FIG. 266. — A wash plain deposit made by water at the margin of a Greenland glacier. (Compare with Figs. 272 and 275.)

FIG. 267. — An iceberg aground near Fig. 264.

FIG. 268. — A tunnel in Fig. 267, perhaps an old stream channel in the ice.

to form on top of the ice; and this water finds its way by crevasses to the bottom. Where this water emerges, either on the land or in the sea, deposits of gravel and clay are being made (Figs. 266, 272). Along the ice front, too, moraines are being built of rock fragments loosened by melting (Fig. 271). Many of these are worn and scratched (Fig. 290) by the grinding they have received.

There is good evidence that the Greenland ice sheet, like valley glaciers, once extended much farther, completely covering some, if not all, of the islands and peninsulas. This evidence is supplied by moraines, erratics, glacial scratches, rounded and deepened valleys, and rock basins. The Greenland ice sheet, like the Muir and many other glaciers, is now melting back.

Summary. — *Greenland is covered by a great ice sheet, with a fringe of land near the coast, and, near the margin, occasional nunataks projecting above the ice. From the high interior, where snow falls summer and winter, there is a movement outward in all directions, the margin of the ice consisting of valley tongues, often ending in the sea into which icebergs are discharged. The ice has little rock material on the surface, but carries much near the bottom, with which it is doing work of erosion and making moraine and wash deposits.*

104. Other Ice Sheets. — On the Antarctic continent there is an enormous ice sheet, of which little is known. It is generally believed that the entire South Polar region is covered by an ice cap, with an area larger than the United States. For a long distance its margin is a great ice wall, rising several hundred feet above the sea and discharging huge tabular icebergs.

On the larger islands of the Arctic there are also ice caps, resembling that of Greenland, though smaller. There is evidence that ice sheets once spread completely over these islands.

Summary. — *There is a great ice sheet on the Antarctic continent, and smaller sheets on some of the larger islands of the Arctic.*

105. Formation of Icebergs. — When a glacier enters the sea the water buoys the ice up, causing great masses to break off, forming icebergs (Figs. 265, 267, 268, 339). Other masses are broken away by undercutting along the water's edge. As the icebergs drift slowly away, they melt, strewing rock fragments along the sea bottom. They often run aground (Fig. 267), pushing and grinding the layers of sediment on the bottom.

It is fortunate that the icebergs drift *away* from the glacier, otherwise the fiords would soon become choked with berg ice. They float away in an outward current of water caused by winds from the ice sheet and by fresh water from the melting ice.

Summary. — *Icebergs are discharged* (1) *by undercutting along the water's edge, and* (2) *by buoying up of ice as it advances into the sea.*

106. Former Ice Sheets in Europe and America. — There is good evidence that, not many thousand years ago, a great ice sheet spread over northeastern America (Fig. 270), and another over northwestern Europe. Scandinavia, Denmark, northern Germany, northwestern Russia, and all of the British Isles, excepting southern England, were then covered by ice. Canada east of the Rocky Mountains, New England, northern New Jersey, nearly all of New York, northern Pennsylvania, much of Ohio, and the states farther west and northwest, as far as Montana, were also ice-covered. These ice sheets, which were quite like those now covering Greenland and the Antarctic continent, have been called *continental glaciers.*

The proofs of these former ice sheets are of the same kind as those of former greater extension of valley glaciers (p. 141) and of the Greenland glacier (p. 145). These proofs include glacial scratches (Figs. 289, 291), glacial pot holes, and erratic bowlders (Fig. 285). The scratches point toward the north, and many of the bowlders can be traced to a northern source, some in the United States having come from Canada. There is also evidence of ice erosion and valley deepening; and there are lakes in rock basins that the ice scoured out (p. 153). Where the ice stood, the land is covered by a sheet of ground moraine, and there are bands of terminal moraine (Fig. 274), with wash deposits in front (Fig. 275). These glacial deposits were called *drift*, because they were thought to

have been brought, or drifted, by great floods of water; and the term *glacial drift* is still applied to them.

Louis Agassiz, in the middle of the last century, first proposed the glacial theory to account for this drift. Being a Swiss, he had studied glaciers in Switzerland, and had seen the clear evidence (p. 141) that Alpine glaciers were formerly more extensive. He saw that the same evidence was present in the British Isles and in America, and proposed the theory that there had been a *Glacial Period.* This at first met a storm of opposition, but is now accepted by every one who has studied the question intelligently.

