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EROSIONAL TOPOGRAPHY OBSERVED ON THE UPPER CONTINENTAL RISE, WILKES LAND, EAST ANTARCTICA

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Abstract: Erosional topography is recognized on the upper continental rise between 123° and 134°E off Wilkes Land, East Antarctica. Erosion of the upper continental rise up to roughly 500 m is observed on seismic lines and is considered to be caused by down-slope density currents of cold shelf water or by thermohaline induced contour currents of Antarctic bottom water. Development of the abyssal channel systems is another bit of evidence that sediments are swept off the sea floor to create erosional depressions on the upper continental rise off Wilkes Land.

Because these eroding currents are only active and effective at the continental margin around Antarctica, erosional depressions of the upper continental rise are responsible for formation of the Antarctic margin type.

key words: erosional depressions, upper continental rise, off Wilkes Land, Antarctic margin type, Antarctic bottom water

1. Introduction

The author has proposed two types of continental margin from Antarctica (KAGAMI, 1995a). One of the types is similar to the Atlantic Margin having a flatter gradient (<0.0075) at the upper continental rise. An example of this type is shown at the continental margin of Bellingshausen Sea, West Antarctica. The other type of Antarctic margin is characterized by a steeper gradient (>0.0075) at the upper continental rise and is found between 123° and 134°E in Wilkes Land, East Antarctica.

The depositional end-member of the Antarctic Margin Type having steeper gradient (>0.0075) was recognized and reported from offshore of Dronning Maud Land, East Antarctica (KAGAMI, 1994). The seabottom offshore of Wilkes Land shows an erosional end-member of the Antarctic Margin Type (KAGAMI, 1995a).

The topographic character off Clarie Coast of Wilkes Land is as follows: the edge of the continental shelf lies at 400–500 m, the lower limit of the continental slope lies at 3000–3200 m which is approximately 400 m deeper than that of the typical Atlantic margin, and the upper continental rise comes down to 3800–4200 m. The slope gradients show prominent character. The continental slope has a gradient of 0.023–0.086, which is almost the same as that in the Atlantic, and the upper continental rise has 0.009–0.022, which is steeper than that in the Atlantic (<0.0075). Based on the deeper and steeper upper continental rise, the Antarctic Margin Type was proposed (KAGAMI, 1995a).

In this paper the author discusses the cause of erosional features observed at the upper continental rise off Wilkes Land. The morphology of the Antarctic continental shelf has been interpreted to be formed by the sum of outer shelf sediment loading and inner shelf unloading associated with a grounded ice sheet (Ten Brink and Schneider, 1994). This interpretation was a clue for the present study.

The topographic information used in this paper off Wilkes Land comes from the GEBCO Bathymetric Chart (IHO and IOC, 1983) and Chase *et al.* (1987). Seismic reflection data were obtained from Sato *et al.* (1984), Tsumuraya *et al.* (1985), Wannesson *et al.* (1985), Tanahashi *et al.* (1987), Eittreim and Smith (1987), Eittreim (1991) and Eittreim and Tanahashi (1994).

2. Description of Erosional Features on the Upper Continental Rise off Wilkes Land

The continental rise off Wilkes Land between 123°and 134°E is highly dissected by dendritic canyons or channels (Fig. 1). The headward branching channels which stream down to the depth of the ocean basin as abyssal channels are clearly identified in Fig. 1. The basemental strata are composed of pre-rift, syn-rift and post-rift sediments and constitute a broad zone of block-faulted continental basement and an offshore zone of the marginal rift basin between the shelf break and the oceanic crust (Eittreim and Smith, 1987; Eittreim and Tanahashi, 1994). The block-faulted continental margins are commonly observed at passive margins around the world (Hellinger and Sclater, 1983). The block-faulted basement zone in this area shows an upward arching structure due to the regional tectonics. The overlying post-rift and

