PRELIMINARY RESULTS OF GEOLOGICAL AND GEOPHYSICAL SURVEYS IN THE ROSS SEA AND IN THE DUMONT D'URVILLE SEA, OFF ANTARCTICA

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Abstract: Geological and geophysical surveys in the Ross Sea and in the Dumont d'Urville Sea were carried out in the 1982–1983 Antarctic summer season.

The presence of two large basins, namely the Eastern Basin lying to the east of the 180° meridian and the Central Basin trending north-south along 175°E, in the Ross Sea region was confirmed and the maximum sedimentary thickness in the two basins was estimated at approximately 6 km. The six-fold seismic reflection profiles indicate seven depositional sequences, which consist mainly of deltaic sediments with admixed glacial sediments in the Eastern Basin. Similar sediments were deposited in a graben structure in the Central Basin. The seismic reflection and refraction data suggest the presence of sediments of pre-Late Oligocene age in the deeper parts of the two basins beneath the Ross Sea.

Four strata in the basin of the Dumont d'Urville Sea are interpreted from reflection data. They were formed by seafloor-spreading associated with rifting between Wilkes Land and South Australia. Seismic refraction indicates a maximum sedimentary thickness in excess of 5 km. The age of the acoustic basement may be older than Late Oligocene.

1. Introduction

Since 1980, we have been conducting marine geological and geophysical surveys in order to study general features of the continental margins off Antarctica. The results of the previous cruises in the Bellingshausen Sea and in the Weddell Sea have already been published (KIMURA, 1982; OKUDA *et al.*, 1983).

During the 1982–1983 season, the TH-82 cruise employed the R/V HAKUREI-MARU in the Ross Sea and in the Dumont d'Urville Sea (Figs. 1a, 1b and 1c). The investigated area is part of the Ross Embayment, in which the Ross Sea and the adjacent Ross Ice Shelf lie along the boundary between East and West Antarctica. We also surveyed the eastern part of the sedimentary basin lying in the Dumont d'Urville Sea, which is located off Wilkes Land.

These regions were previously surveyed geophysically and geologically in several cruises, namely the USNS ELTANIN, the D/V GLOMER CHALLENGER, the M/V BENJAMIN BOWRING and the M/S EXPLORA. Data are available in many publications (*e.g.* HOUTZ and MEIJER, 1970; HOUTZ and DAVEY, 1973; HAYES and DAVEY, 1975; TALWANI *et al.*, 1979; DAVEY, 1981; DAVEY *et al.*, 1982, 1983; HINZ, 1983). We

Table 1. Summary of the TH-82 cruise.

	Dumont d'Urville Sea	Ross Sea	Total
Survey period (days)	11	23	34
Seismic reflection (km)	820	2060	2880
multichannel (km)	680	1670	2350
single channel (km)	140	390	530
Seismic refraction	3	17*	20*
Magnetic and gravity (km)	4000	7000	11000
Heat flow	3	6	9
Piston coring	3	3	6
Gravity coring	—	9	9
Smith-McIntyre grab	1	—	1
Dredging	2	1	3

* SB-10 was troubled.

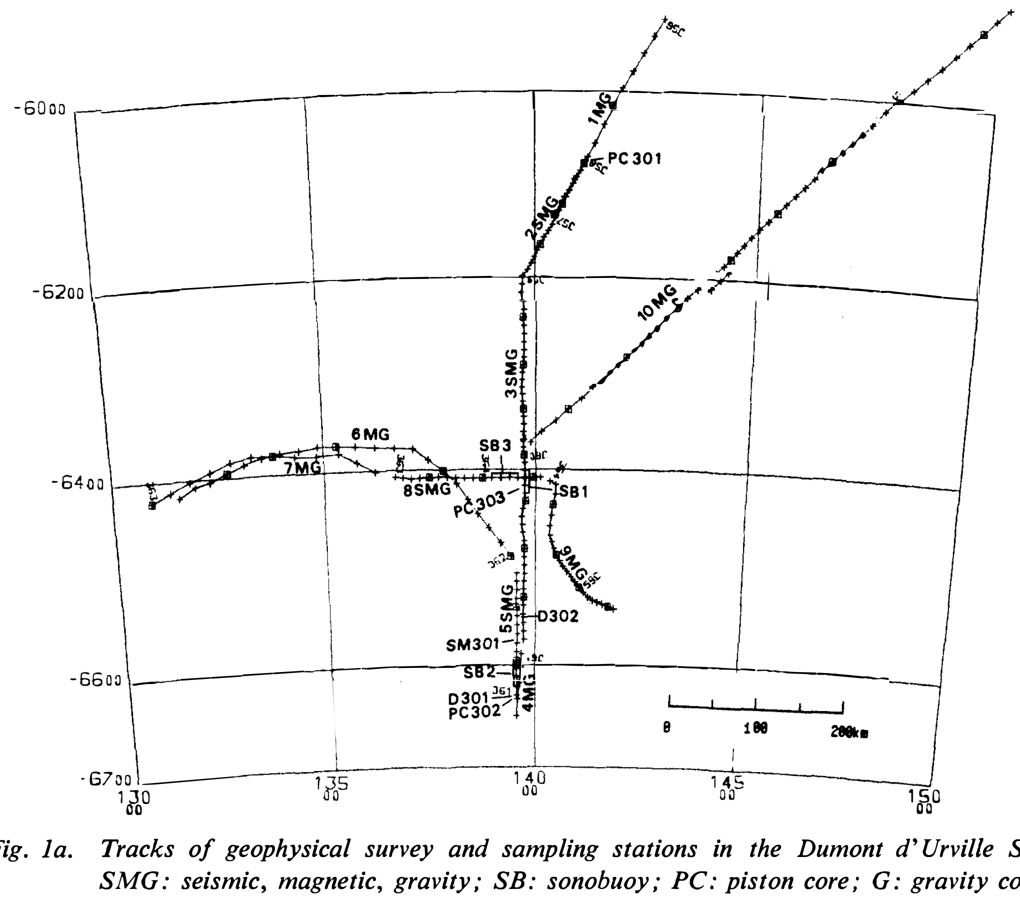

Fig. 1a. Tracks of geophysical survey and sampling stations in the Dumont d'Urville Sea. SMG: seismic, magnetic, gravity; SB: sonobuoy; PC: piston core; G: gravity core; D: dredge; SM: Smith-McIntyre grab.

have combined the data from these previous cruises with our own to outline in a preliminary fashion the distribution of the sedimentary basins. As our next cruise (TH-83) will continue surveying in the Dumont d'Urville Sea, a detailed discussion of this area will be presented in the near future.

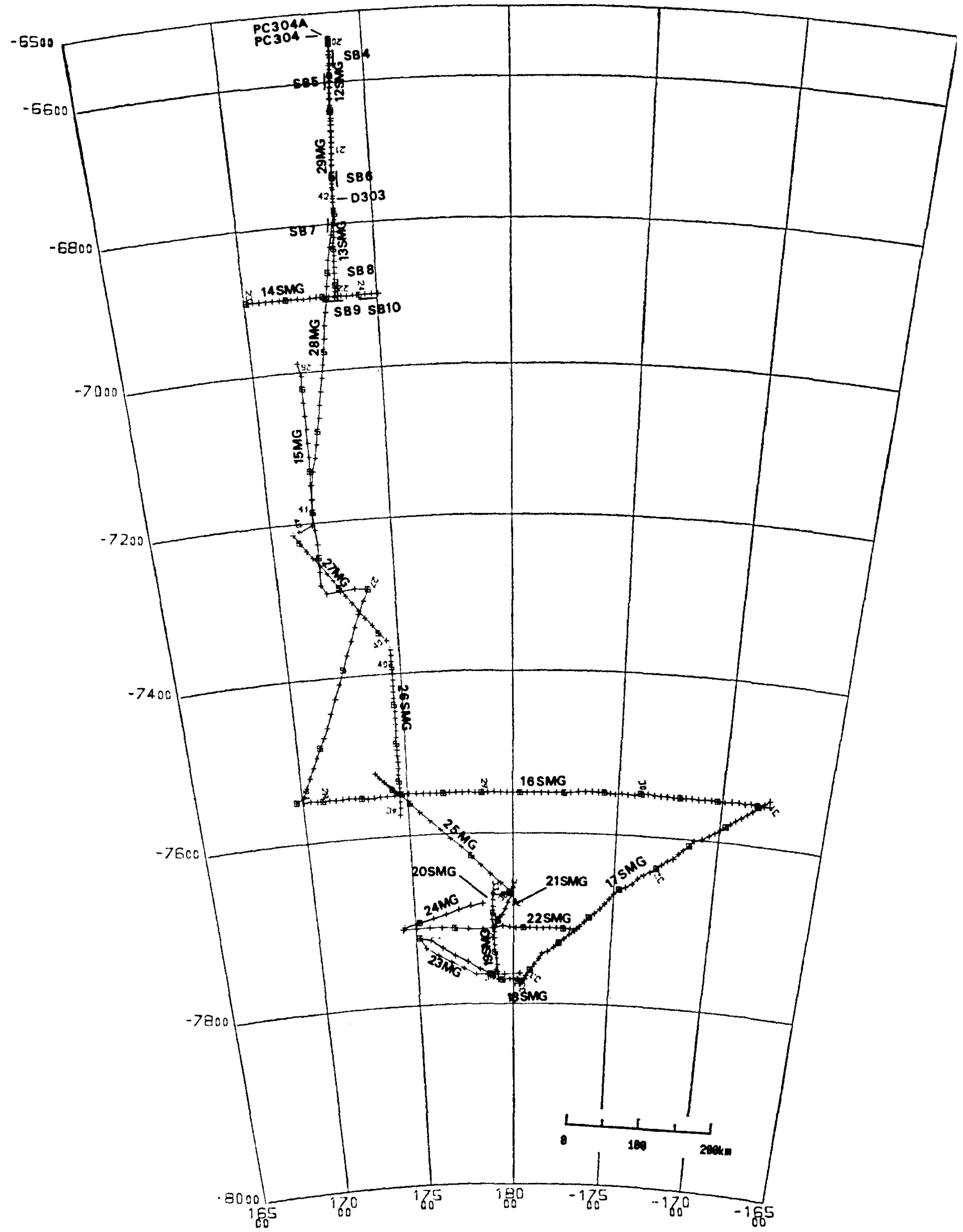

Fig. 1b. Tracks of geophysical survey and sampling stations in the area off Cape Adare.

2. Outline of the Cruise

The R/V HAKUREI-MARU has the following specifications: no ice-class; overall length 86.95 m; 1821.6 gross t; and a main engine rate of 3800 PS $\times$ 230 rpm $\times$ 1.

