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RITSCHER CANYON OFF BREID BAY, DRONNING MAUD LAND, EAST ANTARCTICA

Hideo KAGAMI

Faculty of Science, Josai University, Sakado 350-02

Abstract: Through newly compiled bathymetry, canyons in the Riiser-Larsen Sea show large-scale channel incision throughout their course. This is caused by decreased delivery of sediments during deposition of the R1 sequence, and by the thermal cooling effect of the lithosphere, which deepens the old ocean basin, producing baselevel change. In contrast, canyons in the Bellingshausen Sea develop predominantly on fan complexes on the upper continental rise and fade apparently on the lower continental rise.

After compilation of a new bathymetric map, it is found that tributaries of Ritscher Canyon change their course sharply eastward at latitude 68°S, which indicates the presence of a strong eastward current at the mouths of tributaries during deposition of the R2 sequence. It is also found that the Ritscher deep-sea fan develops at the base of the upper continental rise. This margin shows a steeper gradient (>0.0075) on the upper continental rise, due to enormous delivery of sediments from the continent during deposition of the R2 sequence. The gradient of 0.0075 is found to be a critical value for the continental margin, at which a hydrodynamic jump takes place from turbulent flow to laminar flow, resulting in discharge of sediment load to form a deep-sea fan. The margin distributes from Dronning Maud Land to at least the Weddell Fan area of East Antarctica, and here is called the East Antarctic margin.

This value corresponds roughly to the boundary between the continental slope and the upper continental rise in the Bellingshausen margin, West Antarctica, which is similar to that of the Atlantic margin; thus, it belongs to the Atlantic margin type.

1. Introduction

Since the recent active sampling by the Ocean Drilling Program around Antarctica, geologic knowledge of the deep-sea environment has advanced greatly. Seismic stratigraphies in Antarctic deep-sea waters are being incorporated into ongoing studies (WEBB, 1990; BARTEK *et al.*, 1991).

The submarine canyons in the Antarctic Seas show marked leveed channels. From the development of natural levees on the bank of the canyons, contourcurrents of Antarctic Bottom Water were discussed (KAGAMI and IWASAKI, 1991). During the following discussion, submarine canyons off Dronning Maud Land are recognized to be larger in width and height than those of other areas of the Antarctic Ocean (KAGAMI *et al.*, 1991).

The topographic source of information off Dronning Maud Land came from the

GEBCO Bathymetric Chart (IHO and IOC, 1983), MORIWAKI and YOSHIDA (1989), and the 29th Japanese Antarctic Research Expedition (JARE-29) in 1987/1988, from which the Bathymetric Chart of Breid Bay (HYDROGRAPIC DEPARTMENT, 1989) was produced. New data are integrated from JARE-27 in 1985/1986 to -32 in 1990/1991, except for JARE-31, the area of which covers from 64 to 68°S latitude and from 23 to 30°E longitude.

Seismic reflection data are provided by SAKI *et al.* (1987). The seismic survey was carried out with two water-guns as acoustic source and a 24 channel mini-streamer as receiver, and provided six-fold seismic reflection data. The survey of the TH85 cruise was taken in 1985/1986.

2. Continental Margin : Topographic Setting for Canyon Formation

A bathymetric map off Breid Bay, Dronning Maud Land covering the area from 65 to 71°S and from 20 to 36°E has been newly compiled (Fig. 1). This map is supplemented from the bathymetric data collected during JARE-27 to -32. Dr. Y. FUKUDA plotted all survey lines, but the author takes final responsibility for the figure (Fig. 2). The survey lines are concentrated in the area between 67°20'S and 68°S. This results in the finding that tributaries of the canyon turn sharply eastward at the base of the upper continental rise.

