

d16 Cenozoic climatic proxies < psychrosphere >

Throughout the centuries physicists have followed Democritus [‘... , hot by convention, cold by convention, colour by convention; in truth there are but atoms and the void.’] in separating objective reality from subjective perception. To be sure, they have succeeded in moving both temperature and colour from the subjective to the objective column of the ledger by linking them to real physical properties of atoms, but those insights only underscore Democritus’s dichotomy.
—Hans Christian von Baeyer.¹

In millions of years ago: The Pleistocene Ice Age of the Northern Hemisphere began 1.806. The Greenland ice sheet started to form 2.588 (beginning of the Gelasian Age).² In the Southern Hemisphere, Antarctica’s ice sheet history has been present since 14, absent 14-26, present 26-34, absent before. World climate began its bumpy Cenozoic cooling slide at 40.³

Paleotemperatures can be obtained from measurements of ¹⁸O/¹⁶O ratios in skeletal calcite. These oxygen isotopes have been measured in the tests of planktonic and benthonic foraminifers taken from long-cores obtained at several subarctic Deep Sea Drilling Project (DSDP) sites. Found is that surface and shelf-bottom temperatures declined during the Cenozoic and that the most prominent temperature drop was in the early Oligocene. James P. Kennett and Nicholas John Shackleton in 1976 attributed that to the initial formation of winter sea-ice around Antarctica. Temperature decline before was in a series of lowering steps from the torrid temperatures of the early Eocene.⁴

The production of cold bottom waters in the high southern latitudes instigated the two-layered psychrospheric ocean that has existed since the Oligocene (**Figure d16.1**). Shackleton and Kennett in 1975 found that ice in Antarctica during the Oligocene was in the form of mountain glaciers and was not an ice sheet. The Upper Oligocene glacial sequence on land contains a *Nothofagus* (Southern Beech) palynomorph assemblage. Upper Oligocene and younger glaciomarine sediments found at DSDP sites in the Ross Sea show high sedimentation rates well out into the Ross Sea. These record wet-based temperate glaciers flowing off Antarctica and calving icebergs into a relatively open sea.⁵

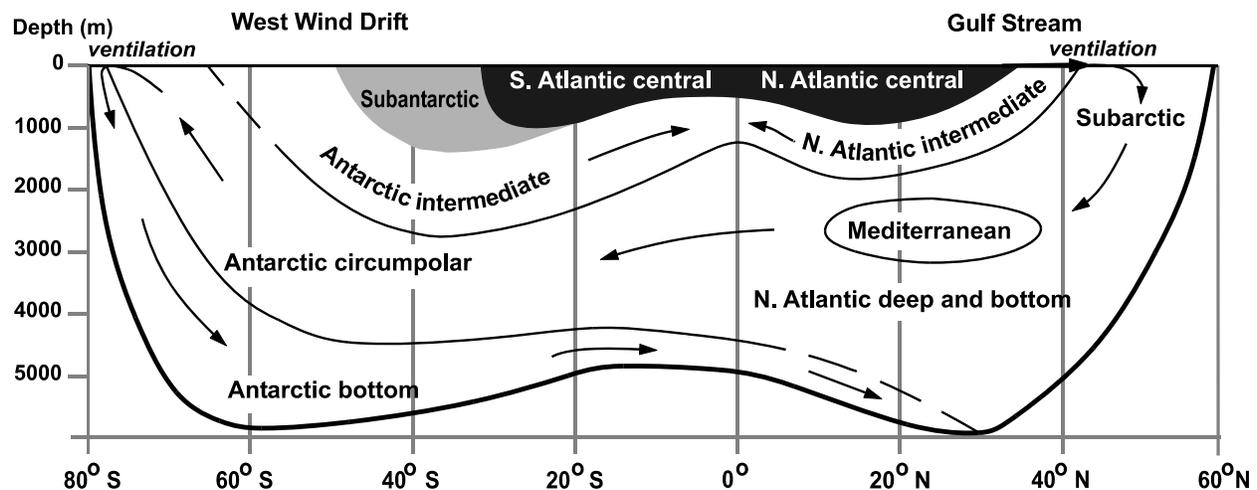
The Eocene and Late Cretaceous was a time of high carbon dioxide levels from which a globally warm climate can be predicted by climate models.⁶ However, a long standing “cool tropics paradox.” is that sea-surface cool temperatures of only about 15-20 °C have been indicated by oxygen-isotope analyses on fossil plankton shells from deepsea cores obtained at low latitudes. How so, and is this because plankton shells on the cold seafloor often recrystallize and/or additional material accumulates there on them?

