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Cenozoic Climate Change: Geochemical Proxy Records from Deep Ocean Sediments

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Cenozoic climate evolved from a the warm Paleocene and Eocene (16 Ma) to the relatively cold conditions of the modern world via three major ice growth events first on Antarctica at the Eocene/Oligocene boundary then during the middle Miocene and finally in the Northern Hemisphere during the late Pliocene. Much of what we know about past climate change comes from the oxygen isotopic composition of benthic foraminifera. Although this proxy outlines large scale changes in the degree of polar glaciation, the absolute magnitude and the relationship between ice extent and ocean temperature cannot be uniquely determined. The recent development of foraminiferal Mg/Ca ratios as a proxy for paleotemperatures provides an opportunity to improve our understanding of climate change on both tectonic and orbital time scales. For example, paired

delta^{18}O and Mg/Ca deep water records show that expansion of ice at the Eocene/Oligocene boundary occurred in steps and was accompanied by cooling of water temperatures by about 2-3C (Lear et al., 2008; Katz et al.2008). During the middle Miocene expansion of ice predates cooling of Southern Ocean surface waters providing evidence for the importance of heat and moisture transport in Antarctic ice growth (Shevenell and Kennett, 2007). Relatively few deep sea studies have focused on late Miocene climate, and foraminiferal

delta^{18}O records do not support major oceanographic and climatic changes. Although, the late Miocene may have been a time of global cooling, especially in the circum-Antarctic region, with the establishment of a grounded West Antarctic ice sheet. The early Pliocene, in contrast, has been the focus of much research because of the relevance to understanding intervals of sustained global climatic warmth with near modern-day tectonic configuration, warm upwelling regions, and elevated CO_2 levels with respect to the pre-industrial atmosphere. The deep sea

delta^{18}O record, however, suggests that Antarctic ice sheet size remained relatively stable during this particular warm period.

Early Pliocene climatic warmth ended with the beginning of wide spread Northern Hemisphere Glaciation at

$sim3$ Ma and enhanced sensitivity of ice sheet variations to obliquity forcing. One hypothesis seeks to explain this climate transition by a change in oceanic heat balance calling for coherent changes in eastern tropical and western subtropical Pacific sea surface hydrographic changes after

$sim3$ Ma (Philander and Fedorov, 2003; Fedorov et al., 2006). Preliminary new isotope data from the subtropical northwestern Pacific (Site 1208) show that, on obliquity time scales, planktonic foraminiferal

delta^{18}O maxima occur slightly before benthic foraminiferal

delta^{18}O maxima (2-3kyr) but are close in time with minima in equatorial Pacific sea surface temperatures in first order support for the hypothesis.