PRELIMINARY REPORT OF THE MARINE GEOPHYSICAL AND GEOLOGICAL SURVEYS OFF WILKES LAND, ANTARCTICA IN 1983–1984

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Abstract: During the 1983–1984 Antarctic summer season, a multi-channel seismic reflection survey of 3700 km along with geophysical and geological surveys was conducted in the Scott Basin lying in the offing of Wilkes Land.

Conventionally processed data of the seismic sections (6–folds) revealed the following geological features. (1) The maximum sedimentary thickness was found to be approximately 3.75 s in two-way reflection time under the abyssal plain. (2) The seismic section through DSDP site 268 indicated the distinct unconformity between Early Miocene and Pliocene. (3) The acoustic basement generally shows a gentle monoclinal slope in the continental shelf to the rise, while it shows remarkably complex relief under the abyssal plain. But the formations lying on the basement are almost flat. (4) A basement high extending from the southeast was observed in the eastern area, and anticlinal features on the time section were observed in the western area.

Terrestrial heat flow measurements were taken at a total of nine sites, indicating between 1.3 and 1.6 HFU. They were almost the same as the world average of 1.5 HFU.

A gravity core obtained from the basement high in the eastern area contained such warm-water planktonic foraminifera as *Globorotalia inflata, G. praeinflata,* and *G. puncticuloides,* suggesting the age of Late Pliocene–Early Pleistocene.

1. Introduction

The Technology Research Center of Japan National Oil Corporation (JNOC) has been conducting geophysical and geological surveys in offshore areas around Antarctica since 1980*. The survey areas include the Bellingshausen Sea in 1980–1981, the Weddell Sea in 1981–1982, and the Ross Sea in 1982–1983, as shown in Fig. 1. The aim of the first three year phase was to clarify the geological features of the West Antarctica offshore area. The results have been published by KIMURA (1982), OKUDA *et al.* (1983) and SATO *et al.* (1984).

In 1983, the second phase of JNOC to survey the East Antarctica offshore area started in cooperation with the Geological Survey of Japan. The offing of Wilkes Land (TH–83 cruise) was selected as the first survey area for this second phase.

This paper reports the results of the TH–83 cruise in the offing of Wilkes Land.

* These surveys were sponsored by the Ministry of International Trade and Industry (MITI) and carried out by JNOC.

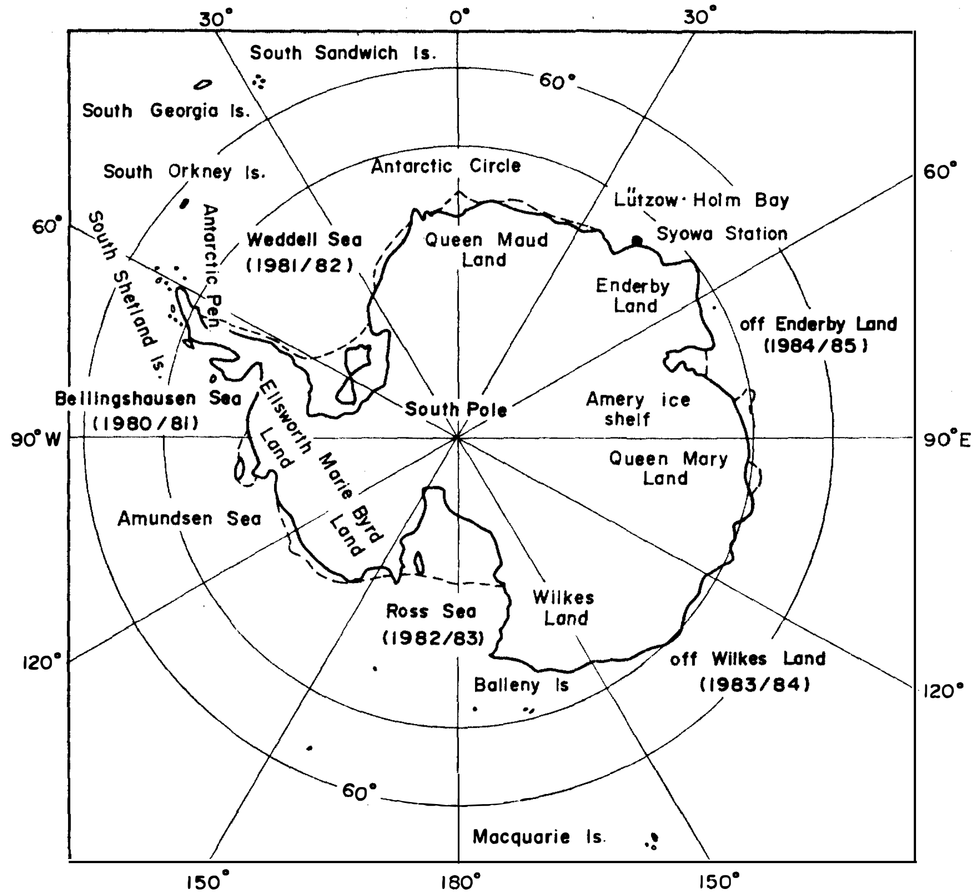


Fig. 1. Survey areas in the offing of Antarctica, from 1980 to 1984.

2. General Information on 1983-1984 Survey

There are roughly six sedimentary basins in the offing of Antarctica (St. JOHN, 1980). They are the Weddell Sea Basin, the Bellingshausen Sea Basin, the Ross Sea Basin, the Scott Basin, the Enderby Basin, and the Queen Maud Basin. The survey area in 1983–1984 is a part of the Scott Basin in the offing of Wilkes Land (Fig. 1). The Dumont d'Urville Sea area, the easternmost part of the Scott Basin, was previously investigated by Institut Français du Pétrole (IFP) in 1981–1982, Japan National Oil Corporation in 1982, and the U.S. Geological Survey (USGS) in 1984 (EITTREIM and COOPER, 1984).

Very little was known about the geological and structural features of this area, though there had been presented some papers related to the plate tectonics. This basin was probably formed by rifting and spreading between East Antarctica and South Australia. According to TALWANI *et al.* (1979), the rifting began in the early Cretaceous time, and the seafloor spreading started in the early Tertiary time. Continental clastics filled the grabens during the initial breakup time. In Early Tertiary, deltaic and shallow marine sediments filled the seafloor of this area.

