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Cenozoic Glacial History Revisited

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Recent geological discoveries have shaken the long-standing view of Earth's Cenozoic glacial history, which traditionally calls for the first continental-scale glaciation of East Antarctica in the earliest Oligocene (~33.6 Ma), followed by the onset of major Northern Hemispheric glacial cycles in the late Pliocene about 30 million years later. For example, new evidence from Arctic and North Atlantic oceans suggests Northern Hemispheric sea ice and glaciers have existed intermittently through much of the Cenozoic, not just the last few million years. In terms of the early glacial history of Antarctica, it has recently been suggested that significant glacial ice might have formed at various times during the overall greenhouse warmth of the Cretaceous and Eocene, and when more permanent, major glaciation began in the earliest Oligocene, a proto-West Antarctic Ice Sheet (WAIS) might have grown in concert with the East Antarctic Ice Sheet, rather than forming much later in the Neogene as is usually assumed. These data hint at previously unconsidered ice accommodation during the Oligocene and Miocene that could help to explain the discrepancy between large variations in global ice volume implied by deep-sea-core records, and the much smaller amplitude variations predicted by numerical climate-ice sheet models of East Antarctica alone. In the more recent Pliocene and Pleistocene, recent sedimentary drilling by ANDRILL has shown that the Antarctic ice shelves and WAIS have waxed and waned with far greater frequency than previously suspected. Here, we review these recent geological findings from the polar regions of both hemispheres, while considering them in the context of globally distributed proxy records from the deep sea and new model results using the latest generation of coupled atmosphere-ocean-cryosphere-isotope models. We offer a revised view of Earth's cryospheric evolution through the Cenozoic, and note important discrepancies between traditional interpretations of proxy ice volume records, based mainly on oxygen isotope and Mg/Ca records from the deep sea, and numerical models simulations that consider the long-term evolution of Cenozoic paleogeography and atmospheric carbon dioxide.