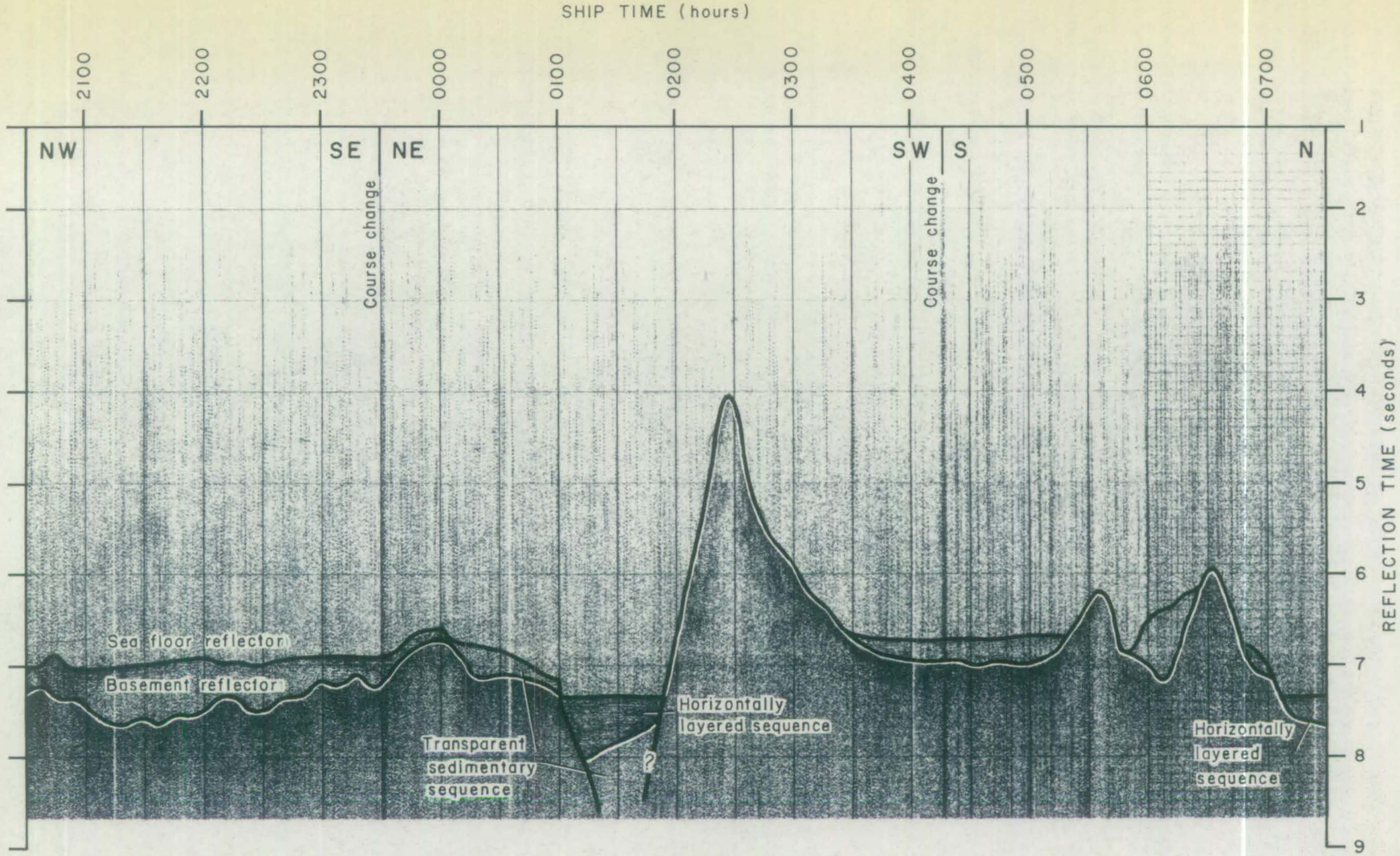
The traverses shown in Figure 2 were located in an endeavour to obtain the answer. The proposed traverses, also shown in Figure 2, were only used as a guide. Markl continually modified the projected track during the cruise. When an interesting feature appeared on the geophysical monitors, he altered the ship's course to obtain maximum information over it.

