As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

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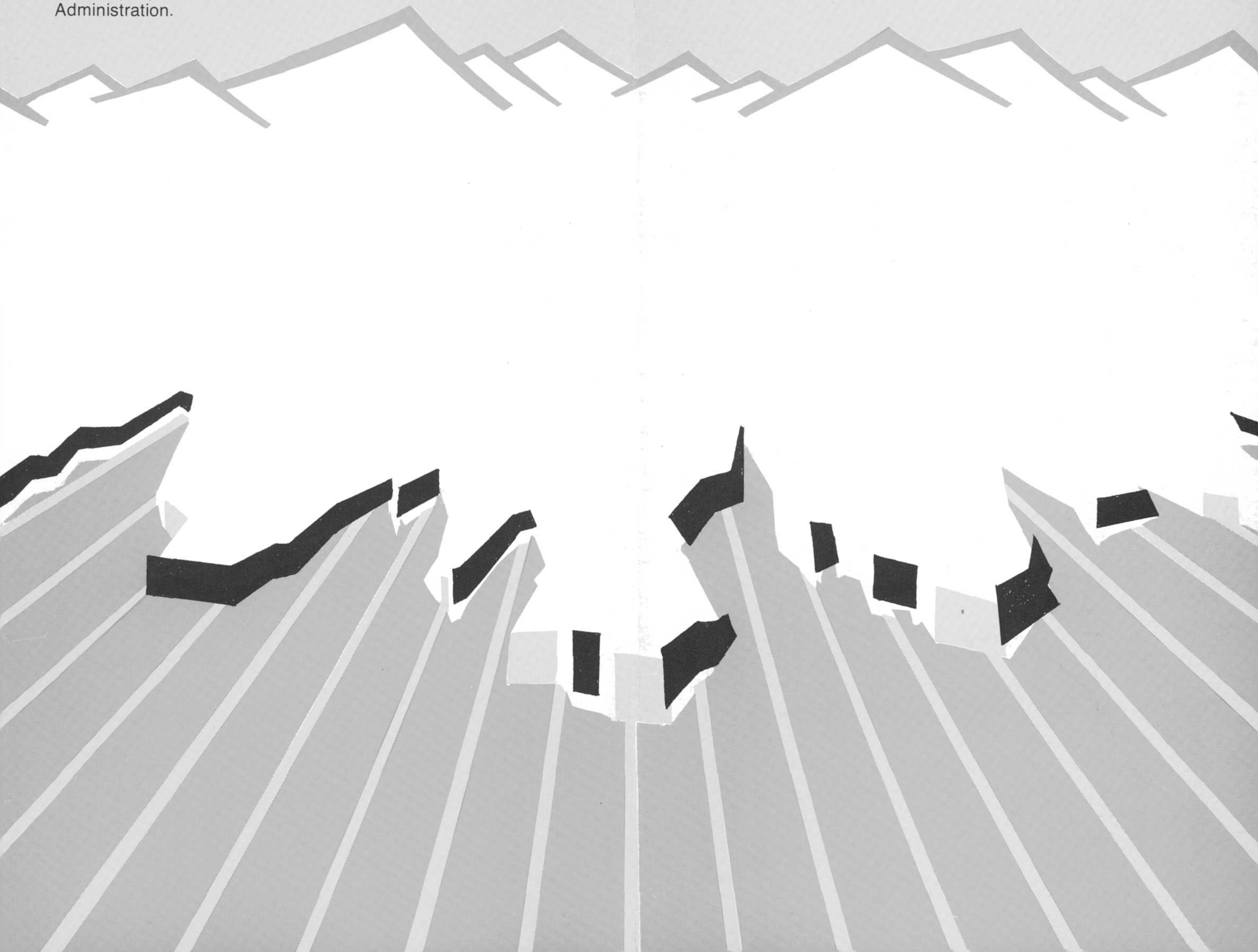
The Great Ice Age



Blue Glacier, Olympic National Park, Washington.

