University of Minnesota

Minnesota Geological Survey

Minnesota at a Glance

Quaternary Glacial Geology

The Quaternary Period, which began about 2.5 million years ago, is divided into the Pleistocene Epoch (2.5 million to 11,700 years ago) and the Holocene Epoch (11,700 years ago to the present). Although 2.5 million years is a relatively short period of time geologically, sediments deposited during this time mask nearly all of Minnesota's previous geologic history (over 3.6 billion years!).

The Pleistocene Epoch, also called the Ice Age, is marked by a series of glacial (cold) and interglacial (warm) periods. Though the Laurentide Ice Sheet (Fig. 1) covered much of northern North America throughout the Pleistocene Epoch, during interglacial periods margins of the ice sheet likely retreated significantly. Because Minnesota was at the edge of the ice sheet, it was not always completely covered with ice during glacial periods. Instead, Minnesota experienced numerous episodes of glaciation followed by ice-free periods.

Glacial Deposits

A glacier is a large mass of ice formed by the compaction and recrystallization of snow that survives from year to year. Commonly, glaciers move slowly across a landscape under the pull of gravitational forces. As a glacier flows, it erodes material that it overrides; boulders, rocks, sand, and trees become entrapped, ground up, and mixed into the bottom of the ice. The debris carried along in the ice eventually is deposited some distance away from where it was originally picked up. When this mix of material, consisting of clay, silt, sand, gravel, and boulders is deposited directly by a glacier it is called *till*.

This sediment is carried by the ice until the glacier reaches its maximum extent and the leading edge stops advancing. Some sediment may continue to be transported to this stationary margin and pile up to form ridges of till called *end moraines*. End moraines mark the extent of ice advance. When the ice eventually melts and retreats from this maximum position, it deposits the debris entrapped in the ice as a till sheet. This till may form low hills and swales. Streamlined hills of till aligned parallel to ice flow direction are called *drumlins*.

Although glaciers are made of ice, there is also commonly a significant amount of flowing water due to melting ice. This meltwater can flow on top of, or in channels within and underneath the ice. Just like rivers, these meltwater streams can be heavily laden with sediment, such as sand and gravel, which is transported (and deposited) within these ice-walled channels. After the ice melts, these filled channels are known as *eskers* and remain as topographic highs on the landscape. 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 help geologists retrace the history of glacier movement. Large boulders, transported a long distance from their source, are called *erratics*. Tracing these erratics back to where they came from is one way to figure out the direction 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, these indicators are how geologists determine where and when a glacier originated.

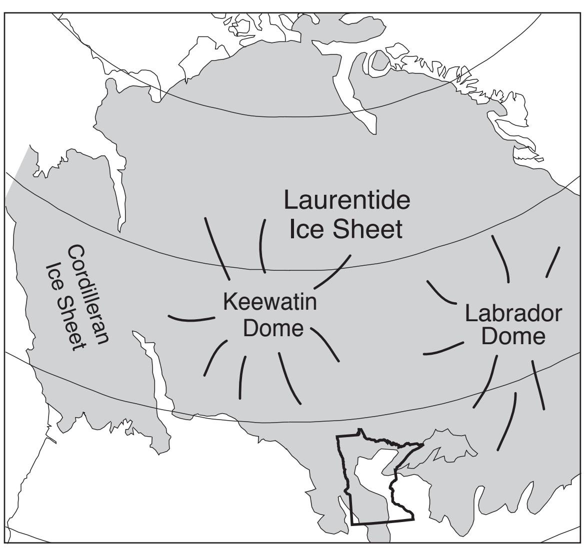

Figure 1. Maximum extent of the Laurentide Ice Sheet in North America about 14,000 years ago.