Six interesting areas are numbered on the track plan in Figure 2. Preliminary study of the data led to the following interpretations:

Area 1 The Diamantina and Naturaliste Fracture Zones appear to converge as shown in Figure 2 and form a dam to sediments possibly transported from the northwest. These sediments become thinner northwest of the convergence. A station was occupied east of the convergence to obtain core, heat flow, and water temperature measurements. A typical section across the NFZ, taken from Area 3, is shown in Figure 3 and is indicative of a tensional regime.

Area 2 Crossings of the NFZ in this area did not reveal the typical structure depicted in Figure 3. However, a buried basement ridge observed on the profiler record may correspond to the typical ridge on the southwest margin of the fracture zone observed in Areas 1 and 3. This and later evidence suggest that the NFZ is an ancient, inactive zone of tension, parts of which may have subsided. A station over the NFZ was occupied to obtain core, heat flow, and bottom water temperature measurements.

Area 3 At the intersection of the NFZ and a similar feature trending west, detailed surveying was necessary to map the physiography of ridges and valleys. The valleys contain sediments of at least two distinct types; a thick transparent sequence, and an overlying horizontally layered sequence. Where the trends of valleys intersect, the transparent sequence is piled up on one side of the valley (see Figure 3 for sections in this area). The top of the layered sequence is 5700 m below sea level over the entire area, indicating continuity between valleys. Predictably, the layered sequence is not observed where valley floors are above the 5700-m level. It is difficult to account for the observed distribution of the sequences in terms of the normal pattern of ocean bottom deposition, unless complex current patterns are proposed. Markl's thesis suggests that cold, dense Antarctic bottom water coming up along the NFZ could have deposited sediment in this manner. However, it is unlikely that such a body of water would be confined to levels below 5700 m. In any case, no anomalies were observed in bottom water temperature within the NFZ.



Notes 1. To correct for inherent delay, add 0·26 seconds to reflection time

2. Ship speed approximately 10 knots

Fig. 3 SECTION FROM NATURALISTE FRACTURE ZONE

Area 4 The ridge of the NFZ peters out before it reaches the large seamount found in this area. The seamount, which lies on the projected trend of the NFZ, features a deep longitudinal crack or fracture trending north and a steep east-facing scarp of average gradient 15°. It is uncertain how the NFZ and seamount are related.

Area 5 The west-trending spur west of the Naturaliste Gorge shown in Figure 2 is probably a seamount. A section from this area is shown in Figure 4. The existence of this feature adds further to the complexity of the plateau's western margin.

Area 6 The lines in this area, and the line between Areas 4 and 5 were made in an endeavour to detect sea-floor spreading anomalies. The anomalies, if they exist, are very obscure.

Further comments relating to the data collected are:

