Antarctic ice sheet sensitivity to orbital forcing, crustal subsidence, and carbon dioxide fluctuations.

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Abstract

Insight into causes of ice sheet variability over a range of time scales is fundamental to our understanding of Earth system response to climate change. Furthermore, there is a need to understand long-term commitments to future sea level rise and the potential for ice sheet 'recovery' if emissions mitigation is able to limit or reverse warming. It is well understood that fluctuations in the volume and extent of Antarctica's ice sheets (AIS) are primarily controlled by changes in global climate due to orbital variations in incoming solar radiation, surface reflectivity (albedo), and greenhouse gas concentrations. Regional changes in ocean circulation also have an effect. Furthermore, the AIS is sensitive to changes in topography over longer time periods[1-3]. However, questions remain regarding the role that these different drivers have played in controlling ice sheet variability through time. Reconstructions of past ice sheet behaviour from the geological record offer a means to examine the influence of predictable orbital variations and to identify critical planetary thresholds that have affected ice sheet behaviour. These ice sheet reconstructions are often derived from far field records, which provide highly resolved, near continuous records over the past 34 million years[4-8]. However, ice sheet proximal data are required to constrain interpretations based on far-field data.

More than forty years of scientific drilling and seismic data acquisition along the Antarctic margin provides a direct record of AIS variability. Drill cores recovered from the Ross Sea region provide a composite stratigraphy that spans the past 34 million years[9-14]. Extensive marine seismic surveys across the region define stratigraphic packages that are linked to glacial and tectonic processes and help constrain glacial history. Importantly, the location of these stratigraphic archives captures the evolution of ice sheets in both East and West Antarctica. We have established an integrated stratigraphy for the Ross Sea using new biostratigraphic data[15] and revised core descriptions. This integrated framework offers a clear and coherent history of AIS variability and extent since the inception of isolated ice caps on Antarctica's continental highs and coastal mountain ranges in the late Eocene. Whereas orbital forcing played an important role in AIS growth and retreat on glacial-interglacial timescales, proxy environmental data highlight thresholds in the climate system, across which the nature and behaviour of the AIS fundamentally shifted. Importantly, these transitions suggest that the AIS was sensitive to changes in atmospheric CO_2 concentration the were similar to values projected for the coming decades. Collection of new geological data from regions that are most vulnerable to climate change are required to test and build on our current understanding of AIS sensitivity. Our community challenge is to identify, fund, and drill these locations soon!

keywords: Scientific drilling, carbon dioxide, orbital forcing, ice sheet sensitivity.

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