The paleoceanography of the Antarctic Circumpolar Current and the Weddell Gyre from sedimentary records, a patchy story

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The Antarctic Circumpolar Current (ACC) developed after the opening of the Tasman Gateway and Drake Passage between Antarctica and the adjoining continents in the upper Eocene (Huber et al., 2004; Francis et al., 2008). We have no information about prior proto Weddell Gyre (WG) conditions, such as the similarly proposed circulation in the Ross Sea (Huber et al., 2004), but models indicate a much warmer Weddell Sea compared to post conditions (Cristini et al., 2012).

Studies on sediment cores from the Atlantic sector of the Southern Ocean and from the Weddell Sea provide information on the history and glacial/interglacial variability of the ACC and the WG. How does ACC flow speed interact with WG dynamics? Is the WG vitality independent from the ACC or is it rather related to seasonal and/or continuous sea ice coverage of this area? Could it be instead related to the brine formation below floating ice shelves, or to Weddell Sea Bottom Water (WSBW) and Antarctic Bottom Water (AABW) formation? Is the configuration of deep outflow passages of WSBW relevant for the WG dynamics? Very little information has been provided to these questions up to now.

The initiation of circumpolar circulation in the upper Eocene changed the oceanography and the sedimentary record drastically. In addition to increasing ice- berg rafted debris (IBRD), the Smectite content of the clay mineral fraction decreased and Chlorite, together with Illite and Kaolinite, were dominating (Ehrmann et al., 1992). Decreasing atmospheric pCO_2, changes in Southern Ocean deep water ventilation, and primary productivity have been recorded in several paleoenvironmental sediment proxies. After the middle Miocene Climatic Optimum, a strengthening in the Antarctic ice sheet growth is evident and clear glacial/interglacial cycles have been described from Gunnerus Ridge in the southeastern part of the WG (Hillenbrand and Ehrmann, 2003) during Pliocene time.

Around the Gauss/Gilbert magnetic reversal and with the onset of Northern Hemisphere glaciation, the sediment composition of the Weddell Sea changed significantly. High biogenic opal contents in the older sediments point to a favorably productive environment with sea ice coverage possibly only during winter (Hillenbrand and Ehrmann, 2005). Interglacials and even extra warm interglacials with a collapsed West Antarctic Ice Sheet (Naish et al., 2009) have dominated these depositions. The Antarctic glaciers may have been warmer and fast flowing, with little or no ice shelves surrounding the Weddell Sea. This may have reduced the cold brine formation as well. The younger sediments recorded colder conditions with lower primary productivity, but with partially high carbonate contents from planktic foraminifera living in sea ice brine channels. Brine formation took place as it does today, mainly during interglacials below ice shelves. East and West Antarctic Ice Sheets covered most of the shelf areas during glacials, therefore, the brine and bottom water production was reduced as indicated by smaller grain-size compositions in the deep western Weddell Sea glacial sediments. Alkalinity of the Weddell Sea waters was increased during the glacials, leading to lower carbonate compensation depths (Rickaby et al., 2010). Oxygen and carbon isotopes from carbonates, geochemical and clay mineral compositions and other sediment proxies vary with past Pleistocene climate changes and provide good environmental records from the Weddell Sea slope, as well as indicating ice sheet dynamics (Grobe et al., 1993, Weber et al., 2011).

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