Water depth of the surveyed area ranges from 500 to 4000 m as shown in Fig. 2. The range in depth of the continental shelf, slope, rise and abyssal plain is roughly

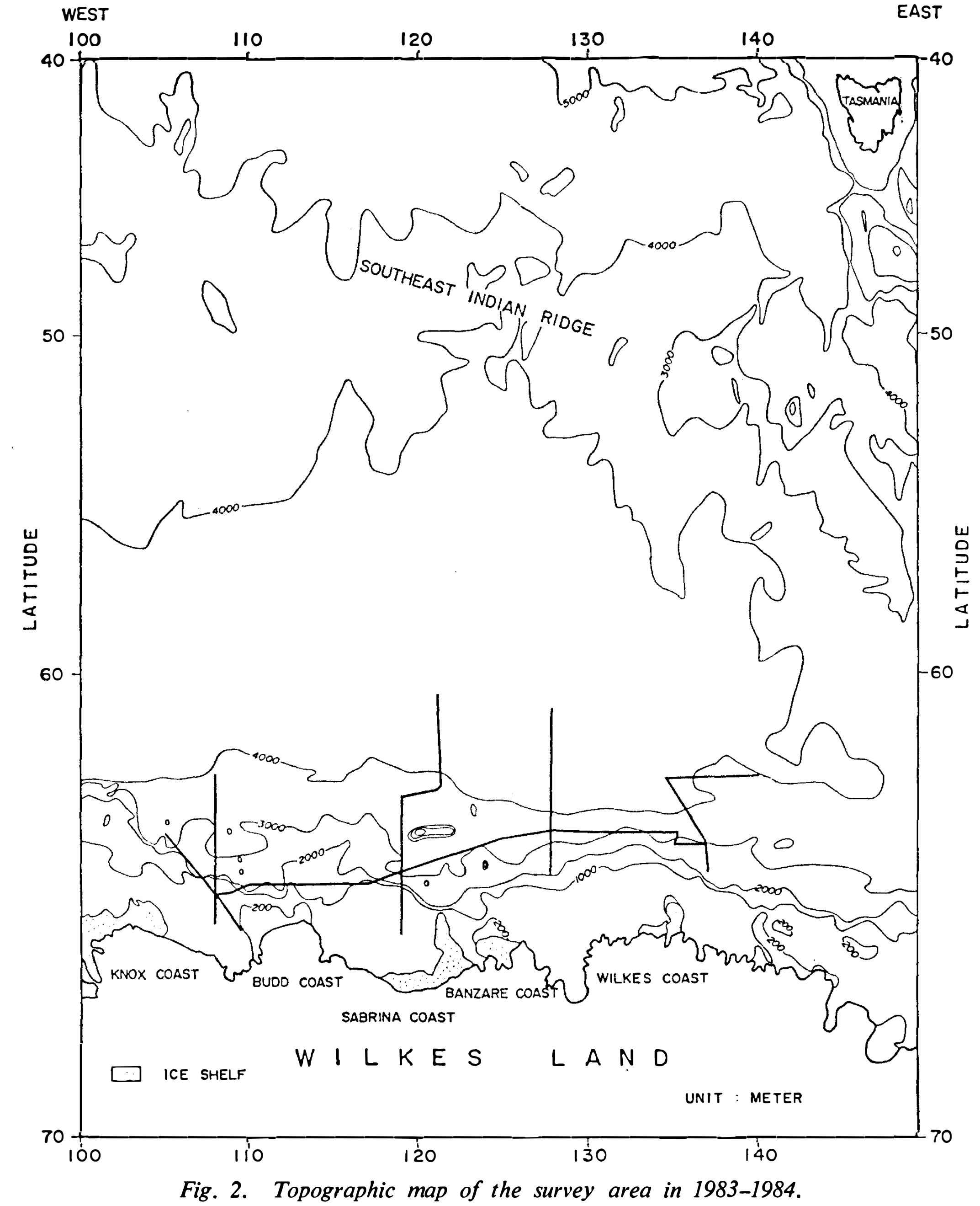


Fig. 2. Topographic map of the survey area in 1983–1984.

divided as follows.

Continental shelf:	500– 800 m
Continental slope and rise:	800–4000 m
Abyssal plain:	over 4000 m.

A marine survey on seismic, gravity, magnetics, and terrestrial heat flow measurements, and bottom samplings, was conducted by Geological Research Vessel HAKUREI-MARU in the offing of Wilkes Land, Antarctica, during the period from December 19, 1983 to February 11, 1984. The total line lengths were 3700 km for the multichannel seismic reflection survey and 11000 km for the magnetic and gravity surveys. These survey lines are shown in Figs. 3 and 4. The data collected during the survey are

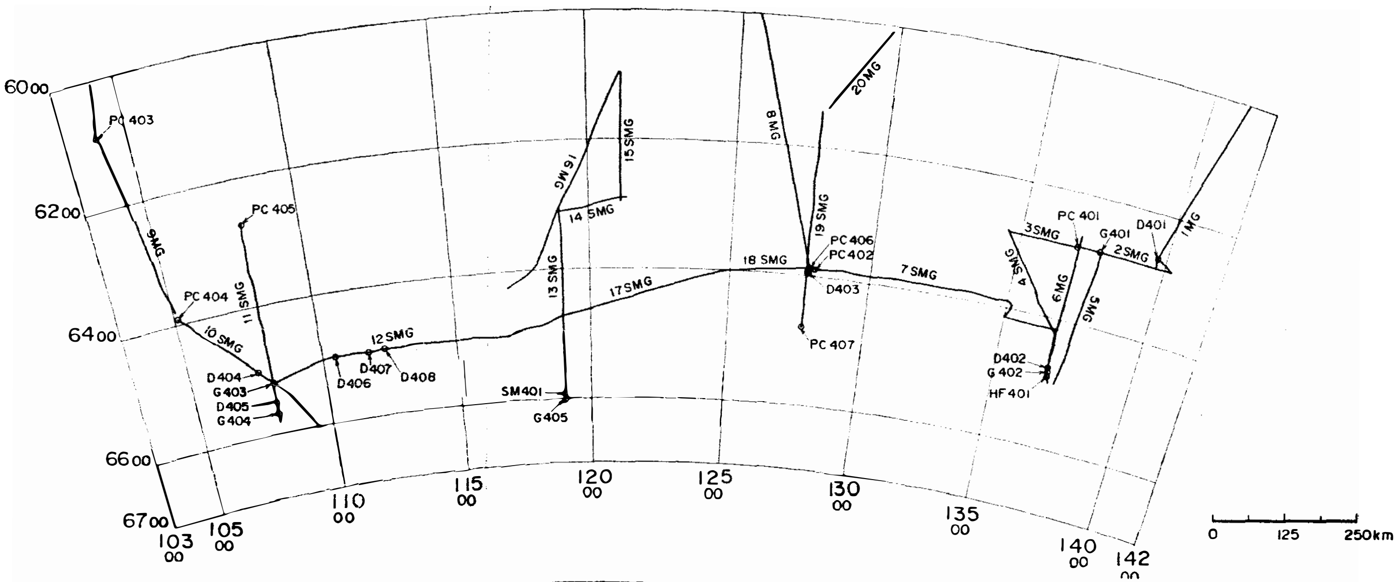


Fig. 3. Geophysical survey lines and bottom sampling stations.

