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著者	MacNeil F., Stearns
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Arctic and Boreal Climate at the Beginning of the Pleistocene

F. Stearns MacNeil*

Abstract

Numerous studies have indicated that northern Atlantic waters experienced a cooling trend prior to the onset of continental glaciation. The distribution and migration of boreal mollusks indicates, however, that the Arctic Ocean was unusually warm at the beginning of Pleistocene time. Apparent Atlantic cooling may have resulted from an enlargement of Bering Strait which permitted an increased flow of water from the Pacific to the Atlantic; water was sufficiently cooled by Arctic transit to effectively lower Atlantic temperatures. Increased evaporation from a warmer and ice-free Arctic is taken as the principle initiator of continental glaciation.

A recent report by Ericson and Wollin (1970) appears to be the first solid departure from a long series of papers supporting the hypothesis that the Pleistocene (Glacial?) Epoch was initiated by a general and synchronous cooling trend. Their study, based on the frequency of *Globorotalia* in cores, and which they take to be an extremely sensitive indicator of temperature, concludes that Atlantic and Pacific temperatures have been out of step for at least the past million years.

Presumably, Ericson and Wollin use the term Pleistocene Epoch as the equivalent of the period of glaciation, a usage in vogue for well over a century. A proposed departure from this practice came at the 18th International Geological Congress (Great Britain, 1948) at which time the council of the Congress unamimously adopted the recommendation of a Temporary Commission to expand the Pleistocene in its type area (Italy) to include the marine Calabrian Formation and its terrestrial equivalent, the Villafranchian. This proposal has not received universal acceptance, due in part to some doubts as to the exact equivalence of the Calabrian and Villafranchian. The revised Pleistocene would include beds formerly assigned to the Late Pliocene. Pleistocene Epoch would span as much or more preglacial time as glacial time; the duration of the glacial stages is approximately one million years whereas the duration of the expanded Pleistocene (to the base of the Calabrian) has been estimated to be 1.7 million years. Some estimates date the base of the Villafranchian at over 2.5 million years.

The writer's own studies over the past 20 years have convinced him that an imbalance of temperature between the Atlantic and Pacific Oceans existed at least as early as the beginning of revised Pleistocene (Early Calabrian) time; then the northern Pacific and Arctic Oceans were considerably warmer than they are now whereas the northern Atlantic was cooler than it is now.

Nineteenth Century paleontologists were aware of the fact that deposits now regarded by many geologists as Early, or preglacial Pleistocene were characterized by an abrupt appearance of mollusks that now live at more northerly latitudes. In the words of S.V. Wood, these mollusks, "came down from the north", and they were taken to mark the onset of a cool period that led eventually to glaciation. It was not realized at the time

* 5958 Prather Drive, Fort Myers, Florida

that these mollusks, which occur in beds now believed to be synchronous in Iceland (*Serripes groenlandicus* zone), England (Red Crag), Belgium and the Netherlands (Scaldesian), and Italy (Calabrian), are species, or belong to genera, that were unknown in the Atlantic or Arctic regions prior to Pleistocene time but which have a long history in the northern Pacific region. The conclusion that these mollusks made a trans-Arctic migration at the beginning of the Pleistocene is inescapable. Inasmuch as most of them are now restricted in habitat to boreal and north temperate waters in both the Atlantic and Pacific Oceans and are unable to live or spawn in cold high Arctic waters, it must be assumed that the Arctic was warmer when they made their passage than it is now.

There is evidence that both the northern Pacific and northern Atlantic experienced warming in Pliocene time. *Fortipecten*, a genus known in Pliocene beds of both Japan and Sakhalin, extended its range to Kivalina north of Bering Strait in latest Pliocene time. The Tjornes beds of Iceland are believed to straddle the Pliocene-Pleistocene boundary. The two Pliocene zones, the *Tapes* and *Mactra* zones, contain species or genera that indicate a milder climate than the present climate of Iceland (MacNeil, 1965a). *Corbulomya* is now confined to the Mediterranean Sea. *Cardium tuberculatum* now lives south of England. *Paphia aurea* now lives as far north as southern Norway. *Glycymeris glycymeris* lives around England and may range to southernmost Norway. *Cyrtodaria siliqua* now lives from Rhode Island to Labrador. *Urosalpinx cinerea* lives off New England and southward (to Florida?). Apparently both European and American species extended their range northward during this period. Two of the species involved, *Glycymeris glycymeris* and *Urosalpinx cinerea*, are known only at the top of the *Mactra* zone, suggesting that the warming trend in the Atlantic culminated at the close of the Pliocene.