Submarine morphology of the continental margin off Dronning Maud Land is shown

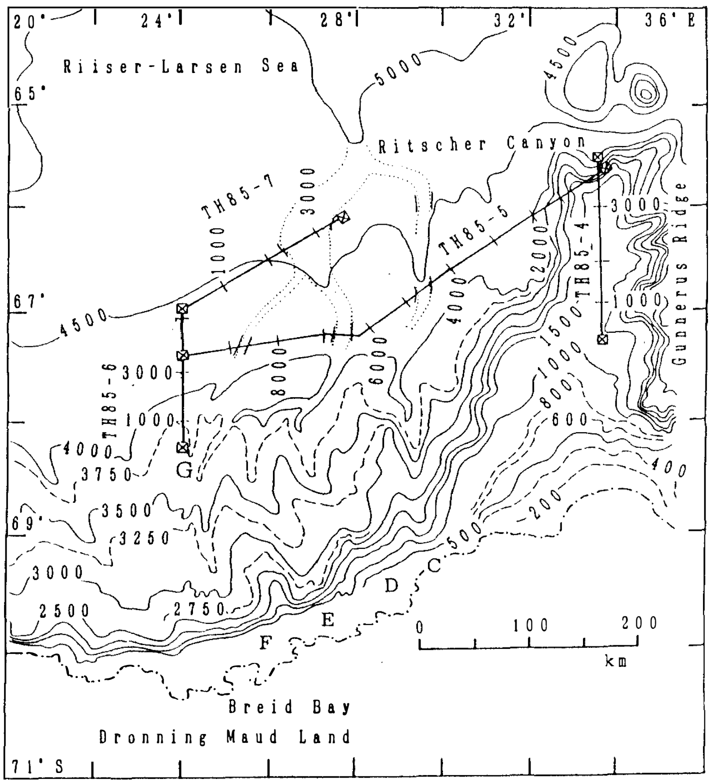

Fig. 1. Bathymetric chart of Ritscher Canyon off Breid Bay, Dronning Maud Land, East Antarctica. The locations of surveyed lines from TH85-4 to TH85-7 are shown. Alphabets (C to G) indicate tributaries of Ritscher Canyon. Depth interval is 500 m with subsidiary interval of 250 m.

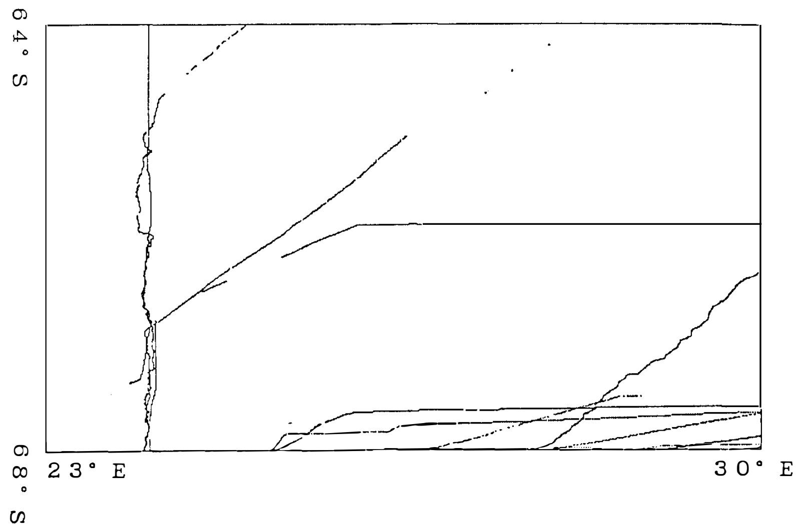

Fig. 2. Bathymetric survey lines collected during JARE-27 to -32 (except JARE-31) in the area between 23° to 30°E longitude and 64° to 68°S latitude.

in Fig. 1. The morphological classification and gradients of the continental margin in the area of Riiser-Larsen Sea are summarized in the following table:

Morphology of continental margin	Slope area Depth(m)	Slope area Gradient	Canyon axis Gradient
Continental shelf			
	750		
Continental slope		0.06	0.025
	3250		
Upper continental rise		0.02	0.006
	4000		
Lower continental rise		0.005	0.003
	4750		
Abyssal plain		0.001	

Compared with those of the Atlantic margin where the base of the continental slope lies at 2600 m depth, the base of the upper continental rise is at 4000 m, and the base of the lower continental rise is at 5000 m (HEEZEN, 1960), the base of the continental slope is about 600 m deeper in the area of Riiser-Larsen Sea. Bases of the upper and the lower continental rise are located almost at the same depth as that of the Atlantic margin. The gradient of the Atlantic continental slope is 0.05, that of the upper continental rise is 0.008 and that of the lower continental rise is 0.002 on average (KENNETT, 1982). Therefore, the gradient of the upper continental rise in Breid Bay is much steeper than that of the Atlantic margin.

These topographic data indicate that the continental slope of Antarctica prograded to form a well-developed continental margin. This is also supported by a steeper gradient of the upper continental rise where rigorous aggradation took place by deposition of a large amount of sediment.

In contrast, the gradients along the canyon axis show almost the same value as that of the Atlantic margin for non-canyon areas. Constant renewal of the baselevel by deepening of the Riiser-Larsen abyssal plain might be responsible for shaping the same stream profile of the Ritscher Canyon as that of the Atlantic margin.

3. Ritscher Canyon

JARE-29 made a grid survey of gravity, magnetics and bathymetry on the continental slope and the upper continental rise off Breid Bay between 24 and 28°E longitude and between 68 and 69°40'S latitude in 1987/1988. Survey lines run parallel to latitudes at intervals of 10 nautical miles.