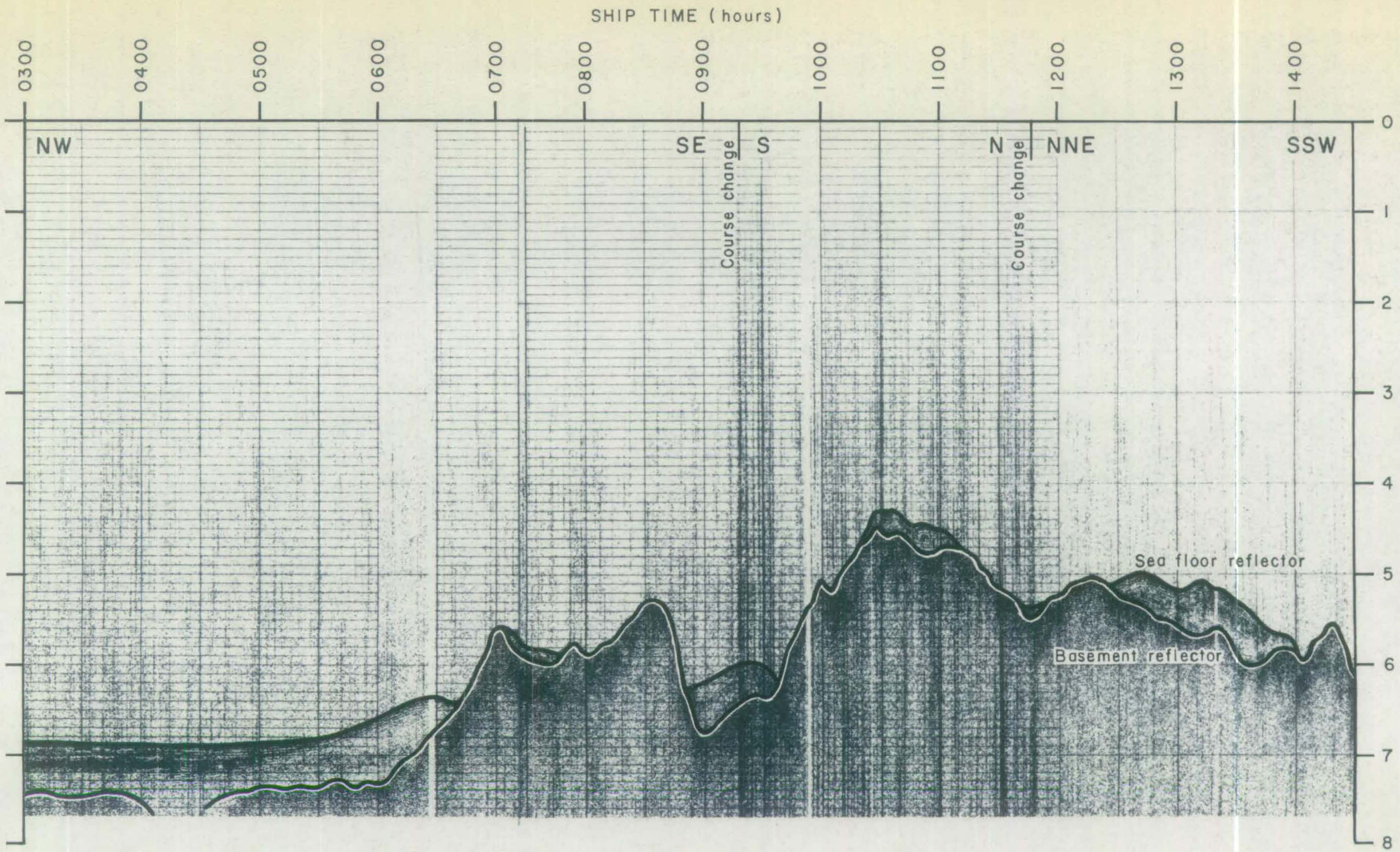
1. Basement topography on the northeast side of the NFZ is mostly featureless, displaying only a few conical seamounts. In contrast, basement topography on the southwest side is variable.

2. On the traverse joining Areas 4 and 5, northeast of the NFZ, the seismic record reveals distinct block-faulting affecting both the basement and overlying sediments (Fig. 5).

3. The only refraction probe of the leg was done in the northwest corner of the Naturaliste Plateau where basement is not identified on any reflection record. Refractor velocities of 4.5 km/s and 6.6 km/s were calculated.

Surveying in leg 4 has helped fill considerable gaps in the geophysical coverage of the Wharton Basin. Several features were surveyed in detail and long lines were made in an attempt to detect magnetic anomalies of the Perth Sequence.

The Wharton Basin is a poorly understood area. Preliminary study of the seismic records from this leg has not led to a better understanding of its origin, but has merely added numerous complexities which must be resolved. The basin was not formed by simple rifting as would be explained by the theory of plate tectonics. The submerged marginal plateaux, and Broken Ridge to the west of the survey area remain enigmas. The variety of trends of seamounts, plateaux, and fractures, the peculiar sediment distribution, and manifestations of vertical motions within basement are atypical of ocean basins. It is suggested here that the Wharton Basin has been subject to vertical block tectonic activity, similar to that observed in continental areas.



