

From the Greenhouse to the Icehouse

Cenozoic cooling

gradual cooling following the PETM with some abrupt cooling events seen during remainder of Cenozoic

evidence:

- oxygen isotope ratios in marine carbonates
- percent of smooth vs. jagged margin plant fossils
- Ca/Mg ratios in marine carbonates

general causes of Cenozoic cooling

probable decrease in rate of seafloor spreading & outgassing at ridges and volc. arcs

decrease in flood basalt/hotspot activity & resultant outgassing

increase in weathering rate due to new mountain building

Himalayas & Tibetan Plateau

the entire Alpine-Himalayan mountain belts

the Rocky mountains & Colorado Plateau (though timing is controversial)

specific causes: onset of Antarctic glaciation

observations:

- sudden positive shift in oxygen isotopes seen in marine sediments around 34 m.y. ago (Eocene-Oligocene boundary)
- first ice-rafted debris (sand, etc.) seen in deep sea muds surrounding Antarctica at this time as well
- marine geophysical data indicates that the Drake Passage between South America and Antarctica opened at this time

scenario:

- before ~34 m.y. ago warm ocean currents of the southern hemisphere subtropical gyres (equivalent of the Gulf Stream) brought "warm" waters to the coast of Antarctica
- since the opening of the Drake Passage between South America and Antarctic ~34 m.y. ago, the Circumantarctic Current has surrounded Antarctica with cold water, leading to the onset of Antarctic glaciation

specific causes: onset of northern hemisphere glaciation

observations

- closure of the Isthmus of Panama ~4 m.y. ago
- rapid cooling indicated by large positive shift in oxygen isotopes ~ 2.7 m.y. ago
- ice rafted debris begins to appear in deep ocean muds in sub-arctic

scenarios:

- **hypothesis 1:** Closure of the Isthmus of Panama diverted more warm water northward via the Gulf Stream. These waters were high salinity (deriving from the subtropical arid belt), inhibiting growth of sea ice, leaving open water yielding more humidity in Arctic to produce glaciers.

- ***hypothesis 2***: Before closure of the isthmus, less-salty, warm Gulf Stream water was able to flow into and warm Arctic Ocean. Since closure, saltier Gulf Stream waters sink (forming North Atlantic Deep Water) around Iceland thereby chilling the Arctic Ocean

in any case, the onset of northern hemisphere glaciation seems connected to ocean circulation changes resulting from the closure of the isthmus