Three large canyons were clearly identified on the bathymetric chart of the grid survey (Fig. 6 of KAGAMI *et al.*, 1991). The middle canyon, labeled E, is the main tributary among the three (D, E and F of Fig. 1). The cross section of canyon E at 3000 m depth on the lower continental slope has a 20 km width and a bank height of 350 m. It becomes 50 km+ wide and 450 m high at 4700 m depth on the lower continental rise (Fig. 3), which is the largest in scale among the whole canyon system. The large canyon is formed by joining D, E, F and G tributaries. It joins tributary C further downstream (Fig. 1), and becomes a deep-sea channel at depth greater than 5000 m on the abyssal plain. Tributary C is called 'Ritscher Canyon' on the GEBCO Bathymetric Chart (IHO and IOC, 1983).

The seismic reflection profile crossing at 4250 m depth on the lower continental rise shows three canyons (Fig. 4). The east canyon seen at SP 4600–4700 (SP is the shot point of the acoustic source in increments of 50 m from the start of the line), only 12 km in width, is canyon C. As seen on the profile, canyon C is a small tributary of erosive character with a terraced wall. The new data from JARE-27∼-32 indicate that the channel of canyon C is located 40' west of the previous position which was taken from the GEBCO Bathymetric Chart at latitude of 68°S. The new data may indicate that the canyon C turns sharply eastward after passing latitude 68°S.

The central canyon seen at SP 6400–6900 is the main tributary with 30 km width and 300 m height. It indicates active formation of natural levees and transportation of coarse

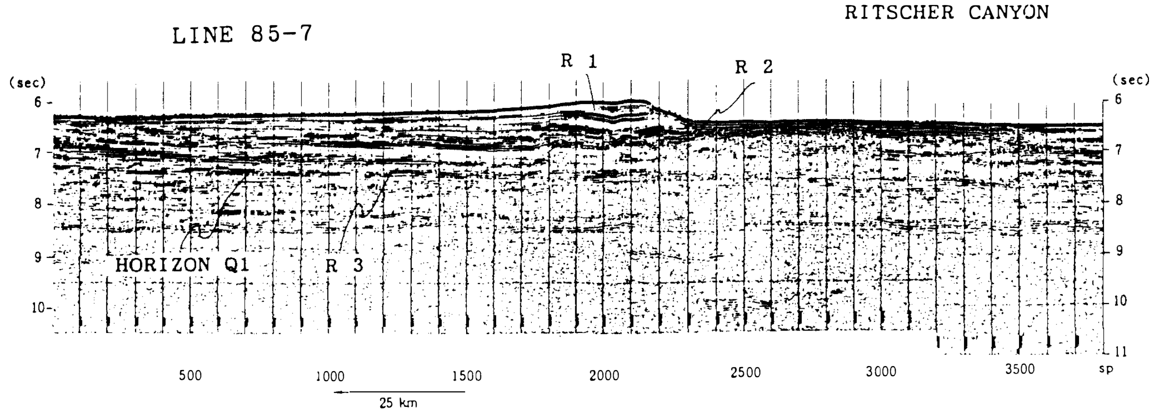

Fig. 3. Seismic reflection profile (Line TH85-7) crossing Ritscher Canyon on the lower continental rise.

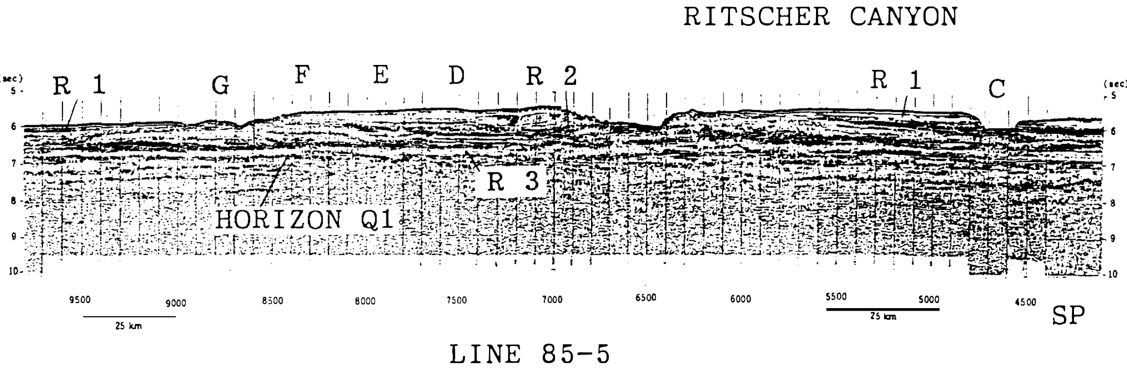

Fig. 4. Seismic reflection profile (Line TH85-5) crossing Ritscher Canyon tributaries. See explanation in text.

clastic bed-load. D, E and F on the profile indicate locations, projected along longitude, of each tributary on the continental slope. Therefore, they evidently turn their courses sharply eastward and join the central canyon at the base of the upper continental rise. The west canyon seen at SP 8700 is only 5 km wide and is thought to be a continuation of canyon G in Fig. 1.