The Great Ice Age

by Louis L. Ray

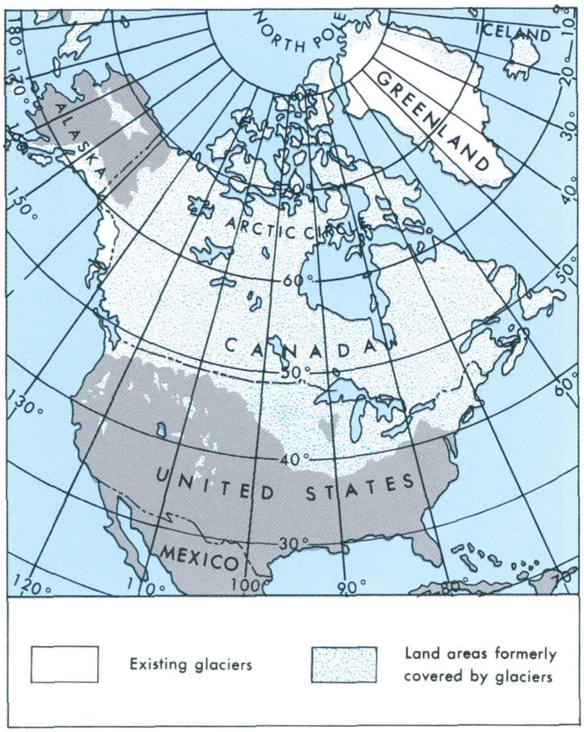
The Great Ice Age, a recent chapter in the Earth's history, was a period of recurring widespread glaciations. During the Pleistocene Epoch of the geologic time scale, which began about a million or more years ago, mountain glaciers formed on all continents, the icecaps of Antarctica and Greenland were more extensive and thicker than today, and vast glaciers, in places as much as several thousand feet thick, spread across northern North America and Eurasia. So extensive were these glaciers that almost a third of the present land surface of the Earth was intermittently covered by ice. Even today remnants of the great glaciers cover almost a tenth of the land, indicating that conditions somewhat similar to those which produced the Great Ice Age are still operating in polar and subpolar climates.

Much has been learned about the Great Ice Age glaciers because evidence of their presence is so widespread and because similar conditions can be studied today in Greenland, in Antarctica, and in many mountain ranges where glaciers still exist. It is possible, therefore, to reconstruct in large part the extent and general nature of the glaciers of the past and to interpret their impact on the physical and biological environments.

During the long course of Earth history, the climate has fluctuated, just as the general character of the Earth's surface has changed. In fact, there is evidence that glaciations occurred long before the Great Ice Age.

After a period of warm and equable climate, a worldwide climatic refrigeration initiated the Great Ice Age glaciers. At times during the Great Ice Age, the climate was cooler and wetter and at times warmer and drier than today. Many attempts have been made to account for these climatic fluctuations, but their ultimate cause remains unclear. Although we cannot predict a period of climatic cooling, another Ice Age in the future is a possibility.

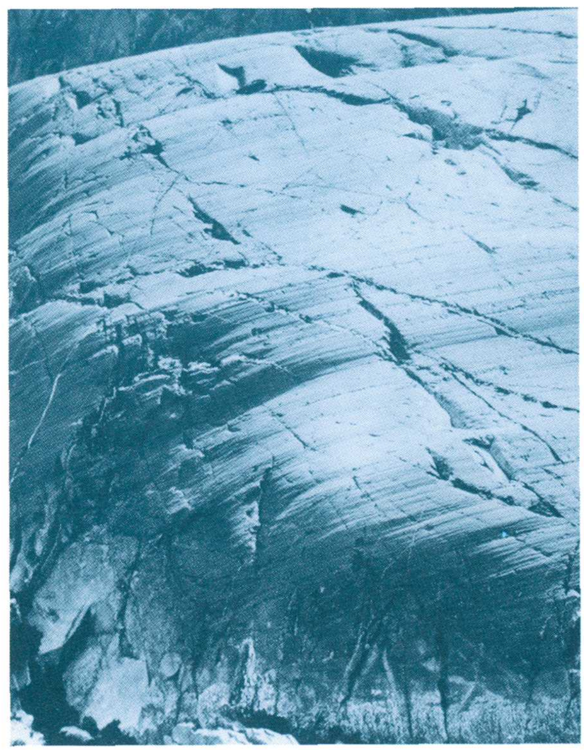
Although the Great Ice Age began a million or more years ago, the last major ice sheet to spread across the North Central United States reached its maximum extent about 20,000 years ago. Waning through a succession of retreats and relatively minor advances, it lingered in Canada until about 6,000 years ago, when it finally melted. Mountain glaciers are the only remnants of the great glaciers on the mainland of North America.



