

Minnesota Geological Survey

Minnesota at a Glance



Quaternary Glacial Geology

The Quaternary Period began about 2 million years ago. It is divided into the Pleistocene Epoch (2 million to 10,000 years ago) and the Holocene Epoch (10,000 years ago to present). Although 2 million years is a relatively short period of time geologically, sediments deposited during this time mask nearly all of Minnesota's previous geologic history (as old as 3600 million years!).

The Pleistocene, also called the Ice Age, is the time when the Laurentide Ice Sheet covered much of northern North America (Fig. 1). Minnesota was at the edge of the ice sheet, and thus was not always completely covered with ice. Instead, Minnesota experienced several episodes of glaciation followed by ice-free periods.

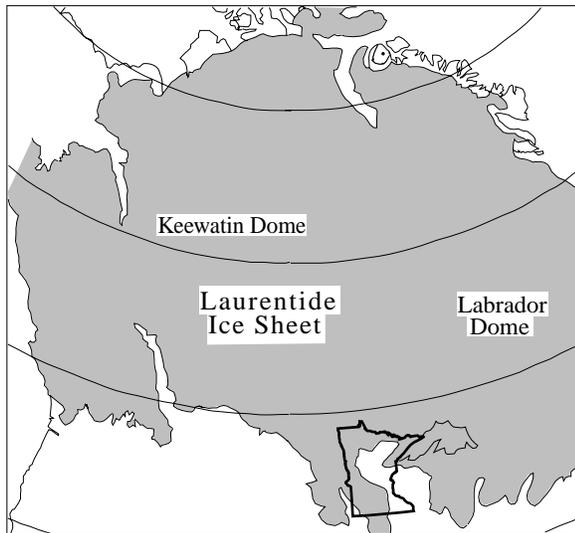


Figure 1. Maximum extent of the Laurentide Ice Sheet in North America about 14,000 years ago.

Glacial Deposits

A glacier is a large mass of ice that very slowly flows. As a glacier moves, it erodes the material underneath. Boulders, rocks, sand and trees become mixed up into the ice. Like sandpaper, they scrape the underlying rock surface leaving behind scratch marks called striations. The debris carried along in the ice eventually gets deposited some distance away from where it was originally picked up. The unsorted mix of material deposited directly by a glacier is called till. It consists of rocks, which range in size from boulders to pebbles, sand, and clay. Large boulders, transported a long distance from their source, are called erratics. Tracing these rocks back to where they came from is one way to figure out the direction of glacier movement.

The leading edge of a glacier may not change position for long periods of time. Sediment continues to be transported to this stationary margin and may pile up to form ridges of till called end moraines. End moraines thus formed along the outer edge of an ice sheet mark the extent of ice advance. When the ice eventually melts, the debris in it is deposited as ground moraine. Ground moraine till forms low hills and swales. Streamlined hills of ground moraine aligned parallel to ice flow are called drumlins.

Glaciers are not always completely frozen. Water from melting ice can flow on top of the ice, in channels within the ice, and underneath the ice. When meltwater streams carve channels in the ice, they transport sand and gravel. When such a channel fills up with sediment, the resulting deposit is a long, snake-like hill called an esker. Meltwater streams that flow beyond the ice margin may deposit their loads of sand and gravel in outwash fans similar to river deltas.

Deposits left by glaciers are the "footprints" that allow geologists to retrace the history of glacier movement. Till of a particular color and containing distinct rock types may indicate the direction from which the glacier advanced. In Minnesota, where the glacial history is complex, it is important to be able to determine where and when a glacier originated.

Minnesota's Glacial History

Large, lobate "tongues" of ice covered Minnesota perhaps as early as 1.2 million years ago. Evidence of the earliest ice advances, however, is buried under later deposits. Only in the southern corners of the state is any older till exposed and that may date back to 600,000-700,000 years ago. The extreme