Tributaries from C to G evidently combine to one large canyon system. This combining downstream may, as will be discussed later, be caused by deepening of the baselevel and decreased delivery of sediments. The name Ritscher Canyon was originally applied to canyon C. But canyon C joins the main canyon (D to G) at around 5000 m depth to form a deep-sea channel. Therefore, the whole canyon system is now called Ritscher Canyon (KAGAMI *et al.*, 1991).

4. Sequence Stratigraphy of the Continental Margin off Breid Bay

In areas where there is sufficient sediment supply to prograde into deep water, the Neogene stratal patterns visible on seismic profiles are thought to be similar in geometry (BARTEK *et al.*, 1991). However, there are still many difficulties in age correlation among deep-sea strata with scarce controlling sites of drilling.

Fortunately, seismic profiles show a regional unconformity called Horizon Q1 that is useful for correlations (SAKI *et al.*, 1987). The estimated age of Horizon Q1 may correspond to the final opening between Antarctica and Australia. After the ODP drilling on the Kerguelen Plateau and in Prydz Bay, the age of the unconformity has been ascertained to be middle Eocene (BARRON *et al.*, 1989). It is also noted that from migration of the Balleny plume, the ocean floor between Australia and Antarctica started to spread rapidly at around 40-45 Ma (LANYON *et al.*, 1993).

The seismic profile on Gunnerus Ridge (Line85-4) is shown in Fig. 5. Gunnerus Ridge is a prominent structural feature separating the Southeast Indian Ridge sector from the Southwest Indian Ridge sector. It is the northward continuation of the Riiser-Larsen Peninsula. On the rugged basement that is interpreted to be continental crust based on low but high-frequency magnetic anomalies (SAKI *et al.*, 1987), there are observed three sequences, which are here termed R1, R2 and R3, from top to bottom. Horizon Q1 is poorly observed at SP 3700. The R1 sequence is a blanket formation covering the ridge.

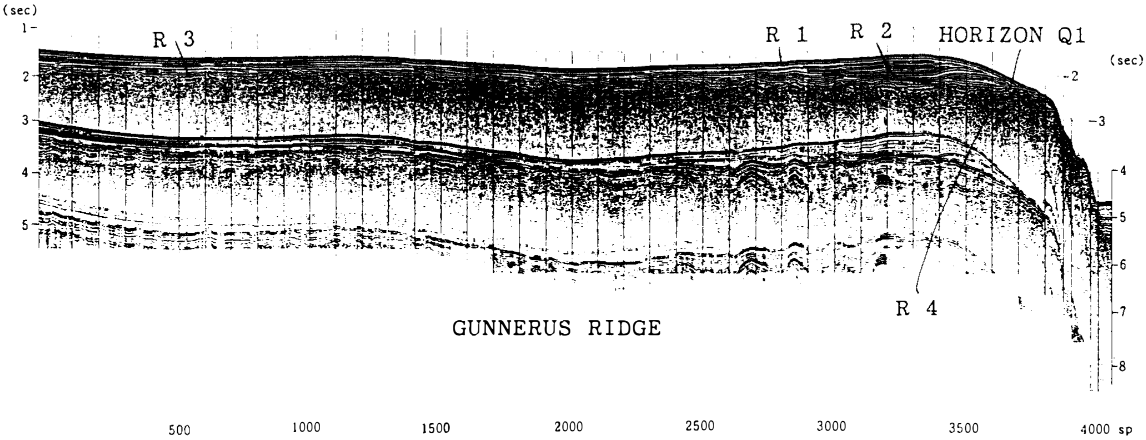

Fig. 5. Seismic reflection profile (Line TH85-4) on Gunnerus Ridge.

R2 forms a bank consisting of current induced sediments at the tip of the ridge. R3 is observed only on the shore-ward side of the ridge.

On the profile more perpendicular to Gunnerus Ridge, Horizon Q1 is clearly observed betweem R3 and R4 (Fig. 6). On the lower continental rise at SP 2500-3000, three sequences are identified above the unconformity. They onlap to Horizon Q1 toward the ridge, which may indicate a basin-fill character of their deposition and are younger than Q1. The unconformity climbs to the ridge and continues to the unconformity between R2 and R4 observed in Fig. 5. This situation indicates that Gunnerus Ridge had uplifted relatively during early spreading of the Australian and Antarctic ocean floor. The R1 and R3 sequences are transparent in acoustic character with weak reflectivity of layering. On the other hand, the R2 sequence shows alternation of high-reflectivity layers. On Gunnerus Ridge, the R2 sequence forms a sand bank on the eastern margin of the ridge.