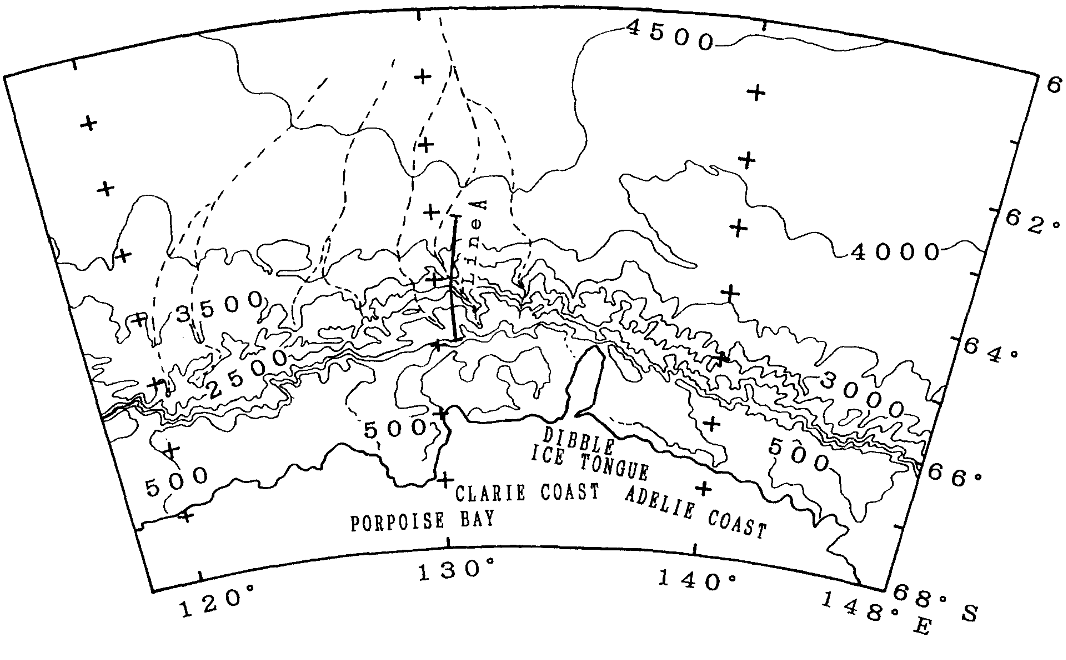

Fig. 1. Submarine topography of the continental margin off Wilkes Land. Depth contour interval is 500 m. The headward branching channel continues to drain to the basin floor (broken line). A seismic profile (Line A) is shown in Fig. 2.

post-glacial strata are highly dissected and thinned by erosion through development of the channels. Erosional thinning of the strata up to 1 s in two-way travel time (TWT) compared with the surrounding area is observed on the multichannel seismic profiles (Fig. 2, and Figs. 5 and 6 of KAGAMI, 1995a).

Concerning erosional features observed at the upper continental rise off Wilkes Land, WANNESSON *et al.* (1985) described the features mainly based on seismic lines ATC 101 and 102 of the 1982 Antarctic survey which passed approximately the 138°E meridian off Wilkes Land, as follows: The continental slope has a steep upper part (gradient 6°) corresponding to the frontal face of oblique progradations of sediments. The lower part of the slope has a very irregular morphology with many indications of erosion, channeling and possible contour currents. And the total sedimentary thickness, which means that Unit 3 was deposited after the late Oligocene unconformity, becomes locally as small as 2.5 s in TWT.

The average thickness in this area is 3.0 s with the thickest being 4.3 s; sediment thickness approximately 0.5 s or 500 m thick has been eroded from this part of the continental margin by down-slope channeling.

Erosion by down-slope channeling has been studied on Crary Fan in the southeastern Weddell Sea between 22° and 40°W. The Crary Fan deposits immediately overlie the regional W4 unconformity of the Mid-Oligocene time, identified on ODP site 693 (DE BATIST *et al.*, 1994). Topographically it is divided into three parts: upper fan from 800 to 2500 m depth, middle fan from 2500 to 3000 m depth where the continental slope terminates and lower fan from 3000 to over 4200 m depth (KUVAAS and KRISTOFFERSEN, 1991; KUHN and WEBER, 1993; ANDERSON *et al.*, 1986).