Summary. — *Striæ, erratics, evidences of erosion, moraines, etc., prove that great continental glaciers, or ice sheets, formerly covered northeastern America and northwestern Europe. Louis Agassiz proposed the now accepted explanation of the Glacial Period.*

107. Cause of the Glacial Period. — Why there should have been a glacial climate in temperate latitudes is not positively known. At present the climate of Labrador, Scandinavia, and other centers from which the ice spread, is very cold; and, if they were elevated several hundred feet, great ice caps might slowly gather on them and spread out into lower and warmer regions. Before the Glacial Period these lands actually were higher than now, and one theory is that this former elevation caused great ice sheets to form and move down into the United States and Europe. In the United States an ice sheet from Labrador joined forces with ice sheets from the Adirondack and New England mountains, and spread over hill and valley, advancing slowly and irresistibly, as the ice sheet of Greenland does. It advanced southward to a zone where melting became so great that it could go no farther.

After many thousand years the climate gradually changed, perhaps because the land was lowered. Then the ice front slowly melted back, or "retreated." We do not know how long ago the ice melted away, but there is evidence pointing to from 5000 to 10,000 years (p. 333). The time since the ice left is so short, however, that the drift deposits are still quite fresh; and even delicate striæ remain (Fig. 289) wherever protected by a thin coating of soil (p. 41).

Summary. — *One theory for the Glacial Period is that when the land was higher in Labrador and Scandinavia, ice caps formed and spread out in all directions, and, after many thousand years, when the land was lowered, melted away.*

108. Terminal Moraines. — While the ice sheet was melting back there were periods when it halted for a time and built terminal moraines (Fig. 274). These bands of moraine, which resemble those now forming at the margin of glaciers, may be easily traced. They consist of irregular, hummocky hills, varying from a few feet to 100 or 200 feet in height, and inclosing many basins, or *kettles*, often occupied by ponds. The moraines are made partly of till, and partly of stratified drift deposited by water from the melting ice.

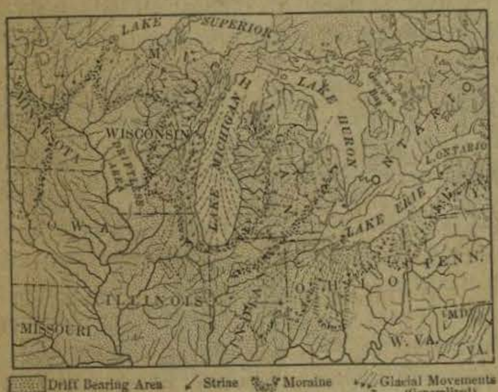

FIG. 269. — Lobate moraines in the Central States, showing the influence of the Great Lakes valleys in causing the ice tongues to extend farther south.

Ice tongues, or *lobes*, extended farther in the valleys than on the hills, and on this account the moraines bend southward in the valleys, forming looped or *lobate moraines* (Figs. 269, 273). Terminal moraines were built at each halt of the receding ice sheet, and they are called *moraines of recession* (Fig. 273).

Summary. — *At each halt of the receding ice sheet a terminal moraine was built with lobes extending down the valleys. These moraines are low, hummocky hills, with inclosed basins, or kettles, often occupied by ponds.*

FIG. 270. — The ice sheet in eastern United States. (Photograph of a model made by E. E. Howell, Washington.)

FIG. 271. — Edge of the Greenland ice sheet on the land (near Fig. 264). The dark layers of ice are due to rock fragments, and the ridge in the foreground is a moraine built by the falling of these from the ice margin.

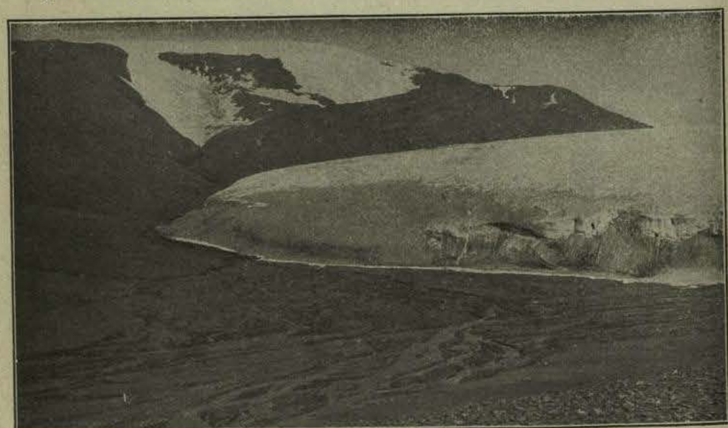

FIG. 272. — A stream extending from a Greenland ice tongue and flowing in braided course over a wash plain which it is building up (see also Fig. 266).