Map of North America showing extent of the Great Ice Age glaciers.

Prior to the 19th century, observant Swiss peasants concluded that the glaciers in the Alps had formerly been much larger. They noted that the existing glaciers were slowly transporting and depositing boulders downvalley and correctly inferred that the boulders *(erratics)* strewn about their pastures had been transported and deposited in the same manner long ago. Also, they observed that the polished and scratched or finely grooved and rounded bedrock knobs *(roches moutonnées)* along the valley walls and floors were similar to those emerging from beneath the melting ice of the existing glaciers. The similarity suggested that the *roches moutonnées* had been produced by the moving glacial ice at a time when the glaciers extended farther down the mountain valleys.

In Germany and Scandinavia similar features, though far removed from existing mountain



Roche moutonnee surface, Alaska.

Shaped, scratched, and finely grooved glacial cobble, Indiana (actual size).

glaciers, were recognized to be of glacial origin. The idea that such features resulted from an expansion of distant mountain glaciers was gradually modified by the early naturalists. They reached the conclusion that widespread sheets of moving ice had advanced from the far north to the plains of northern Germany. This conclusion was supported by the fact that many of the erratics on the north German plains were of rock types common to Scandinavia. Such an ice sheet, moving from north to south, had to be distinct from the expanded mountain glaciers of the Alps. Thus was born the concept of the Great Ice Age—the time when vast glaciers spread as ice sheets over the northern lands and mountain glaciers were greatly expanded.

This concept was enlarged and popularized by the eminent Swiss geologist, Louis Agassiz, whose arrival in the United States in 1846 marks the beginning of the study of this fascinating period of Earth history in North America. Since that time many significant contributions have been made to the understanding of the glaciations, as continuing studies, especially in the United States, Greenland, and Antarctica, reveal the complex history of glaciers and of past glaciations.

Early observations in the country indicated that large parts of the North Central and Northeastern United States had once been overridden by thick ice sheets. Telltale traces of glacial erosion and deposition were widespread. Rock outcrops were smoothed, polished, and scratched or striated; hills were rounded and mantled by glacial debris; and valleys were choked by sand and gravel deposited by glacial melt waters. All evidence indicates that slowly advancing ice sheets plowed up the soil and loose rock, plucked and gouged boulders from outcrops, and carried this material forward, often for great distances. Using the material in transit as an abrasive, the glaciers smoothed, polished, and scratched the rock outcrops, producing a more subdued landscape. The great glaciers commonly softened the contours by wearing down the tops of hills and filling the valleys.

