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TOPOGRAPHIC CHARACTER OF THE EAST ANTARCTIC CONTINENTAL MARGIN OFF WILKES LAND

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Abstract: The canyons off Clarie Coast show a large-scale erosive channel without terraced walls throughout their course. This shape might be formed by basemental upwarp deformation during the glacial period, and by the ocean basin deepening due to the thermal cooling effect of the lithosphere. In contrast, canyons off Adēlie Coast develop predominantly on the continental slope and the upper continental rise, and fade apparently on the lower continental rise.

By re-examination of the seismic profiles, it is found that the continental basement forms an arching structure under the continental slope and the upper continental rise off Clarie Coast, which was originally block-faulted during the rifting stage of the continental margin. The arching structure might be formed during addition or subtraction of ice sheet weight, which could be called repeated isostatic rebound at the continental margin since the Pliocene.

1. Introduction

Ritscher canyon off Dronning Maud Land incises the continental slope and forms a deep-sea fan at the base of the upper continental rise. The gradient of the upper continental rise is steeper than 0.0075 and that of the lower continental rise is gentler than 0.0075, which is the critical value for hydrodynamic jump from turbulent flow to laminar flow resulting in discharge of sediment-load to build a deep-sea fan. The margin with the steep upper continental rise distributes from off Dronning Maud Land to the Weddell Fan area of East Antarctica; the type is called the East Antarctic margin (KAGAMI, 1994).

This paper intends to clarify margin types in the area off Wilkes Land, East Antarctica. The topographic information off Wilkes Land comes from the GEBCO Bathymetric Chart (IHO and IOC, 1983), and CHASE *et al.* (1987). Seismic reflection data are provided by TSUMURAYA *et al.* (1985) and EITTREIM and SMITH (1987).

One reason to select Wilkes Land is that high-quality seismic profiles have been obtained by France (WANNESSON *et al.*, 1985), USA (EITTREIM and SMITH, 1987; EITTREIM, 1991) and Japan (SATO *et al.*, 1984; TSUMURAYA *et al.*, 1985; TANAHASHI *et al.*, 1987).

2. Topographic Setting of the Continental Margin off Wilkes Land

The submarine topography off Wilkes Land covering the area from 60° to 68°S and from 118° to 147°E can be divided into two provinces (Fig. 1). The eastern province off Adēlie Coast, east from the Dibble Ice Tongue, is characterized by broad contour-intervals between 3500 and 4500 m in depth. The western province off the Clarie Coast, west from the Dibble Ice Tongue, is characterized by an embayment of Porpoise Bay, and by another embayment of 4500 m contour toward the base of the continental slope, which represents a large-scale channel or submarine canyon system at the continental margin.

Topographic profiles off Wilkes Land are shown in Fig. 2. Profiles off Adélie Coast are characterized by shallow depths of the continental shelf, only 300 m, and of the lower limit of the continental slope, about 2900–3000 m. Topographic characteristics of the East Antarctic continental margin are shown in Table 1 together with those of the Atlantic margin. The gradient of the upper continental rise off Adélie Coast is gentler than 0.007, which is similar to that of the Atlantic margin.

Profiles C, D, E and F off the Clarie Coast are characterized by a deeper continental shelf at 400–500 m and by a mid-slope topographic bulge at around 2000–2400 m (Fig. 2). The lower limit of the continental slope has a choice of either 3000–3200 m or 3800–4200 m. The gradient of the area deeper than 3800–4200 m is on average 0.002 (Table 1). The sediment thickness starts to increase on the seismic profiles below 3800–4200 m depth. The latter evidence seems to favor a slope-rise relationship. However, the depth 3800–4200 m is too deep to define the lower limit of the standard continental slope, and the gradient of 0.002 is similar to that of the lower continental rise. For these reasons, the depth 3000–3200 m is chosen for the lower limit of the continental slope.

In the Atlantic margin, the base of the continental slope lies at 2600 m depth, the base of the upper continental rise at 4000 m, and the base of the lower continental rise at 5000 m as shown in Table 1 (HEEZEN, 1960). The base of the continental slope is 300–400 m deeper and the base of the upper continental rise is 200–300 m shallower off the Adélie Coast. Off Clarie Coast, the base of the continental slope is 400 m deeper and the base of the upper continental rise is located at almost the same depth as that of the Atlantic margin. These differences in depth will be discussed in the following chapter.