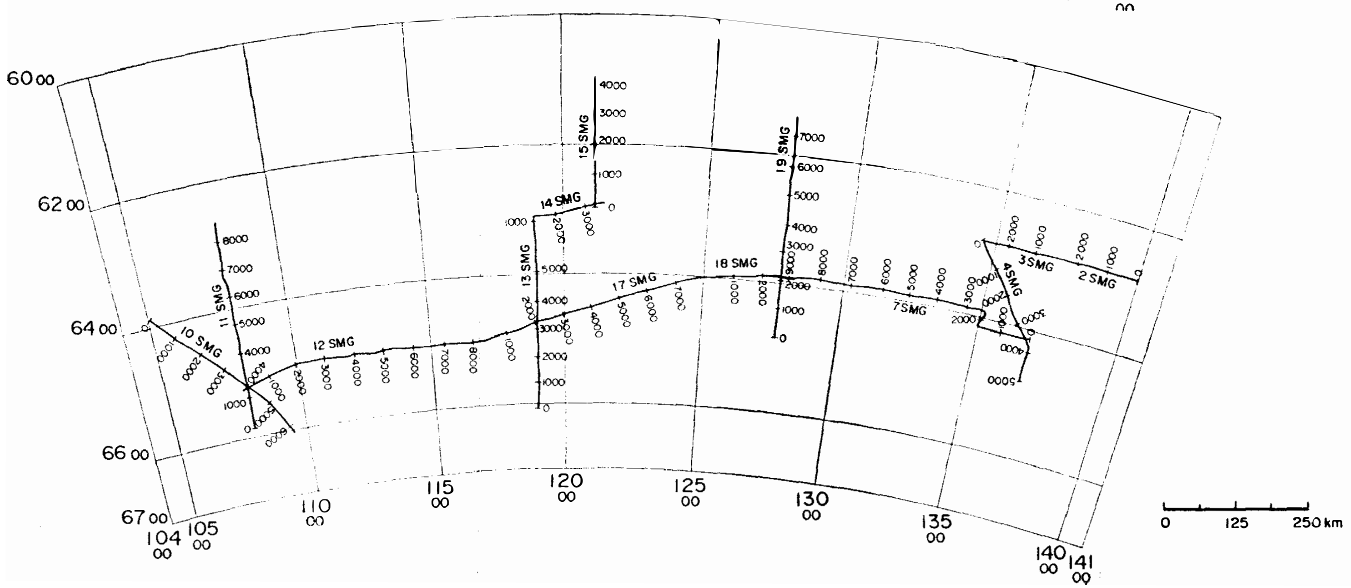


Fig. 4. Seismic lines.

Table 1. Summary of TH-83 cruise.

	Total
Survey period	34 days
Seismic	
Reflection method	3700 km
24 channels	
600% coverage	
Refraction method	19 sites
Gravity and magnetics	11000 km
Heat flow measurements	9
Piston coring	7
Gravity coring	5
Smith-McIntyre grab.	1
Dredging	8

Table 2. Recording parameters.

A. Seismic Survey	Recording length	5 s
	Sampling rate	4 ms
	CDP coverage	600%
	Receiver interval	25 m, 24 channels
	Shotpoint interval	50 m
	Recording instrument	TI DFS V
		Low: out
		High: 64 Hz, 72 dB/Oct.
	Air gun volume	450 cu. in. or 550 cu. in.
	Streamer cable	600 m
B. Gravity survey	Recording interval	10 s
	Recording instrument	Lacoste & Romberg S-79
	Assumed density of bottom sediments and water	2. 67 g/cc, 1. 03 g/cc
C. Magnetic survey	Recording interval	10 s or every shot
	Normal field	IGRF 1980
	Recording instrument	Geometrics G-866
	Distance from stern to sensor	200 m

listed in Table 1. Recording parameters are listed in Table 2.

Refraction surveys were conducted at 19 sites by means of expendable sonobuoy. Analysis of the refraction data is not yet completed.

3. Seismic Interpretation

All data for the multi-channel seismic survey were recorded with 6-fold geometry, and were properly processed on the basis of the conventional seismic data processing flow. The quality of the processed seismic data was generally fair to good, except for shallower water depth areas where water bottom multiples were strong and consistently present. Interpretative geologic sections are given in Figs. 5–11 with a cross line from the eastern area to the western area (Fig. 6, Line 7 SMG; Fig. 7, Line

18 SMG; Fig. 8, Line 17 SMG; and Fig. 10, Line 12 SMG).

In this survey area, the average water depth of the continental shelves is between 0.5 and 1.0 s in two-way travel time (TWT: 375–750 m). This depth is three to six times deeper than the world average, that is 130 m. This fact probably shows that the continental shelves might have isostaticaly subsided due to the thick ice sheets on land. As Line 11 SMG in Fig. 11 shows, outgrowth of the shelf margin is clearly indicated by the seaward progradational pattern.

Dips of the continental slopes are rather steep. They are 7° on Line 10 SMG

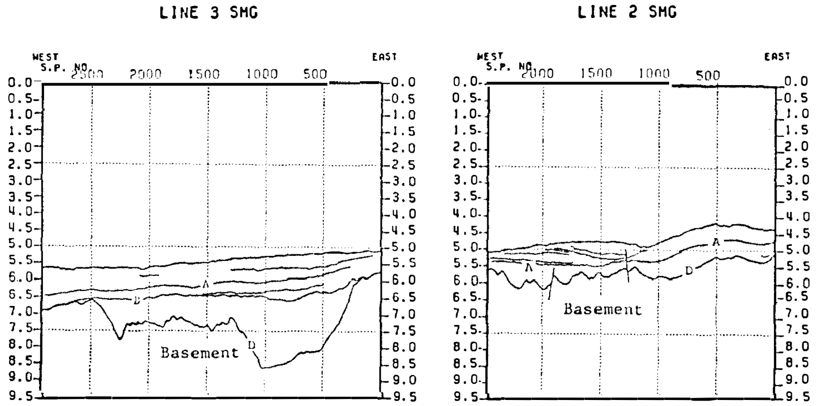


Fig. 5. Interpretative sections (Line 2 SMG and Line 3 SMG).