In 2001, core samples from the Mandawa basin, southern Tanzania, yielded calcareous shells of foraminifera 50 million years old (Eocene) and about 70 million years old (Late Cretaceous) which show no evidence of alteration as a result of temperature or pressure changes of deep burial and uplift since the time the sediments were deposited on the seafloor. Their exceptional preservation could have been because they were encased in fine-grained clay (which is very impermeable, so fluids don’t pass through it). These fossils record sea-surface temperatures in the tropics to have been at 28-32 °C (much warmer than today!). “We almost couldn’t believe these were ancient rocks, and not modern mud,” says Paul Pearson who can now state that the “once believed ‘cool tropics’ is a case of faulty fossil data.”⁷

The cooling of the world climate through the Cenozoic, from the torrid Eocene climate that enabled then such present-day-strangeness as redwood forests flourishing on Axel Heibergland high in the Canadian Arctic, cannot be accounted for by a progressive decrease in atmospheric CO₂ as the study of two proxies (**Footnote d16.1**) for the partial pressure of this greenhouse gas show that it has been close to historical levels of 300-370 ppm (parts per million) since the Eocene.

During the Paleocene, atmospheric CO₂ had peaked briefly: David J. Beerling in 2003 described stoma-density analyses of evergreen ferns that indicate that just after the beginning of the Cenozoic these grew in an atmosphere in which CO₂ spiked to at least 2,300 ppm. That could have raised average global temperatures about 7.5°C. This is markedly different from CO₂ concentrations in the air that followed and preceded. Prior to the time of end-Cretaceous final extinction of the dinosaurs, evidence from stomata spacing on ginkgo leaves is that for millions of years, CO₂ levels in the air had fluctuated between 350 and 540 ppm.⁸ □

Figure d16.1⁹ Named major oceanic water masses and circulations (arrows show longitudinal component) **in the Atlantic Ocean** (shown in cross section looking west). Ventilation is where photosynthetic planktonic life oxygenates surfacing seawater that then mixes downward.



At the ocean surface, Atlantic central waters across the equator, from about Lat. 30°S to about Lat. 35°N, constitute a warm shallow pool (dark shaded) stirred by south- and north-Atlantic gyres and an easterly Equatorial counter current between. This warm water (planetwide such is only about two percent of the whole ocean!) is separated from frigid (psychrosphere) water below by a zone of rapid temperature decrease (called the *permanent thermocline*) at a depth of ~300 m in the equatorial Doldrums and ~900 m in the Trade wind belts. South and north respectively of the warm saline gyre waters are Subantarctic waters of the West Wind Drift easterly surface current and Subarctic waters of the cold surface currents flowing from the Arctic ocean. Both are of low salinity due to added freshwater from cyclonic storm systems in their latitudes. Antarctic and N. Atlantic intermediate waters flow toward the equator beneath the permanent thermocline. They originate by winter cooling and by summer evaporation that increases salinity. Antarctic intermediate waters, which derive from the West Wind Drift, have low to moderate temperatures due to a low input of solar heat. N. Atlantic deep and bottom waters have high salinity due to evaporation of their source waters (Subarctic waters mixed with N. Atlantic central water from the Gulf Stream) that winter cooling causes to sink and flow southward beneath intermediate waters as far as Lat. 60°S where this flow turns to become the easterly Antarctic circumpolar current that at its top is rich in oxygen due to the photosynthetic activity of marine algae (diatoms mostly). The densest of all is Antarctic bottom water (salinity of 34.66 parts per thousand) that originates as the water left out of pack ice (sea-ice of crushed together pans, floes, and brash) that forms about Antarctica in winter (60-70% of it flows from the Weddell Sea).¹⁰ The same named bodies of water (with the exception of the warm saline Mediterranean inflow) and circulations occur at like latitudes in the Pacific and Indian oceans. At low latitudes, vertical mixing heats deep waters and so decreases their density.¹¹ Wind pumping can cause old (oxygen depleted) dense seawater to upwell and surface. At high latitudes, “ventilation” oxygenates seawater.¹²