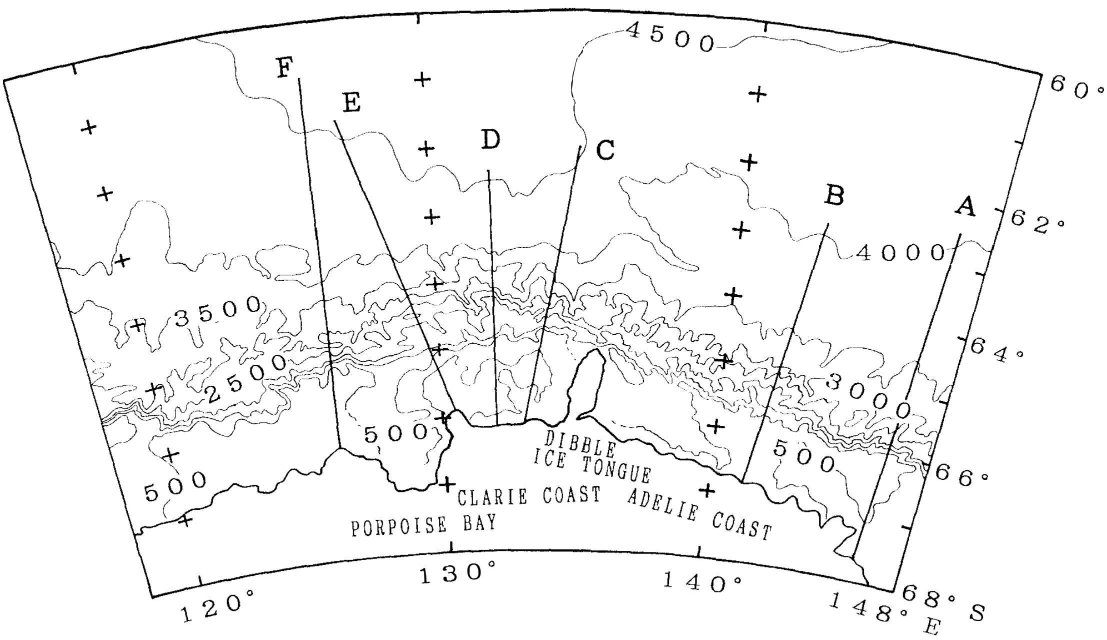

Fig. 1. Submarine topography of the continental margin off Wilkes Land. The locations of topographic profiles are shown. Depth interval is 500 m.

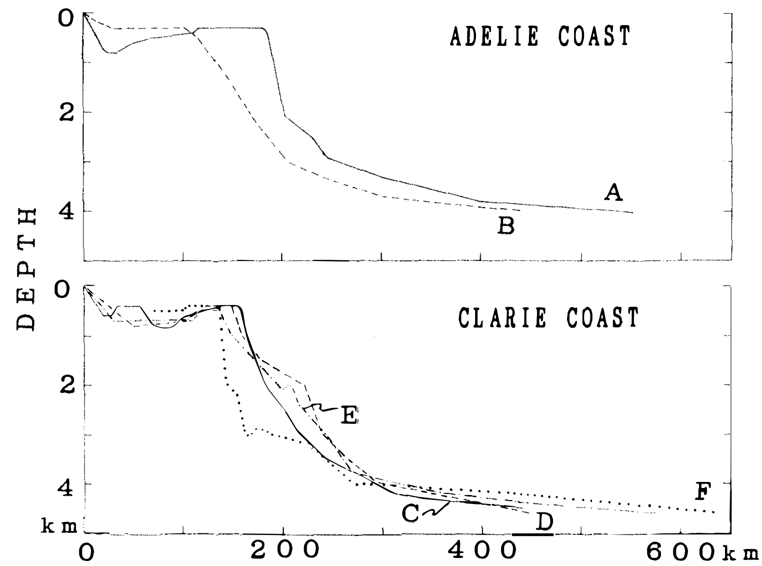

Fig. 2. Topographic profiles of the continental margin off Wilkes Land. Two types of the margin are identified.

