In the Deep Midwinter

By Lorraine Manz

On days like today, when the mercury reads a chilly 20° F, the wind is blasting across the empty prairie and lowering gray clouds are heavy with the threat of snow, it is not hard to imagine that just over the northern horizon huge glaciers are poised and ready to plunge us into another ice age. Of course, nothing could be further from the truth. The last remnants of the continental ice sheets that covered much of North America during the last major glaciation (fig. 1) disappeared thousands of years ago, and global warming is a reality (although its causes continue to be a highly contentious issue). Nevertheless, when a North Dakota winter storm unleashes its full fury upon us, the question "is the ice age really over?" raises its snow-crusted head and begs a response. Before this question can be answered, however, we must consider another one, and that is: "what causes ice ages?"

Figure 1: Maximum extent of glaciation across North America during the Pleistocene Epoch. The present-day coastline is outlined in black. North Dakota is the hatched area in the center of the drawing.

The Pleistocene Epoch, which began about 1.8 million years ago, is the most recent of at least three major prolonged periods of glaciation that have occurred throughout earth's history. The first of these took place during the late Precambrian Era, about 700 million years ago, and the second about 300 million years ago in Pennsylvanian/Permian time. Compared to the Pleistocene little is known about these ancient glaciations beyond the evidence in the rock record that they occurred. Most of the theories that have been proposed to explain the causes of ice ages are based almost exclusively on what happened during the forty or so million years preceding the Pleistocene and the nature of the Pleistocene itself.

Although the arguments continue, there is general agreement among geologists that the onset of earth's ice ages was probably not due to any single cause. Rather, they were brought about by a combination of factors, some of whose effects were (or are) more profound and long lasting than others. Theories about ice ages need to be able to explain one of two things: one, what causes the gradual cooling of the earth's climate and the growth of polar ice caps that lead to the onset of ice ages? And two, what controls the cycles of glacial advance and retreat such as occurred throughout the Pleistocene Epoch? Similar problems but vastly different in scale – geologic periods versus millennia.

Long-term global cooling may be related to the configuration of the continents. Throughout geologic time the mechanisms of plate tectonics have caused the world's great land masses to range across the surface of the globe, continually changing their positions relative to each other and to the poles. For much of the geologic past, one or both of the Polar Regions have been relatively free of large landmasses. Such an arrangement allows the oceans to circulate around the poles, and for ocean currents to carry warm, equatorial water to high latitudes, thereby distributing heat more uniformly across the globe. Today, the continent of Antarctica lies over the South Pole, and large regions of Europe, North America and Asia occupy high Arctic latitudes. These landmasses form very effective barriers against the delivery of heat by the oceans to the poles, and so they have grown bitterly cold. Diversion of major ocean currents in this way may also have caused global weather patterns to change, increasing precipitation in some areas, and reducing it in others. The events that led to this situation happened very slowly, and probably began about 40 million years ago as the continents began to approach their present configuration. There is evidence to suggest that glaciers were already well developed in Antarctica and were beginning to appear in high northern latitudes by the Miocene Epoch, about 20 million years ago (Atkins, 2001; Jansen and others, 1990). The final blow that triggered the onset of the Pleistocene Epoch may have come about 3.5 million years ago with the formation of the Isthmus of Panama and the joining of the North and South American continents (Murdock, 1997). This thin neck of land, a mere 31 miles wide at its narrowest point, was sufficient to interrupt the east-west circulation of ocean currents and increase the flow of warm water into the northern hemisphere via the Gulf Stream. The resultant increase in precipitation at higher latitudes led to the formation of the Pleistocene ice sheets.

The climate throughout the Pleistocene Epoch was not continuously cold. Several cycles of glaciation, or glacial stages, occurred, each separated by an interglacial period of warmth during which the ice retreated. During these intervals, climatic conditions were similar to those we experience today. Glacial stages are subdivided into stades and interstades. A glacial stade is a period of relative cold during which glaciers grow and advance. Stades are separated by interstades, which are warmer intervals when glacial ice temporarily retreats. Like glacial stages, stades and interstades are cyclic, and within these are yet more cycles of minor glacial advance and retreat.

The most recent major cooling cycle, the Wisconsinan Stage (Würm Stage in Europe), began about 100,000 years ago. For the next 90,000 years glaciers advanced and retreated across North America, Asia, and Europe several times, with the most recent southward expansion occurring about 26,000 years ago.