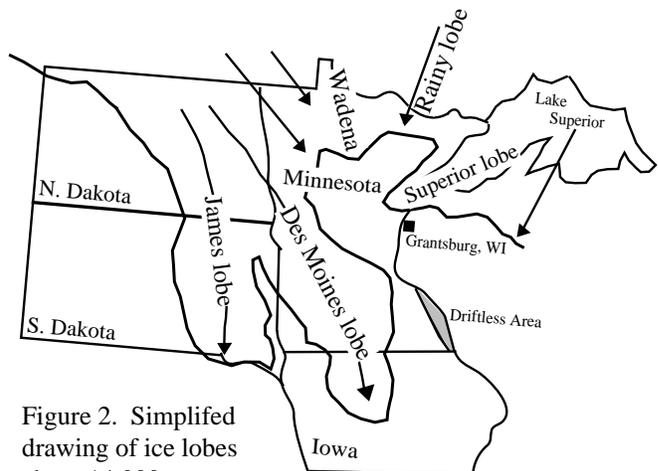


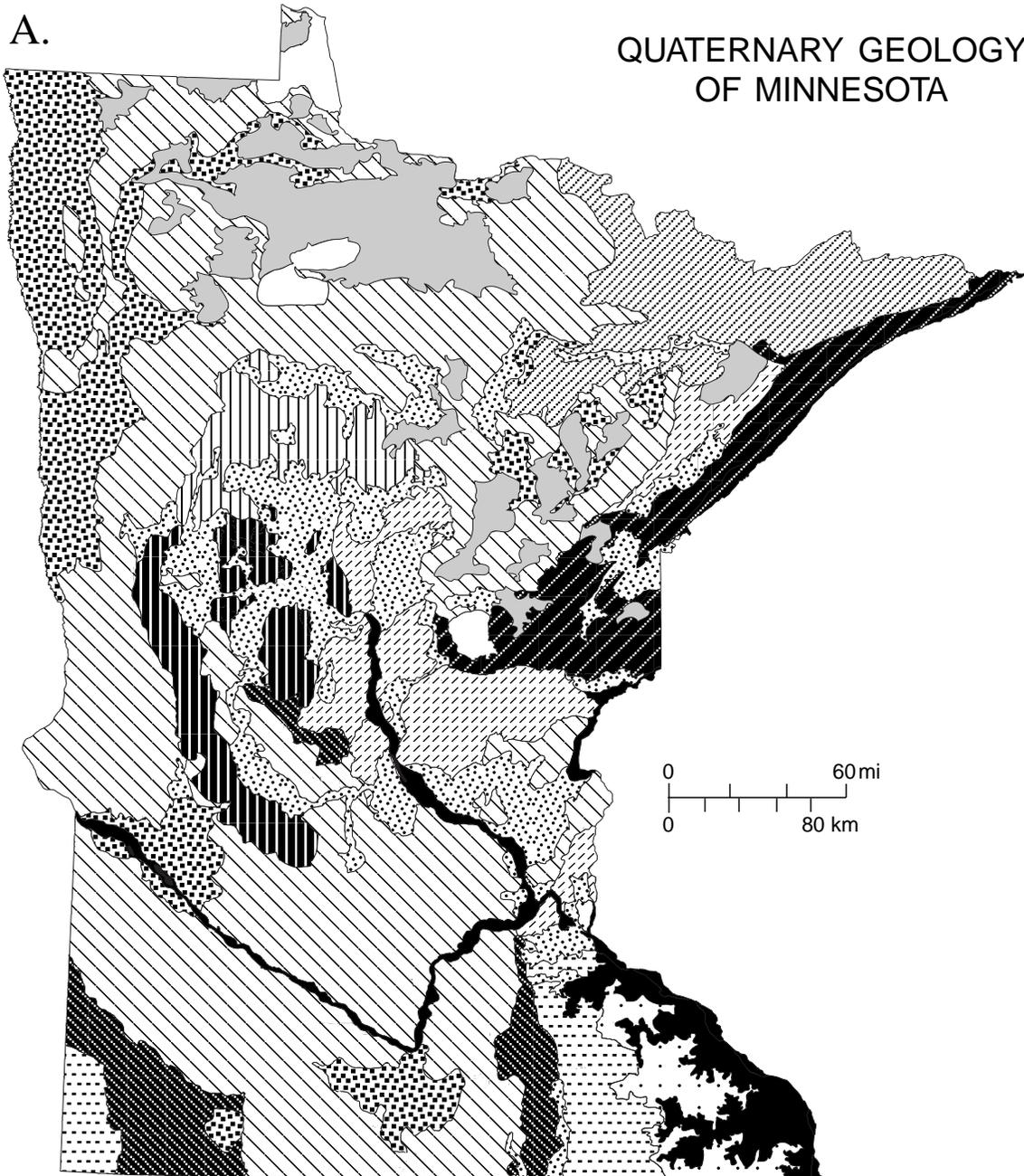
Figure 2. Simplified drawing of ice lobes about 14,000 years ago.

southeastern corner of the state is called the "driftless area" (Fig. 2). Exposures of till are unknown or uncommon in this area and it is believed that this region remained ice-free during most of the Ice Age.