Data for the seismic reflection work were collected from a digital recording unit of the DSF V type, a 24-channel SEC ministreamer, and a Bolt type airgun. The airgun has a total volume of 9.2 *l* (approximately 550 cubic inches) with an operating

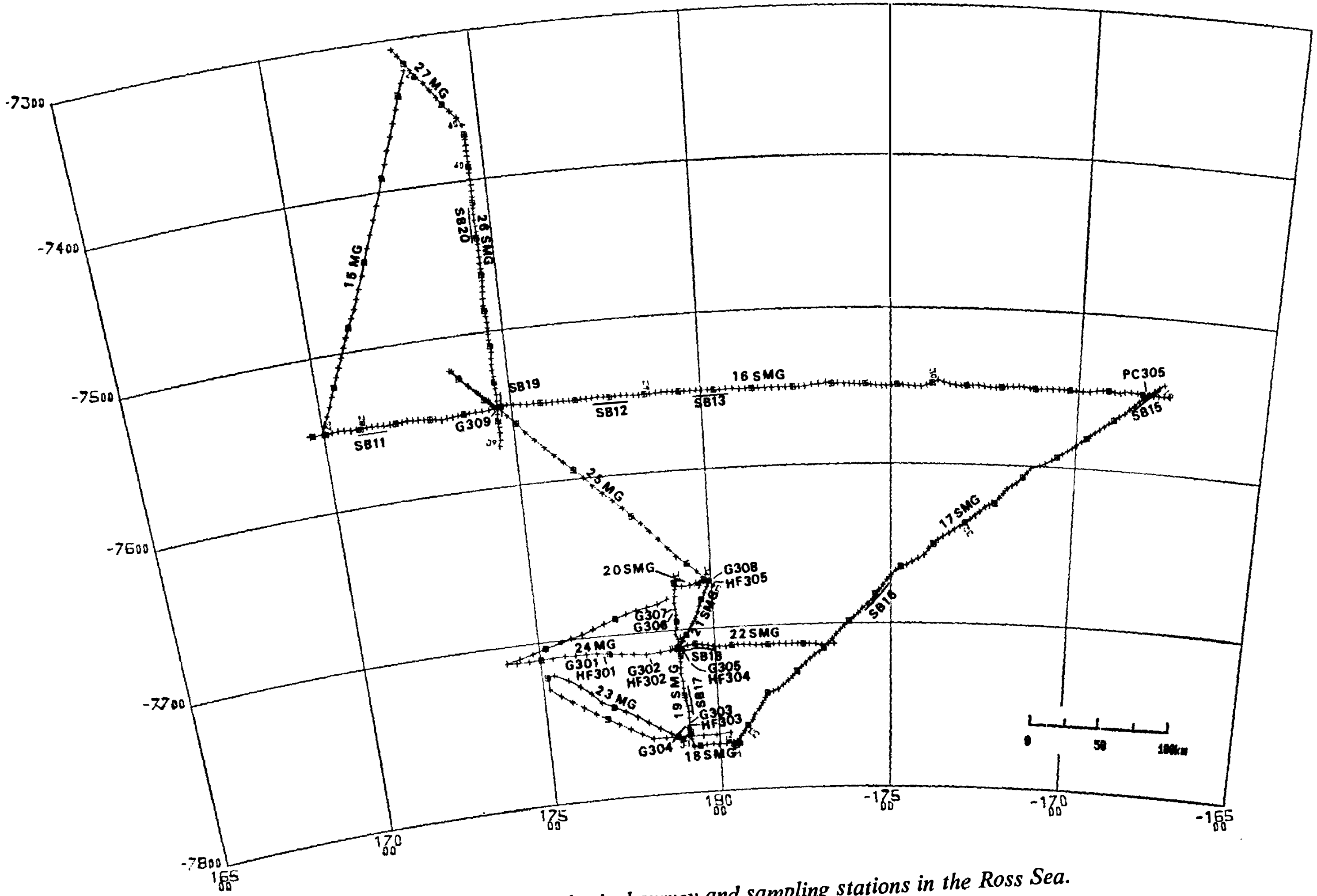

Fig. 1c. Tracks of geophysical survey and sampling stations in the Ross Sea.

Table 2. Summary of bottom sampling and terrestrial heat-flow measurements.

St. No.	Sample No.	Date	GMT	Lat. (S)	Long.	Depth (m)	Description	Fossils	Heat flow data K	Q(HFU)	Recovery (m/m)
1	PC301	357	0615	60°44.5′	141°07.6′E	4400	Diatom Ooze-slightly sili. Silt		1.98	2.78	5.60/8
2	PC302	2	0116	66 19.5	139 30.7E	827	Diatom Ooze-slightly sili. Silt	abundant Radiolaria/	1.55	1.63	7.55/8
6	PC303	3	0023	64 11.8	139 44.9E	3553	slightly sili. Silt-slightly sili. sdy Silt	Diatom	2.33	1.60	6.51/8
7	PC304	20	0106	65 22.2	173 52.4E	3369	slightly sili. Silt		1.91	0.386	6.26/8
7A	PC304A	42	2022	65 22.2	173 51.8E	3370	slightly sili. Silt		1.98	0.202	3.56/4
8	PC305	31	0047	75 30.0	168 06.5W	2554	rhythmic Silt/slty. Sand alternation	N.F.			0.79/4
9	G301	34	2234	77 07.4	176 45.2E	637	pebbly sdy. Silt-pebbly slty. Sand	rare Diatom			1.66/2
10	G302	35	0315	77 06.8	178 00.4E	600	pebbly sdy. Silt	N.F.			1.00/2
11	G303	35	0135	77 38.7	179 18.9E	648	pebbly Silt-pebbly sdy. Silt	rare Radiolaria			1.41/2
12	G304	36	1952	77 34.1	179 04.1E	697	Silt-pebbly sdy. Silt	N.F.			0.75/2
13	G305	37	0030	77 06.5	179 00.1E	685	Silt-pebbly sdy. Silt.	common Diatom			1.78/2
14	G306	37	1937	76 47.2	178 54.5E	340	sdy. Silt	common Diatom			0/2
15	G307	37	2044	76 43.0	179 05.1E	180	Silt-Sand	common Radiolaria/ Diatom			0.56/2
16	G308	37	2248	76 42.4	179 58.9E	617	Silt-pebbly sdy. Silt	rare Diatom			1.66/2
17	G309	38	1947	75 29.9	174 38.1E	302	Silt-pebbly sdy. Silt	N.F.			0.60/2

3	D301	2	0305	66 17.2 66 17.1	139 33.3E 139 32.9E	740	Sedi. R.-30%; Igne. R.-35%; Meta. R.-35% (Sst. Cht. Balt. Gb. Gr. Sch. Gn.)				
5	D302	2	0939	65 31.6 65 31.4	139 32.1E 139 31.4E	550	Sedi. R.-24%; Igne. R.-63%; Meta. R.-13% (Sst. Sh. Lst. And. Balt. Gb. Gr. Apl. Sch.)				
18	D303	42	0108	67 46.8 67 47.0	173 37.0E 173 36.9E	3080 2900	Sedi. R.-25%; Igne. R.-58%; Meta. R.-17% (Sst. And. Balt. Gr. Sch.)				
4	SM301	2	0649	65 46.0 65 45.9	139 31.8E 139 31.8E	450	Diatom Ooze-slightly sili. Silt	v. common Radiolaria/ Diatom			*
9A	HF301	35	0028	77 07.2	176 43.7E	638			3.25	1.74	
10A	HF302	35	0405	77 06.7	178 02.1E	597			3.40	2.65	
11A	HF303	36	0206	77 38.9	179 19.2E	675					
13A	HF304	37	0128	77 06.7	179 00.2E	692			2.91	2.85	
16A	HF305	38	0031	76 42.3	179 58.0E	602			3.04	2.72	

PC: Piston corers.
G: Gravity corers.
D: Dredges.
SM: Smith-McIntyre spring-loading grabs.
HF: POGO type heat flow probe.
* Deep-sea camera (3 points).

pressure of 133 kg/cm^2 (approximately 1900 psi) from a Norwalk APS-120 compressor, and a shot interval of 50 m.

Sonobuoys (Oki Electric OC-01) and a receiver (Japan Radio NRE-8A) were used with this airgun.

Magnetic and gravity measurements were made using a proton magnetometer (Geometrics G801) and a gravimeter (LaCoste & Romberg S-79). Magnetic anomalies and free-air gravity anomalies were obtained by subtraction of the IGRF 1975 and the IGSN 71, respectively.

A 12 kHz precision depth recorder (Nippon Electric NS-16) and a 3.5 kHz subbottom profiler (Raytheon) were employed.

For heat-flow measurements, thermistors attached to a piston corer of the Nippon Oil & Fats GSJ-type, a probe-type heat flow apparatus (Nippon Oil & Fats NTS-5DR), and a thermal conductivity meter (Showa Denko QTM-DII) were used.

Bottom sampling was done with a GSJ-type piston corer, with a GSJ-type gravity corer, with a GSJ-type dredger, and with a Smith-McIntyre grab sampler.

Positioning was made with the Navy Navigation Satellite System (Magnavox MITI-1), consisting of navigation and data acquisition units.

The TH-82 cruise was carried out by the Technology Research Center of the Japan National Oil Corporation, in cooperation with the Geological Survey of Japan. Data obtained during this cruise are summarized in Table 1.

3. Bottom Samplings and Terrestrial Heat-Flow Measurements

Sampling tools were selected on the basis of seismic records. The piston corer with heat-flow thermistors was used where there were muddy, silty and unconsolidated sediments. In sandy or consolidated sediments, the gravity corer was used. After observation of the sediments in the gravity corer, heat flow was measured at the same stations by a probe-type apparatus. The dredger was used where either the slope was relatively steep or hard rocks were encountered.

The results of bottom samplings and terrestrial heat-flow measurements are shown in Table 2.

In the Dumont d'Urville Sea, unconsolidated sediments were collected using either an 8-m piston corer with heat-flow thermistors at 3 stations (PC301 to PC303) or a Smith-McIntyre grab at one station (SM301). Most of the sediments are composed of diatomaceous ooze and siliceous silt. PC302 core in the continental shelf is predominantly ooze with sponge spicules and microfossils. The dredged rocks (D301 and D302) were composed of angular clasts of sedimentary rocks, and rounded pebbles of metamorphic and igneous rocks with unconsolidated sediments. The diatom, *Nitzschia kerguelensis* which is Quaternary in age (ABBOT, 1974), is common in most of the sediments except for D302. D302 in the continental slope contained a carbonate rock. Diatom compositions of the carbonate rock are of different species from the other samples. Most dominant species is *Stephanopyxis* spp. and the representative species are *Synedra miocenica*, correlated with Miocene in age (SCHRADER, 1976), and *Pseudotriceratium chenevieri*, correlated with Late Oligocene by SCHRADER and FENNER (1976). This carbonate rock may have been derived from the carbonatecemented silt in the deepest core of Site 269.

The heat-flow value in PC301 was higher than the others which are near the average value in the world oceans.

In the Ross Sea, subsurface sediments were obtained using a 2-m gravity corer at 9 stations (G301 to G309), and either an 8-m or a 4-m piston corer with heat-flow thermistors at 3 stations (PC304 to PC305). PC304 and PC304A cores in the continental margin off Cape Adare are predominantly of siliceous silt. The sediments in the Ross Sea region (G301–G309 and PC305) are composed of pebble-bearing sandy silt and silty sand. Dredging was done at only one station (D303) off Cape Adare; the sample consisted of unconsolidated sediments with cobbles of sedimentary, metamorphic and igneous rocks. All microfossils were of Quaternary age.

The heat-flow measurements off Cape Adare were done in the same places (PC304 and PC304A). Their values were very low, probably due to the influence of a fracture zone. On the other hand, the heat-flow values within the Ross Sea were higher than the world average.

4. Gravity and Magnetic Anomalies

Free-air gravity anomalies and magnetic anomalies in the surveyed area are shown in Figs. 2 and 3.