Large erosive channels or deep furrowed canyons develop on the middle and lower fans of Crary Fan. The headward branching canyons or ocean-ward confluent channels are interpreted as drainage systems for density currents of "ice shelf water" running down the slope of the fan. The drainage channels can also be used by thermohaline induced continuous flow (contour current). These bottom flows in the channel showed velocity up to 50 cm/s (KUHN and WEBER, 1993). The development of these furrowed channels between the fan and the continental slope played an important role in erosion of the continental slope-oceanic floor junction.

EITTREIM and SMITH (1987) described areal distribution of thickness of the most recent, highly stratified Sequence A off Wilkes Land. They notice that sediment thickness is controlled by the canyon-channel systems and the minimum thickness in the Sequence A occurs at the boundary between the upper and lower rises, where there is a break in slope separating the dissected-fan topography of the upper rise from the smooth slope of the lower rise.

Minimum thickness of Sequence A is observed to be 0.5 s in TWT at around 132°E. Comparing with the surrounding thickness of 1.0 s, erosion of the surface sediment is estimated to be 0.5 s or roughly 500 m, although the isopachus interval of thickness is 0.5 s.

Utilizing a very precise bathymetric map off Wilkes Land made by CHASE *et al.* (1987), an example of the dissected-fan topography is observed at around 148°E. A dissected mound has width of 70 km parallel to the continental slope and length of 50 km toward the ocean with a relative height of 700 m.

Regarding the dissected-fan topography on the continental rise, there are observed eight large mounds of 150 km×50 km west of the Antarctic Peninsula between 63° and 80°W (REBESCO *et al.*, 1994). From their eroded shape, an Antarctic bottom current prevails from NE to SW related to the opening of Drake Passage since the early Miocene (MCGINNIS and HAYES, 1994). Erosion of the mound was worked out either by along-slope processes, *i.e.* an Antarctic bottom current and contour currents, or by down-slope processes, *i.e.* canyon cutting and slumping of sediments.

The development of the abyssal channel systems from the lower continental rise to the abyssal plain off Wilkes Land, which is shown in Fig. 1, would suggest a prominent conduit for the erosive bottom water.

Thus, erosion at the upper continental rise off Wilkes Land is estimated to be roughly 500 m and is evidently caused by down-slope density currents induced by thermohaline contour currents in the case of Wilkes Land near 132°E.

3. Model of Continental Margin Erosion around Antarctica

The continental shelf around Antarctica, 400–700 m deep at the shelf edge, is deeper than the world normal value, and is characterized by a nearshore trough up to 1 km deep in many areas. Unlike a fjord on a high latitude of ice-free coast, the nearshore trough developed roughly parallel to the coastline and was generated by multiple cycles of ice sheet advance across the shelf, whereby in each cycle a thin uniform layer of sediment was eroded under the ice sheet and was redeposited seaward of the grounding line (TEN BRINK and COOPER, 1992). Their regional isostatic model assuming variable flexural rigidity across the shelf indicates a moderate amount of net erosion, 300–900 m, across the majority of the shelf, forming the nearshore trough.

A model of erosion at the continental rise around Antarctica will now be considered. Before glaciation in the early Miocene or Oligocene, the margin had a simple shape of subsidence associated with initial thinning of the continental crust (MCKENZIE, 1978) and with prolonged thermal subsidence of the oceanic crust since its breakup of 95 Ma (VEEVERS, 1986). At present, after glaciation, deepening of the upper continental rise through erosion by down-slope density currents and long-term thermal subsidence occurs. It is evident that the lower depth of the continental slope off Wilkes Land is 3000 to 3200 m, which is approximately 400 m deeper than the surrounding areas with a classical Atlantic profile.