The bulk of glacial sediment in Minnesota is attributed to one time interval, the Wisconsin Age, which began about 75,000 years ago. During this time, the Laurentide Ice Sheet covered much of North America (Fig. 1). The ice radiated outward from two high points, or domes, in the ice sheet. Changes in climate and precipitation caused these domes to shift periodically, which changed the direction of ice flow to the margins. Thus, throughout the Ice Age, ice lobes advanced across the

state several different times from several different directions (Fig. 2).

The Wadena lobe was active in the early to middle Wisconsin Age. Deposits from this lobe are gray in color and contain Paleozoic limestone from the Winnipeg lowland in southern Manitoba. The Alexandria moraine and the Wadena drumlin field (Fig. 3) in west-central Minnesota may mark the passing of this glacier. The Rainy lobe, which was active at about the same time, deposited a brown, sandy till which contains basalt, gabbro and other rocks indicating a northeast source. A complex moraine system—the Itasca moraine and the St. Croix moraine (Fig. 3)—marks the advance of the Rainy,



Wadena, and Superior lobes together during the late Wisconsin Age. In addition, two separate drumlin fields, the Toimi drumlins in central Minnesota and the Pierz drumlins (Fig. 3) south of Brainerd, record the combined movement of these ice lobes. Till from the Superior lobe is distinctly red in color and contains rocks derived from the Superior basin—red sandstone, shale, and agates. The Mille Lacs-Wright-Cromwell-Highland moraine complex, combined here with till of the Nickerson, and Cloquet moraines (Fig. 3), marks a later readvance of Superior lobe ice into east-central Minnesota. The Automba drumlins also mark this readvance (not shown on Figure 3). The most recent glacier to cross the state was the Des Moines lobe. About 14,000 years ago, this ice extended through the Red River lowland in northwestern Minnesota south to Des Moines, Iowa. Two offshoots of the Des Moines lobe (not shown in Figure 2) spilled over into other parts of the state: the St. Louis sublobe across northern Minnesota—marked by the Culver moraine—and the Grantsburg sublobe through east-central Minnesota (including the Twin Cities area)—marked by the Pine City moraine. Des Moines lobe till

is gray to brown and is distinctive because it contains Cretaceous shale imported from North Dakota and Canada. The Bemis moraine marks the farthest extent of the Des Moines lobe and can be traced from northeastern South Dakota, through southwestern Minnesota and down into northern Iowa (Figs. 2 and 3). In eastern Minnesota, the moraine is a less-distinct ridge of material. Within the Bemis moraine is a series of “recessional” moraines deposited during the retreat of the ice.

By 11,000 years ago, the glaciers had retreated north into Canada, and Minnesota was essentially ice-free. At different times, water from the melting ice flooded the landscape and formed large glacial lakes (Fig. 4). Glacial Lake Grantsburg was dammed north of the the Twin Cities by the Grantsburg sublobe. Farther to the north, Glacial Lakes Upham and Aitkin were formed in front of the St. Louis sublobe. Glacial Lake Duluth partly filled the Lake Superior basin in front of the Superior lobe. The largest lake, Glacial Lake Agassiz, formed in the Red River lowland in northwestern Minnesota. At its maximum, Lake Agassiz covered over 300,000 square kilometers across northern Minnesota, Manitoba and Ontario.