In the Dumont d'Urville Sea, free-air anomalies were minus several tens of mgal

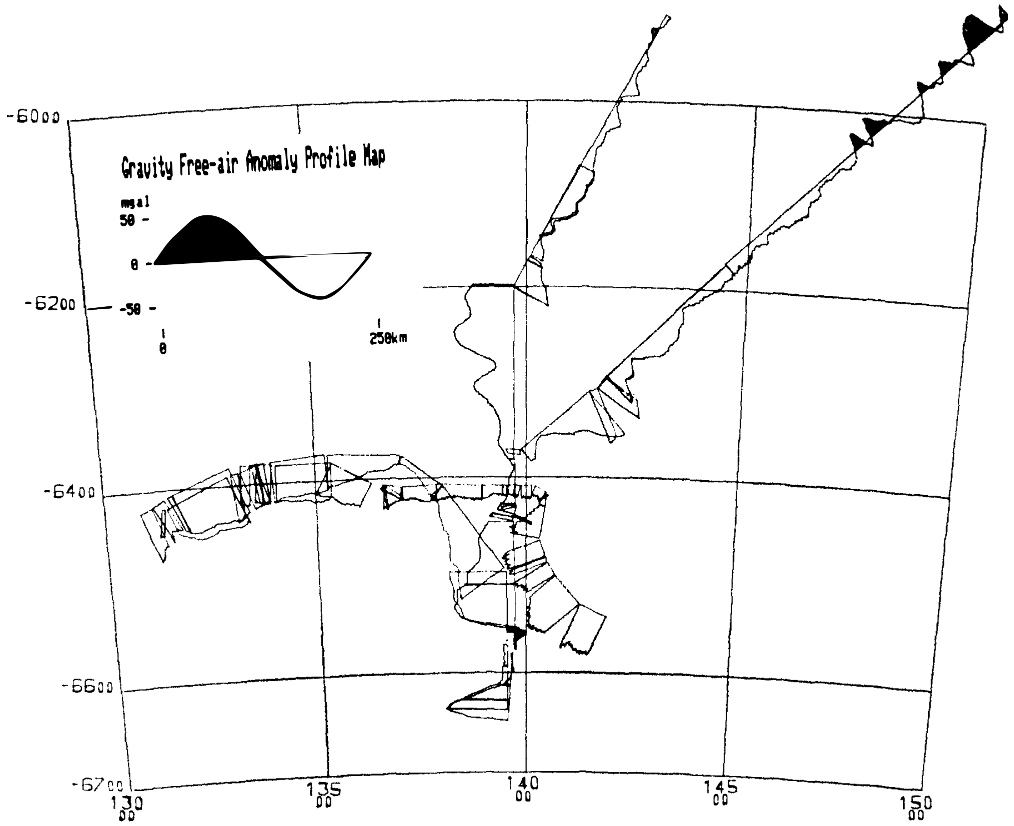

Fig. 2a. Free-air gravity anomaly profile in the Dumont d'Urville Sea.

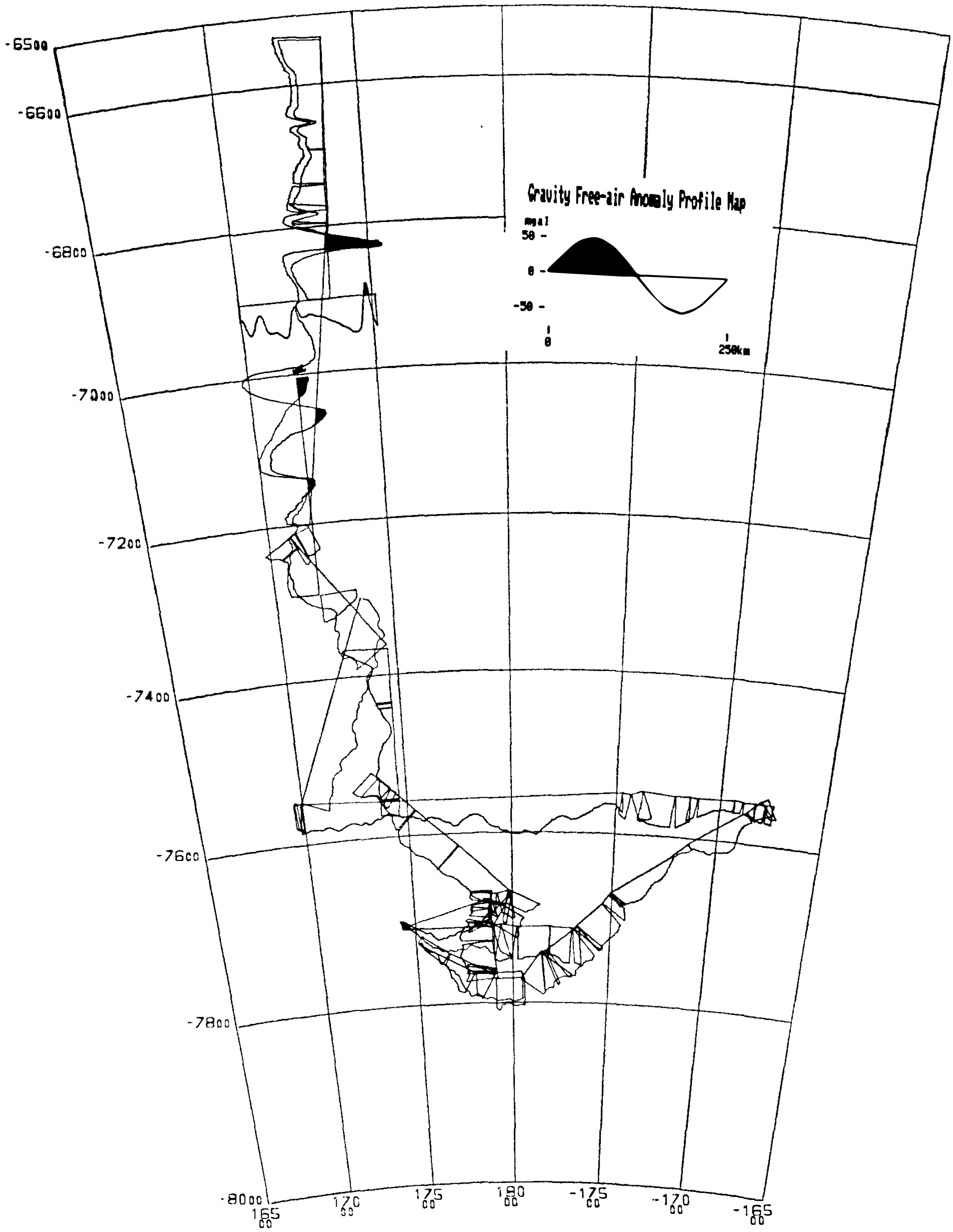

Fig. 2b. Free-air gravity anomaly profile in the Ross Sea region.

except for a few positive anomalies. Over the continental shelf, these anomalies had a −10 mgal bias as compared with those in the continental margin. Typical paired anomalies were obtained in the outer part of the continental shelf.

Magnetic anomalies in the continental margin were lower than the average value observed in this area.

Everywhere over the Ross Sea, free-air anomalies has a −10 mgal bias. Although these anomalies on the continental slope and rise reflected well the submarine

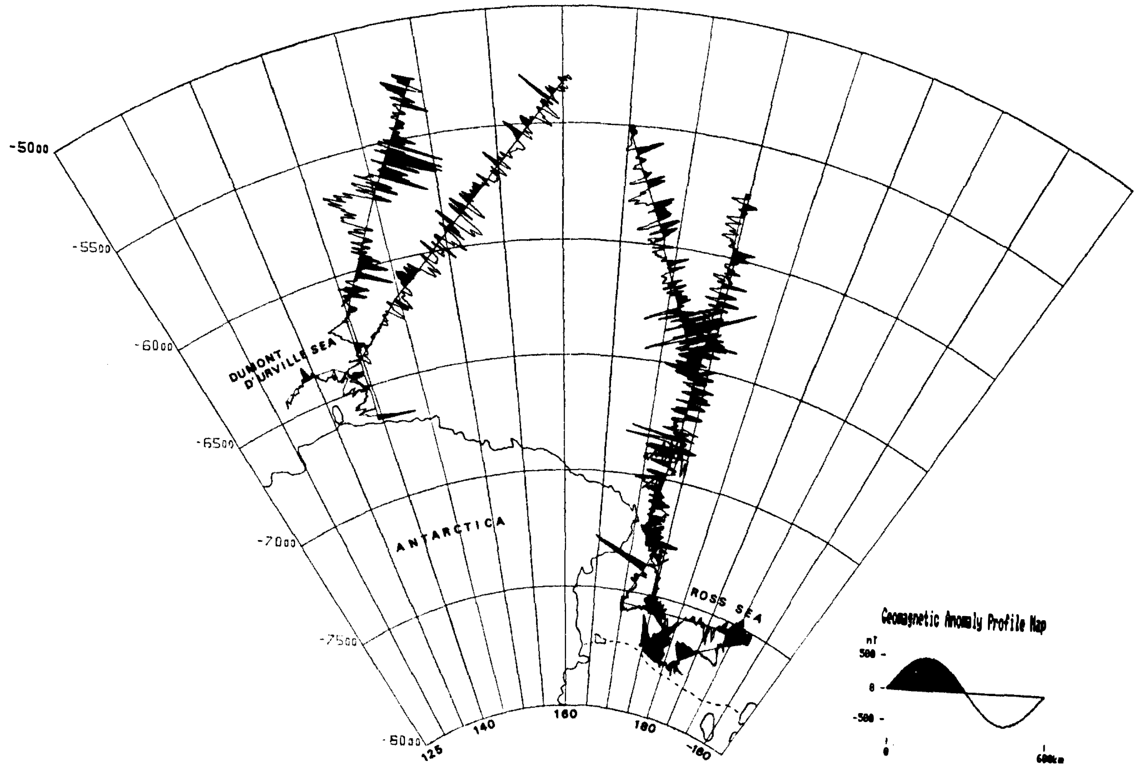

Fig. 3. Magnetic anomaly profile in the surveyed area.

topography, this tendency was not recognized on the continental shelf.

Magnetic anomalies on the shelf showed low amplitude characteristics with some short periodic noises, except for the value in the area of 175°E and 77°S (Fig. 3). Magnetic anomalies on the continental margin reflected well the submarine topography, and there the anomalies associated with seafloor-spreading were observed. On the continental shelf, a few magnetic anomalies were several hundreds of nT in amplitude with 200 km in wavelength; however, this is caused obviously by 24-hour periodicity.

Gravity and magnetic anomalies in this survey nearly agree with the results by HAYES and DAVEY (1975).

5. Seismic Reflection and Refraction Surveys

A series of holes were drilled on Leg 28 of the Deep Sea Drilling Project in our surveyed areas, namely Site 269 in the Dumont d'Urville Sea, Site 274 in the area off Cape Adare, and Sites 270, 271, 272 and 273 in the Ross Sea. Thus, our seismic lines passed all of these sites.

Lines of seismic reflection and refraction surveys in the investigated areas are shown in Figs. 4a, 4b and 4c.

A total of 2350 km of 6-fold seismic reflection data, 530 km of single channel data and 19 sonobuoy refraction data were obtained. The interpretation of the refraction measurements is given in Fig. 5. Based upon the obtained refraction data, the maximum sedimentary thickness in the Dumont d'Urville Sea is approximately

