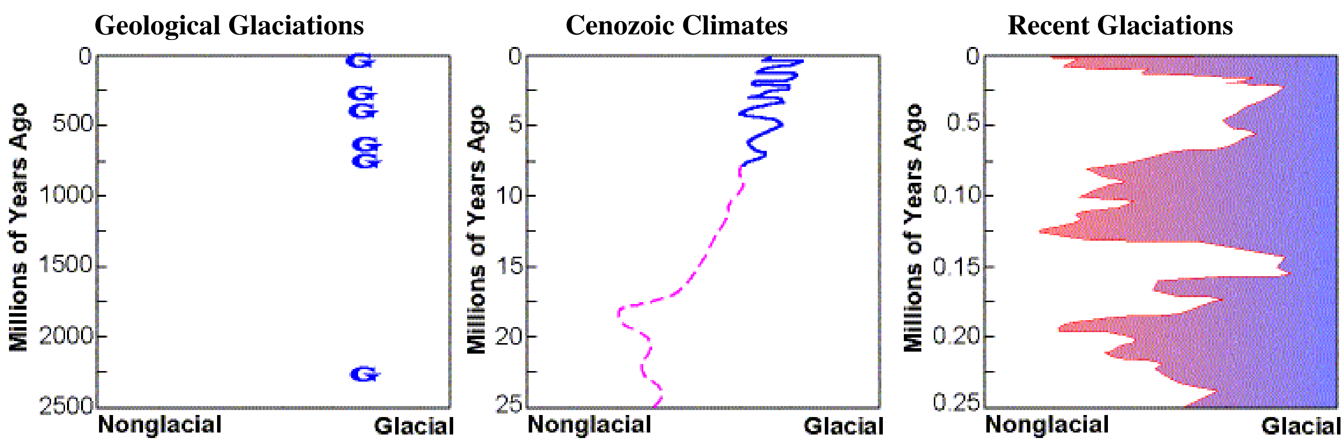
Geologic Time and Glacial Cycles

The Earth's glaciers oscillate on all time scales from decades to hundreds of thousands of years. These dramatic glacial pulsations are due to Earth's changing climate in relation to spatial variability (Glaciers With Space) and time. With respect to time, glaciers are influenced by two major processes, Plate Tectonics and the Milankovitch Cycles, and numerous minor processes. Before we get into our in depth discussion of Tectonism and the Milankovitch Cycles we need to establish some historic trends in the Earth's Glaciation.

Earth's Glacial Record

Conditions have been favorable for glaciation during a number of periods in the Earth's existence. Evidence from *ice sheets* has been preserved, but mountain glaciers, of which all evidence has been erased, may have occurred far more often. In addition to glacial erosional and depositional features, such substitutes as marine oxygen isotope ratios are considered in extending the glacial record.



Geological Glaciations

Across Earth history, ice sheets have periodically covered large continental regions. Evidence for such *glaciations* is largely *tillites* (glacial deposits) and *striations* (glacial erosion), and such evidence has been found in places as apparently unlikely as the modern Sahara Desert. Most interpretations of such glaciations suggest that they relate to clustering of continental landmasses over polar regions (see Plate Tectonics), although changes in the chemistry of the atmosphere (such as a reduced "Greenhouse Effect" because of consumption of carbon dioxide in weathering) are also suspected.

