The first continent-wide Antarctic ice sheet formed in earliest Oligocene times, now dated at about 34 million years ago. Given its global significance, and that the past is one of the few ways we have of peering into our climatic future, understanding that event has been among the main aims in palaeoclimatology. On page 245 of this issue, DeConto and Pollard provide an account that differs from the commonly accepted explanation in invoking changes in atmospheric CO₂, rather than in ocean circulation, as the determining factor.

The previous scientific story goes back to the 1970s, when Shackleton and Kennett pioneered the recovery of long-term temperature data from deep-sea sediments, in the form of oxygen isotope ratios preserved in calcium carbonate microfossils. They identified a progressive global cooling over the past 65 million years, with step-like falls in temperature at about 34 and 15 million years ago, as shown in Fig. 1, overleaf. Kennett linked these steps to the separation of Australia and South America from Antarctica, which opened ocean gateways that forced current systems in the Southern Hemisphere from primarily north-south flows in the Pacific, Atlantic and Indian Oceans to west-east flows around Antarctica. The inferred consequence was cooling of the Antarctic region by thermal isolation, through a reduction in heat transfer between the Equator and the South Pole, permitting sea ice to form. Subsequent further cooling allowed the formation of a large permanent ice sheet, although sediment cores from the Antarctic margin have since shown that the first cooling...
DeConto and Pollard² report modelling studies of two further influences on the Antarctic climate—changes in atmospheric CO₂ levels and in the Earth’s orbital parameters. They show how a decline in CO₂ content, from four times to double that of our atmosphere before the past century (a baseline termed the pre-industrial atmospheric level), can result in a climate in which winter snow eventually survives through the summer and over a large enough area to start forming an ice sheet. They also show how the exact timing of ice-sheet initiation can be affected by a combination of the Earth’s orbital parameters that results in minimal summer insolation of the Antarctic.

DeConto and Pollard also checked on the likely influence, previously queried⁶, of the ocean gateways opening south of Australia and South America at about the time that the first big ice sheet grew. To do this they compared the effects on simulated ice-sheet growth of an open and a closed Drake Passage, using the estimate of 20% for the reduction in southward ocean heat transport resulting from gateway opening. The Drake Passage lies between South America and the Antarctic Peninsula, and when closed represented the final barrier to circum-Antarctic circulation. The result of the experiment showed a shift in the threshold CO₂ level for ice-sheet growth from 2.4 (closed) to 2.8 (open) times pre-industrial levels. However, there was no significant change in the pattern or magnitude of ice-sheet formation, confirming the primacy of atmospheric CO₂ as the controlling factor.

This study² is a fine example of how modern computer technology can be applied to major questions about climate processes and history. It also highlights areas where further research is needed, such as the relative influence of temperature and ice volume on the deep-sea isotope curve, and the effects of the roughness and hardness of the terrain beneath an ice sheet on its behaviour. But as with all models of past events, however elegant, it requires validation through concrete evidence from observations of today’s world, and the records in ice and sediment layers on land and beneath the sea. For the first Antarctic ice sheet, the relevant timing and geography have been fairly well established from the evidence cited by DeConto and Pollard, and the orbital variations they call upon to trigger the first ice sheet are recorded in younger, cyclic sequences evident in cores drilled off Antarctica². However, a sedimentary record of the transition from ‘greenhouse’ to ‘icehouse’ Antarctica on the continent itself, with information on the extent and rate of the change in climate and vegetation, has yet to be recovered. Drilling programmes such as ANDRILL⁴ and SHALDRIL⁵ have under way, should provide the relevant data—for example on changes in coastal temperatures through the transition period.

What of other climate transitions in the past? For instance, the small step at about 24 million years ago that coincides with a widely recognized fall in sea level⁶ and a shift in Antarctic coastal vegetation from beech forest to tundra⁷. Or the larger step at 15 million years ago, which is widely interpreted as the transition from an ephemeral to a permanent Antarctic ice sheet? These two episodes are still not understood. There is also continuing curiosity over the response of the Antarctic ice sheet during the worldwide warming about 3 million years ago. Here uncertainties need to be resolved in dating glacial deposits in the Transantarctic Mountains. On the basis of rare microfossils, some contend that the deposits date to this time; others, however, have shown how the microfossils could be windborne contaminants, and the deposits should be much older⁸.

As to the future, it is now clear that land-surface and ocean temperatures are rising in response to human-induced emissions of greenhouse gases—and remarkably fast on a geological timescale. The present concentration of greenhouse gases is 30% above the benchmark pre-industrial content, rising to that level in only a century, and is likely to be the highest for the past 20 million years¹⁴. According to the ‘warmest scenario’ projections of the Intergovernmental Panel on Climate Change, the projected doubling of CO₂ concentration by the end of this century is expected to result in a climate that the planet last experienced about 70 million years ago (Fig. 1).

The effects of this change are difficult to predict, but they will plainly be profound. Finding out more will require closer collaboration between geoscientists who work at extracting data on past climates from ice and sediment cores and from rock strata, and modellers who use complex mathematical representations to approximate events in the physical world. An example of such collaboration is the formation of the Antarctic Climate Evolution planning group¹⁵.

More generally, DeConto and Pollard’s study² brings a new understanding of the effects of CO₂ emissions on climate, and adds force to the arguments for reducing greenhouse-gas emissions beyond those agreed in the Kyoto Protocol. At the same time it is clear that regional responses to climate change through interactions between the oceans, atmosphere and ice sheets vary considerably from the global average. The science of mitigating the effects of greenhouse emissions is in some countries and cases taking priority over research into understanding climate behaviour, especially regionally. Both areas of research will need sustained support, along with an international commitment to an effective solution, if we are to survive the worst consequences of this grandest of all human experiments.
9. www.arf.fsu.edu/arfhtml/arfpages/shaldril.html
15. www.geo.umass.edu/ace