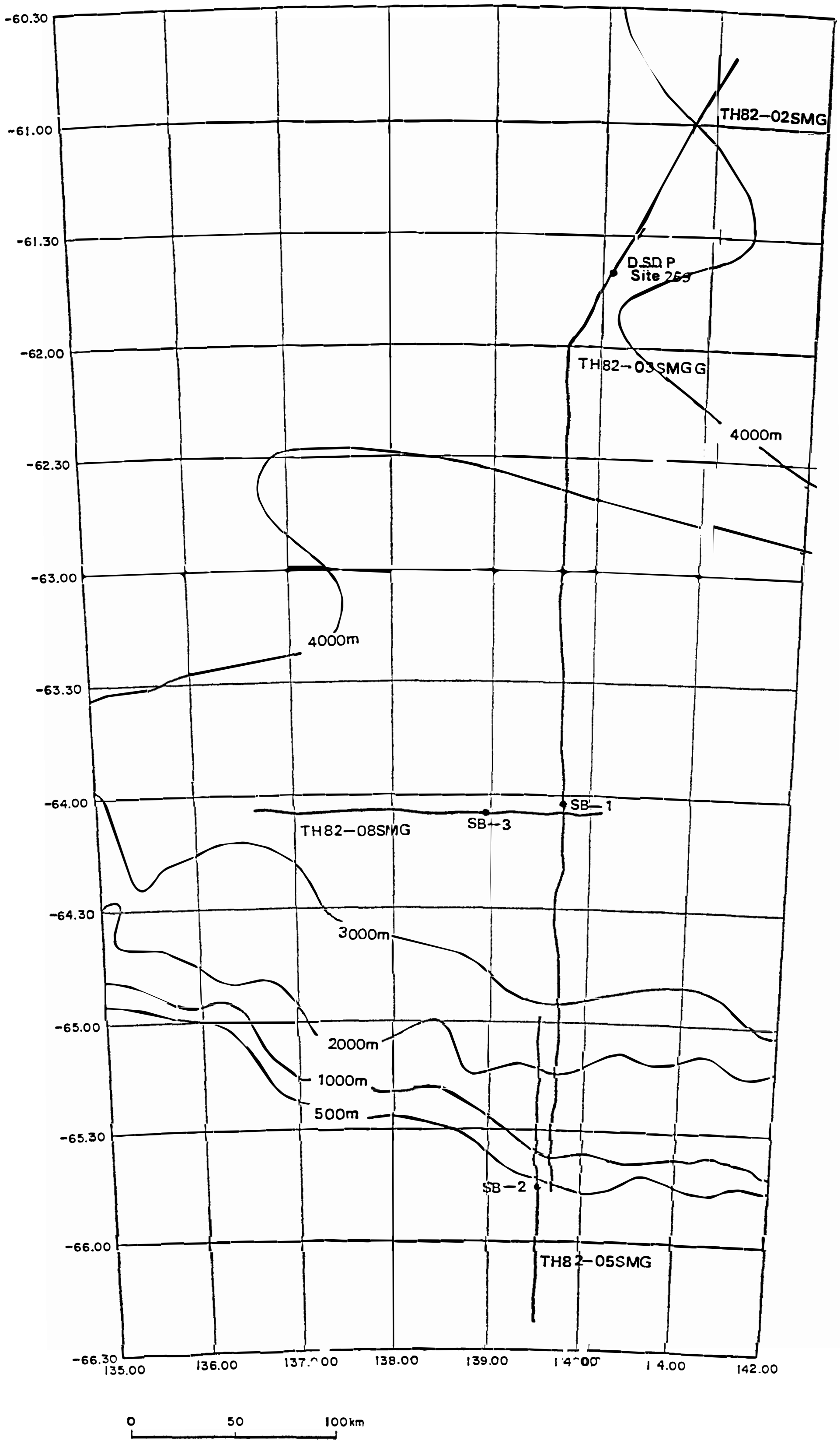

Fig. 4a. Lines of seismic reflection and refraction surveys in the Dumont d'Urville Sea.

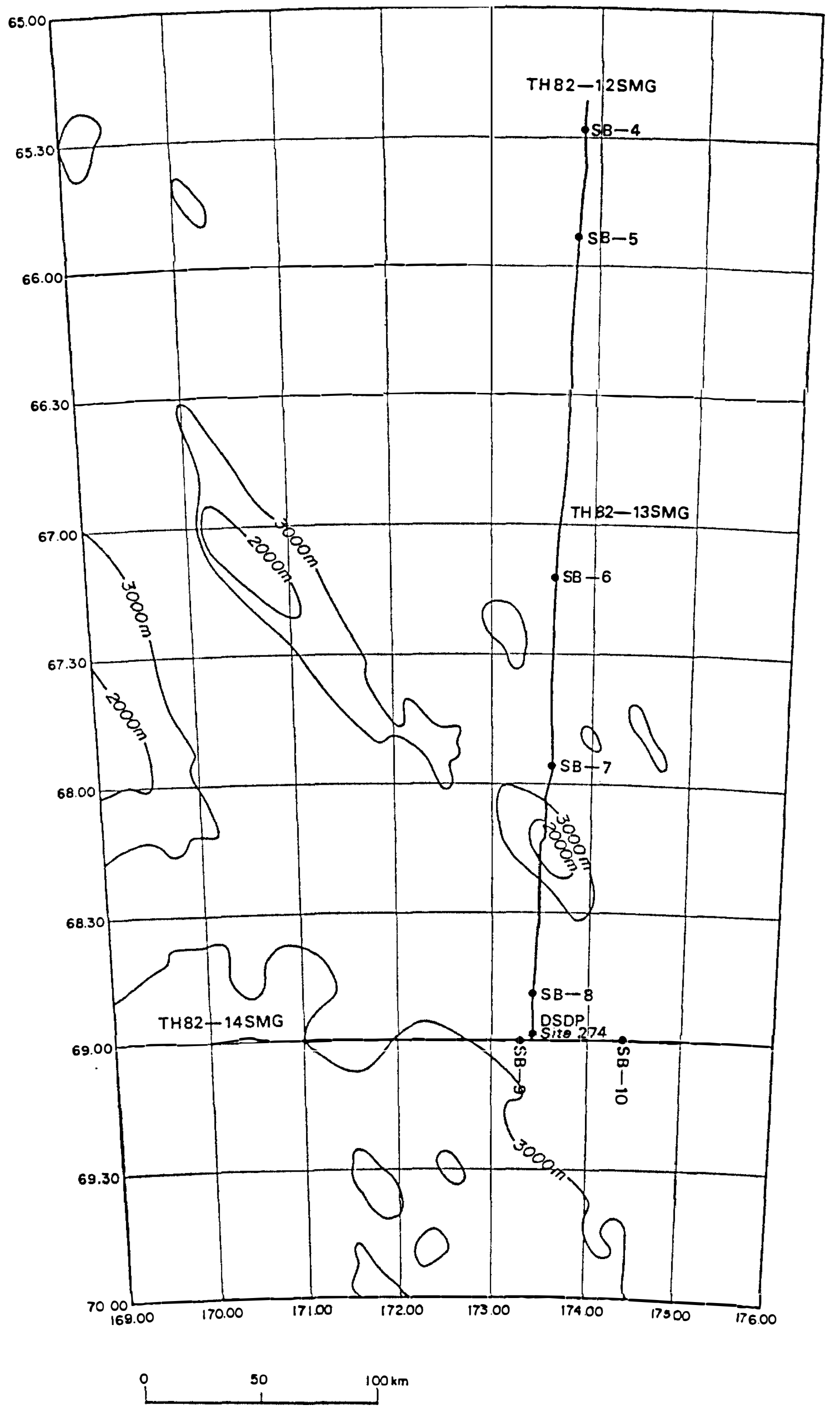

Fig. 4b. Lines of seismic reflection and refraction surveys in the area off Cape Adare.

5 km, and in the Ross Sea, 6 km.

In the Ross Sea, we identify seven strata as A1, B1, C1, D1, E1, F1 and F′1 (Figs. 6a, 6b and 6c) on the basis of a seismic profile (Line 17) from Sites 270 to 273. The results of the BGR seismic lines (HINZ, 1983) near Line 17 helped identification of strata.

Site 270 penetrated rocks from Recent sediments to Early Paleozoic metamor-

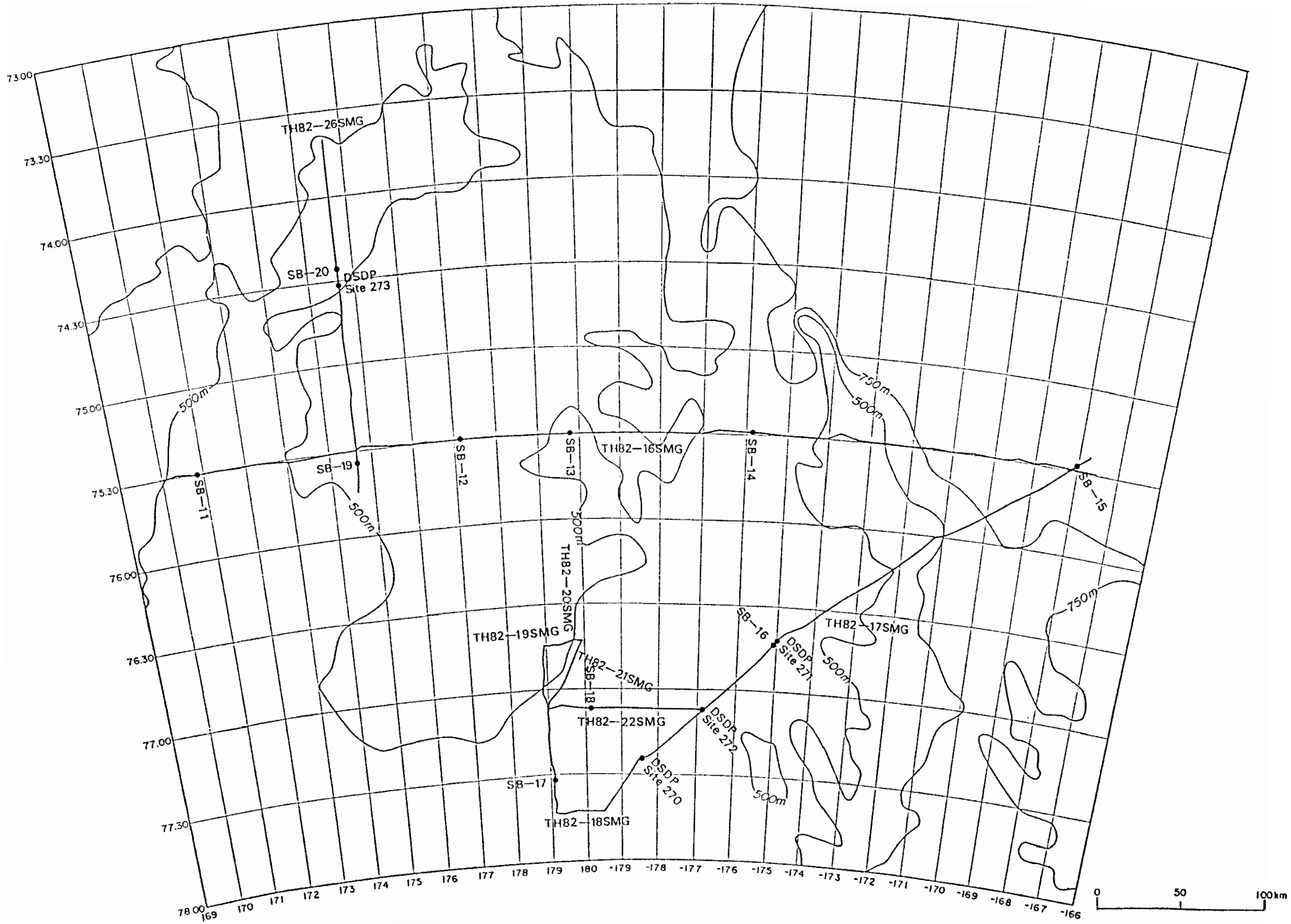

Fig. 4c. Lines of seismic reflection and refraction surveys in the Ross Sea.

