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Quaternary Sedimentation at the Antarctic Continental Margin

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Sedimentological and geochemical investigations were carried out on gravity cores collected during POLARSTERN expeditions in the South Atlantic part of the Southern Ocean to provide a high resolution record of paleoenvironments over the last 300 kyr.

The distribution of Quaternary sediments in the Southern Ocean is related to complex interactions of glaciological, oceanographic and biological processes. Stratigraphic framework had been difficult to obtain because core samples do not have adequate carbonate for stable isotope measurements. Therefore, the first marine geological work on Quaternary sediments in the Southern Ocean initially focused on general sedimentation processes (e.g. Anderson, 1972; Anderson et al., 1983a; Elverhoi & Roaldset, 1983). Several models were developed to explain the cryogenic depositional processes in the marine environment and the behaviour of the Antarctic ice sheet, based on the analysis of Pleistocene sediments (Anderson et al., 1983a; Kellogg et al., 1979). More recently, sedimentation patterns across the Weddell Sea continental margin have been studied to reveal environmental variations of the hydrosphere and cryosphere and to unravel the Quaternary climatic history of Antarctica (Grobe & Mackensen, 1992). The following results and interpretations are based on investigations of the late Quaternary sediments from the eastern Weddell and Lazarev seas. Similar records have also been found in sediments of the Antarctic continental margin between the Bellingshausen Sea (90° W) and Gunnerus Ridge (35° E), an area covering more than a third of the Antarctic coast line. Our models for paleoenvironmental reconstruction may thus be applicable to most of the Antarctic continental margin.

We use a lithostratigraphy, adjusted to a stable isotope record from the eastern Weddell Sea (Mackensen et al., 1989) to array the late Quaternary paleo-environmental changes in relation to the climatic cycles. The sedimentary processes considered are ice rafting, current transport, and gravitational downslope transport. These processes are controlled by a complex interaction of sea -level changes, paleoceanographic and paleoglacial conditions in response to global climate and local environments. Sedimentation rates at the continental slope of the Weddell Sea are mainly controlled by ice rafting, which reflects mass balance and behaviour of the Antarctic ice sheet. The sedimentation rates decrease with distance from the continental slope and from interglacial to glacial. Due to the sea level controlled retreat of the grounding line and the formation of new ice shelves, highest rates occur at the very beginning of interglacials. These are up to five times higher than those during glacials.

We classify the sediments into five distinct facies which we correlate to different paleoenvironments. At glacial terminations (isotope events 8.0, 6.0, and 2.0), the Antarctic cryosphere adjusts to new climatic conditions. The sedimentary processes are controlled by the rise of sea level, the destruction of ice shelves, the retreat of sea ice and the recommenced feeding of warm North Atlantic Deep Water (NADW) to the Circumpolar Deep Water (CDW). During peak warm interglacial periods (isotope events 7.5, 7.3, 5.5, and 1.1), the CDW promotes warmer surface waters and thus the retreat of sea ice which in turn provides more light to surface waters (Fig. 1). At distinct

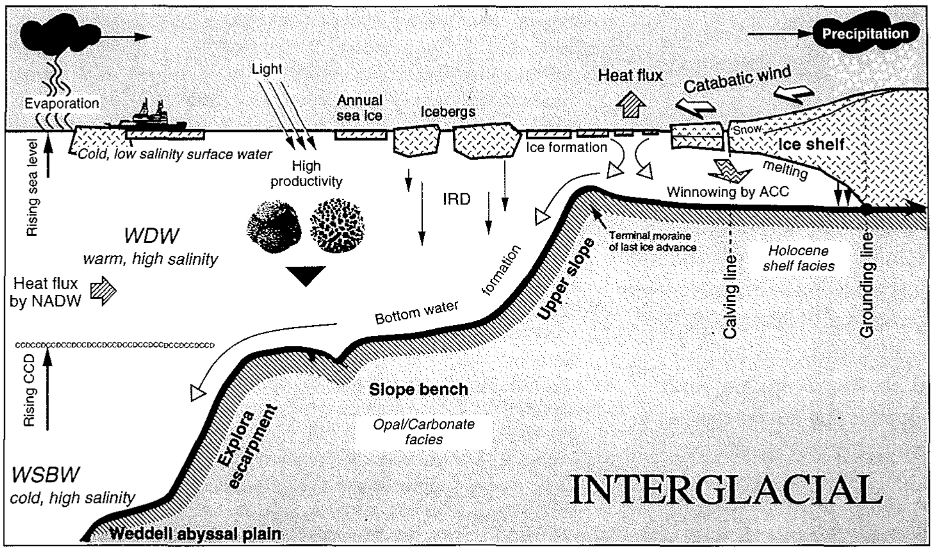

Fig. 1 - Model for the environmental conditions at the Antarctic continental margin during interglacial periods. Included are the processes which are caused by the postglacial sea-level rise, such as the retreat of the grounding line accompanied by intense calving and ice rafting. (WDW=Weddell Deep Water (a branch of the Circumpolar Deep Water), NADW=North Atlantic Deep Water, WSBW=Weddell Sea Bottom Water, CCD=Carbonate Compensation Depth, ACC=Antarctic Coastal Current, IRD=Ice Rafted Debris).