The base of the *Serripes groenlandicus* zone (Early Pleistocene) marks both the disappearance of the more southern Atlantic species and the abrupt appearance of a large number of Pacific genera and species. Among these are *Neptunea* (an undescribed dextral form close to a Late Pliocene and Early Pleistocene form in the Gulf of Alaska), *Buccinum* cf. *B. plectrum*, *Liomesus canaliculatus*, *Cryptonatica clausa*, *Searlesia* sp., *Beringius turtoni* (related to *B. adelphicus* Dall), *Admete couthouyi*, *Musculus niger*, *Serripes groenlandicus*, *Clinocardium ciliatum*, *Macoma calcarea*, *Panomya arctica*, *Mya pseudoarenaria* and others (Durham and MacNeil, 1967, p. 336).

The *Serripes groenlandicus* zone of Iceland appears to approximate the base of the Red Crag of England where many Pacific derivitives also make their first appearance. Some of the Red Crag species do not occur in Iceland, however, suggesting that different Pacific species followed different migration routes; *Acila*, for instance, has not been found in Iceland deposits. According to Baden-Powell (1955, p. 280), the Red Crag can be correlated with the Calabrian of Italy on the same basis. The occurrence of such genera as *Mya* in Calabrian deposits suggests cooling but, together with other cool water indicators in the Calabrian fauna, it does not indicate necessarily world-wide cooling.

As reconstructed from these circumstances, a warming trend took place in Late Pliocene time in both the Atlantic and Pacific Oceans, causing normally boreal and north temperate species to extend their range northward. At about the beginning of Pleistocene time Bering Strait was either reopened or enlarged, or an ice barrier in the Arctic was broken, allowing a large flow of warm water to enter the Arctic Ocean from the Pacific; even at the present time the flow through Bering Strait is northward. The increased flow of water to the Arctic meant also that an increased volume of water flowed from the Arctic to the Atlantic. The polar region was still sufficiently cold, however, to lower the temperature of water flowing through it and, in turn, to drastically lower the temperature of the North Atlantic. Thus, whereas the northern Atlantic Ocean was abnormally cool in preglacial Pleistocene time, the cooling marked a period of abnormal warmth — a seeming paradox.

The question of when the Arctic Ocean was first frozen and whether any ice was present prior to the time of glaciation has been discussed by several authors. Ewing and Donn (1956), in their now classic theory of an ice-free Arctic as the source of moisture for northern continental glaciation, presumed the Arctic to have frozen at the termination of the glacial stages and that the glacial-interglacial events were caused by alternating ice-free and ice-covered states of the Arctic Ocean. Whether they believed the Arctic to have been frozen previously is not clear. Donn and Ewing (1966) later modified their theory to attribute only the northern parts of the continental glaciers to Arctic evaporation; the southern extension of the glaciers was fed by moisture from the south. They further modified their theory to explain the termination of a glacial stage as the result of a dearth of atmospheric moisture caused by glacial growth rather than by freezing of the Arctic Ocean because of the lowering of sea level below some critical sill depth.

The paleontological evidence for a completely ice-free Arctic prior to glaciation is inconclusive. It seems probable, however, that periods of ice formation have been intensifying in the Arctic since Miocene time. The earliest migration of Pacific mollusks across the Arctic, and probably the first opening of Bering Strait, took place in Late Miocene time (MacNeil, 1965b, p. G8), followed by sporadic migrations during the Pliocene. The first great migration took place in Early Pleistocene time. Later migrations occurred during the interglacial stages and after Wisconsin glaciation. These sudden influxes of Pacific species into the northern Atlantic can be attributed only to successive openings of Bering Strait or to successive breakdowns of a climatic barrier. Possibly climate took over with increased severity what once were purely tectonic events.

The writer sees little reason to doubt the role of Arctic evaporation in the formation of glaciers to the extent that Donn and Ewing now believe. Once the vast ice sheets had accumulated, however, they performed the dual functions of extracting heat from the northern latitudes and of lowering sea level to the point were flow of water through Bering Strait was reduced or stopped. Consequently, Arctic ice reformed, Arctic currents became circulatory, the flow of water to the Atlantic decreased, and the glaciers, no longer sustained on the critical northern side by abundant Arctic evaporation, waned and disappeared. The reccurrent phenomenon of Pleistocene glaciation probably would not have occurred if Bering Strait had not come into being in Late Tertiary time.

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