Cenozoic Seismic Stratigraphy of Prydz Bay (Antarctica)


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Prydz Bay is one of the most long-lived continental margins with episodic expansion of grounded ice sheets. Ice sheet grounding is thought to have occurred since Eocene time. An easily accessible, continuous, cross-section through the different marginal environments (from inner shelf to abyssal plain) also make Prydz Bay an ideal area to study glacial-related depositional processes.

The major structural feature on the Prydz Bay shelf is a northeast-trending late Paleozoic (?) to early Mesozoic grabenlying at the termination of the onshore Lambert-Amery continental rift zone. The latter has been overlapped during glacial time by the worlds largest glacial system which presently drains more than 1 million square kilometers, or about 20% of the East Antarctic Ice Sheet. During the post-rift period (late Mesozoic to Cenozoic time) the Prydz Bay shelf has been characterized by smooth oceanward flexural subsidence and low amplitude, late Cenozoic block faulting of the inner shelf (Leitchenkov, 1991). A narrow trough system running along the eastern Prydz Bay coast clearly marks the transition from crystalline shield to rift basin.

Prydz Bay bottom morphology is typical of glacial margins elsewhere. A generalized geometry (Fig. 1) shows planer banks up to 200 m deep crossed by a wide, longitudinal, glacially-eroded trough (Prydz Channel) which descends 700-800 m below sea level. The latter correlates with a steep Mesozoic rift fault and faint, possibly neotectonic, dislocations that obliquely cut the basement high (Fig. 1).

In this study we discuss the joint interpretation of approximately 17,500 km of seismic data obtained by Australian, Russian, and Japanese expeditions, together with Ocean Drilling Program (ODP) Leg 119 results. A newly compiled bathymetry map (Fig. 1) is used to provide the physiographic and morpho-structural context.

Different, glacially-formed features are distinguished in the Prydz Bay (Figures 1 and 2) showing the complex glacial history of this area.

ODP data (Barron et al., 1991) suggest that grounded ice sheets first advanced onto the shelf in late Eocene to early Oligocene time. On the seismic records this event seems to be marked by development of the landwardmost wedge-shaped deposits which can be best interpreted in terms of the till-toungue stratigraphy model of King et al. (1991). These deposits overlay a gently sloping preglacial unconformity that appears to have been eroded or deformed by grounding of ice. Till-tounges are traced laterally along the entire Prydz Bay shelf within the area between the till-toungue root (TTR) and the original (preglacial) paleo shelf edge (OPSE) (Fig. 1). They are most pronounced, thick, and extended, in the mid-shelf part of Prydz Channel, which appears to have already been an active ice-conduit by the early glaciation time. Apparently, no extensive shelf edge progradation occurred during the very first ice advance, because only overlapping sequences built out the OPSE. Grounded ice appears to have moved seaward from the TTR but lifted up off the shelf decreasing the rate of sedimentation.

It was not possible to determine in detail the subsequent ice advance - retreat history on the Prydz Bay shelf using the available data. However, at least three successive events of shelf-edge progradation in post-early Oligocene time can be identified. As the result of these the sizable sedimentary wedges up to 4 km total thick have been formed building out the shelf edge from 30 to 60 km (Figs. 1 and 2).

The first event is recognized by distinct steepening of reflectors within the sequence located seaward of OPSE (Fig. 1). The pattern of foreset reflectors along strike between OPSE and paleo-shelf edge (PSE) I is quite similar from line to line suggesting a steady rate of sedimentation beyond the shelf edge and sufficiently stable advance dynamics of the grounding ice. The first prograding sequence is correlated with the middle Oligocene to early Miocene hiatus defined landward at ODP Site 739 (Barron et al., 1991), and its origin is likely due to late Oligocene glaciation.

The second prograding cycle (PSE1-PSE2, Fig. 1) is not distinct in the seismic records but can be inferred by a change in dip of the reflector pattern, which in places overlies the clearly distinguishable unconformity (Fig. 2). Local lateral thickening of the PSE1-PSE2 prograding wedge is observed at the central outer shelf (Fig. 1) testifying that enhanced grounded - ice flow, and higher sediment supply to the slope, took place there, perhaps as a result of trough-mouth deposition. This prograding cycle corresponds to the late Miocene glacial maximum.