The gradient of the Atlantic continental slope is 0.050, that of the upper continental rise is 0.007, and that of the lower continental rise is 0.003 on average as shown in Table 1 (KENNETT, 1982). The gradient of the upper continental rise off Adēlie Coast shows almost the same value as that of the Atlantic margin. However, that of the Clarie Coast is 0.009–0.022, which is much steeper than that of the Atlantic margin. In a previous paper (KAGAMI, 1994), the steeper gradient of the upper continental rise off Dronning Maud Land was explained as rigorous aggradation at the continental margin due to deposition of a large amount of sediment, because the gradient along the canyon axis showed almost the same value as that of the Atlantic margin for non-canyon areas.

3. Canyons off Wilkes Land

Several canyons were clearly identified on the GEBCO bathymetric chart off Adēlie Coast (Fig. 3). These canyons start to develop from the edge of the flat continental shelf at 400 m depth, come down to the base of the continental slope at 3000 m depth, and disappear at around the 4000 m contour line on the lower continental rise.

The seismic reflection profile (TH83–7) crossing at 3469–3900 m depth on the upper continental rise off the Dibble Ice Tongue shows a couple of canyons with erosive features (Fig. 4). The shape of these canyons is 7 to 10 km wide and 300 to 400 m deep. The terraced wall of the channel is not observed on this profile. Therefore, erosive does not mean post-depositional process but syndepositinal or regional crustal processes. The profile indicates evidence of formation of natural levees or active transportation of coarse clastic bed-load. These features may indicate a depositional character for the Adēlie Coast.

Canyons observed off the Clarie Coast start to develop at the edge of the continental shelf at 500 m depth, continue to maintain their channels further downstream, and become deep-sea channels at depth greater than 4800 m on the abyssal plain. The canyons on the

Table 1. Characteristics and classification of the continental margins. The end member of the continental margins is Atlantic margin versus East Antarctic margin.

Province	Atlantic margin type						East Antarctic margin type					
	(US east coast)			(Adélie coast)			Structural type (Clarie Coast)			Depositional type (Doronning Maud Land)		
	Depth (m)	Width (km)	Gradient	Depth (m)	Width (km)	Gradient	Depth (m)	Width (km)	Gradient	Depth (m)	Width (km)	Gradient
Continental shelf		120			100-180			135-155			60	
	200			300			400-500			550		
Continental slope		50	0.050		63-105	0.025-0.041		30-105	0.023-0.086		100-120	0.03
	2600			2900-3000			3000			3250		
Upper cont. rise		200	0.007	-	95-155	0.005-0.007		35-107	0.009-0.022		90-120	0.008
	4000			3700-3800			3800-4200			4000		
Lower cont. rise		350	0.003		(140-150)	(0.001-0.002)		(125-175)	(0.002)		150-170	0.005
	5000											
Abyssal plain			0.006									