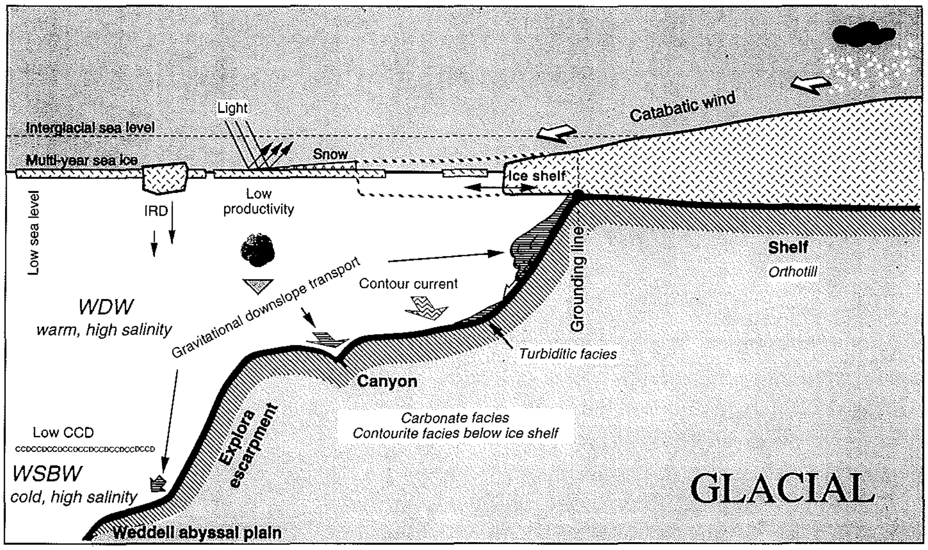

Fig. 2 - Model for the environmental conditions at the Antarctic continental margin during glacial periods. Possible further advances of the ice margin during more severe glacial settings are indicated. A contourite facies is deposited on the slope below ice advances and sea-ice cover.

climatic thresholds, local insolation also influence sea-ice distribution and/or productivity. Primary production and bioturbated mixing of the sediments increase, the CCD rises and carbonate dissolution occurs in slope sediments even at water depth shallower than 2000 m. Ice shelves and coastal polynyas favour the formation of very cold and saline Ice Shelf Water (ISW) which contributes to bottom water formation.

During the transition from an interval of peak warmth to a glacial episode (isotope stages 7.2-7.0, and 5.4-5.0), the combination of intense ice rafting and reduced bottom currents produces a typical facies that occurs with a distinct lag in the time of response of specific sedimentary processes to climatic change. With the onset of a glacial episode (isotope events 7.0, and 5.0) the Antarctic ice sheet expands owing to the lowering of sea level caused by the extensive glaciations in the northern hemisphere. Gravitational sediment transport becomes the most active process on the continental slope, and sediment transfer to the deep sea is provided by turbidity currents through canyon systems. During Antarctic glacial maxima (isotope stages 7.0-6.0 and 5.0-2.0) the strongly reduced input of NADW into the Southern Ocean favours further advances of the ice shelves far beyond the shelf break and the continuous formation of sea ice (Fig. 2). Below ice shelves and/or closed sea-ice coverage, contourites are deposited on the slope (Grobe & Mackensen, 1992).

Recent results from geochemical analyses allow for the first time a quantitative description of biogenic opal and barium content in the sediments of the inner part of the Southern Ocean. Together with other sedimentological parameters and physical properties, these records represent the cyclicity of paleoproductivity and sedimentary processes in response to the glacial/interglacial changes. The good correlation between barium and opal records indicate that dissolution of opal in the deep sea and sediment pore waters does not obscure the surface productivity signal. Using opal and barium as proxy parameters of paleoproductivity (Dymond et al., 1992; Berger et al., 1989), it appears that close to the Antarctic continent lower productivity (20-65 g C/m^{2}y) occurred during glacial times and higher productivity during interglacials (120-270 g C/m^{2}y). Another result of our investigations is the fact of a decreasing trend in productivity from the East to the West of our investigation area which is mentioned in the maxima of the opal values, supported by the maximum values of barium.

Our results show that opal and barium used as proxy parameters give a clear indication of paleoproductivity variations in correlation with the climatic cycles in sediments of the Antarctic continental margin.

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