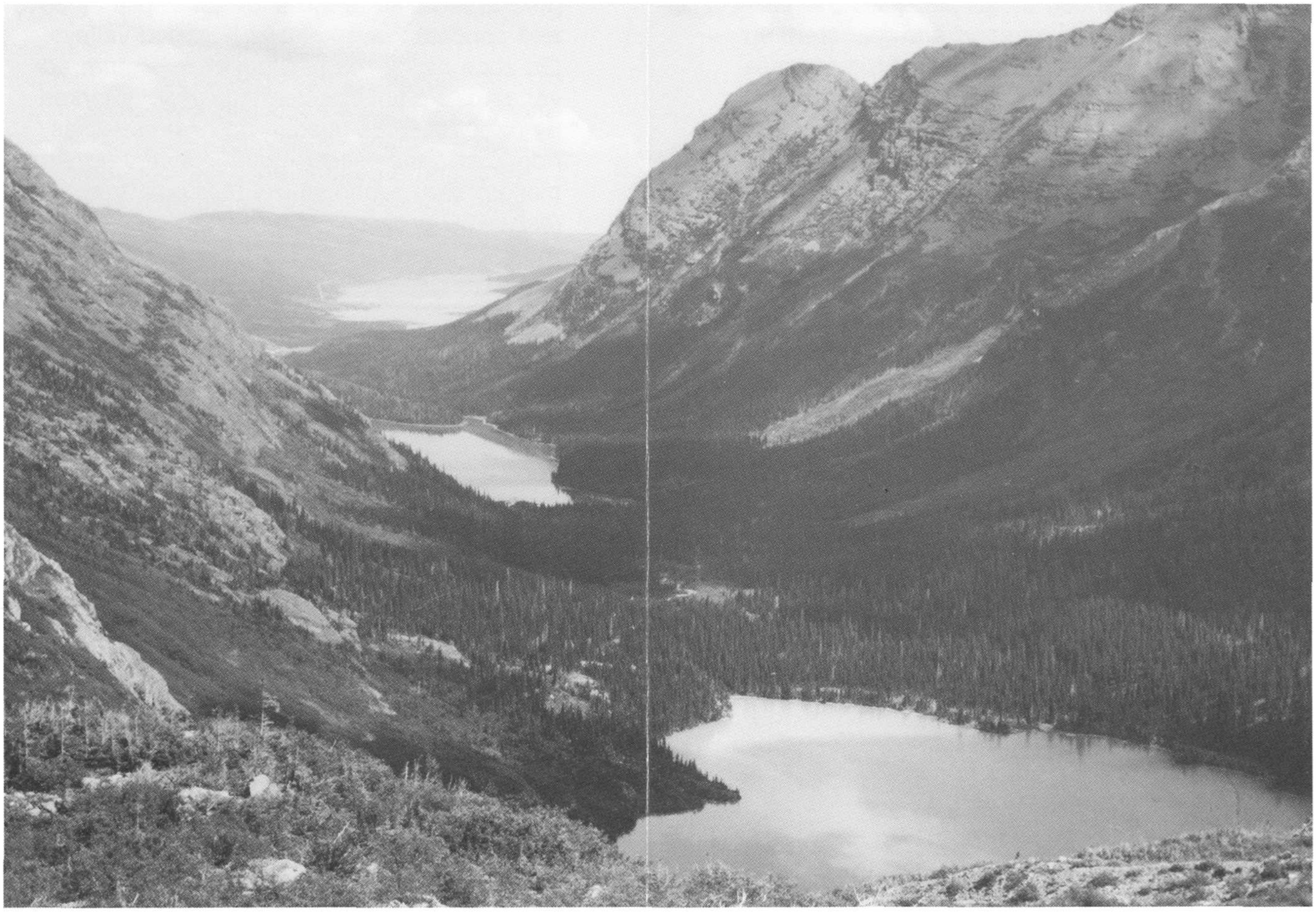
As the glaciers melted, unsorted mixtures of clay, sand, gravel, and boulders *(till)* were generally deposited as an unconsolidated mantle on the countryside *(ground moraine)*. Extensive level to gently rolling plains of thick ground moraine in the Midwest in places cover and conceal the preglacial hills and valleys. On such plains the position of maximum advance of a glacier is commonly well marked by deposits of till pushed up or dumped as ridges or hummocky belts *(moraines)*. In some places narrow, hummocky, sinuous ridges *(eskers)* may occur, or perhaps swarms of rounded, elongate hills *(drumlins)*.

Drumlins, Canada.

Where great river valleys such as the Mississippi and Ohio were overwhelmed by ice sheets, the rivers were forced into new channels. Where smaller preglacial drainage systems were completely covered by glacial ice, they were commonly obliterated. Glacial deposits remaining after disappearance of the ice were usually poorly drained. Bogs, swamps, and many lakes, typical of parts of Wisconsin and Minnesota, characterize such areas.

In mountain areas, valley glaciers modified the landscape in an entirely different manner. Scooping out and widening the valleys through which they moved, the glaciers produced valleys with a U-shaped cross profile, in contrast to the normal V-shaped profile produced by stream erosion. Intervalley divides were sharpened, valley walls were oversteepened, and precipitous cliffs were developed. As a result, glaciated mountain areas are often scenically spectacular, as in Glacier National Park, Mont., and Yosemite, Calif. Arcuate or curved moraines loop across the mountain valleys or out onto the plains at the foot of the mountains. These moraines mark terminal positions of valley glaciers that either have disappeared or survive only as small ice masses or short tongues moving down valleys from the theater-shaped valley heads *(cirques)*.

Debris of all sizes transported by glaciers was released by the melting ice and was carried forward by melt-water streams or deposited near the ice margin. Melt-water streams were commonly so loaded that they could not transport all the debris supplied to them, and valleys became clogged with sand and gravel.



U-shaped glaciated valley with moraine in foreground, Glacier National Park, Montana.