The western section of the Profile, TH85-5, is located in front of the canyon mouth and/or on an apex area of a deep-sea fan at the base of the upper continental rise (Fig. 4). Here is observed a huge mound of high-reflectivity complex that forms the deep-sea fan

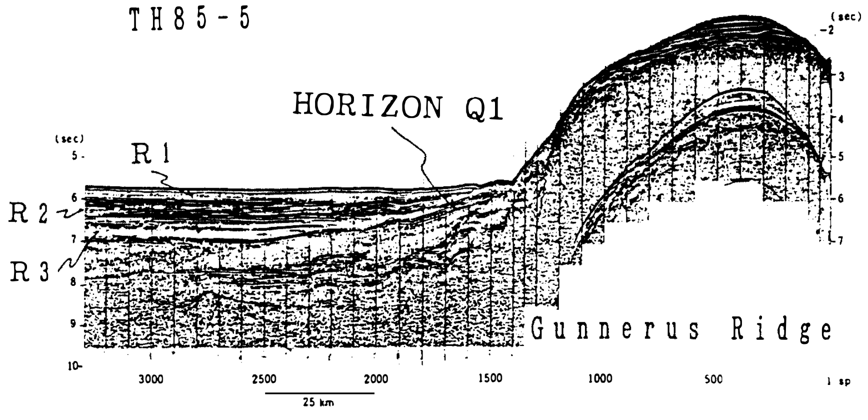

Fig. 6. Seismic reflection profile (Line TH85-5) crossing from Gunnerus Ridge to the lower continental rise of the Riiser-Larsen Sea.

between SP 5800 and 8500. This is a place where three tributaries of Ritscher Canyon discharge their sediment loads to construct the huge mound of fan deposits. The main body of the fan consists of the R2 sequence with strong reflectivity of layering. The R1 sequence is observed only at the periphery of the fan from around SP 5500 eastward and from SP 9000 westward. The R3 sequence is distributed horizontally throughout the area. There are observed eastward dipping strata within the R2 sequence between SP 7000 and 8500. The dipping strata indicate eastward migration of the fan complex. As a result of the fan migration, channels of the canyons changed their courses sharply eastward. Thus, the overall structure of the deep-sea fan shows an aggradation stage during deposition of the R2 sequence. Sediment supply from the continent was overwhelming during the period of R2 deposition. Hereafter, it may be convenient to name this the Ritscher deep-sea fan that develops at the base of the upper continental rise.

On the other hand, sediment supply may decrease during the R1 sequence, therefore, channel incision may take place to form terraced walls. Canyon C observed at SP 4600–4700 shows a good example of such channel incision.

The boundary between the upper and the lower continental rise is clearly shown on Line 85–6 in Fig. 7. Here, the base of the upper continental rise is located at SP 1100 in water depth of 4000 m (5.3 s in two-way travel time). As a unique reflection pattern, Horizon Q1 cannot be identified in this area. However, correlation to trace the horizon to this area is possible, because of the short distance from Gunnerus Ridge. At SP 1 on the shore-side end of the profile on the upper continental rise, Horizon Q1 can be correlated to a level at depth of 6.0 s. If this correlation is correct, sedimentary sequences above Horizon Q1 have thickness of 1.5 s (approximately 1500 m) and can be divided into the R1, R2 and R3 sequences. The R1 and R3 sequences are characterized by weak sediment reflectivity. The R2 sequence consists of an upper thin transparent layer and a lower layered sediment of high reflectivity, both of which may represent coarser clastics of post-Eocene glacial sediments forming the upper continental rise.

The R2 sequence observed on the upper continental rise changes northward to become a huge massive mound between SP 1300 and 1900. This mound represents a deep-sea fan

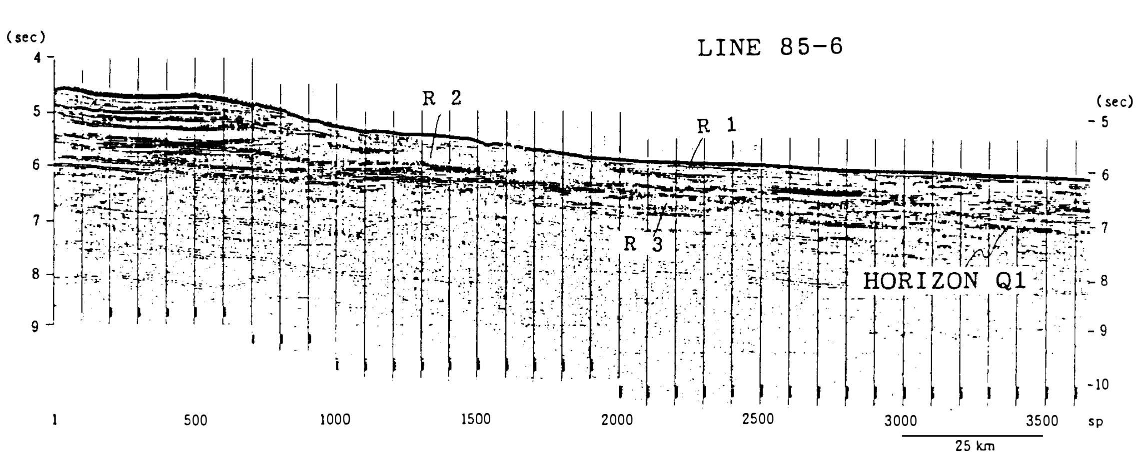

Fig. 7. Seismic reflection profile (Line TH85–6) showing the topographic boundary between the upper and the lower continental rise off Breid Bay, Dronning Maud Land.