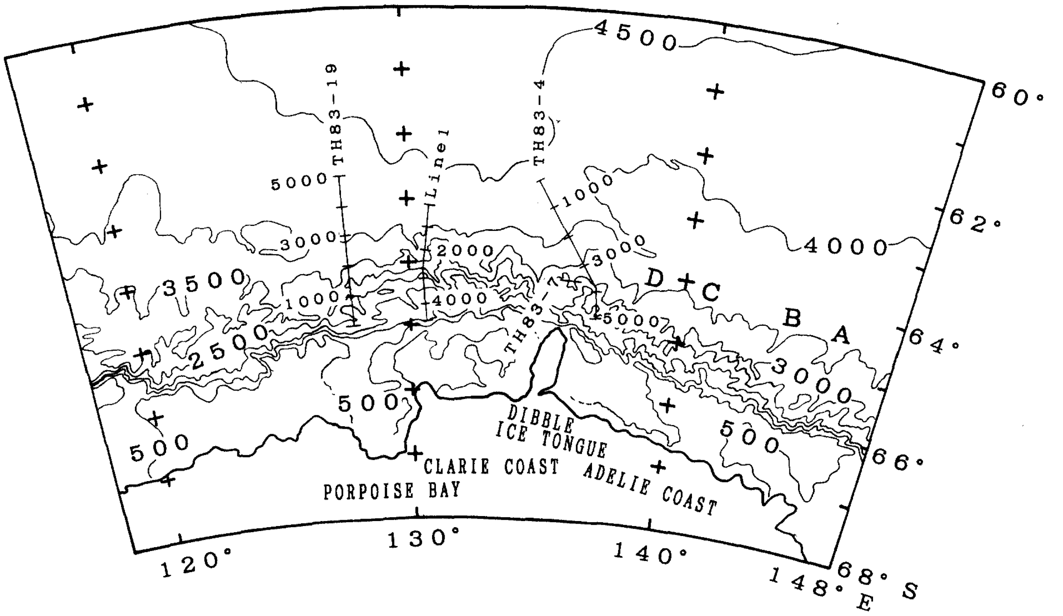

Fig. 3. Locations of seismic profiles and canyons off Wilkes Land. Canyons A, B, C, and D are named in the GEBCO Bathymetric Chart.

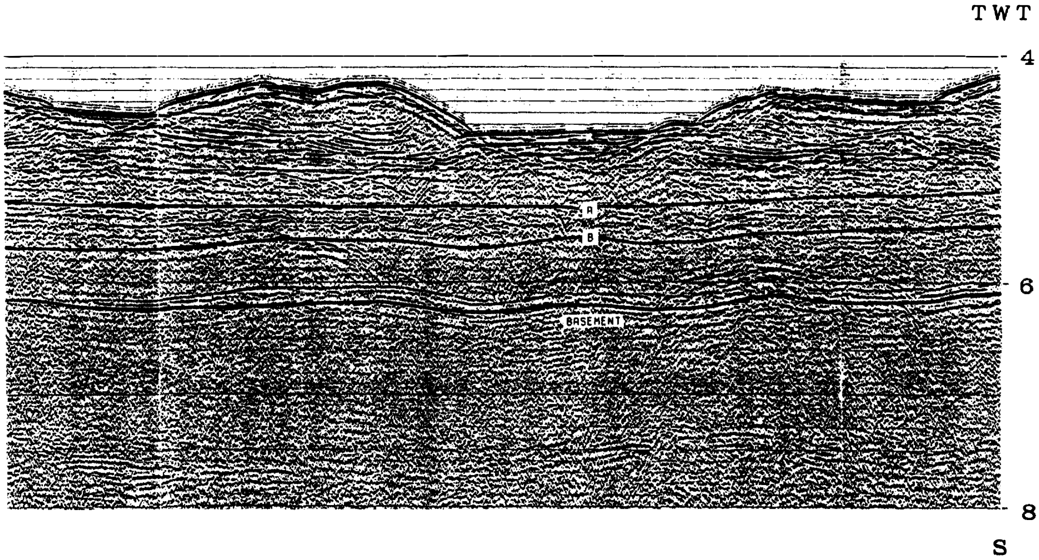

Fig. 4. Seismic reflection profile TH83-7 crossing a canyon in the depth of 3900 m on the upper continental rise.

continental slope evidently join into one large channel system on the abyssal plain. This combining channel system may be caused by deepening of the baselevel and decreased delivery of sediments.

4. Re-examination of Seismic Profiles

Seismic reflection profile TH83-4 was located between the French line (ATC-102) and the American line (Line 8) off the Adélie Coast. Location and interpretation of the Profile TH83-4 are shown in Figs. 3 and 5, respectively. Regional marker reflectors "A" and "B" are recognized. The sequence above "A" is characterized by a laminated unit of glacial marine deposits (Fig. 5 and WANNESSON *et al*., 1985). The sequence between "A" and "B" is an acoustically transparent unit and is observed typically near the continental side. It may be a condensed sequence due to its thinness. The sequence below "B" is a chaotic unit above the basements.

Two types of acoustic basements are recognized on the profile TH83-4. One is the steeply dipping continental basement (CB in Fig. 5), and the other is the undulated oceanic basement (OB in Fig. 5) observed between SP 1000 and 3000.

The seismic profile TH83-19 is located off the Clarie Coast (Fig. 6). The nearest profile is Line 1 taken by the US Geological Survey (Fig. 7). The profile TH83-19 has a prominent arched structure of the continental basement. This structure pushes the upper continental rise upward, causing the steeper gradient of the upper continental rise. The rugged oceanic basement is clearly identified on its low but high frequency magnetic anomalies (TSUMURAYA *et al*., 1985). There are observed three sequences, which are the same as profile TH83-4.

