b16 Pleistocene climatic history recorded in marine sediments < drop stones, ooze >

A monk said to Joshu, "Your stone bridge is widely renowned, but coming here I find only a heap of rocks." Joshu said, "You see only the stones and not the bridge." The monk said, "What is the bridge?" Joshu said, "What do you think we are walking on?"
— a koan by an ancient anonymous author.[1]

Terrestrial erosion during interglacials (at present, rivers discharge to sea some 20 billion tonnes per year of detritus)[2] erases much of the evidence of past glaciations. Also, during glacials, earlier "drift" (till, erratics, and outwash) is widely reworked. So on land, the best record of past glaciations (excluding ice-core data now available, *see* Topic *b28*) has been only of details of the *last* retreat of former glacial ice. However, within the marine realm, a very complete history of Ice Age climate fluctuations can be found. For example:

Temperature variations in ocean-surface waters during glacials (cold times) and interglacials (warm times) are recorded by planktonic life's sedimented shells (size variations, right- or left-coilings, oxygen isotope ratios, and species's population compositions).

Advances and retreats of ice on the land are recorded by datable eustatic sealevel changes that have resulted in organic-reef erosion or upward growth.

During glacials, drop stones from melting icebergs are deposited in the ocean basins to low latitudes.

In the 1950s, oceanographers first discovered such signs of Pleistocene glacial cycles in deepsea sediments. Warm and cold epochs were then designated, starting with the present "interglacial" (the Holocene) named Stage 1, and going back in time, through a glacial named Stage 2, through an interglacial named Stage 3, and so on. **Cesare Emiliani** (1922-1995) in 1955 began this imperfect art of numbering cold stages in the marine oxygen isotope record back from the present: odd numbers for small ice-volume warm times, as now, and even ones for large ice-volume cold times (durations are given in calendar years BP). However, the boundaries of the oxygen-isotope stages and, the end and onset of physically observable glacial events, cannot be exactly matched. This is not too surprising as more than a dozen discordant versions of the former have been published. What is true, however, is that the time intervals represented by glacial deposits span across the time intervals represented by the 'cold' marine oxygen isotope stages.[4] Alan C. Mix and William F. Ruddiman (1984) have concluded that oxygen isotope variations in the marine record lag 500-3,000 years behind corresponding glacier-volume variations. "That is, the beginning of each glaciation occurred during the late part of a 'warm' isotope stage and the end of each glaciation occurred during the early part of the next younger 'warm' isotope stage."[5]

By the early 1960s, evidence from records of climate fluctuation recorded in cores of deepsea sediments brought-up by the multination Ocean Drilling Program (ODP), showed that Pleistocene history is far more complex than continental detritals can reasonably be expected to record. Glacials of pre-Illinoian age are *no longer assigned* to 'Kansan' and (older) 'Nebraskan'. These names, even in the type areas of those glacials, have been abandoned ('Independence' now replaces 'Kansan 'in the type area for that glacial between 620,000 and 780,000 years ago).[3] Pre-Illinoian time in North America is now known to include at least seven Pleistocene pre-Illinoian glacials and at least three Pliocene glacials. ***Figure b16.1*** shows the currently recognized subdivisions of the Pleistocene.

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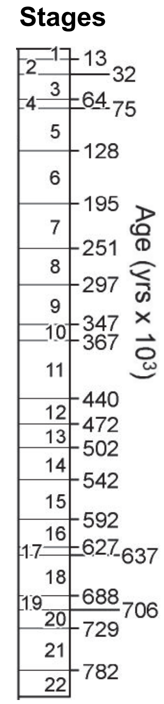
Table b16.1 Subdivisions of the Pleistocene

Formal Geochronologic Units			Informal Time Divisions		Age in years
Quaternary	Holocene		Post-Pleistocene		
					11,800
	Pleistocene	Late Pleistocene	Wisconsin	Late Wisconsin	
				Middle Wisconsin	
				Early Wisconsin	
				"Eowisconsin"	
			Sangamon interglacial		
					126,000
		Late middle Pleistocene	Illinoian	Late Illinoian	
				Early Illinoian	
		Middle middle Pleistocene	Pre-Illinoian		
		Early middle Pleistocene			
					781,000
		Early Pleistocene			
					1,806,000
Tertiary	Pliocene	Pre-Pleistocene			



The Pleistocene-Pliocene boundary in deepsea sediments is defined by the 1.770-1.960 million years ago Olduvai remanent-magnetism reversal event (subchron C2n, *see* Topic *g4*) — above it the *Globorotalia menardii* lineage becomes uniform (from complex and diverse below), near its top Discoasteridae are found to have gone extinct, and near its base *Globigerinoides sacculifera* and *Globorotalia truncatulinoides* first occur in abundance.

Figure b17.1[1] Sealevel has risen (Flandrian transgression) since the last glacial maximum and on the continental shelf the sea now floods about terminal (end) moraines of Long Island, NY,[2] and Cape Cod, MA,[3] which during the Wisconsin glaciation were deposited on what was then a coastal plain. The Wisconsin ice sheet's most southward advance during glacial Stage 2 is marked by Harbor Hill terminal moraine that here includes Long Island's northern branch (Orient Point) and southern Cape Cod. In western Long Island, this moraine rests upon the Ronkonkoma terminal moraine which marks the Wisconsin ice sheet's most southward advance during glacial Stage 4 and here includes Long Island's southern branch (Montauk Point), Martha's Vineyard island, and Nantucket island.[4] (Stage 5 is the Sangamon interglacial.)