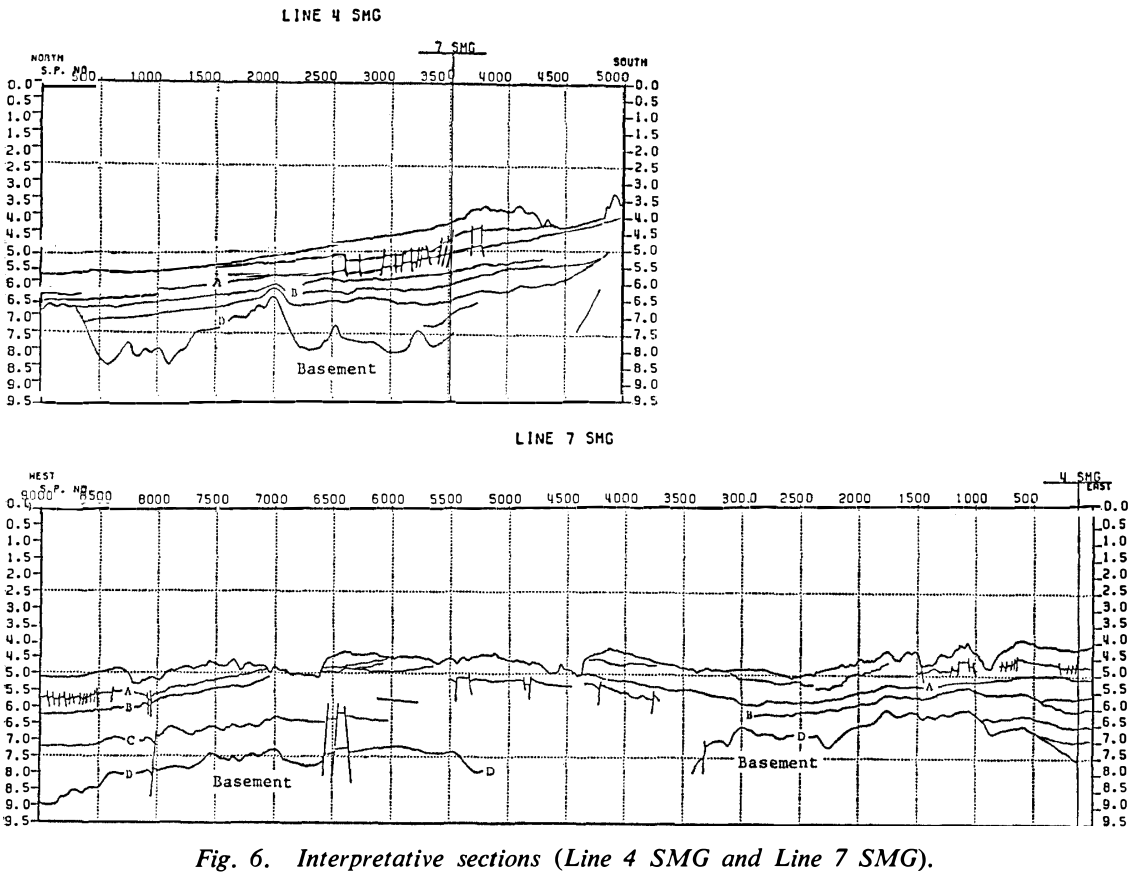
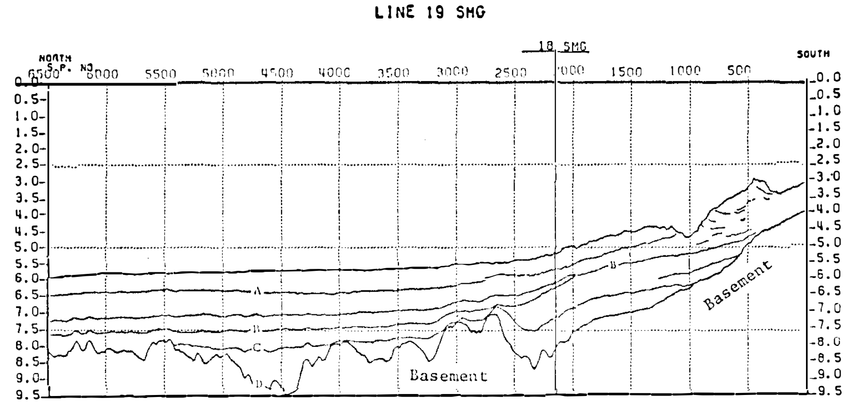


Fig. 6. Interpretative sections (Line 4 SMG and Line 7 SMG).



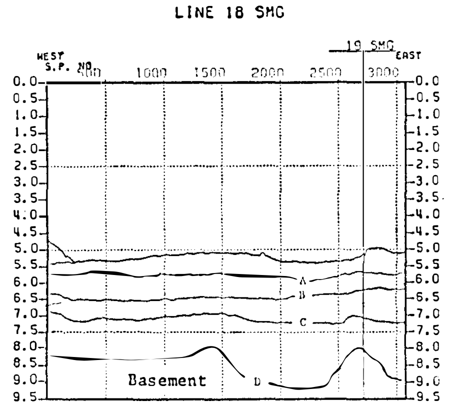


Fig. 7. Interpretative sections (Line 18 SMG and Line 19 SMG).

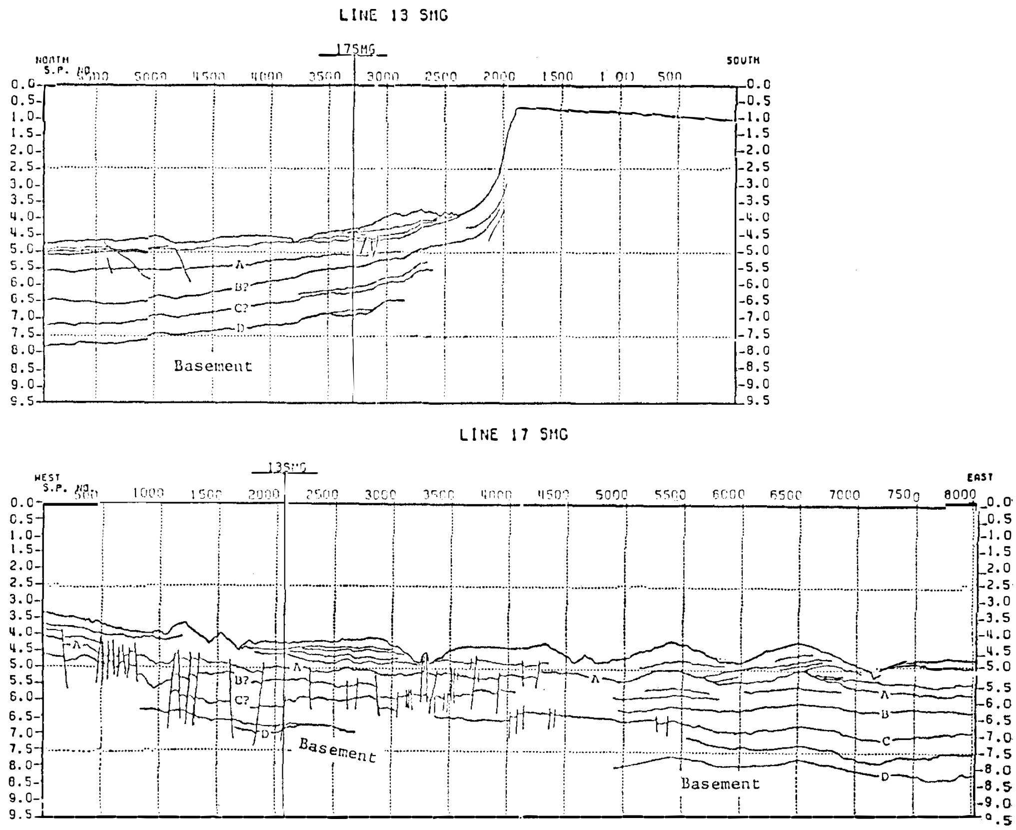


Fig. 8. Interpretative sections (Line 13 SMG and Line 17 SMG).

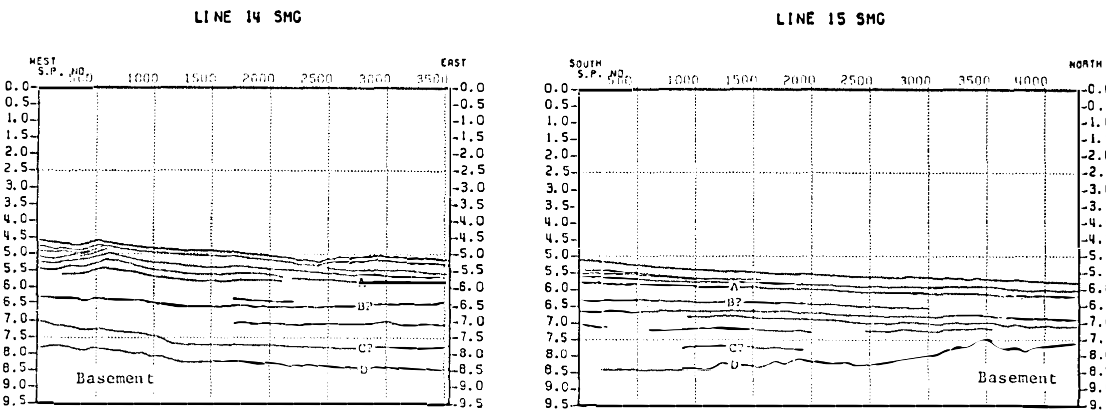


Fig. 9. Interpretative sections (Line 14 SMG and Line 15 SMG).