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 (Fig. 2) exposed and that may date back to 600,000 to 700,000 years ago. The extreme southeastern corner of the state is called the "driftless area" (Fig. 2), where exposures of till are unknown or uncommon 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 Wisconsinan Episode, which began about 75,000 years ago. During this time, the Laurentide Ice Sheet covered much of northern North America (Fig. 1), with ice radiating outward from two high points, or domes, in the ice sheet. Changes in climate and precipitation caused these domes to shift periodically, changing the direction of ice flow. Thus, throughout the Ice Age, ice lobes advanced across the state several times from different directions (Fig. 2).

The Wadena ice lobe (Fig. 2) was active in the early to middle Wisconsinan glaciation. Deposits from this lobe are gray in color and contain limestone from the Winnipeg lowland in southern Manitoba. The Alexandria moraine and the Wadena drumlin field (Fig. 3) in west-central Minnesota are attributed to this ice lobe. The Rainy lobe (Fig. 2), which was active at about the same time (as well as several times subsequently), deposited a brown, sandy till that contains basalt, gabbro, and other rocks indicating a northeast source. A complex moraine system made up of the Itasca and St. Croix moraines (Fig. 3) marks the extent of the Rainy, Itasca, and Superior lobes together during the late Wisconsinan glaciation. In addition, two separate drumlin fields, the Toimi drumlins in northeast Minnesota and the

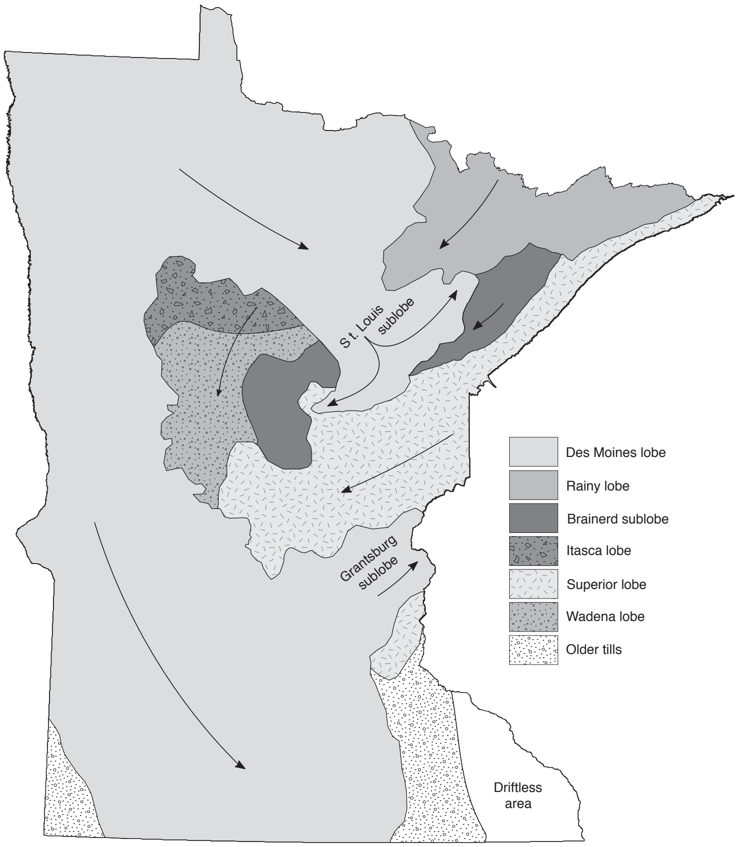

Figure 2. Simplified map showing the extent and flow directions of ice lobes that covered Minnesota during the Ice Age.