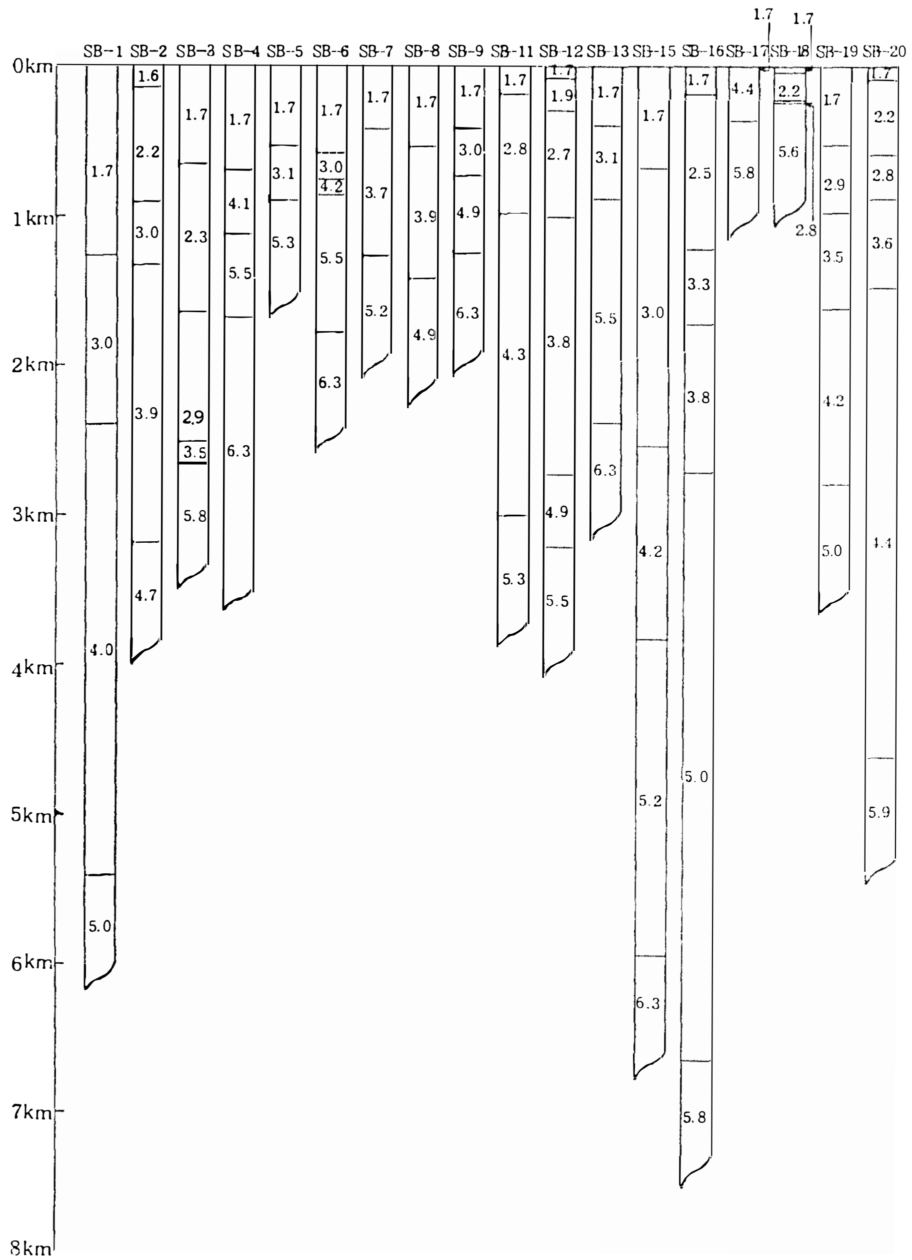

Fig. 5. Velocity-depth profiles for sonobuoy surveys.

phics; we interprete the latter as acoustic basement in Line 17.

After comparison with the DSDP data (HAYES and FRAKES, 1975) and HINZ (1983), the assumed ages of seven strata are A1 (Quaternary), B1 (Quaternary to Pliocene), C1 (Pliocene to Late Miocene), D1 (Late Miocene to early Late Miocene), E1 (early Late Miocene to early Middle Miocene), F1 (early Middle Miocene to Late Oligocene) and F′1 (Late Oligocene).

In the area off Cape Adare (Fig. 6d), five layers are A2 and B2 (probably Quaternary to Early Pliocene), C2 (Early Pliocene to Late Miocene), D2 (Middle Miocene to Early Miocene) and E2 (possibly Early Miocene to Early Oligocene).

In the Dumont d'Urville Sea (Fig. 6e), we define four strata geophysically and

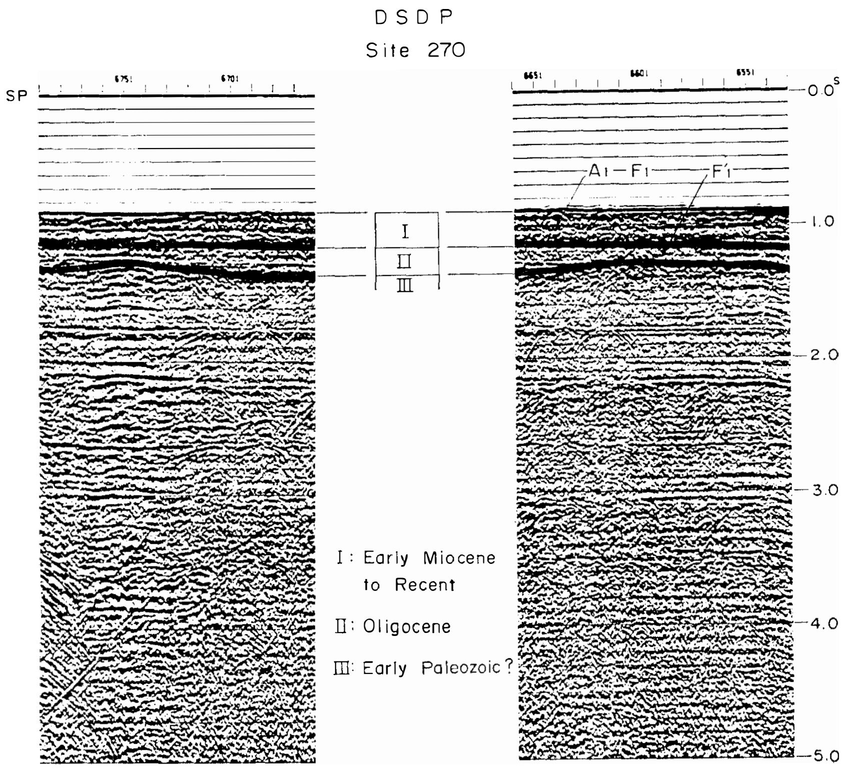

Fig. 6a. Correlation of the interpretative profile (Line 17) with the DSDP data (Site 270) in the Ross Sea.

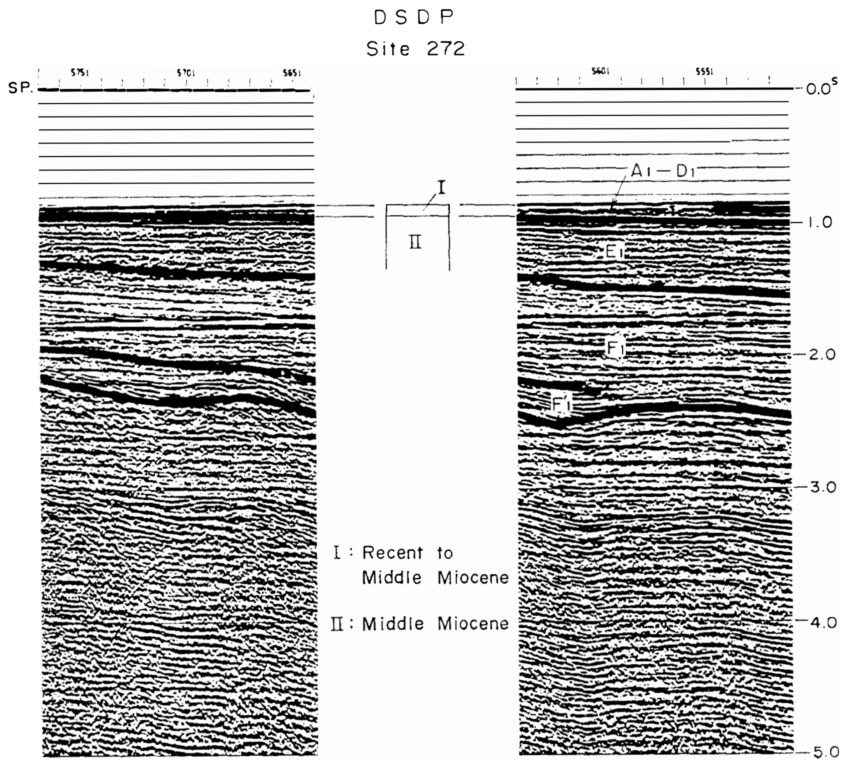

Fig. 6b. Correlation of the interpretative profile (Line 17) with the DSDP data (Site 272) in the Ross Sea.

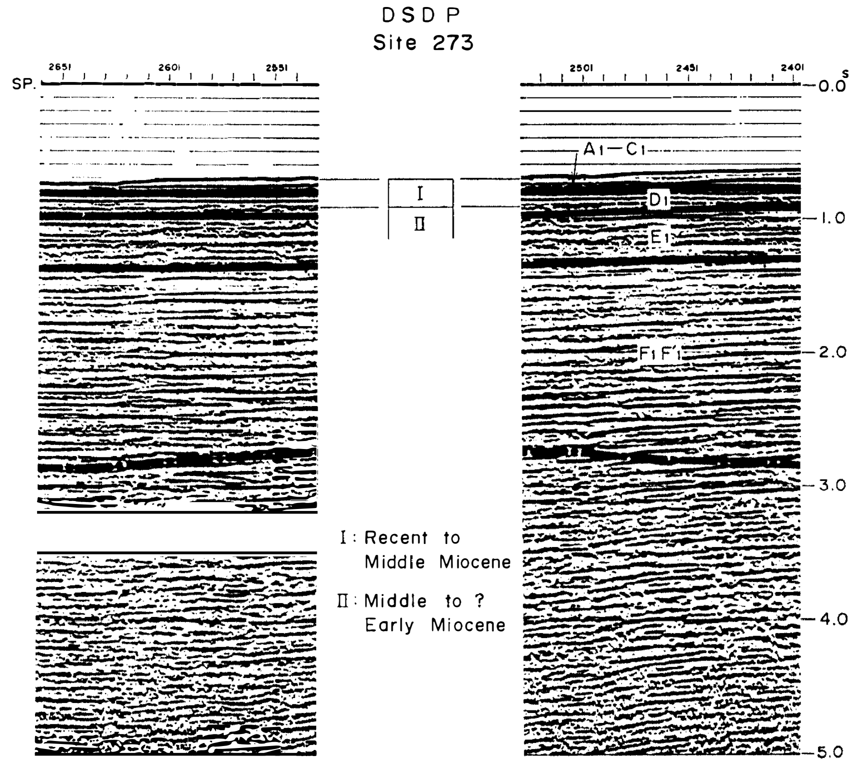

Fig. 6c. Correlation of the interpretative profile (Line 26) with the DSDP data (Site 273) in the Ross Sea.

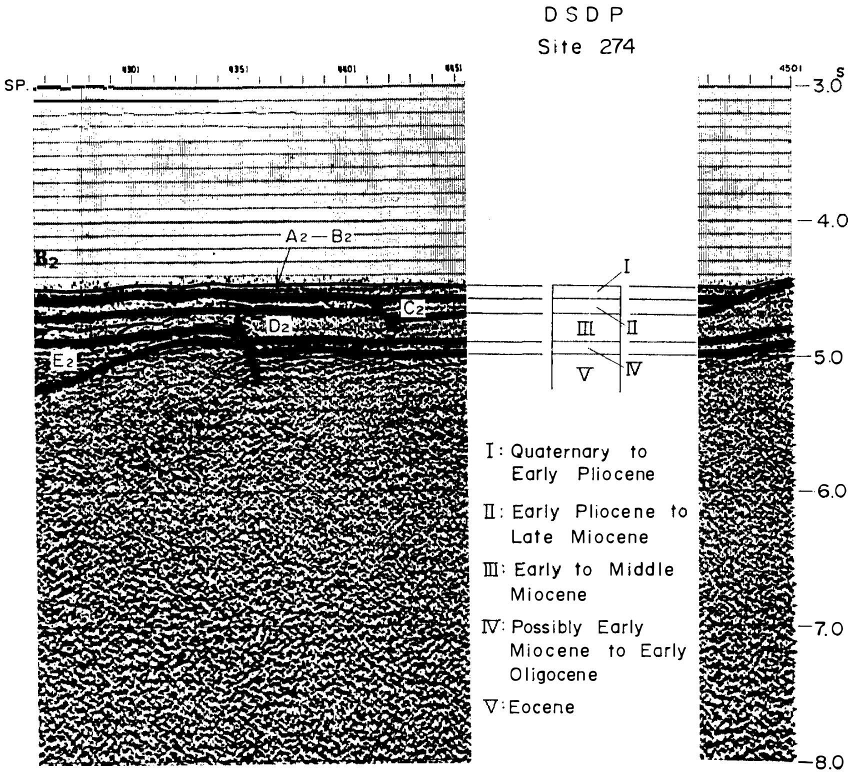

Fig. 6d. Correlation of the interpretative profile (Line 13) with the DSDP data (Site 274) in the area off Cape Adare.