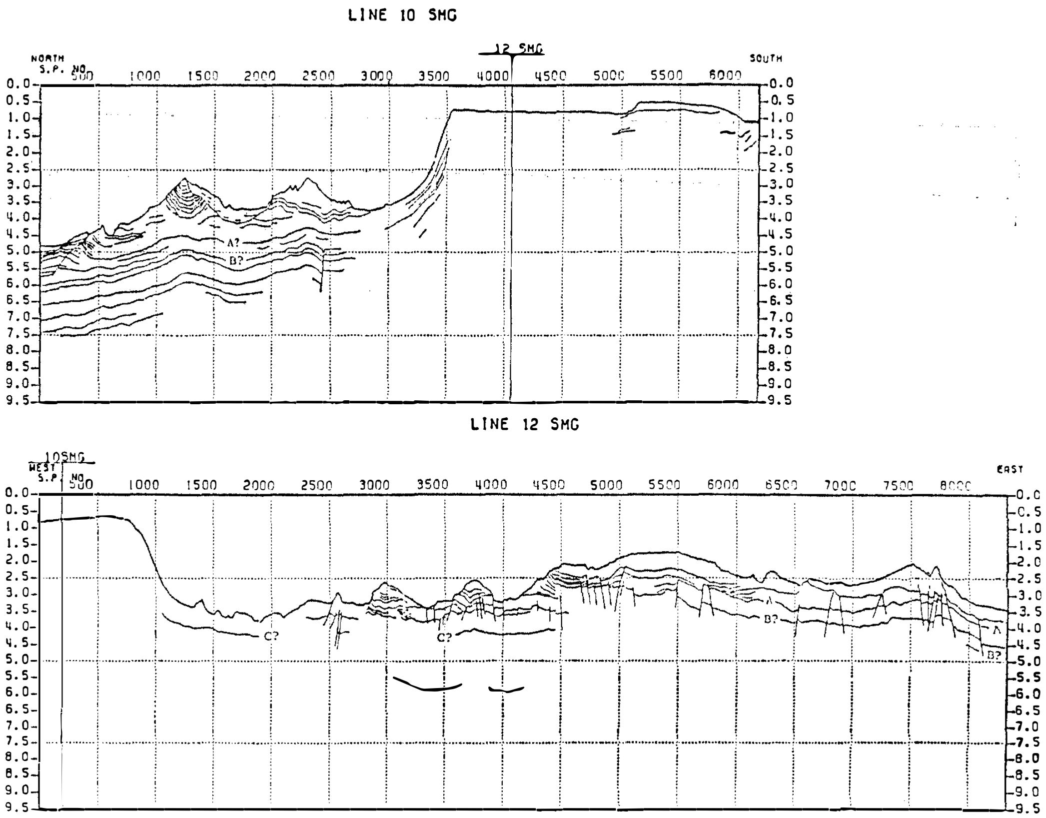


Fig. 10. Interpretative sections (Line 10 SMG and Line 12 SMG).

in Fig. 10, 5° on Line 11 SMG in Fig. 11, and 9° on Line 13 SMG in Fig. 8. The maximum water depth reaches 6 s (4500 m) in TWT under the abyssal plain.

The reflections from the acoustic basement are relatively clear in the eastern area, where the basement shows a gentle monoclinal slope from the continental slope to the upper rise. On the other hand, under the abyssal plain, the basement shows complex relief as shown on Line 19 SMG in Fig. 7. The sediments overlying the basement relief are almost flat without any structural deformation. The thickest depositional sequence is 3.75 s in TWT at SP 4500 on Line 19 SMG.

In the northeastern area, a large basement high was observed on the profiles (Fig. 5). This basement high, which was observed in the previous survey in 1982, extends from the southeast. The top of the basement high is about 5.0 s on Line

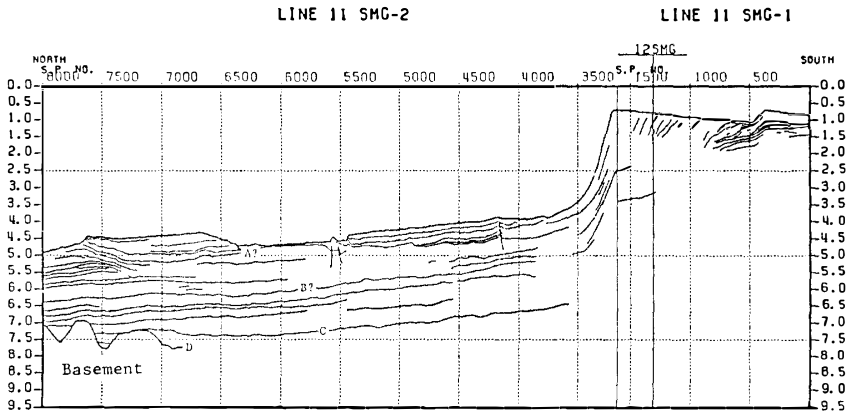


Fig. 11. Interpretative sections (Line 11 SMG).