Cenozoic Climates

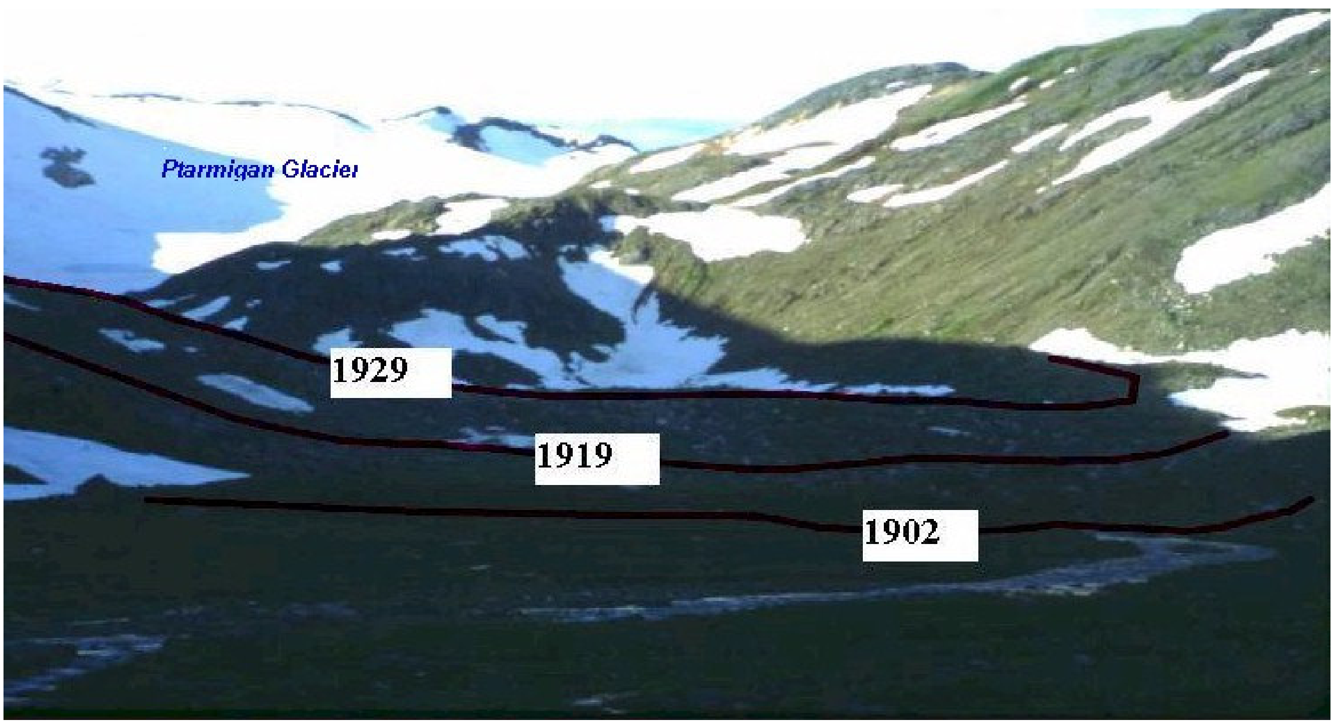
In the last 65 million years (the Cenozoic Era), significant global cooling has occurred. This cooling accelerated in the last 20 million years, and the Earth's climate became more variable, in addition to being cooler. We suspect that Antarctica moving over the South Pole initiated cooling, and that the growth of the Antarctic Ice Sheet provided positive feedback, further intensifying global cooling. Cooler ocean waters holding more carbon dioxide (just like cold soda!) provided further positive feedback. Finally, changes in ocean currents fed moisture into the North Atlantic region. At this time, cyclical fluctuation in seasonal incoming solar radiation (*insolation*) could trigger episodic expansion and contraction of ice sheets - the Milankovitch Hypothesis.

Recent Glaciations

The current glaciation began at least 1.5 million years B.P (before present) in the Northern Hemisphere, and continues. The Pleistocene was not continually dominated by glacial times. Lengthy interglacial periods (times of little or no ice cover, other than on Antarctica) occurred during the Pleistocene. The present interglaciation (often termed the Holocene) has lasted about 10,000 years. Prior to that, climates were glacial for about 60,000 years, with two major glacial stades about 25,000 and 70,000 years ago separated by an interstade. At the Pleistocene maximum, ice covered approximately one third of Earth's total land area. The most extensive ice sheet, the Laurentide of North America, covered the vast majority of Canada and extended southward into the United States to Long Island, and the Ohio and Missouri rivers. About 130,000 to 75,000 years ago was an interglaciation, initially slightly more intense than the modern one, but later marked by minor glacial stades. And, before that, a glaciation slightly more extensive than the last one covered the landscape.

Holocene Glaciation

The Holocene interglaciation has been characterized in the past few hundred years by minor glacial fluctuations. The period from about 300 to 100 years ago has been termed the "Little Ice Age", and was marked by observed glacier advances, especially in Europe. Since then, however, most glaciers have retreated markedly. In the following sequence of images we will explore this recession through a small cirque glacier in Southeast, Alaska. The below picture illustrates three of the recessional moraines in the Ptarmigan valley. The receding Ptarmigan glacier still resides in the uppermost portion of the valley.