formed at the base of the upper continental rise. A typical sediment facies on the lower continental rise is observed at around SP 2700 where densely layered strata at the middle part represent the R2 sequence.

Clearly more energetic, coarser and greater sediment supplies formed the steep upper continental rise and, thereby, a deep-sea fan at the base of the upper continental rise during deposition of the R2 sequence.

5. Discussion

5.1. Hydraulic jump to create the deep-sea fan

A theoretical approach to the massive wasting of sediments on the upper continental rise and a sudden hydraulic jump at the base of the upper continental rise to leave a deep-sea fan has been discussed on the basis of studies on density currents (MIDDLETON, 1966; KOMAR, 1975).

The well-known Chezy formula for river flow is:

$$V=\sqrt{gDS/f_0},$$

where V is the average velocity of the river flow, S is a slope gradient, D is a current thickness, f_0 is a resistance coefficient or frictional drag for the bottom interface, and g is gravitational acceleration.

In deriving submarine density currents from the Chezy formula, MIDDLETON (1966) obtained the following velocity equation (U) for steady flow:

$$U=\sqrt{8\Delta\rho gDS/(f_0+f_i)}, \quad (1)$$

where f_0 and f_i are resistance coefficient for the bottom and fluid interface, respectively, and $\Delta\rho$ is excess density of the current. Here, we apply the following equation:

$$\Delta\rho gDS=\varsigma_0+\varsigma_i,$$

where ς_0 and ς_i are shear stresses acting at the bottom and fluid above, respectively.

One of the factors controlling density currents is mixing between the density current and the fluid above. The criterion for hydrodynamic stability depends on the current velocity and is expressed by the Froude Number (Fr) as follows:

$$Fr=U/\sqrt{\Delta\rho gD}. \quad (2)$$

Solving eqs. (1) and (2) simultaneously, we obtain:

$$Fr=\sqrt{8S/(f_0+f_i)}.$$

Therefore, whether the density current is subcritical ($Fr<1$) or supercritical ($Fr>1$) depends only on the bottom slope gradient (S) and on the resistance coefficient (f_0+f_i). KOMAR (1975) gave the following values: $\Delta\rho=0.2$, $f_0=0.04$, and $f_i=0.02$, and did a series of computations on the current velocity; then he came to the conclusion that the density current was subcritical on the continental rise.

Utilizing these same values for the currents responsible for the Ritscher fan, this study comes to the conclusion that density currents are subcritical on a slope gentler than 0.0075 and supercritical on a slope steeper than 0.0075.

In the case of the Atlantic 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 in the Breid Bay margin. This is the reason that the deep-sea fan develops at the base of the upper continental rise in East Antarctica.

5.2. *Classification of the continental margin*

The eastern coast of the United States is a mature continental margin, where the slope gradient of the continental slope is 0.05, that of the upper continental rise is 0.008, and that of the lower continental rise is 0.002. In the previous chapter, it was argued that density currents have a hydrodynamic jump when slopes become less than 0.0075. When the value is applied to the Atlantic margin, the continental slope and the continental rise are definitely separated (HEEZEN *et al*., 1959).

Compared with the Atlantic margin, the critical value of 0.0075 comes to the middle of the continental rise in the East Antarctic margin. One of the well-surveyed margins in East Antarctica is the Weddell Fan area. ANDERSON *et al*. (1986) placed the boundary between the upper-fan and mid-fan at around 3750–4000 m depth. This depth corresponds roughly to the boundary between the upper and the lower continental rise in the Breid Bay margin. The upper-fan of the Weddell Fan has a gradient of 0.01–0.02, and the upper part of the mid-fan has a gradient of 0.005. These values are almost identical to those of the Breid Bay margin. Therefore, the upper-fan might be fed by supercritical currents such as sediment gravity flows or debris flows, and the lower part of the mid-fan by subcritical currents such as steady turbidity currents.

As to the classification of the continental margin, the slope gradient break is clearly identified with the base of the continental slope (see table in Section 2). A steep upper continental rise in Antarctica might be a special case formed by delivery of large amounts of glacial sediments from the continent.