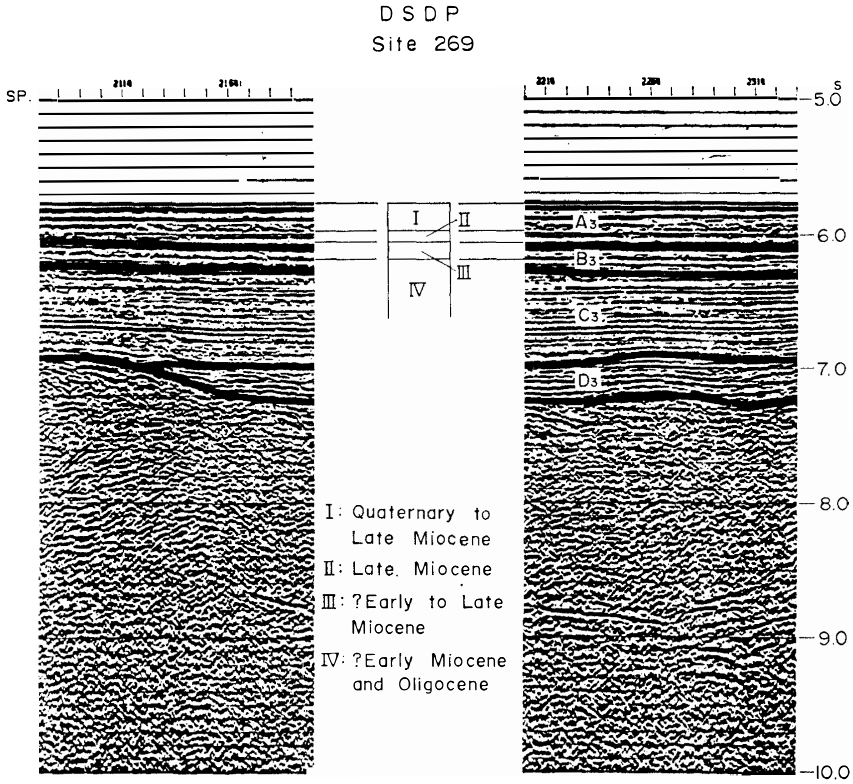

Fig. 6e. Correlation of the interpretative profile (Line 2) with the DSDP data (Site 269) in the Dumont d'Urville Sea.

have called them, in descending order, A3, B3, C3 and D3. Their ages are considered from DSDP data to be A3 (Quaternary to Neogene), B3 (Neogene to Late Paleogene), C3 (Middle Paleogene) and D3 (Early Paleogene).

6. Geological and Geophysical Features of Sedimentary Basins

6.1. The Ross Sea

In this area, three basins contain thick successions of sediments; these have been called the Eastern Basin, the Central Basin, and the Victoria Land Basin (DAVEY, 1981; DAVEY *et al.*, 1983).

A schematic isochron map of total sediments and a schematic acoustic basement map of two-way travel time are given in Figs. 7 and 8. We confirm the findings of previous workers (HAYES and DAVEY, 1975; DAVEY, 1981; DAVEY *et al.*, 1983; HINZ, 1983). Along the 180° meridian from the Ross Ice Shelf, a basement high (Central High) separates two large basins (the Eastern Basin and the Central Basin).

6.1.1. The Eastern Basin

The Eastern Basin underlies the greater part of the Ross Sea to the east of 180° and extends from the continental slope southwards under the Ross Ice Shelf (DAVEY *et al.*, 1983).

The interpreted geological sections presented in Figs. 9 and 10 indicate that the Central High extends from 178°E to 179°W and that the sedimentary thickness increases eastward. These sections, dipping slightly basinward, show a series of the

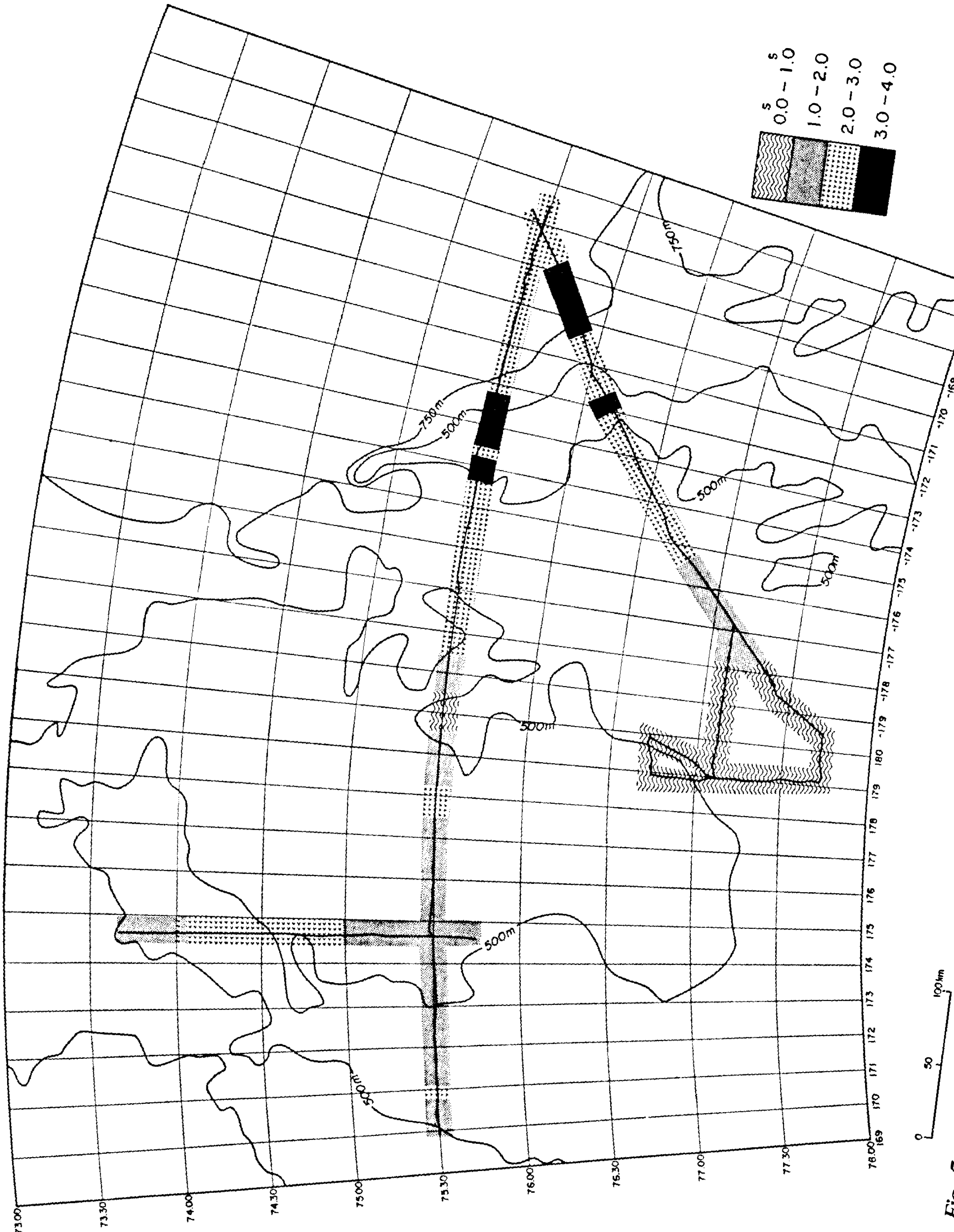

Fig. 7. Schematic isochron map of total sediments in seconds in the Ross Sea. 500 m; Water depth.

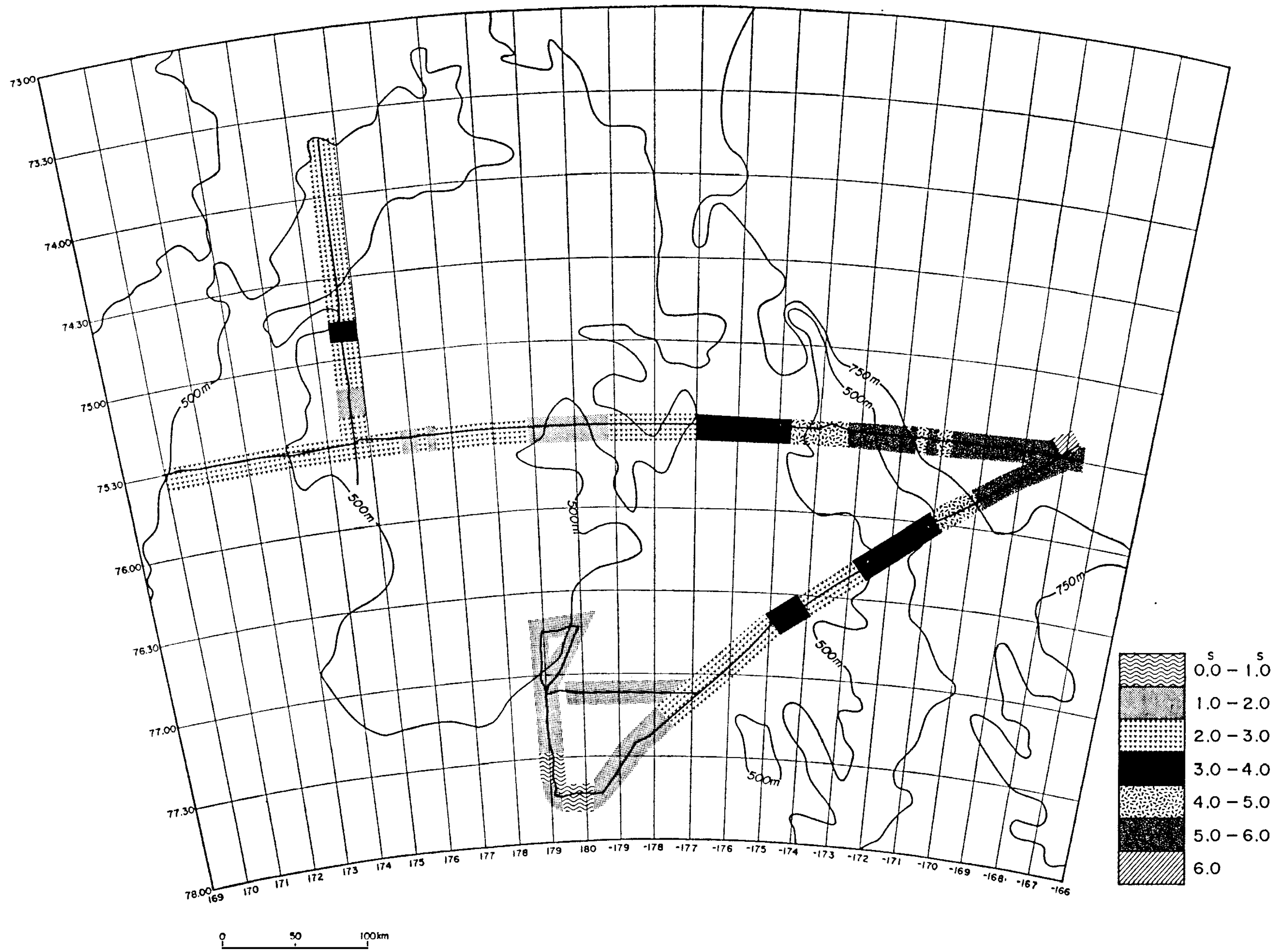

Fig. 8. Schematic acoustic basement map of two-way travel time (s) in the Ross Sea. 500 m; Water depth.