On the profile Line 1, the basemental arching is clearly observed under the continental slope and the upper continental rise off the Clarie Coast (upper boundary of D in Fig. 7). EITTREIM (1991) also showed the upwarp structure of the prerift crustal surface on the composite view of three seismic profiles off the Clarie Coast.

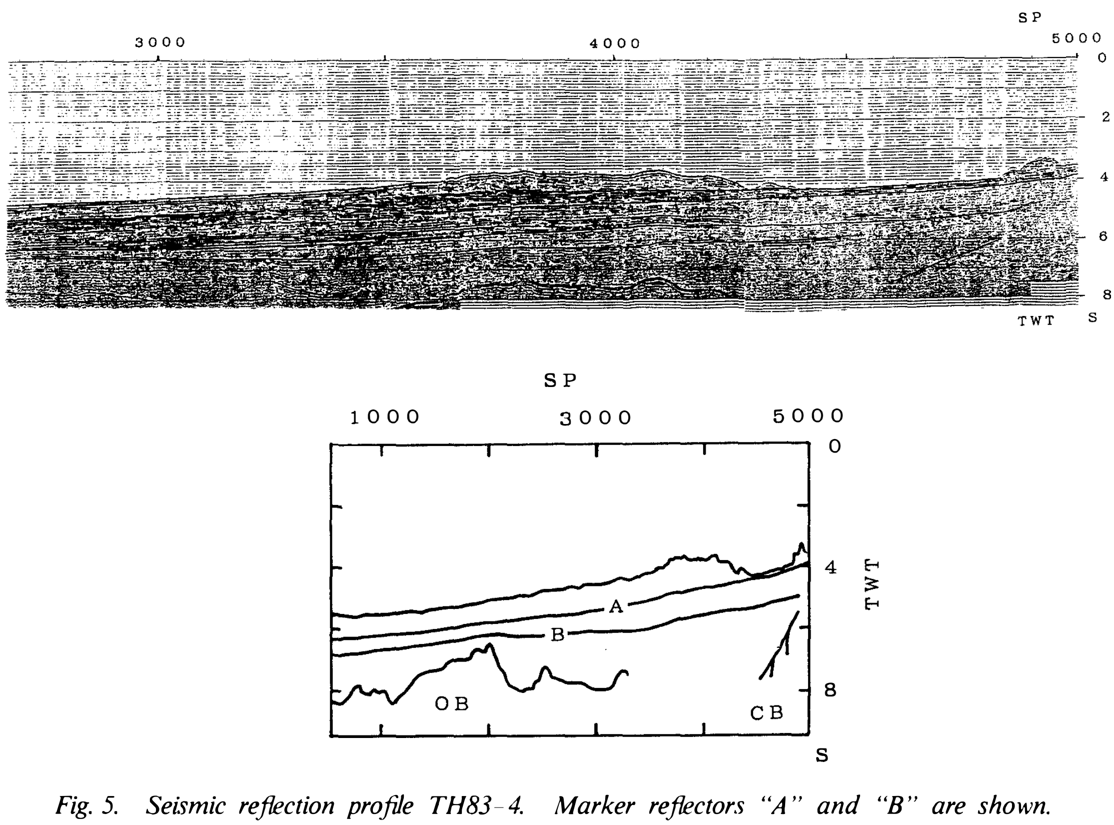

Fig. 5. Seismic reflection profile TH83-4. Marker reflectors "A" and "B" are shown. OB is the oceanic basement and CB is the continental basement.