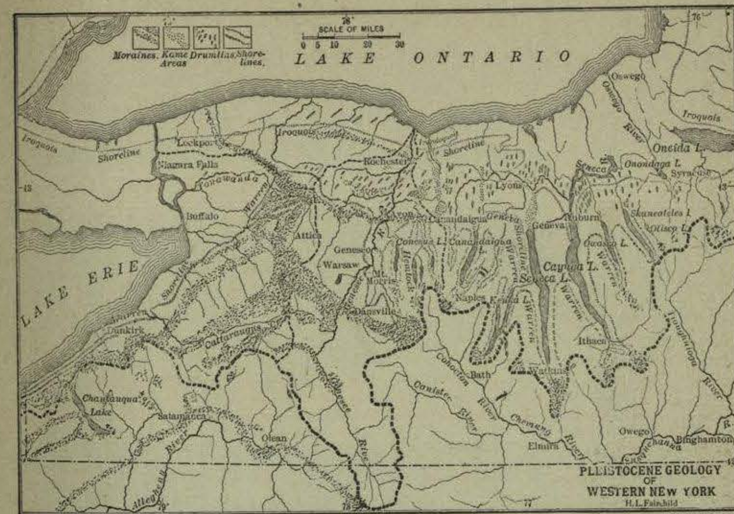

FIG. 273. — The lobate moraines of recession in western New York. The outermost terminal moraine is the one that bends up from Pennsylvania to Salamanca and Olean. Also location of drumlins, and of shore lines of glacial lakes. The heavy line is the divide. The lakes have all been caused by glacial action.

FIG. 274. — Photograph in the terminal moraine near Ithaca, N.Y. Notice how hummocky the surface is; this is characteristic of moraines.

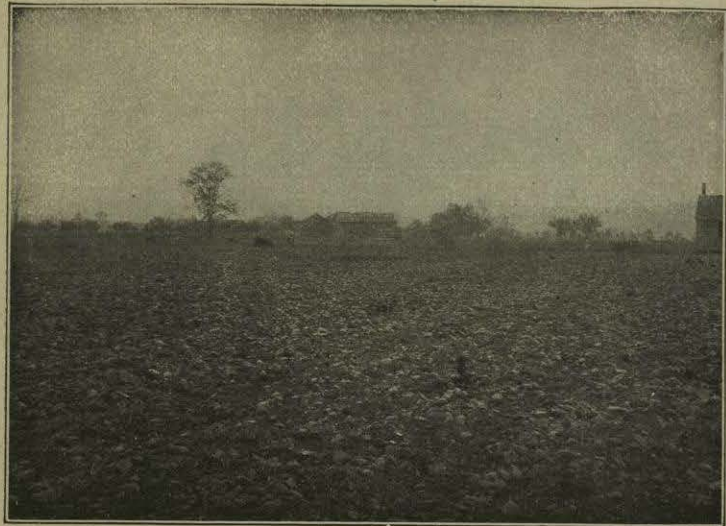

FIG. 275. — A wash plain near Fig. 274, deposited by a stream flowing from the glacier when the moraine was being built. Compare Figs. 251, 266, and 272.

FIG. 276. — A kame near Fig. 275. It is made entirely of stratified gravel, and in the center, just above the tree to the right of the horse, has a very deep kettle hole that looks like a crater.

109. Stratified Drift. — Water issuing from the melting glacier built several classes of deposits. All these are stratified, because water assorts rock fragments (p. 32). These stratified deposits are called ***stratified drift.*** Of these the most extensive are the ***wash plains*** (Fig. 275), which resemble those now forming in the Swiss valleys (p. 139). Many valleys in eastern America are filled to a depth of from 100 to 300 feet with these level, gravelly plains, built by ancient glacial streams. Wherever the ice front rested on fairly level land the glacial streams built a series of low, flat alluvial fans. The plains on the south side of Long Island are of this origin.

At and under the ice front the water built irregular, hummocky hills of gravel, called *kames* (Fig. 276), in which deep basins, or kettles, are often found. Some of the kames were apparently made by streams, bearing much gravel, which tumbled to the bottom of the glacier through crevasses. This gravel occasionally covered blocks of ice which, on melting, allowed the gravel to settle, forming the kettle holes.

Long, narrow ridges of gravel, sometimes miles in length, and with an irregular, serpentine course, are called *eskers* (Fig. 282). These are the gravel beds of streams that flowed in tunnels or gorges in the ice, usually at the bottom. Where these streams emerged from their ice tunnels they built wash plains; or, if the end was in small, ice-dammed lakes, they built deltas. These level-topped deltas are called *sand plains.*

Summary. — *Water from the melting ice made stratified deposits: kames where streams tumbled to the base of the ice; eskers where they flowed in ice tunnels; wash plains where they emerged upon the land; and sand plains in small, ice-dammed lakes.*

110. Ice-dammed Lakes. — In some places the ice front stood in large lakes (Figs. 278, 279), formed where north-flowing streams were dammed by the ice. Clay and gravel deposits were made in these, and along their shores deltas and beaches were built.