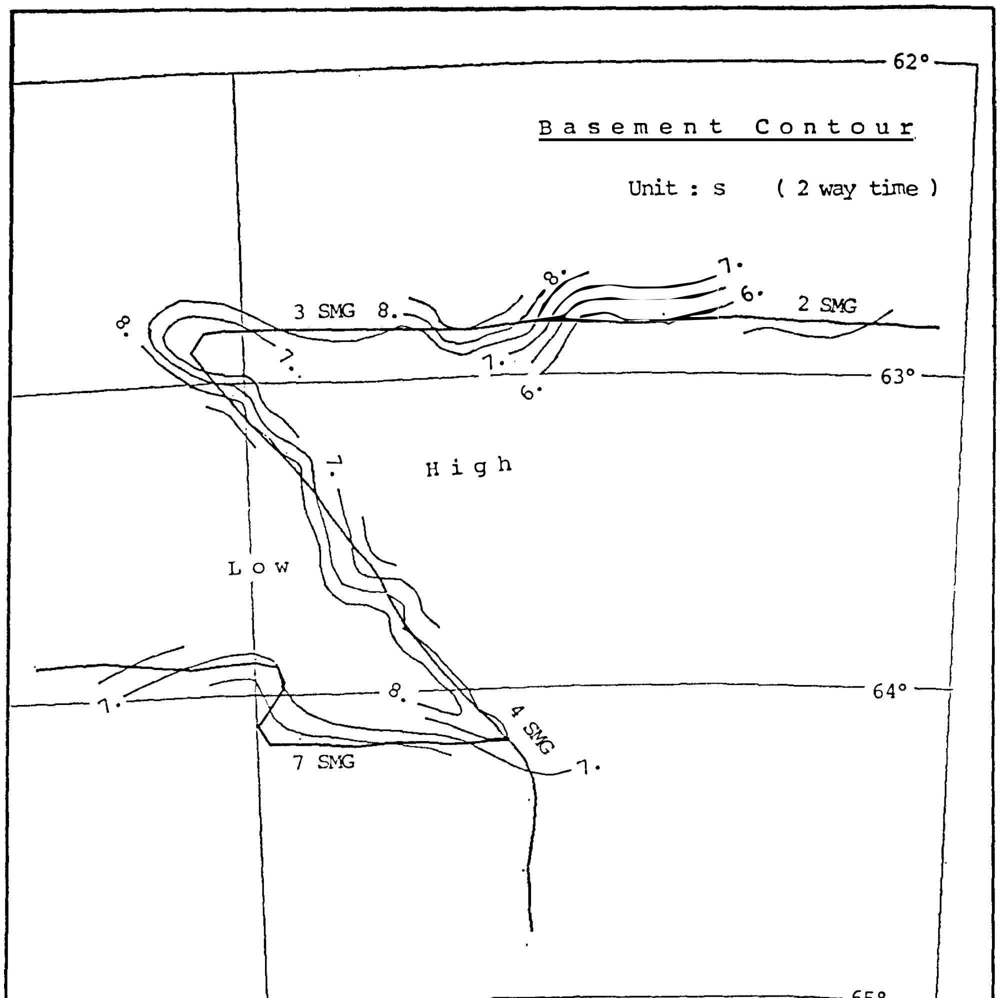


Fig. 12. Basement contour of the eastern area.

2 SMG and the sedimentary thickness is approximately 1.0 s in TWT on this basement high. Figure 12 shows the basement contour of this high. The detailed interpretation and compilation of this high by using the previous results are still in progress.

On the other hand, in the western area, the deeper reflectors relating to the basement were obscurely observed, because of strong water bottom multiples. The younger horizons are highly disturbed with diffractions caused by chaotic bedding and faulting. These discontinuous reflection patterns are due to the unstable depositional conditions in the continental slope to the upper rise. Furthermore, numbers of submarine canyons or canyon-like configurations formed by the turbidity currents or bottom currents are well recognized in west-to-east profiles as shown in Figs. 6, 8 and 10 (Lines 7, 17 and 12 SMG). The younger sedimentary sequences in the slope and rise are deeply eroded or truncated at the seafloor by the currents.

Although two broad anticlinal features are observed on Line 10 SMG in Fig. 10, they apparently are pitfall structures due to the complexity of velocity structures. Because convex sub-bottom configurations have higher velocities than that of the surrounding water layer and they cause the travel time differences, the reflections from the lower horizons are pulled up, thus forming broad anticlinal features. Any other remarkable structural features were not observed in this area.

DSDP Site 268

Geological and geophysical interpretations of this area were made by taking into account the stratigraphic data from site 268 of the Deep Sea Drilling Project (DSDP).

Line 10 SMG was planned to pass through the DSDP site 268, which was drilled to the Middle Oligocene sediments as shown in Table 3.

By using the results of DSDP drilling, the reflection events of Line 10 SMG were correlated as shown in Fig. 13. On the seismic section, we can easily identify a remarkable unconformity which shows an inclined reflector pattern near 5.0 s in TWT. The younger formations above this unconformity show onlap reflection patterns. The DSDP drilling result clearly indicates that this inclined reflector is the depositional break between Early Miocene and Pliocene. Although the unconformity seems to be very local on the section and not applied to the whole offshore area of Wilkes Land, the similar indications are recognized on Line 11 SMG (shot-point number: 7500) and

Table 3. Lithologic units, Site 268.

Position: 63°56.99'S; 105°09.34'E
Water depth: 3529 m
(HAYES et al., 1975)

Unit	Lithology	Subbottom depth (m)	Unit thickness (m)	Age
1	Clay, silty clay, sand, and diatom ooze	0–~160	~160	Pliocene to Quaternary
2	Clay, silty clay, and clay nanno ooze	~160–228	~68	Early Miocene
3	Silty clay, laminated silty clay and clayey silt, and chert	228–>474.5	~256.5	Mid-Oligocene or older to Early Miocene

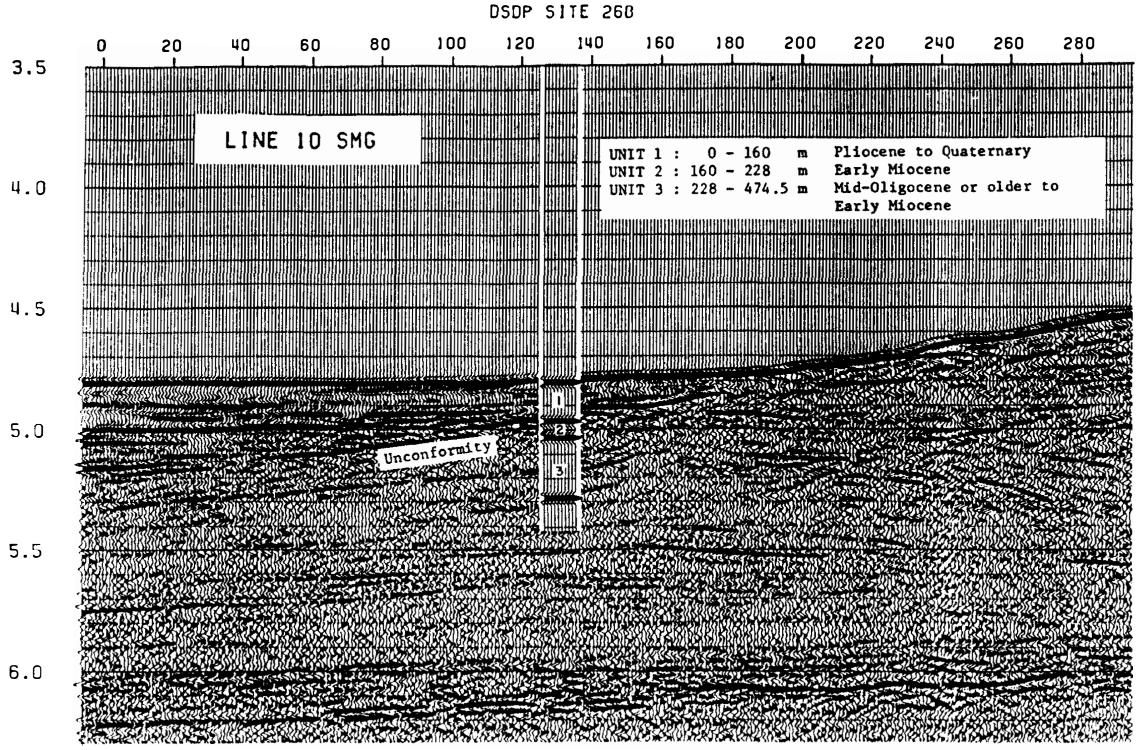


Fig. 13. The correlation between Line 10SMG and DSDP Site 268.

Line 14 SMG (shot-point number: 500). Because of this, it is anticipated that it may possibly extend further eastward.