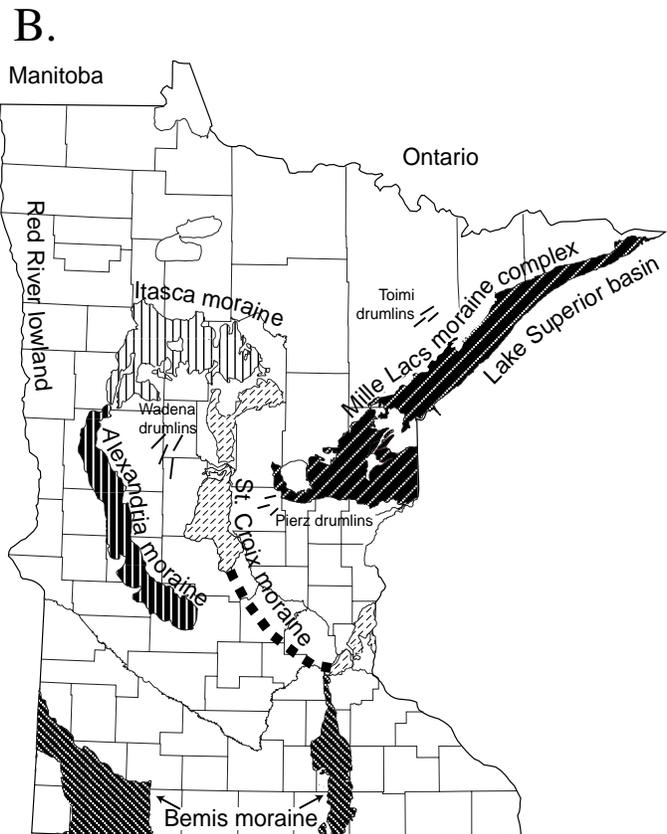
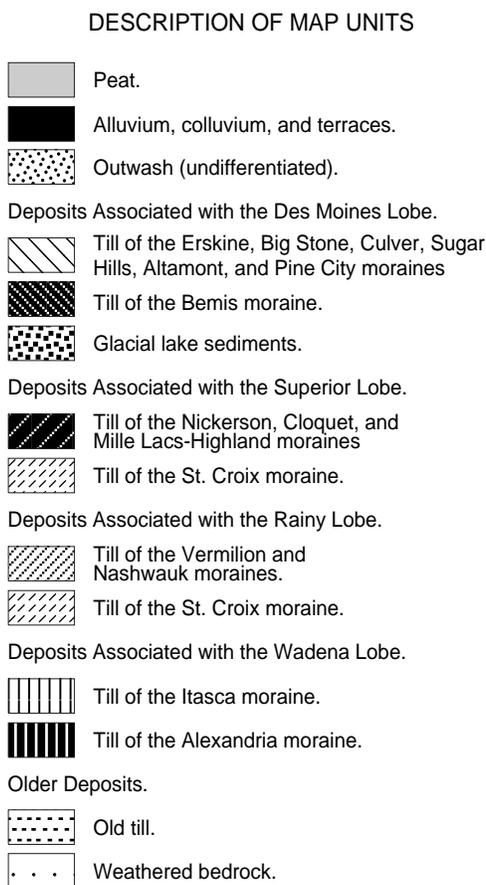


Figure 3. A. Simplified Quaternary geology of Minnesota. B. Map showing major end moraines (dashed where inferred) and schematic location and orientation of drumlins (modified from Lusardi, 1996).

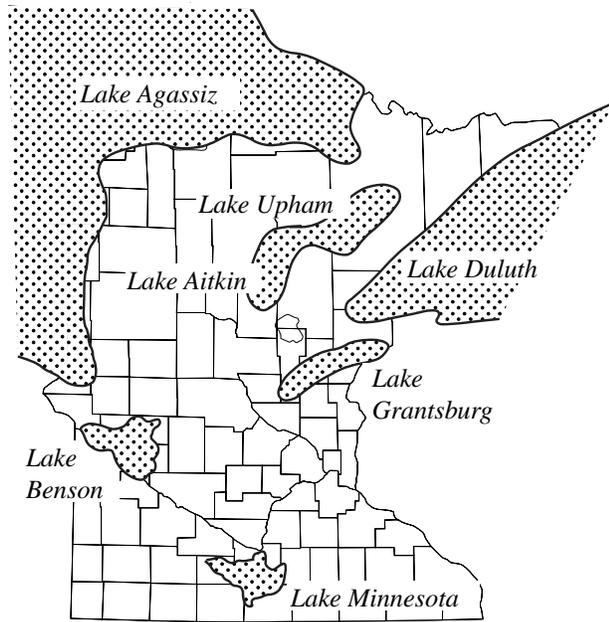


Figure 4. Major glacial lakes during Wisconsin Age (not necessarily contemporaneous).

In other words, the surface area of Glacial Lake Agassiz was greater than the surface area of all the Great Lakes combined! Water drained southward from this lake in Glacial River Warren. This raging river created the large valley in which the Minnesota River now flows.

Eventually, these large lakes drained and the landscape was left much as we see it today. The glaciers are gone—for the time being—but the gently rolling hills of ground moraine; the deep river valleys; and even Minnesota's "10,000 lakes" are a testament to their passing.

Suggested Readings

- Bray, E.C., 1977, Billions of years in Minnesota—geological story of the state: St. Paul, Sexton Printing, Inc., 102 p.
- Lusardi, B.A., compiler, 1996, Quaternary geology of Minnesota: Minnesota Geological Survey postcard.
- Ojakangas, R.W., and Matsch, C.L., 1982, Minnesota's geology: Minneapolis, University of Minnesota Press, 255 p.
- Wright, H.E., 1990, Geologic history of Minnesota rivers. Minnesota Geological Survey Educational Series 7, 20 p.

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