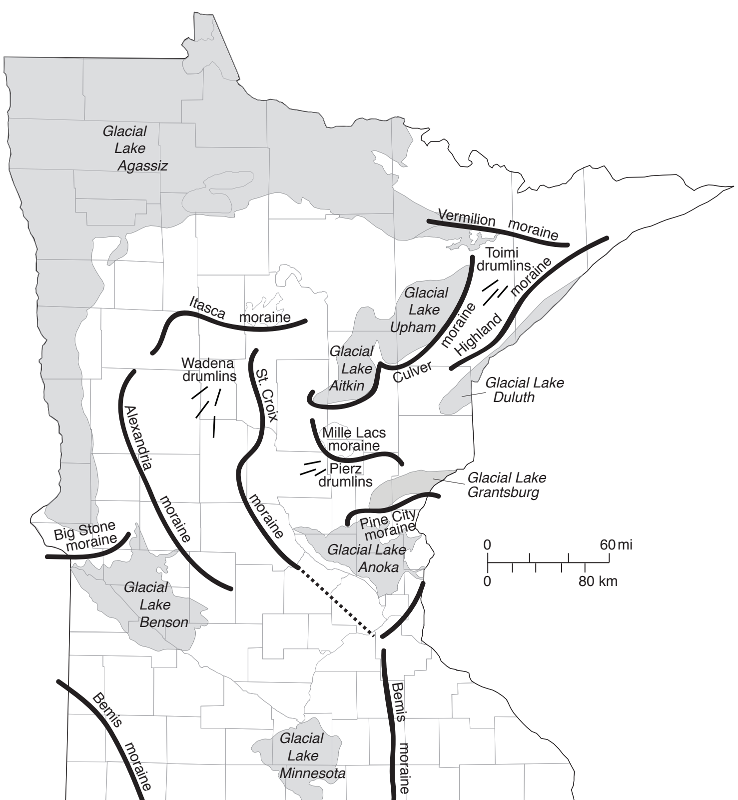

Figure 3. Map showing the major end moraines and glacial lakes during the Wisconsinan episode (not necessarily contemporaneous).

Pierz drumlins (Fig. 3) south of the Mille Lacs moraine, record the combined movement of these ice lobes. Till from the Superior lobe is distinctly red in color and contains rocks derived from the Lake Superior basin, such as red sandstone and agates. The Mille Lacs and Highland moraines (Fig. 3) mark a later readvance of Superior-lobe ice into east-central Minnesota.

The most recent glacier to cross the state was the Des Moines lobe (Fig. 2). 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 spilled over into other parts of the state: the St. Louis sublobe (Fig. 2) across northern Minnesota (marked by the Culver moraine [Fig. 3]) and the Grantsburg sublobe (Fig. 2) through east-central Minnesota (marked by the Pine City moraine [Fig. 3]). Des Moines-lobe till is gray to brown and is distinctive because it contains shale carried from North Dakota and Canada. The Bemis moraine (Fig. 3) marks the farthest extent of the Des Moines lobe and can be traced from northeastern South Dakota, through southern Minnesota and into Iowa (Figs. 2, 3). By 11,000 years ago, Minnesota was mostly ice-free; however, the Rainy lobe and the St. Louis sublobe were still present (though retreating) in the northern landscape and arrowhead region.

Throughout the Wisconsinan Episode, large lakes containing glacial meltwater formed along the margins of the ice lobes (Fig. 3). Glacial Lake Grantsburg was dammed north of 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, glacial Lake Agassiz covered over 300,000 square kilometers across northern Minnesota, Manitoba, and Ontario. In other words, the surface area of glacial Lake Agassiz was greater than the surface area of all the Great Lakes combined! Water from glacial Lake Agassiz drained southward from this lake in glacial River Warren. This raging river created the large valley in which the Minnesota River now flows.

With each glaciation, the landscape was altered by the ice; in places the glaciers eroded the bedrock or previously deposited sediment, and in other places deposited enough sediment to form hills. As the ice retreated for the last time, the variable topography left behind resulted in numerous lows that then filled with water, becoming the lakes we know today. The glaciers are gone but the gently rolling hills, the deep river valleys, and even Minnesota's "10,000 lakes" are a testament to their passing.

Suggested Reading

Bray, E.C., 1977, Billions of years in Minnesota—Geological story of the state: St. Paul, Minn., Sexton Printing, Inc., 102 p.

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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