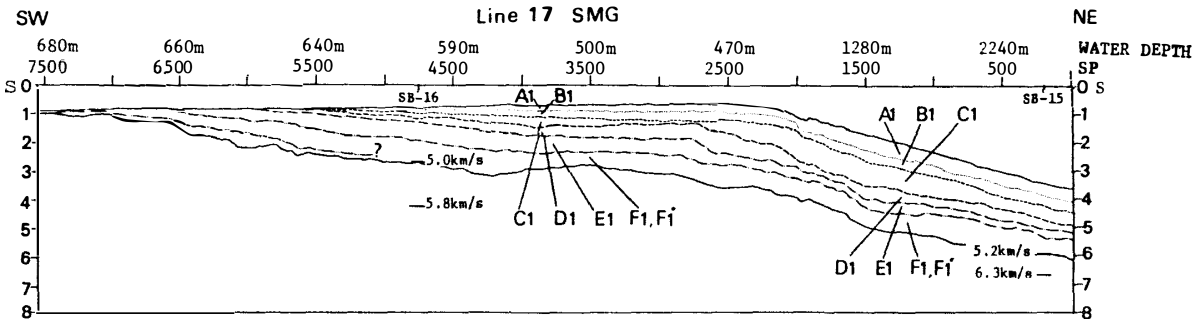

Fig. 9. Interpretative geologic section (Line 17) in the Ross Sea.

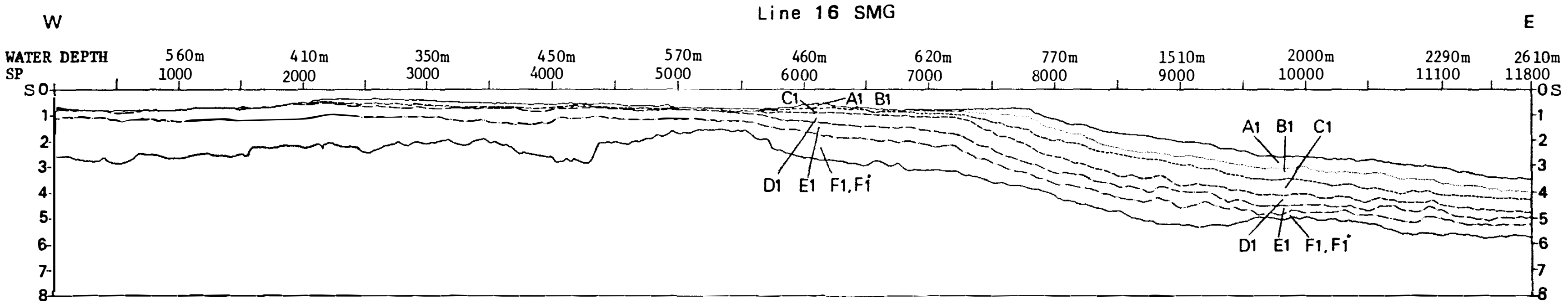

Fig. 10. Interpretative geologic section (Line 16) in the Ross Sea.

depositional sequences prograding seaward, as noted by HINZ (1983).

According to DSDP data (HAYES and DAVEY, 1975), the sediments in the Eastern Basin are composed mainly of siliceous silt and clay, together with sandy sediments derived from glacial erosion. They might be the result of transportation by the Antarctic coastal current and the Antarctic bottom water, and by melting of icebergs as well as the floating extension of the Ross Ice Shelf. The sedimentary strata in the west of the Eastern Basin thin toward the Central High, and are truncated against the seafloor probably by glacial erosion.

In the outer part of the Ross Sea Shelf, the strata of A1 to E1 in Lines 16 and 17 indicate a prograding clinoform, and the stratum C1 shows a characteristic pattern of oblique seismic reflection. HINZ (1983) interpreted the prograding strata as a series of mainly fluvial delta lobes, and the oblique reflection pattern as a prodelta facies. The strata of A1 to E1 were deposited by a delta which prograded over a subsiding platform. This platform was somewhat affected by glaciomarine transport.

The presence of multiple reflection prevents interpretation of the deeper structure in the Ross Sea. Therefore, the refraction survey is useful in recognizing the distribution of sedimentary basins and basement depth. The velocity in the Eastern Basin increases linearly with depth (Fig. 11). No measurement of the basement velocity could be carried out in the Eastern Basin.

DAVEY *et al.* (1983) present an isopach map of sediments on the basis of velocities of 5.0 to 5.5 km/s in sub-basement.

They assumed that a metamorphic basement exceeding 6 km/s underlay the sub-basement.

A sonobuoy (SB-15) was placed near the center of the Eastern Basin, which is located in the continental slope of the eastern Ross Sea. Strata with a velocity of 5.2 km/s (Late Oligocene) overlies a layer of 6.3 km/s. This layer may be metamorphic basement at 6 km in sub-bottom depth.

In the reflection profile (Line 17), the equivalent reflector to the velocity of 6.3 km/s can be observed.

A sonobuoy (SB-16), which was located near Site 271 in the western margin of the Eastern Basin, measured a velocity of 5.8 km/s at 6.7 km in sub-bottom depth. The BGR seismic survey was carried out near SB-16. HINZ (1983) determined that the sediments of 6 km thickness are present on the acoustic basement which is graben-like and trends north-south along 170°W. Therefore, we assume a velocity of 5.8 km/s by SB-16 as the acoustic basement velocity.

6.1.2. The Central Basin

The Central Basin lies along the north-south trend through the central areas of the Ross Sea along 175°E and 74°S (DAVEY *et al.*, 1982).

The interpreted section as shown in Fig. 9 indicates grabens in the acoustic basement. The sediments in this basin are folded, and axes trend approximately north-south. HOUTZ and DAVEY (1973), and HAYES and DAVEY (1975) interpreted grabens in the Central Basin to have resulted from an east-west extension. DAVEY (1981) suggested that this extension was due to a spreading center, and that the graben is a failed arm that abutted against the continental margin of the western Ross Sea approximately 55 Ma ago *i.e.* in the Early Tertiary (WEISSEL *et al.*, 1977).

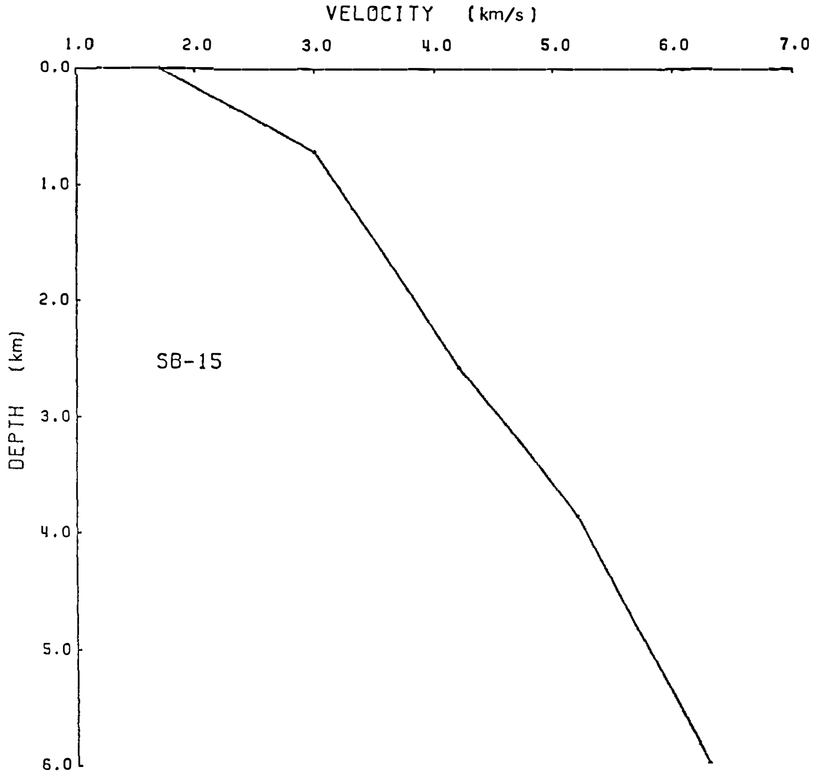

Fig. 11. The velocity-depth profile in the Eastern Basin.

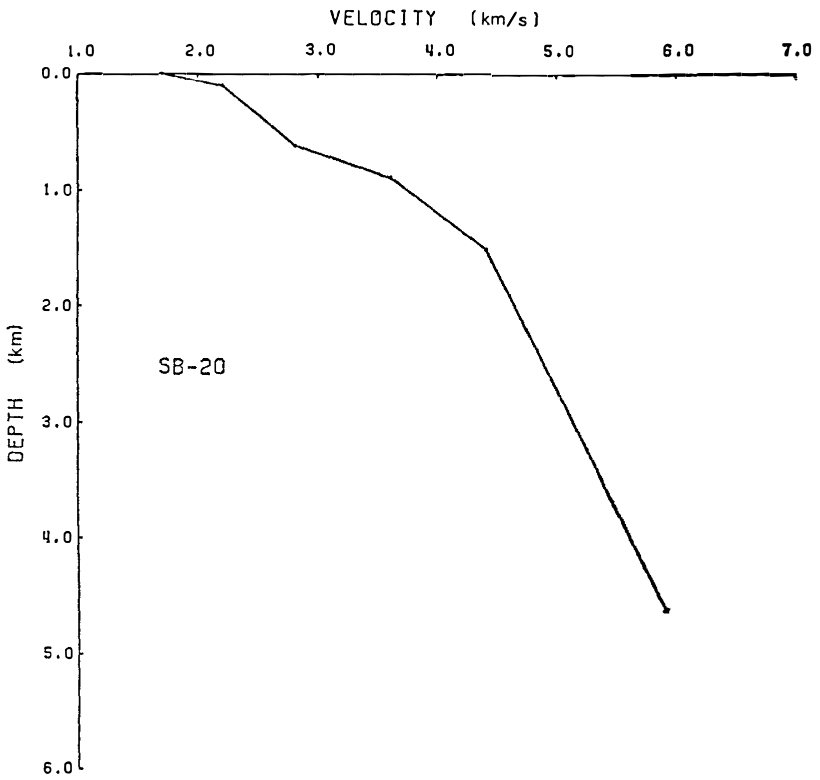

Fig. 12. The velocity-depth profile in the Central Basin.

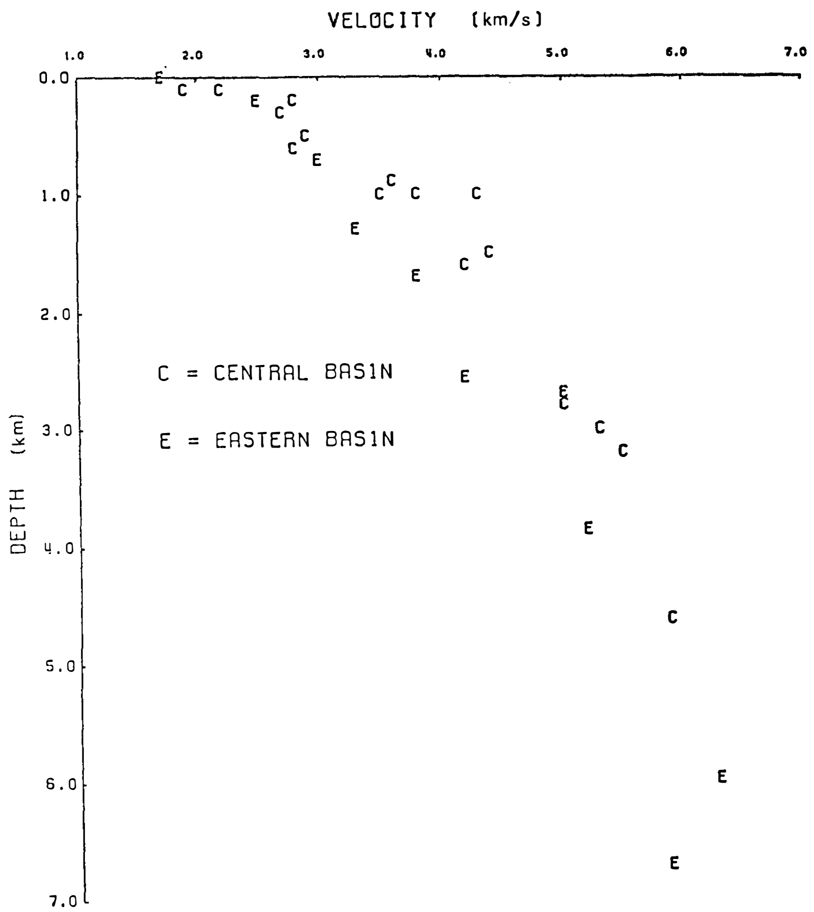

Fig. 13. Comparison of the velocity-depth profiles between the Eastern Basin and the Central Basin.