Notes 1. To correct for inherent delay, add 0·26 seconds to reflection time
2. Ship speed approximately 10 knots

Fig. 4 SECTION FROM WESTERN MARGIN OF NATURALISTE PLATEAU

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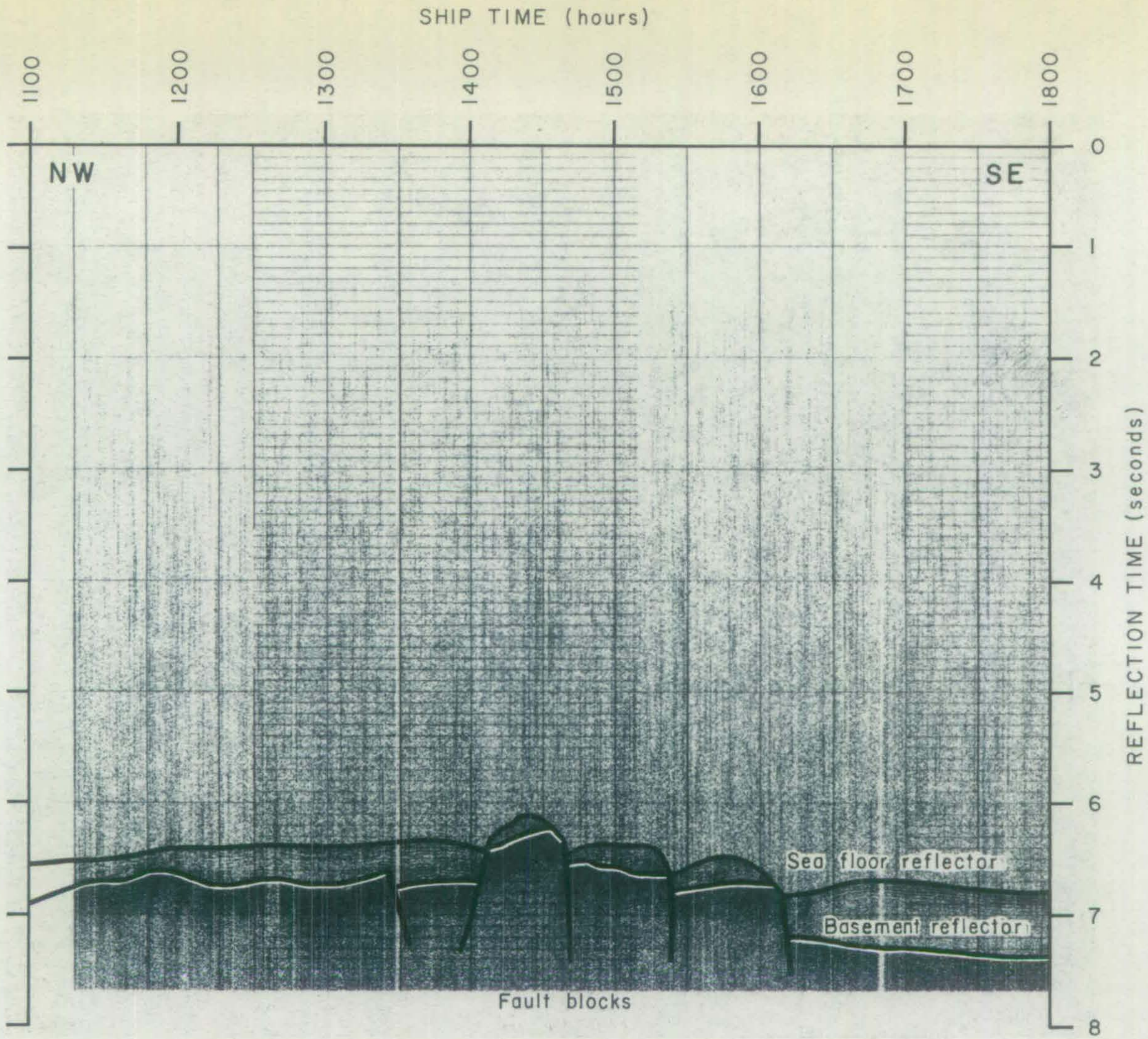

Notes 1. To correct for inherent delay, add 0·26 seconds to reflection time

2. Ship speed approximately 10 knots

Fig. 5 SECTION FROM PERTH ABYSSAL PLAIN

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