The third ice-sheet advance event is identified by the unique acoustic character of the youngest prograding sequence that it formed, and by the distinct, underlying unconformity (Fig. 2) named reflector A (RA) by Mizukoshi et al. (1988).
Fig. 1 - Cenozoic depositional (glacially formed) and morphostructural features of Prydz Bay shown against the background of the principle tectonic lineaments.

1 - position of initial offshore grounding lines formed during early ice sheet expansions; TTR - rear Till Tongue Root (oldest ice sheet grounding line); OPSE - Original (preglacial) Paleo Shelf Edge; PSE 1, PSE 2 - prograded (Neogene) Paleo Shelf Edges; 2 - thickness of till strata deposited predominantly during the last (post-late Pleocene) glaciation (seconds two-way traveltime); 3 - asymmetric ridges and mounds interpreted as grounding line moraine (arrows show direction of steeper slope); 4 - axis of (a) present day, and (b) buried channels; 5 - basement ridges outcropping at sea bottom; 6 - major preglacial (Cretaceous) fault escarpments; 7 - line of the section shown in figure 2.

The most remarkable feature of the terminal prograding wedge is the large sedimentary fan located offshore from the mouth of Prydz Channel. It is clearly outlined by seaward-convex 500 to 2500 m isobaths, and by thickening of deposits overlying RA. RA exhibits the highest amplitude reflection on the seismic records in this area, allowing it to be mapped with a high degree of confidence (Fig. 1).

The development of the terminal prograding wedge was, likely, a result of post-late Pliocene glacial expansion. Variable ice-sheet dynamics occurred over the Prydz Bay shelf throughout this time, controlling erosional/depositional conditions, rate of the shelf edge progradation and bottom morpho-structure.

The wide, glacially-eroded, longitudinal Prydz Channel which crosses the shelf, and the shallow, flanking Four Ladies and Fram banks are major features of shelf topography. The former was, apparently, formed by a fast flowing ice stream that eroded pre-existing substrate, rapidly supplying debris to the upper slope and significantly enhancing shelf-edge progradation relative to adjacent areas. In contrast, in the bank areas, subglacial deposition occurred due to slow, grounded, ice-sheet motion and low basal shear stress (Boulton, 1990). This conditions was favorable for production of flat-lying sequences up to 200 m thick. Progradation of the shelf edge also took place up to 5 to 10 km beyond the banks, but was not as productive as build up in the trough mouth.
fan setting (20 to 40 km).

Distinctive, meso-scale, glacially-formed features were mapped in the inner- and mid-shelf area using MCS and high-resolution seismic (HRS) data (Fig. 1). Most of the features are a result of recent endogenous (and possibly neotectonic) processes. The most pronounced, rugged, relief occurs in the south-western quarter of the Prydz Bay shelf where linear ridges and deep troughs dominate (Fig. 1). Two extensive, sub-parallel, and slightly westward-arcuate ridges, 50 to 80 m high and up to 20 km across extend to 120 to 140 km seaward of the Amery Ice Shelf front. The ridges have asymmetric (cuesta-like) shape with a steeper western side (Fig. 2) and are aligned mostly along the eastern flank of Prydz Channel according to its strike.

The internal acoustic pattern of the ridges often shows westward-dipping foreset reflectors (prograding the steep faces of the ridges, Fig. 2). The character and location of the ridges suggest that they are most likely grounding line moraines which were formed during the last deglaciation due to irregular lifting of the grounded ice sheet following sea-level rise. Initially ice mass released from the bottom, within Prydz Channel, and the grounding line successively retreated eastward to two major still-stand positions forming morainal ridges (Fig. 1). Minor, closely spaced, asymmetric ridges (up to 10 to 30 m high and 40 to 50 km long) observed between troughs on the inner shelf (Fig. 1) have a similar origin.

In the south-eastern corner of Prydz Bay a somewhat different type of glacial deposit is seen at the terminus of the deepest erosion trough. There, an asymmetric mound, up to 250 m high, with a jagged, deepward, gentle slope and a steep opposite slope (Fig. 1) has likely formed as a grounding ice end morain within the local interglacial ice fluctuation.

Other small-scale (less than 10-15 m high) glacially formed features are identified in HRS lines and could be interpreted in terms of advance and retreat ice accumulation as well as iceberg-related facies. However, more detailed description of these features is hampered by the sparse coverage of the HRS survey.

REFERENCES