One of these large lakes was formed in the valley of the Red River of the North (p. 78). Other north-flowing streams were dammed by the ice, some of the valleys having small, others large, glacial lakes. The case of the Great Lakes is especially interesting. At first a few small lakes were formed, one outflowing past Chicago, one past Duluth, and one past Fort Wayne, Ind. (Fig. 280). As the ice melted back these grew larger, uniting and outflowing past Chicago (Fig. 280). Then an enormous volume of water, comparable to Niagara, escaped into the Illinois River. The small lake harbor around which Chicago has grown up was scoured out by this outflow. As the ice continued to melt back, a still lower outlet was opened eastward through the Mohawk valley (Figs. 277, 280), the Chicago outlet was abandoned, and for a while the glacial lakes outflowed into the Hudson past Little Falls, N.Y. Finally, when the ice disappeared from the St. Lawrence valley, the present course was established.

FIG. 277. — The Ontario region during the stage of outflow through the Mohawk (Fig. 280; see also Fig. 273).

The beaches that were formed at the levels of the different outlets of these various lakes may still be clearly seen. For example, the beach ridge from Syracuse to Lewiston (Fig. 273), on which the "ridge road" is built, was recognized as a beach by the early explorers. The fine-grained clay that was deposited on these lake bottoms makes a level, fertile soil. Consequently, the region between the elevated beaches

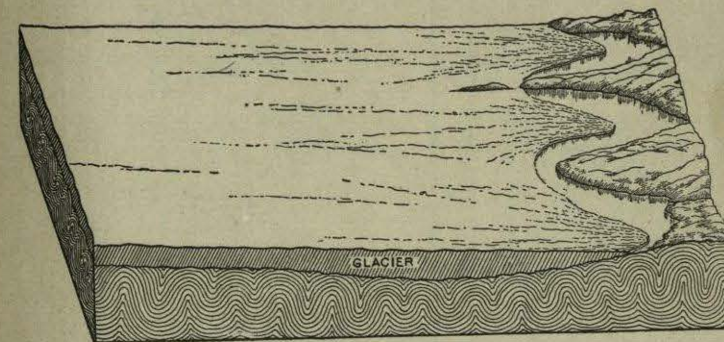

FIG. 278. — Diagram of an ice sheet on an irregular land, damming up a series of lakes along its margin. Describe what you see.

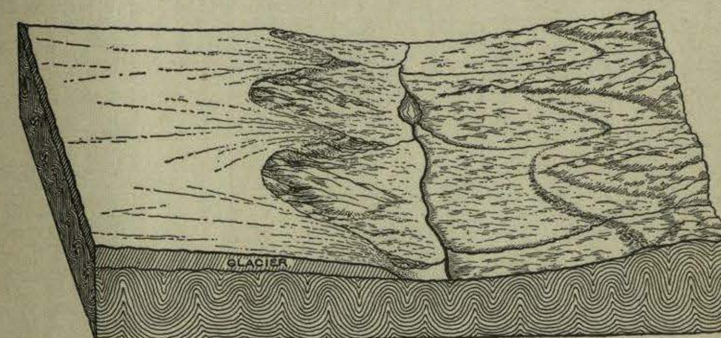

FIG. 279. — The same as Fig. 278 with the ice melted back somewhat, uncovering a valley which it had crossed. A moraine marks the former position of the ice front in the glacial lake. Describe what you see in this.

