with the sea-level fall[12], although the data were later reinterpreted as being consistent with a seawater δ^{18}O change on the order of ~0.2–0.3 ‰ (ref. 13), which could allow for Antarctic ice growth.

The most recent paper to enter the fray comes from Ando and coauthors[2], who analysed the δ^{18}O of carbonate shells from both surface- and bottom-dwelling foraminifera. They used closely spaced samples of a relatively well-preserved mid-Cenomanian section from Blake Nose, Florida. Their work showed an increase in δ^{18}O values in the bottom-dwelling foraminifera during the sea-level change, but no accompanying increase in the surface dwellers. As shifts in seawater δ^{18}O should be reflected throughout the water column, they question the interpretation of ice-sheet growth as a driver of this sea-level fall.

Part of the discrepancy between the studies may lie in the small magnitude of the global sea-level fall, estimated to be about 25 m. The seawater δ^{18}O change predicted for such a drop at this time is also small (<0.25‰) and near the detection limits. Yet, δ^{18}O shifts in the shells of surface dwellers have been detected at other low-latitude sites for other proposed periods of ice growth[11,14], and it is surprising that no change was observed during the Cenomanian at this site.

One of the primary challenges to any study of the links between sea level and ice volume during the Cretaceous is chronology. Both research groups were careful to bracket the events they described using biological and chemical stratigraphic constraints[1], and microfossil and carbon isotope analyses[2]. These excellent temporal correlations, together with those of Gale and coauthors[10], provide confidence that the sea-level changes were global, and that their δ^{18}O records can be tied to the sea-level events recorded in various locations.

So although the isotopic records remain to be reconciled, it does seem that our view of greenhouse intervals as long monotonic periods of warmth is incorrect. The 'cool snaps' indicated by Galeotti and coauthors' study (among others) were relatively short, lasting less than 200,000 years during a 1–2 Myr interval[11], and the associated δ^{18}O increase suggests they only require small ice sheets on Antarctica (for example, equivalent to one-third of the modern Antarctic ice sheet[5–7], Fig. 1).

Galeotti and coauthors[1] compare oxygen isotopes and stratigraphy to show that the mid-Turonian sea-level fall was driven by ice-sheet growth, and evidence from other sea-level falls[10] supports the global nature of this event[11]. It is, however, puzzling that the sea-level fall in the mid-Cenomanian described by Ando and coauthors[2] does not show a similar δ^{18}O shift to the other Cretaceous greenhouse events; a resolution of this question awaits further studies of this enigmatic interval. ❐

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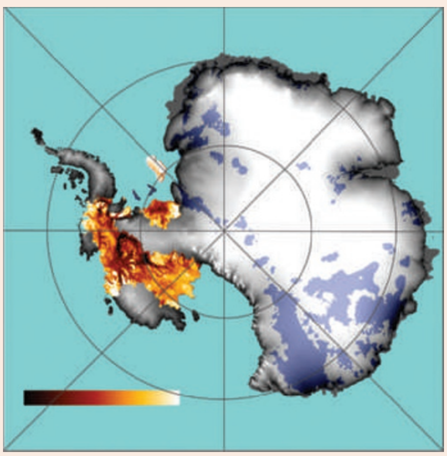
GLACIOLOGY

Melt revisions

Kilometres of ice have built up over Antarctica. From today's perspective, the vast sheet of ice and snow looks like an eternal feature. Yet the part of Antarctica that lies west of the Transantarctic Mountains is largely below sea level today, and its ice sheet has probably collapsed at least partly during past warm episodes. The West Antarctic ice sheet has therefore been flagged as a possible location of exceptional climatic sensitivity where a large mass of land-based ice may be lost to the ocean in response to relatively moderate changes in climate.

According to the fourth assessment report from the Intergovernmental Panel on Climate Change, global sea level would rise by about 5 m if the West Antarctic ice sheet were to collapse. However, Jonathan Bamber, of the University of Bristol, and colleagues have estimated the potential rise in global mean sea level from the disintegration of this ice sheet at only about 3.3 m (*Science* **324,** 901–903; 2009).



They base this value on a detailed reassessment of the volume of potentially vulnerable ice: ice resting on bedrock below sea level (the brown colours in the image) that slopes downwards inland. According to the so-called marine ice-sheet instability hypothesis, land ice under these conditions can be subject to rapid and irreversible removal if the buttressing ice shelves — such as those holding the West Antarctic ice sheet in place — disintegrate.

A sea-level rise from West Antarctic ice-sheet collapse would not be globally uniform. Mainly because of the ice mass's gravitational pull on the surrounding oceans, Bamber and colleagues project regional sea-level rise to be about 25% above the global mean (or about 4 m in absolute terms) along the US Pacific and Atlantic coasts. In contrast, coasts at the tip of South America would only be affected by about half the global mean rise.

But even with this lower estimate, a potential disintegration of the West Antarctic ice sheet would affect millions of people around the world who live in low-lying areas.

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