The above picture, taken in the Summer of 1997, is a view looking South, up the Ptarmigan Valley. The three bold lines and corresponding dates delineate prominent terminal moraines. As is seen below, on the overhead view of Lemon Creek, Ptarmigan, and Thomas glacier's historical variations, these three moraines are the initial Ptarmigan terminal moraines after separating from the lower Lemon Creek Glacier. The distance between each of the three moraines above is on the order of 20-40 meters, illustrating the relatively slow changes of ice masses.

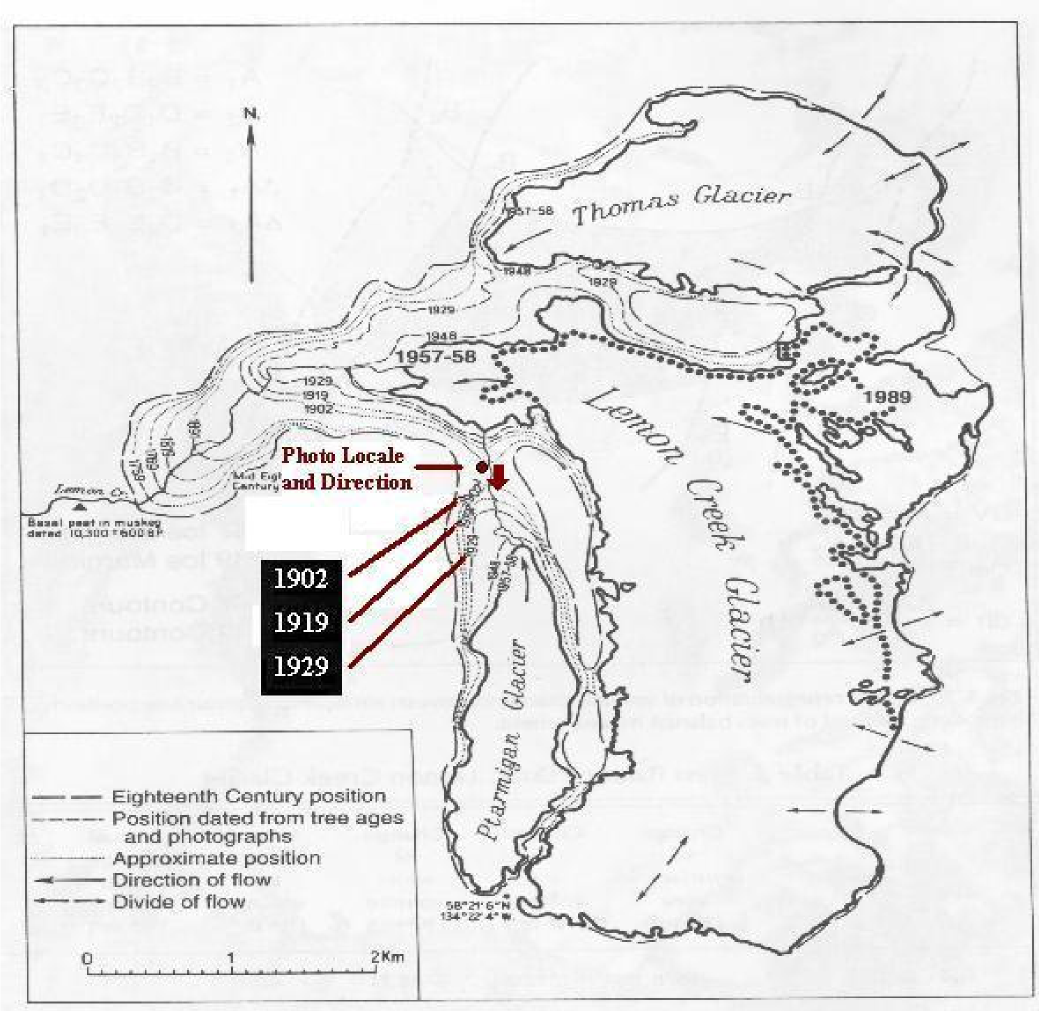


Image adapted from Chambers *et al.*, 1995.

The maximum Lemon Creek extent during the Little Ice Age can be seen by the bold line just beyond the 1759 moraine. This maximum extent for the most recent ice advance illustrates the slow advancement and recession of glaciers, in comparison to a human perspective of time. The Lemon Creek Glacier has receded approximately three kilometers since 1759. Prior to that time it was as extensive as at any time in the previous 10,000 years.

Up to Glaciers With Time	On to Plate Tectonics and Glacier Formation