4. Gravity and Magnetics

Free air anomalies of the area are shown in Fig. 14. Here, a marked difference of the lines is recognized between the eastern and western areas. In the eastern area, the free air anomalies are mainly negative. They are due to the negative bias of 40 to 50 mgal in the continental shelf edge, and 10 to 20 mgal in the abyssal plain. On the other hand, in the western area, the positive anomalies are predominant in both the continental shelf edge and the abyssal plain. The anomalies have a slightly positive bias. The fact probably implies the presence of a regional anomaly in the eastern area. The boundary between positive and negative values may exist at around 120°E.

According to BEHRENDT and BENTLEY (1968), a negative free air anomaly zone exists along the Transantarctic Mountains. This probably supports the idea that the above mentioned boundary would be considered the western limit of this negative zone.

Magnetic anomalies are shown in Fig. 15. In the southwestern area, the polarity of almost all of the anomalies is positive. Especially, large amplitude anomalies more than 500 nT are prominent between 65.7° and 66.3°S. The anomalies are located at 50 to 100 km inside of the continental shelf edge. They might be related to the event like volcanic intrusions during the pre-breakeup between South Australia and Antarctica (EMERY and UCHUPI, 1972).

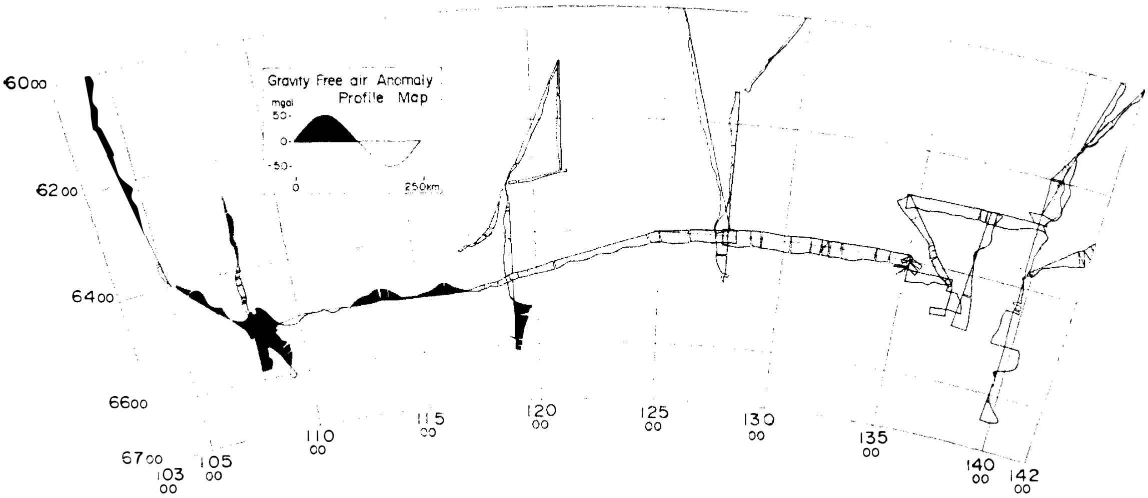


Fig. 14. Free-air gravity anomaly profile.

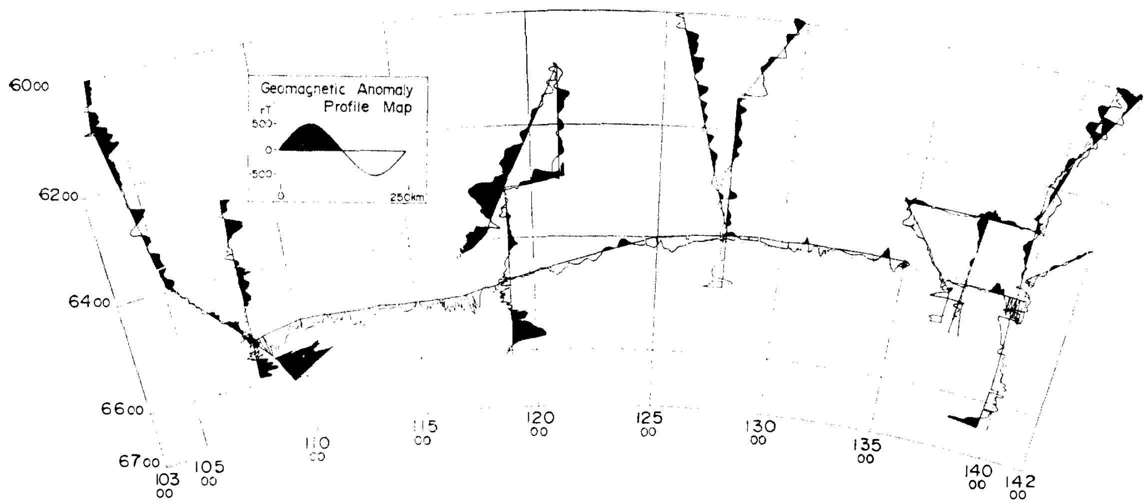


Fig. 15. Magnetic anomaly profile.

5. Bottom Samplings and Terrestrial Heat Flow Measurements

5.1. Bottom samplings

Bottom sampling sites were decided by careful observation of monitor records and sub-bottom profiles on board the ship. Piston coring was chosen under conditions of muddy, silty or unconsolidated sediments. Gravity coring was selected for sandy or consolidated sediments. Dredging was also made use of where outcrops would be expected. The results of bottom sampling are listed in Table 4.

(1) Foraminiferal fossils

A gravity core, G401 contained such warm-water planktonic foraminifera as *Globorotalia inflata*, *G. praeinflata* and *G. puncticuloides*, suggesting the core ranges from Late Pliocene through Early Pleistocene in age. Planktonic foraminiferal assemblages of other cores are monospecific as represented by a cold-water form, *Globigerina pachyderma*, which ranges from Pliocene to Recent.

Table 4. Summary of bottom samplings.

St. No.	Sample No.	Date GMT	Lat. (S)	Long. (E)	Depth	Description	Fossils	Recovery
3	PC401	358 0515	62°49.84′	137°01.05′	3816 m	siliceous silt	common Diatom	7.20m/8m
6	PC402	362 0220	63 53.54	127 53.29	3667	clayey silt & silt	common Radiolaria/Diatom	7.75 /8
8	PC403	017 0054	60 53.95	104 03.40	4432	sili. silt	common Diatom	5.35 /8
9	PC404	018 0031	63 56.17	105 09.19	3536	diatom ooze-clay-red clay	common Diatom	7.84 /8
13	PC405	024 0052	62 37.82	108 00.21	3868	silt	abundant Diatom	7.64 /8
19	PC406	039 0128	63 53.48	127 50.48	3671	silt-sand	common Diatom	7.86 /8
20	PC407	040 0122	64 49.20	127 45.66	2227	ooze-clay	common Radiolaria/Diatom	7.37 /8
2	G401	358 0025	62 49.30	137 48.31	3632	sili. silt	common Radiolaria/Diatom	2.00 /2
5	G402	359 0507	64 51.80	136 59.36	2509	sili. silt	rare Diatom	0.13 /2
11	G403	021 0238	65 12.45	107 59.69	541	silt-coarse sand-red clay	common Radiolaria/Diatom	0.98 /3
12	G404	021 0704	65 48.07	108 00.10	555	silt-sand	common Radiolaria/Diatom	1.35 /3
18B	G405	029 0834	66 01.23	118 59.28	720	silt-sand	N.F.	1.90 /3
1	D401	353 0330	62 40.20	139 43.54	3889	Igne. R.-40%; Sedi. R.-35%;		
			62 40.62	139 44.22	3854	Meta. R.-25%		
4	D402	359 0047	64 45.36	136 59.53	2805	Igne. R.-65%; Sedi. R.-15%;		
			64 45.78	136 59.30	2606	Meta. R.-20%		
7	D403	362 0611	63 53.70	127 47.10	3864	no gravels		
			63 53.74	127 47.23	3694			
10	D404	021 0001	65 03.62	107 40.58	827	Igne. R.-65%; Sedi. R.-25%;		
			65 03.64	107 40.93	641	Meta. R.-10%		
14	D405	024 2318	65 39.89	107 59.73	658	Igne. R.-65%; Sedi. R.-30%;		
			65 40.71	108 00.21	591	Meta. R.-5%		
15	D406	028 0001	64 59.84	110 51.81	2361	Igne. R.-80%; Sedi. R.-10%;		
			65 00.17	110 54.24	2282	Meta. R.-10%		
16	D407	028 0501	65 01.14	112 02.05	2087	Igne. R.-70%; Sedi. R.-10%;		
			65 00.31	111 58.94	2050	Meta. R.-20%		
17	D408	028 0903	65 00.48	112 25.99	1992	Igne. R.-55%; Sedi. R.-10%;		
			65 00.48	112 27.75	1937	Meta. R.-35%		
18A	SM401	029 0730	66 01.15	118 59.39	720	clay		