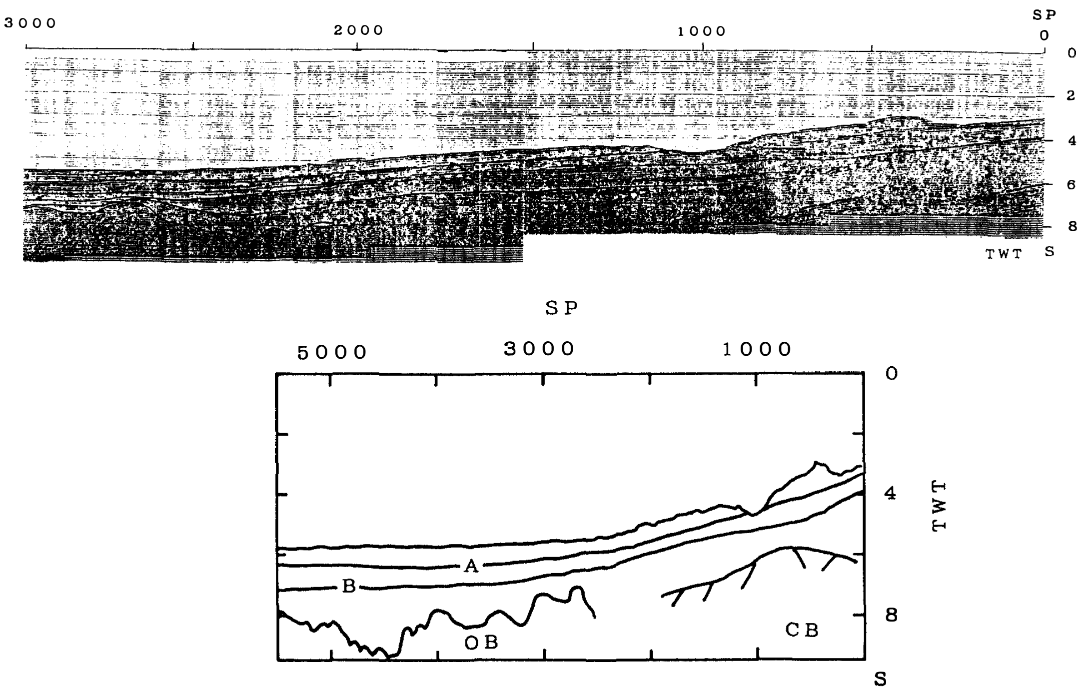

Fig. 6. Seismic reflection profile TH83-19. The arched structure of the continental basement is clearly observed.

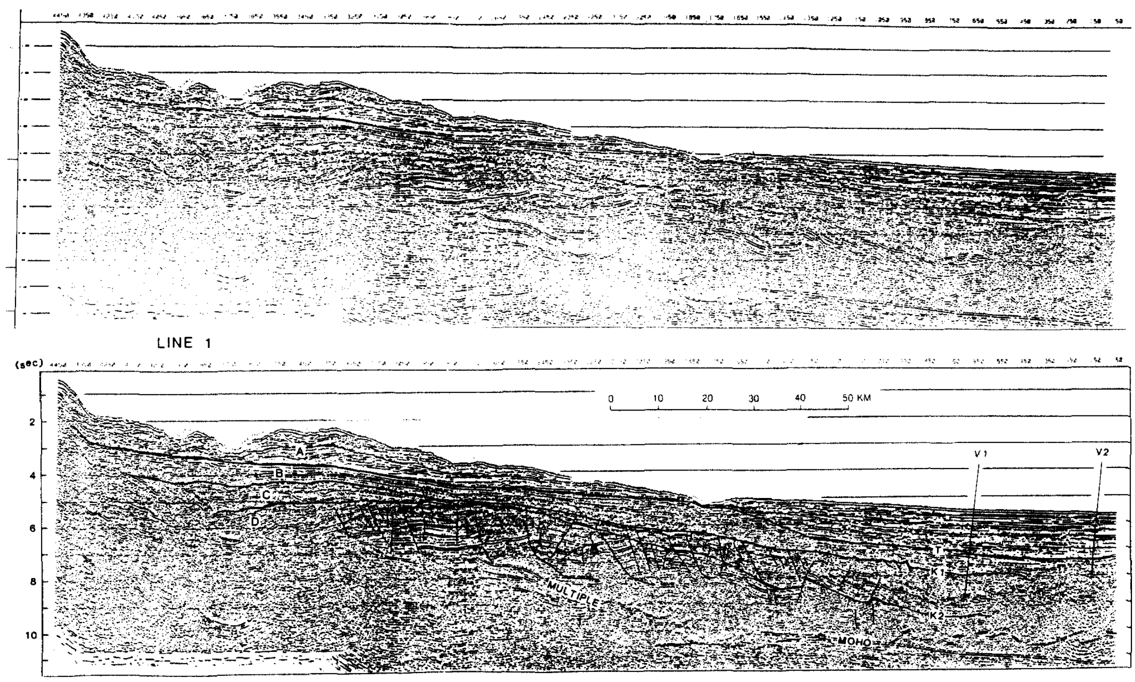

Fig. 7. Seismic reflection profile Line 1 showing the basemental arching of the upper boundary of D under the upper continental rise.