5.3. *The grade change of Ritscher Canyon*

The baselevel of submarine canyons is the imaginary horizontal level of the lower limit to which canyon erosion proceeds. It corresponds generally to the abyssal plain. This definition of baselevel follows a study on land (SCHUMM, 1993).

There is a balanced level in the stream profile that slopes toward the abyssal plain and is determined by the gradient of a mature canyon, which is termed the grade. Changes of the baselevel and sediment supply are the main factors controlling the grade of stream profiles.

Regarding baselevel change, KAGAMI *et al*. (1991) discussed constant subsidence of the abyssal plain in the Riiser-Larsen Sea. Regarding sediment supply, the period of the R2 sequence was the main phase of formation of the Ritscher deep-sea fan. During R2 deposition there was accelerated sediment delivery downstream to the continental rise. Large accumulations of sandy and gravelly sediment formed a topographic mound, which can be called a fan complex. Considerable lateral migration of canyon channels might take place to adjust their equilibrium profile to the sediment filled margin. The stream profile grade might be smooth and aggrading on the upper continental rise during the R2 period.

The combination of continuous lowering of the baselevel and decreased sediment supply caused upstream channel degradation during the period of the R1 sequence. By the headward incision with vertical cutting of the channel, the channel gradient approximated a mature grade similar to the one observed in the Atlantic margin. Also, the discharge flow was concentrated in a narrow deep channel increasing the energy of flow. Thus, the whole system of canyons became a single deep-sea channel.

As shown in the table in Section 2, the present gradients of the canyon represent channelization (vertical cutting) mentioned above. The gradient of the channel between 750 and 3250 m depth is 0.025, which covers the depth range of the continental slope. The gradient between 3250 and 4000 m depth is 0.006, which corresponds to the upper continental rise, and the gradient between 4000 and 4750 m depth is 0.003, corresponding to the lower continental rise. These gradients are similar to those of the Atlantic margin. This is true because both continental margins are similar in the change of their baselevels, as both passive margins are subsiding. The Atlantic margin has already reached equilibrium in the margin profile, but the East Antarctic margin began to change only in the grade of channel profiles.

5.4. Sequence stratigraphy and estimated age

There are three sequences above Horizon Q1 in the Riiser-Larsen Sea as shown in Table 1.

The R1 sequence: The R1 is 0.3 s (240 m) thick at the eastern part of the lower continental rise (Fig. 6) and 0.48 s (380 m) thick at the base of the upper continental rise (Fig. 7). The *P*-wave velocity of the R1 sequence is 1600 m/s according to SAKI *et al.* (1987). The acoustic character of the sequence shows weak reflectivity. Because the period of the sequence corresponds to the glacial ages, this weak reflectivity may reflect glacioeustatic fluctuations. The rate of sedimentation may be low from the observation of channel downcutting. Therefore, the 300 m thickness of the sequence may correspond roughly to the Plio-Pleistocene (SAKI *et al.*, 1987).

The R2 sequence: The *P*-wave velocity for the R2 sequence is 2000 m/s (SAKI *et al.*, 1987). The R2 is 0.46 s (460 m) thick at the eastern part of the lower continental rise. It becomes 0.8 s (800 m) thick at the center of the deep-sea fan as shown in Fig. 4 and 0.52 s (520 m) thick at the lower part of the upper continental rise. The acoustic character of the sequence is the strong reflectivity and sometimes great thickness indicating sand and gravel layers. Eastward inclined bedding within the sequence shows fan deposits.

Table 1. Sequence stratigraphy in the Riiser-Larsen Sea and Gunnerus Ridge, Dronning Maud Land, East Antarctica.

Sequence	Estimated age	Acoustic nature	Sedimentary nature
R1	Plio-Pleistocene	Week reflectivety less stratified	Slow sedimentation channelization
R2	Miocene	Strong reflectivity inclined bedding	High sedimetation fan formation
R3	Oligo-Eocene	Weak reflectivity horizontal continuity	Slow sedimentation glacial-marine ?
Q1	Mid Eocene	Regional uncoformity	Erosion/tectonics uplifting
R4	Paleogene or Mesozoic		

Accumulation of coarse clastic sediment indicates high sedimentation to form a fan complex during the period. Ages are not identified, but R2 may represent Miocene progradational episodes.

The R3 sequence: The P-wave velocity of the R3 sequence is 2400 m/s (SAKI *et al*., 1987). R3 is 0.4 s (480 m) thick at the eastern part of the lower continental rise. It is also the same thickness, 0.4 s (480 m), at the center of the deep-sea fan. It is 3.5 s (420 m) thick at the lower part of the upper continental rise. The acoustic character of the sequence is weak reflectivity similar to the one in the R1 sequence. Because the glacio-marine character of the R1 sequence is evident, the R3 sequence would also be glacio-marine sediment. The glacio-marine character of R3 is partly evidenced from ODP Legs 113, 119 and 129 drilling on the Maud Rise and Kerguelen Plateau. Stable isotope and sedimentological studies of these ODP sites indicated that early Oligocene ice-sheet expansion took place on Antarctica, and rafted ice reached to the Kerguelen Plateau and Maud Rise (ZACHOS *et al*., 1992; DIESTER-HAASS *et al*., 1993).