PC: Piston corers; G: Gravity corers; D: Dredges; SM: Smith-McIntyre spring-loading grabs.

(2) Diatom fossils

Cores PC401 and G401 range from Late Pliocene through Late Pleistocene based on the occurrences of such age diagnostic diatoms as *Coscinodiscus elliptipora* and *Rhizosolenia barboi*. All the other cores lacked these two species, which suggests that they are Late Pleistocene in age. A part of dredge materials at D408 was Early

Table 5. The result of terrestrial heat flow measurements.

Site	Location		Water depth (m)	Terrestrial heat flow (HFU)
	(lat.)	(long.)		
3	62°49.04′ S	137°01.05′ E	3816	1.28
6	63 53.54	127 53.29	3667	1.40
8	60 53.17	104 03.40	4432	1.52
9	63 56.17	105 09.19	3536	1.55
11	65 12.45	107 59.69	541	12.50
12	65 48.07	108 00.10	555	3.50
13	62 37.82	108 00.21	3868	1.56
19	63 53.48	127 50.48	3671	1.48
20	64 49.20	127 45.66	2227	1.44

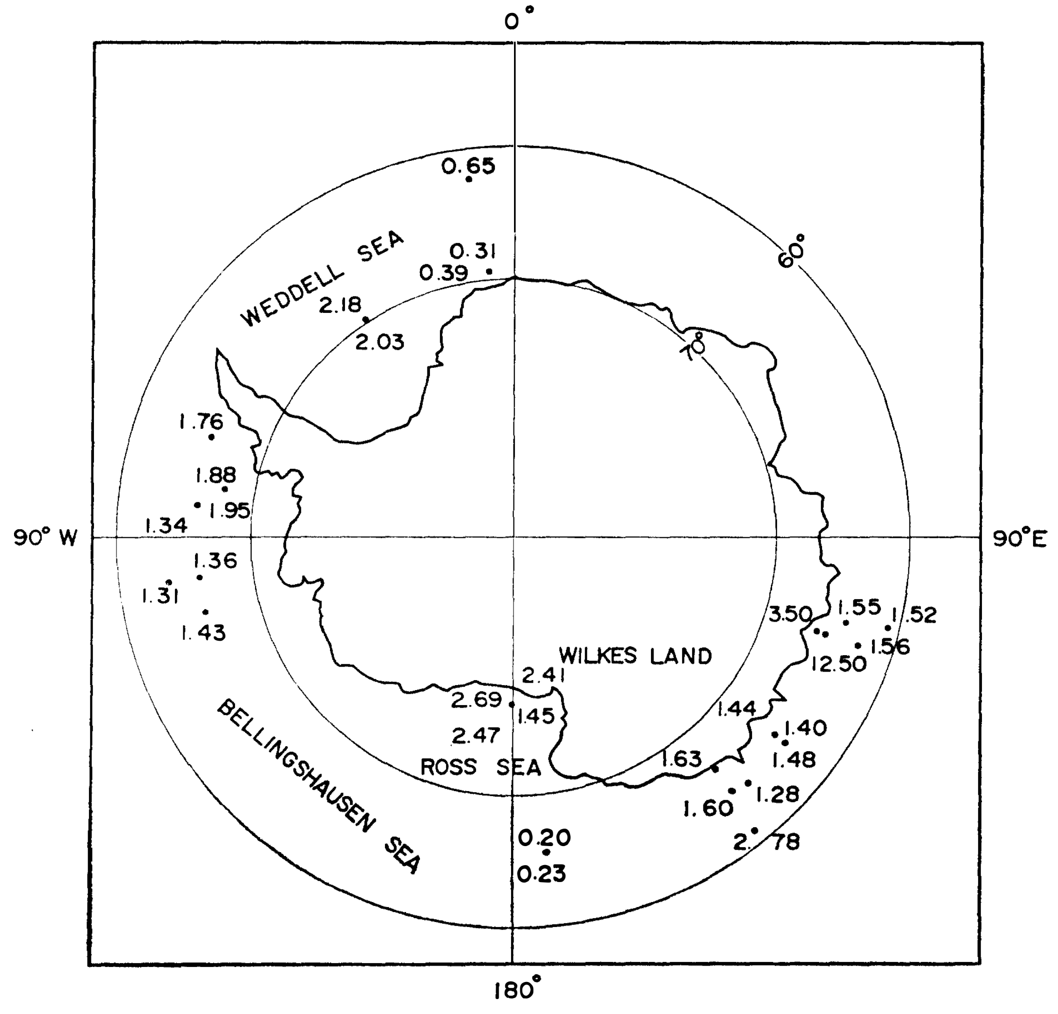


Fig. 16. Terrestrial heat flow distribution.

Miocene in age as indicated by the occurrences of *Kisseleviella* sp. and *Pseudotriceratium chenevieri*.

(3) Radiolarian fossils

Radiolarian assemblages of cores PC401 and G401 were characterized by such age diagnostic species as *Clathrocyclus bicornis*, *Eucyrtidium calvertense*, *Saturnalis circularis* and *Stylatractus universa*, which suggests that the two cores range from Late Pliocene through Late Pleistocene in age. Other cores yielded predominantly extant Radiolarian species with few reworked ones, and were regarded as Late Pleistocene to Recent in age.

5.2. Terrestrial heat flow

Heat flow measurements were carried out at a total of nine sites in the area. Generally, observed values were 1.3 to 1.6 HFU as shown in Table 5. These heat flow values are almost the same as the world average of 1.5 HFU.

There are two exceptions, the values of sites 11 and 12 being quite different from those of the other sites. But this seems to be due to some troubles in the operations. Heat flow distribution around the Antarctic offshore area investigated by JNOC is shown in Fig. 16 as the summary of our measurements.

Acknowledgments

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