The erosion of the upper continental rise off Wilkes Land in relation to arching of the basemental strata was once considered to be due to ice sheet loading (KAGAMI, 1995a). However, ice loading, isostatic response of the lithosphere, thermal and tectonic subsidence of the margin and sea level changes had much less influence on the observed morphology and stratigraphy on the shelf around Antarctica (TEN BRINK and SCHNEIDER, 1994). They considered that there were not great differences in these values, despite the varied tectonic histories of different segments of the Antarctic margin, and they proposed that erosion by a grounded ice sheet was the only agent that could form the nearshore trough on the continental shelf.

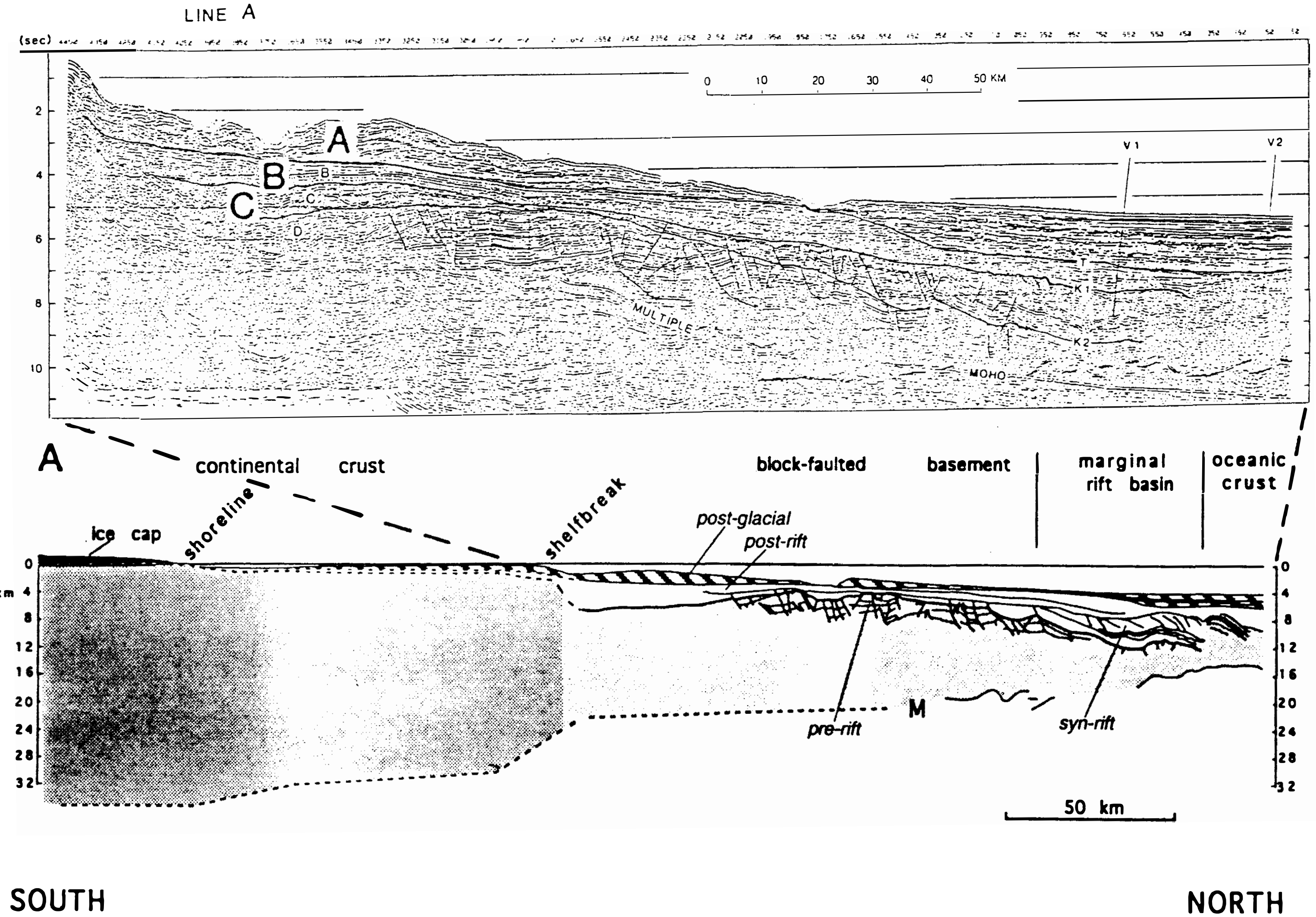

Fig. 2. A representative cross section (Line A) of the continental margin off Wilkes Land (Lower; EITTREIM and TANAHASHI, 1994; Upper; EITTREIM and SMITH, 1987). Post-rift and post-glacial sediments are labeled as Sequence A in the upper seismic profile.

The present author agrees on this point even though the process occurred on the midcontinental rise, and thinks that erosion by upward arching of the basement is unlikely at present. EITTREIM and SMITH (1987) mentioned that the arch structure was already formed at the time of normal faulting of the Gondowana crust, and that synrift Sequence C was deposited on both sides of the arch. It is now believed that erosion on the upper continental rise by a down-slope density current of cold shelf water or by a thermohaline induced contour current entrapped into canyons is only responsible for thinning (at least 500 m) of post-rift and post-glacial sediments (Fig. 2), because these eroding currents are only active and effective at the continental margin around Antarctica as reviewed in the previous chapter.

Also, development of the abyssal channel associated with Antarctic bottom water could contribute to sweep sediments off the sea floor and create a shallow erosional depression at the upper continental rise.

Because the cold shelf water and thermohaline bottom water only develop around Antarctica, erosional depressions of the upper continental rise are responsible for formation of the Antarctic margin type.

4. Discussion and Conclusions

To explain the deeper and steeper upper continental rise off Wilkes Land, glaciation-related phenomena must be taken into account.