From the findings of DSDP Site 273, sediments at a depth of 365 m are Early Miocene in age (HAYES and DAVEY, 1975).

The velocity-depth profile in the Central Basin is shown in Fig. 12. The basement velocity here ranges from 5.0 to 5.9 km/s (sonobuoy measurements SB-11, 12, 19 and 20). This agrees with the data of DAVEY *et al.* (1983).

The maximum sedimentary thickness exceeds 4 km. Therefore the sediments in the deeper part of the Central Basin are probably older than Early Miocene.

Figure 13 gives the velocity-depth profile combined from Figs. 11 and 12. The velocities in the Central Basin are faster than those in the Eastern Basin. This difference of the velocity-depth profile in the two basins was observed by previous works (DAVEY *et al.*, 1982, 1983). It may reflect the characteristic geophysical features of both basins in the Ross Sea. DAVEY *et al.* (1982) suggested that this difference could be due either to different sources of sediments supplied in both basins or to the presence of sediments of high density in the Central Basin. They also suggested that the changes of the velocity gradients in the Central Basin could be caused either by changes in the rate of sedimentation or by a hiatus. However, their interpretations have never been confirmed because the maximum drilling depth in the DSDP was only approximately 450 m at Site 272.

6.2 The area off Cape Adare

This area is located on the lower continental rise of Antarctica. The age of the crust is Early Oligocene to Late Eocene on the basis of magnetic lineations (WEISSEL and HAYES, 1972).

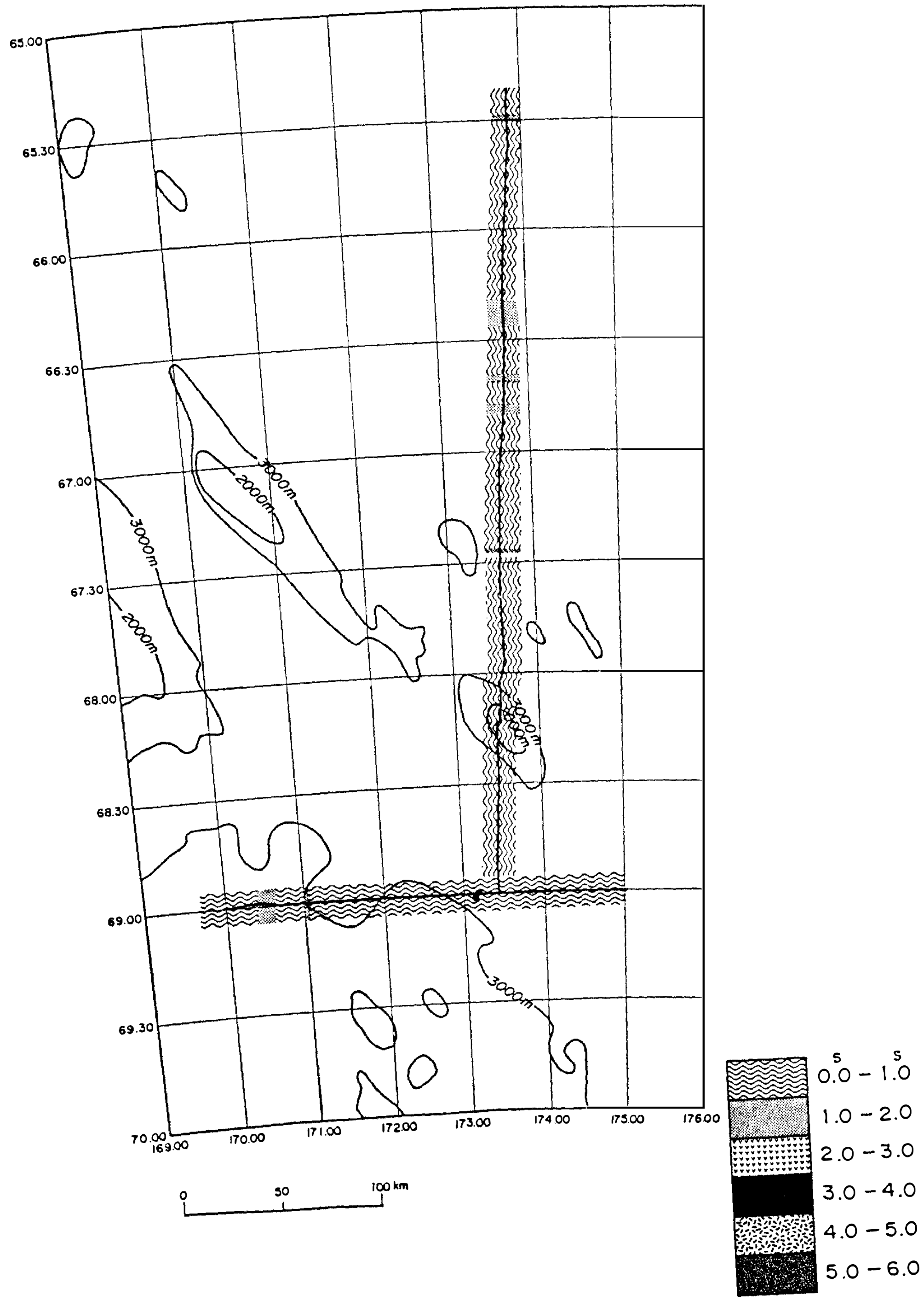

Fig. 14. Schematic isochron map of total sediments in seconds in the area off Cape Adare. 3000 m; Water depth.

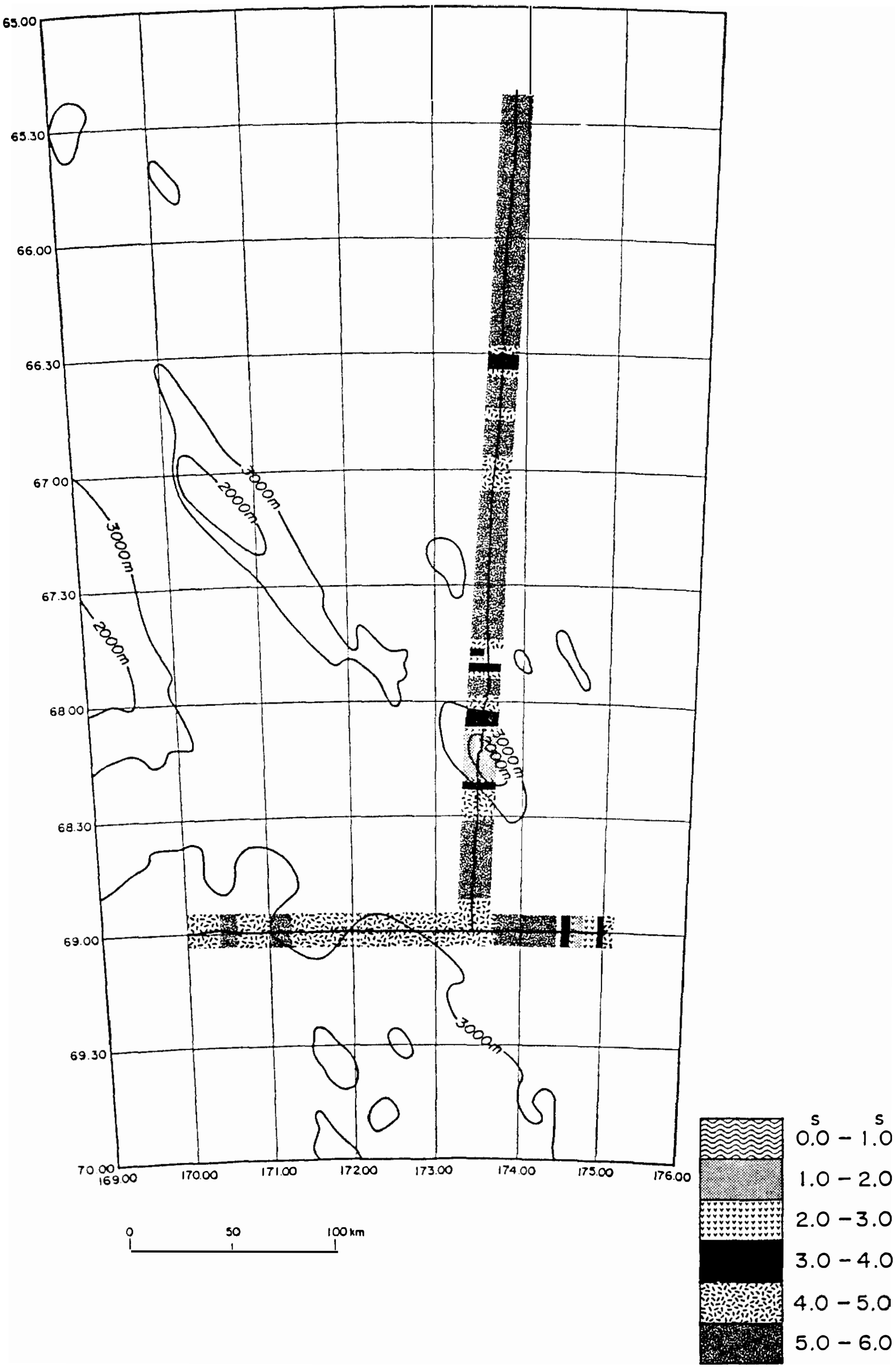

Fig. 15. Schematic acoustic basement map of two-way travel time (s) in the area off Cape Adare. 3000 m; Water depth.

A schematic isochron map of total sediments and a schematic acoustic basement map of two-way travel time are given in Figs. 14 and 15. The interpreted section is presented in Fig. 16.

Thicker sediments were expected in this area than off Wilkes Land which has

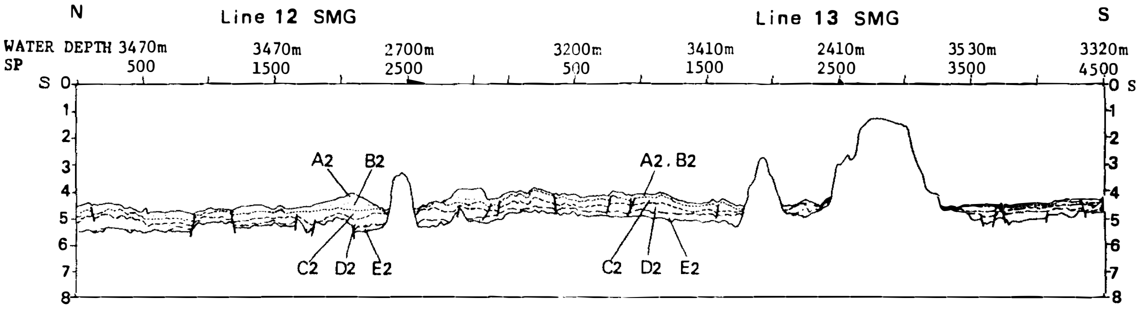

Fig. 16. Interpretative geologic section (Line 13) in the area off Cape Adare.

a similar crustal age. However, a large graben crosses the middle of Cape Adare and Iselin Bank, which is located 50 km southwest from the southern end of our Line 13 (HOUTZ and MEIJER, 1970; HOUTZ and DAVEY, 1973; HAYES and DAVEY, 1975). This graben acted as a trap in preventing input of sediment from Antarctica into the area of our survey.

6.3. The Dumont d'Urville Sea

This basin may have resulted from seafloor-spreading when Wilkes Land was separated from South Australia during the Early Cretaceous time (TALWANI *et al.*, 1979).

We observed four strata over the acoustic basement in this basin. The maximum sedimentary thickness according to the refraction data is 5 km. The acoustic basement in this area is probably older than Late Oligocene because Site 268, located in the west of the sedimentary basin that we surveyed, penetrated the Late Oligocene sediments.

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