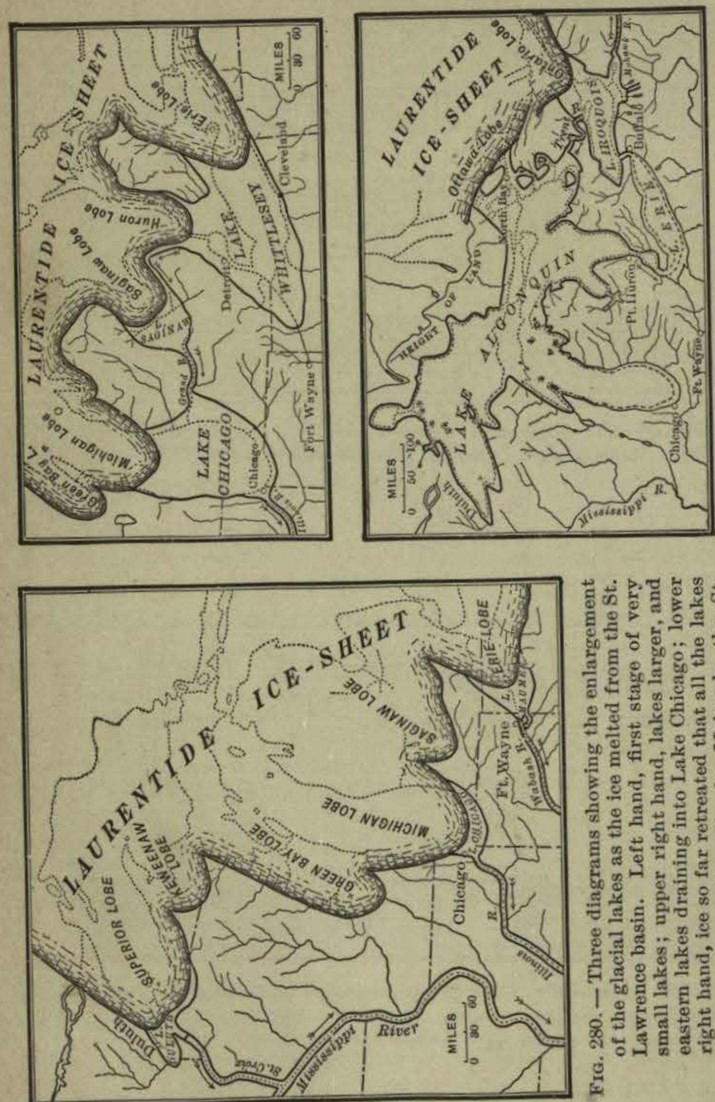

FIG. 280. — Three diagrams showing the enlargement of the glacial lakes as the ice melted from the St. Lawrence basin. Left hand, first stage of very small lakes; upper right hand, lakes larger, and eastern lakes draining into Lake Chicago; lower right hand, ice so far retreated that all the lakes drain eastward through the Mohawk, the St. Lawrence being still ice-filled. The upper lakes then flowed through the Trent river, because the land in the north was then so low that the Detroit channel could not be occupied. The dotted lines in Lake Erie and southern Lake Michigan represent the outline of the lakes at this stage, when the land was so low in the north that the water did not completely fill these basins. Elsewhere the ice dam forced the water to rise beyond the margins of the present lakes.

and the present lake shores is the seat of prosperous farms, orchards, and vineyards.

The beaches are not horizontal, but rise toward the northeast at the rate of about three to five feet a mile; and this is taken as proof that the land has been tilted since they were formed. As a result of this tilting, the lakes have changed from one outlet to another (Figs. 280 and 281).

Uplift of the land is still in progress at a very slow rate, and if it continues, the upper Great Lakes will eventually abandon the Detroit channel and once more outflow past Chicago. At the present rate of tilting the water will begin to spill over the Chicago rim in 500 or 600 years; and in 3500 years Niagara will be changed to a very small stream.

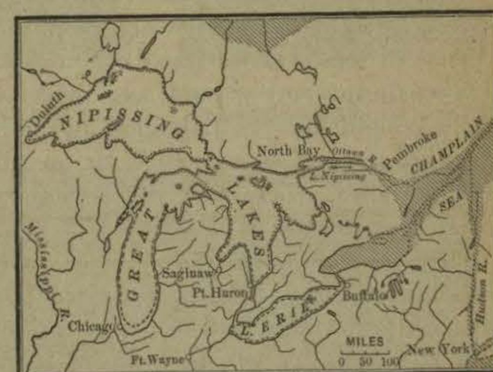

FIG. 281. — After the ice had entirely left the St. Lawrence valley, the land in the north was so low that the sea (shaded) entered the Champlain and Ontario basins, and the upper Great Lakes outflowed through the Ottawa River. Then Niagara carried the water only of Lake Erie. As the land in the north rose, the upper lakes were tilted until they finally overflowed past Detroit.

Summary. — *As the ice was melting from the land it dammed north-flowing streams, causing temporary glacial lakes which disappeared when the ice dam melted away. Lakes of this sort were formed in the valleys of the Great Lakes, shifting their outlets as lower ones were uncovered by ice melting, or made possible by land tilting. The tilting of the land is still in progress.*

111. Loess. — In central United States there is a sheet of fine-textured clay known as *loess*, a German name for a similar deposit in that country. Some of the loess was evidently drifted by winds, and some of it was brought from the ice front in slowly