5. Discussion

5.1. Two kinds of the upper continental rise

A theoretical approach to the two types of the upper continental rise, with and without well-developed deep-sea fans, has been discussed on the basis of studies of density currents (MIDDLETON, 1966; KOMAR, 1975). They conclude that a density current with a subcritical flow will construct well-developed deep-sea fan on the upper continental rise with a gradient gentler than 0.0075, while one with a supercritical flow on a slope steeper than 0.0075 will deposit bed load on the lower continental rise.

CLARK *et al.* (1992) classified 16 submarine fans in the world between two extremes; 1) high-sinuosity and low-gradient system such as the Indus, Mississippi and Cascadia fans, and 2) low-sinuosity and high-gradient system such as the Porcupine, Rhone and Hudson fans. The first system corresponds to suspended-load deposition on a slope gentler than 0.0075, while the second system correlates with bed load deposition on a slope steeper than 0.0075.

In the case of the Adélie Coast margin, this value (0.0075) corresponds roughly to the boundary between the continental slope and the upper continental rise. In contrast, it corresponds roughly to the boundary between the upper and the lower continental rise of the Clarie Coast margin.

Two kinds of continental margins have been identified (HEDBERG, 1970; ROSS *et al.*, 1994). One is a progradational margin with prograding clinoform wedges; the other is an erosional margin with erosional slope surface and onlapping fan deposition in a base-of-slope setting. The slope-readjustment model of ROSS *et al.* (1994) represents a modification of the sequence stratigraphic models (POSAMENTIER *et al.*, 1988; POSAMENTIER and VAIL, 1988), which relates the timing and geometry of basin-fill stratal architecture to the interaction of four factors: eustacy, subsidence, sediment input and basin physiography. The sequence stratigraphic models, however, emphasize the role of eustacy in controlling basin-fill sequences, while the slope-readjustment model emphasizes the role of changing basin physiography as a steepening of the slope.

As to the two types of the upper continental rise in East Antarctica, the difference of the slope gradient is clearly identified. A steep upper continental rise off the Clarie Coast might be a special case formed by the arching structure of the continental basement, as it was observed on the seismic profiles. Thus, the present author emphasizes the role of tectonic oversteepening in controlling the slope grading.

5.2. The upwarp structure of the continental basement

The model of the continental basement is shown in Fig. 8. During the rifting stage of the continental margin, the continental margin was block-faulted. Each faulted block was rotated to form an extensional base level, and subsided with the opening of the ocean. The present structure of the continental margin does not maintain the scheme. Profile TH83-19 shows an arched basemental surface with faults radiating from the center of the upwarp structure (Fig. 6). Changes of the basemental structure might occur during the ice sheet development stage on the Antarctic continent, although other tectonic events are not exclusive. However, the weight of the ice sheet was the main factor controlling the re-adjustment of the basement structure (MORNER, 1987; HAGIWARA, 1993).

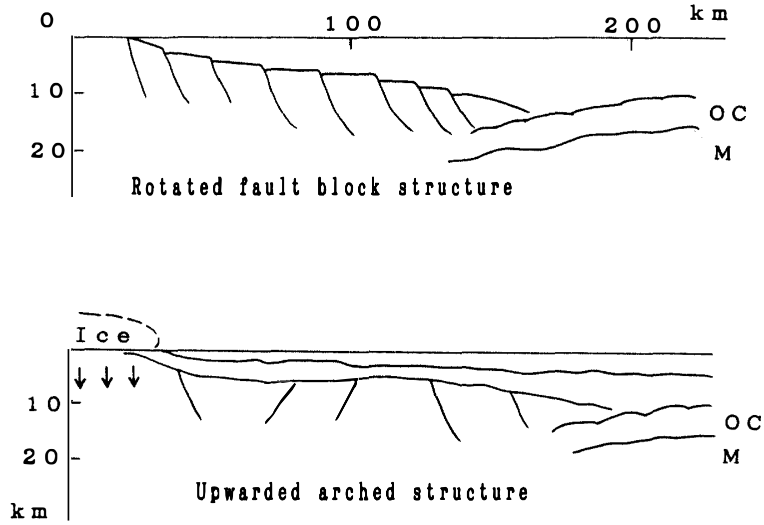

Fig. 8. Models of the continental basement. Upper: a block-faulted margin at the beginning of rifting. Lower: present margin.