At times such streams flowed in a shifting maze of shallow channels across the exposed surface of the valley fill they had deposited *(valley train)*. Winds sweeping across valley-train surfaces picked up the finer particles exposed between the shifting channels and spread them as a dustlike mantle *(loess)* over the countryside. The loess of the last great glaciation may be as much as 20 feet thick. It is thickest near the great river valleys, such as the Mississippi, that served as sluiceways for glacial melt water. Throughout large parts of the Central United States, soils have been developed on a mantle of loess whose source areas were the great river valleys.

In lakes that formed in front of retreating ice sheets, glacial melt waters deposited well-sorted sediments. Where only finer sediments were deposited, alternate layers of silt and clay accumulated in the lake basins. It is generally believed that the lighter silty layer was deposited in summer and the dark clayey layer in winter, the two layers forming an annual deposit *(varve)*. By counting the varves and matching thicknesses of varves deposited simultaneously in the many lakes along a retreating glacier margin, scientists can determine both the time in years necessary for varve deposition and the rate of retreat of the ice margin.

During the long periods of glacier recession, when the great ice sheet may have disappeared completely, the unconsolidated glacial deposits were deeply weathered, and distinctive soils were developed. With readvance of the glaciers, the older weathered deposits were overridden by the younger ice and were either removed by glacial erosion or covered by new ice deposits.

The most complete stratigraphic succession of such deposits indicates at least four major glaciations in the United States, named, from the oldest to the youngest: Nebraskan, Kansan, Illinoian, and Wisconsin. The glaciations were separated by warm interglacial periods. These are named, also from oldest to youngest: Aftonian, Yarmouth, and Sangamon. Minor fluctuations of the earlier ice sheets may have taken place, although detailed evidence is generally lacking. Waxing and waning of the youngest ice sheet, the Wisconsin, is indicated by many moraines that mark terminal positions of the ice during readvances after periods of recession. Such moraines are especially well developed in Illinois, Indiana, and Ohio.

More than a century ago, the intimate relationship between glacial ice and the amount of water in the ocean basins was recognized. When the great ice sheet covered vast land areas, sea level was lowered because the normal return of water from the land to the oceans was reduced. Conversely, sea level rose as Ice Age glaciers melted, permitting the melt waters to flow into the ocean. If all the glacial ice on the surface of the Earth today should melt, sea level might rise by more than 150 feet.

Shoreline fluctuations are also produced through elevation or depression of the land. During times of glaciation the great weight of the ice slowly depressed the Earth's mobile

Loess-like silt being blown from valley train, Alaska.

crust. Removal of the ice through melting permitted the slow rebound of the crust to its former position of relative equilibrium. Such movement, common in glaciated areas, is best documented in Scandinavia and Finland. Evidence of similar uplift can be observed in the region of the Great Lakes and Lake Champlain, where old shorelines, originally horizontal, are now raised and tilted so that the greatest uplift is to the north.

Fluctuations of the Great Ice Age climates from cool and wet to warm and dry produced marked environmental changes far from the glaciated areas. For example, at times of cool-wet glacial climates, levels of inland lakes rose in contrast to the depression of sea levels. During the warm-dry interglacial climates, lake levels were lowered. Ancient Lake Bonneville, largest of the many glacial lakes in the Western United States, once covered more than 20,000 square miles and had a maximum depth of more than 1,000 feet. Great Salt Lake, Utah, is a shrunken remnant of this once enormous lake.

Although the first appearance of mankind is veiled in obscurity, we are largely a product of the Great Ice Age. Available information indicates that during this time we evolved rapidly both physically and culturally. Our most primitive tools and skeletal remains have been recovered from some of the oldest deposits contemporary with the Great Ice Age in Africa, Asia, and Europe. These are commonly associated with remains of extinct animals. With the waning of the great ice sheets, the Bronze and Iron Age cultures evolved. About this time many animals suited to cooler climates became extinct, especially larger mammals such as woolly mammoth, mastodon, dire wolf, and saber-toothed tiger.

Although much remains to be learned, the general story of the Great Ice Age is unfolding through the efforts of specialists in many fields. Field observations, new theories and techniques, and worldwide studies of existing glaciers are bringing a clearer understanding of the Great Ice Age. This eventful period of Earth history is a time of spectacular human development, of drastic changes in climate, sea level, and plant and animal life, and of the great glacial ice sheets whose periodic overriding of the land produced so many marked changes in its character. Our present environment has been greatly influenced by events of the Great Ice Age.

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