The alternating glacial and interglacial episodes that occurred throughout the Pleistocene Epoch are best explained in terms of astronomical cycles. The earth's orbit around the sun is elliptical (eccentric) and it changes periodically, sometimes putting the planet a little closer to, sometimes a little farther away from, the sun. The tilt of the earth's axis of rotation also changes over time, and as it turns it wobbles, or precesses, slightly on this axis. All these movements occur in regular, predictable cycles of about 100,000, 40,000 and 20,000 years respectively, and each cycle affects the insolation, or the amount and distribution of heat that the earth receives from the sun. During the 1920s and '30s Milutin Milankovitch, a Serbian geophysicist, showed, by some very careful calculations, that glacial and interglacial stages are related to these cycles: that during the Pleistocene Epoch glaciers advanced at times when insolation was at a minimum, while warm periods coincided with times of maximum insolation. When the maxima or minima of these cycles coincided, their effects were enhanced. These cyclical variations in the earth's eccentricity, axial tilt and precession are known collectively today as Milankovitch Cycles (Schwarzacher, 1991).

Recent research has shown that glacial advances also seem to occur when the level of carbon dioxide in the atmosphere is low, a sort of reverse greenhouse effect (Siegenthaler and others, 2005). Sunspot activity and variations in the intensity of solar radiation may also have some influence on earth's climate patterns (Easterbrook, 2005). Other theories link cool periods with increased volcanic activity (Prueher and Rea, 1995), and even large meteorite impacts (Shijie and others, 1999), when the huge amounts of dust and gas that such events might throw into the atmosphere would block out enough sunlight to cause a significant reduction in global temperatures.

Figure 2: This aerial photograph of the Greenland ice sheet shows what part, or all, of North Dakota might look like again one day when the glaciers return. (*Photo by Keith Brugger*).

The Pleistocene Epoch ended and the Holocene Epoch began about 10,000 years ago as the last ice sheets receded. We are living in the Holocene Epoch, which is actually an interglacial period. So the answer to the question: "Is the Ice Age over?" is almost certainly "no". The period of warmth that we enjoy today is merely a temporary respite. It probably won't happen in our lifetime, but when the conditions are right, the glaciers will begin to grow again and they will return: not once, but many times as the cycle of cooling and warming that began about two million years ago continues to repeat over and over again (fig. 2). The cycle will end only when, millions of years from now, the continents finally drift away from the poles.

Keep those snow shovels handy.

References

Atkins, C.B., 2001, Glacial influence from clast features in Oligocene and Miocene strata cored in CRP-2/2A and CRP-3, Victoria Land Basin, Antarctica: Terra Antarctica, v. 8, no. 3, p. 263-274.

Easterbrook, D.J., 2005, Causes and effects of Late Pleistocene, abrupt, global climate changes and global warming [abs.]: Geological Society of America Abstracts with Programs, v. 37, no. 7, p. 41.

Jansen, E., Sjoholm, J., Bleil, U., and Erichsen, J.A., 1990, Neogene and Pleistocene glaciations in the Northern Hemisphere and late Miocene-Pliocene global ice volume fluctuations; evidence from the Norwegian Sea: NATO ASI Series C – Mathematical and Physical Sciences, v. 308, p. 677-705.

Murdock, T.Q., 1997, Paleoclimatic response of the closure of the Isthmus of Panama in a coupled ocean-atmosphere model: Victoria, BC, University of Victoria, Master's dissertation.

Prueher, L.M. and Rea, D.K., 1995, Sudden onset of Northern Hemisphere glaciation; are volcanoes the smoking gun?: Eos, Transactions, American Geophysical Union, v. 76, no. 46, Suppl., p. 306.

Schwarzacher, W., 1991, Milankovitch cycles and the measurement of time, *in* Einsele, G., and others, eds., Cycles and events in stratigraphy: Berlin, Springer Verlag, p. 855-863.

Siegenthaler, U., Stocker, T.F., Monnin, E., Lüthi, D., Schwander, J., Stauffer, B., Raynaud, D., Barnola, J., Fischer, H., Masson-Delmotte, V., and Jouzel, J., 2005, Stable carbon cycle-climate relationship during the Late Pleistocene: Science, v. 310, no. 5752, p.1313-1317.

Wang Shijie, Ouyang Ziyuan, Xiao Zhifeng, and Li Chunlai, 1999, Formation of paleoclimatic cycles and a new glacial period induced by the impact of extraterrestrial bodies: Earth science, Journal of China University of Geoscience, v. 24, no. 6, p. 568-572.