TEN BRINK and COOPER (1992) found that grounded ice sheets on the continental shelf have eroded to form the shelf trough, a typical morphology on the Antarctic shelf. Here, the author proposes that down-slope density currents or thermohaline induced contour currents have eroded substantial surface strata at the upper continental rise to form erosional depressions. From the multichannel reflection records, submarine erosion up to 500 m thick is observed off Wilkes Land.

However, due to its location at a hinge between the continental margin and the oceanic crust, the eroded morphology mentioned above is often concealed and is not well separated from continuous subsidence by thermal cooling of the oceanic crust. For this reason, erosional depressions at the upper continental rise have not been noticed (KAGAMI, 1995b). From combined observation of the steeper gradient of the upper continental rise and the arching structure beneath the upper continental rise, we can recognize eroding of the post-rift and post-glacial sediments.

The above-mentioned erosional model on the upper continental rise is different from the slope-readjustment model on the erosional margin proposed by ROSS *et al.* (1994). Their model requires a great sea-level fall and steepening of the slope to cause an erosional slope; then onlapping fan deposition on the base of the slope comes later. However, the present author emphasizes the role of submarine erosion by Antarctic bottom water to cause a steeper and deeper upper continental rise.

The down-slope density current of cold shelf water and thermohaline induced contour current trapped into thalwegs are responsible for erosion of the surface sediments on the upper continental rise. These erosive currents are important agents for submarine erosion. They evidently suggest not only formation of the canyon-channel system, but also construction of a regional steeper and deeper continental rise around Antarctica. PRATSON and COAKLEY (1996) did a model simulation on evolution of the canyon by down-slope eroding sediment flows. The author understands the importance of triggering flows from their work, and is convinced that there are many chances to trigger down-slope flows in Antarctica, because of glacial activity.

The studies on bottom-current erosion on the abyssal plains around Antarctica by LEDBETTER *et al.* (1983) and LEDBETTER and CIESIELSKI (1983) further suggest that erosive bottom currents sweep frequently from the base of Antarctica to the abyssal plain.

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