Regarding basemental structure change, KAGAMI *et al.* (1991) discussed constant subsidence of the abyssal plain in the Riiser-Larsen Sea. Deepening of the ocean basin might be associated with the upwarp structure of the continental basement. Regarding ocean basin breakup between Australia and Antarctica, 95 ± 5 Ma age is estimated from magnetic and seismic data (VEEVERS, 1986). The combination of continuous lowering of the ocean basin and the upwarped movement of the continental basement caused a steeper gradient of the upper continental rise off the Clarie Coast.

The upwarp movement caused vertical cutting of the channel, and discharge flows were concentrated in the narrow deep channel, increasing the flow energy. By these flows, the whole system of canyons became a single deep-sea channel associated with deepening of the basin.

5.3. Sequence stratigraphy and estimated age of the sequences

There are three sequences above the continental basement off Wilkes Land. WANNESSON *et al.* (1985) named them sequences (1), (2), and (3) from lower to upper. The upper sequence (3) above "A" is characterized by a laminated unit of glacial marine deposits. The middle sequence (2) between "A" and "B" is an acoustically transparent unit and is observed typically near the continental side. Therefore, it may be a thin condensed sequence. The lower sequence (1) below "B" is a chaotic unit above the basements.

According to EITTREIM and SMITH (1987), the sequences above "B" are thought to be Tertiary strata, and that below "B" belongs to Cretaceous strata. WANNESSON *et al.* (1985) indicated that the sequence (3) is Miocene and younger strata, the sequence (2) is Eocene strata, and the sequence (1) is Cretaceous strata. Fortunately, the seismic profile ATC-102 of WANNESSON *et al.* (1985) crossed DSDP site 269, providing a limited but definite stratigraphic correlation.

The glacio-marine character of sequence (3) is partly evidenced from DSDP Site 269 drilling in the Antarctic Australian Basin off Wilkes Land. Submarine canyons develop on sequence (3) (Figs. 4, 5, 6 and 7). This is the reason why the continental basement upwarped during the last glacial period.

6. Conclusions

(1) A bathymetric map, compiled from data of CHASE *et al.* (1987) and the GEBCO Bathymetric Chart for the area between 60° and 68°S latitude and between 118° and 147° E longitude off Wilkes Land, shows two types of continental margin: complex channel-joining configuration off the Clarie Coast, and a regular Atlantic type of margin off the Adêlie Coast.

(2) The canyons off the Clarie Coast show large-scale erosive channels without terraced walls throughout their course. This shape might be formed by basemental upwarp deformation during the glacial period, and by ocean basin deepening due to the cooling effect of the lithosphere. In contrast, the canyons off the Adêlie Coast develop predominantly on the continental slope and the upper continental rise, and fade apparently on the lower continental rise.

(3) It is found that the continental basement forms an arching structure under the continental slope and the upper continental rise off the Clarie Coast, which was originally block-faulted during the rifting stage of the continental margin. The arching structure might be formed during addition or subtraction of the ice sheet weight, which could be called isostatic rebound at the continental margin with growth of the Antarctic ice sheet since the Pliocene.

(4) The Ritscher deep-sea fan off Dronning Maud Land is another example of the steeper upper continental rise, to which delivery of enormous amounts of sediments can contribute (KAGAMI, 1994). This type of margin probably exists from Dronning Maud Land to the Weddell Fan of East Antarctica (ANDERSON *et al.*, 1986). The continental margin in the eastern part of East Antarctica thus is of two types: depositional and structural types. Both of them have a steeper upper continental rise, which will be called the East Antarctic Margin, one of the end members of the continental margin.

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