Likely and unlikely ocean feedbacks on global climate during the Eocene-Oligocene Transition

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The initiation of 'thermal isolation' of Antarctica from warm, subtropical currents has long been thought to have been the trigger for cooling of Antarctica and its subsequent glaciation. Recently published geologic evidence indicates that the gateway changes thought to have caused this isolation occurred significantly (2 mya) before glaciation and proxy records from the Southern Ocean also paint a different picture of the ocean circulation than previously assumed. Modeling studies indicate that changes in ocean currents were unlikely to have strongly and directly affected temperature and precipitation inputs within the Antarctic interior even if they had occured. The alternative hypothesis, that the transition from Eocene warmth to a cooler and ice-prone Oligocene was driven by changes in greenhouse gases, can be argued to be a more likely explanation given the plausible variations in greenhouse gases derived from proxy records. This nevertheless raises interesting questions about the potential feedbacks between ocean gateway opening (and tectonic/bathymetric change associated with it) and the carbon cycle. We present results which suggest that high latitude climate responded strongly to greenhouse gas changes to variations through the Eocene, in the absence of major alterations in ocean heat transport. The greenhoues gas changes may have been driven by changes in ocean basin configuration and major climate events may have been triggered by gateway changes, but new results raise the possibility that Southern Hemisphere glaciation may have had less to do with changes in the Southern Ocean than shifts in the Arctic. We also address how changes in the climate of Antarctica may have fed back on climate and the ocean's carbon cycle.

The stuttering greenhouse and Cenozoic carbonate compensation depth

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Marine carbonate burial and glaciations are linked. High carbonate deposition tends to occur with cooler conditions and development of polar ice. The first development of a continent-wide Antarctic ice cap in the earliest Oligocene, for example, is marked by the largest deepening of carbonate compensation depth (CCD) in the Cenozoic--1200m in less than 300 kyr beginning at about 33.9 Ma (Coxall et al., 2005). The event more than doubled the area of sea floor subject to $CaCO_3$ burial. Falling sea level caused by glaciation and ensuing shelf-basin fractionation, is unlikely to be the sole cause of the increased deep-ocean $CaCO_3$ burial since the exposed carbonate shelf area (3-4% of total world surface area) is significantly less than the increase in area of deep-ocean Oligocene $CaCO_3$ burial (ca.: 25% of the Earth's surface; Rea and Lyle, in press).

A series of orbitally-driven CCD oscillations associated with cooling occurred at 2 myr intervals in the middle and late Eocene. Oxygen isotope data indicate that the CCD events mark cooling and perhaps small glaciations in the Eocene. However, climate conditions reverted back to warmth until the Eocene/Oligocene boundary. A shallow CCD represents conditions where the ocean reservoir of total carbon is high relative to the weathering flux of cations, where atmospheric CO_2 is also high. The oscillations in the Eocene carbon cycle were driven past an important threshold at the Eocene/Oligocene boundary apparently causing a permanent drop in atmospheric CO_2.

References

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Rea, D.K., and M. Lyle (in press), Paleoceanography.