5.5. *Comparison of East and West Antarctic margins*

This canyon in the Riiser-Larsen Sea is larger in scale and older than those of West Antarctica. The basement age of the Riiser-Larsen Sea is approximately 145 Ma (MARTIN and HARTNADY, 1986), which is the oldest abyssal sea-floor around Antarctica. The constant subsidence of baselevel controls the shape of canyons. The other factor controlling the shape of canyons is the volume of sediment supply from the continent.

DSDP drilling in the Bellingshausen Sea revealed that a period of intensive activity of turbidity currents and debris flows might correspond to extensive continental glaciation (TUCHOLKE and HOUTZ, 1976; TUCHOLKE, 1977). Drilling at DSDP Leg 35 sites indicates that very rapid sedimentation, up to 10 cm/1000 y, started from 6 Ma and ended at around 3 Ma. This period corresponds to the maximum expansion of the Antarctic glaciation. According to KENNETT (1982), the maximum glaciation in Antarctica was between 5 and 7 Ma. The deglaciation period immediately after the maximum glaciation was between 3 and 4 Ma (PICKARD *et al*., 1988).

Because of its topographic setting, canyon formation continues to the present time in West Antarctica (STUIVER *et al*., 1981; KAMGAMI, 1993). The depth and gradient of margin topography have been summarized for the Bellingshausen Sea (KAGAMI *et al*., 1991). The continental slope ranges from 500 m to 3300 m with a gradient of 0.03. The upper continental rise lies between 3300 m and 3980 m with a gradient of 0.004, and the lower continental rise between 3980 m and 4700 m has a gradient of 0.002. These values

Table 2. Comparison of Antarctic continetal margins.

Margin	Bellingshausen Sea	Dronning Maud Land
Margin type	Atlantic type	East Antarctic type
Canyon configuration	Depositional channel	Incised channel
Tributary pattern	Downstream branching	Downstream joining
Abyssal channel	none	Deep-sea channel
Fan type	Complex fans at the base of continental slope	Mid-rise fan
Fan age	S2~1 (Plio-Pleistocene)	R2 (Miocene)

are exactly the same as those of the Atlantic margin. This topographic setting can explain why well-developed fans are located at the base of the continental slope in the Bellingshausen margin.

Comparison of the continental margin is summarized between Breid Bay of East Antarctica and Bellingshausen Sea of West Antarctica (Table 2). The Breid Bay margin shows an extremely different topographic setting relative to others around the world; therefore, this type can be called the East Antarctic margin. On the other hand, the Bellingshausen margin is similar to the Atlantic margin, although it is located in the Pacific sector of West Antarctica.

6. Conclusions

(1) A new bathymetric map, compiled using JARE-27 (1985/1986) to JARE-32 (1990/1991) data (except JARE-31) for the area between 65 and 71°S latitude and between 20 and 36°E longitude off Breid Bay, Dronning Maud Land, East Antarctica, shows a complex channel-joining configuration.

(2) Four or five tributaries of Ritscher Canyon change their course sharply eastward at latitude 68°S. It is concluded that the canyon discharged a large amount of sediment to construct a deep-sea fan at the base of the upper continental rise at 68°S. The deep-sea fan is here called the Ritscher deep-sea fan. A strong eastward bottom current might have existed during development of a fan complex (the period of the R2 sequence) at the mouth of tributaries, and caused migration of tributaries. This is partly evidenced by development of the sand bank of the R2 sequence on Gunnerus Ridge, where the bank develops only at the eastern side of the ridge.

3) The Ritscher deep-sea fan exists at the base of the upper continental rise. This is only possible by delivery of enormous amounts of sediments on the upper continental rise; the local slope became steeper than 0.0075. This type of margin probably exists from Dronning Maud Land to the Weddell Fan of East Antarctica. The continental margin in the eastern part of East Antarctica will be discussed in a following paper. Here, it is called the East Antarctic Margin, one of the end members of the continental margin. It was formed during the period of the R2 sequence.

(4) From experiments done by Middleton (1966) and calculations done by Komar (1975), it becomes clear that a hydrodynamic jump from turbulent flow to laminar flow takes place to form a deep-sea fan at depths where the slope becomes less than 0.0075. This value corresponds to the boundary between the upper continental rise and the lower continental rise in the Breid Bay margin, East Antarctica, and to the boundary between the continental slope and the upper continental rise in the Bellingshausen margin, West Antarctica; the latter is called the Atlantic margin type.

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