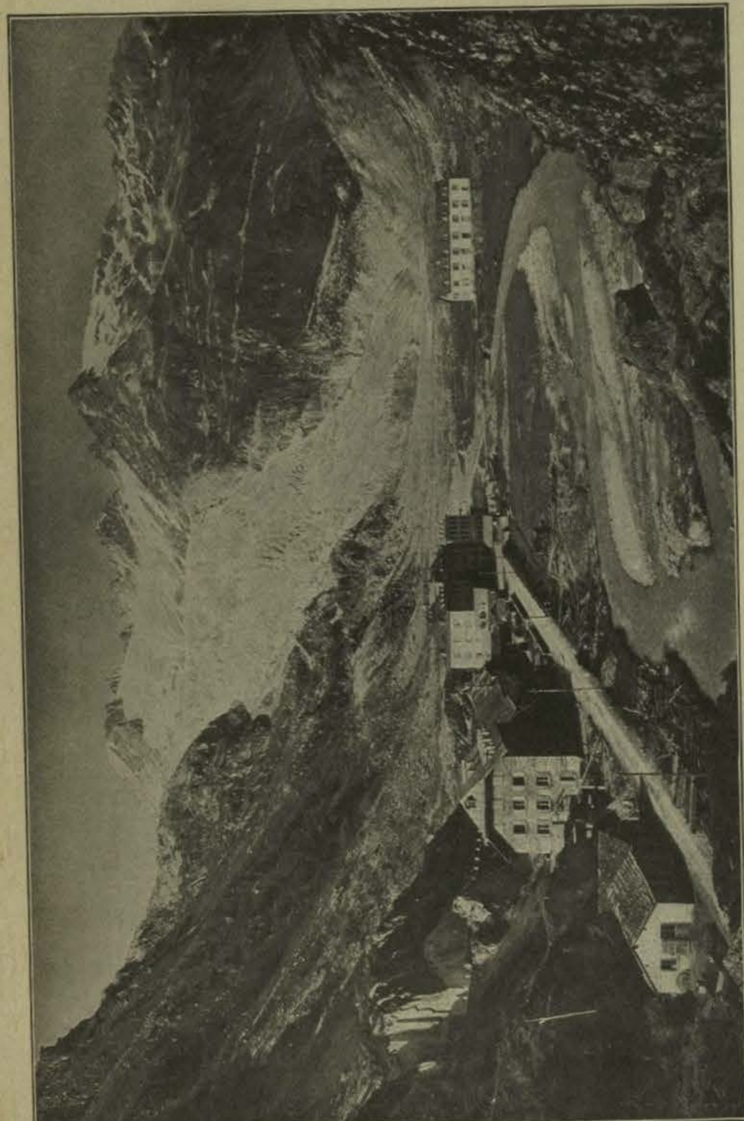

FIG. 251. — The Rhone glacier in Switzerland. This glacier formerly occupied the whole of the valley. Some of its deposits are seen on the left, and the ice-scoured cliffs on the right. The glacier-born stream (the Rhone) is here so embarrassed with sediment that it is aggrading its bed, building a wash deposit (see also Fig. 185).

CHAPTER VIII.

GLACIERS AND THE GLACIAL PERIOD.

99. Valley Glaciers. — The snow line in the Alps is about 9000 feet above sea level. Above this line is a great *snow field* (Fig. 245, 249), in which snow accumulates year after year, in some places reaching a depth of hundreds of feet. Some of the snow is whirled away by the wind, settling in valleys; some slides down the steeper slopes (Fig. 246), as snow slides from the roof of a house. There is so much snow falling into the valleys, both as small slides and great avalanches, that they would be completely filled if it could not in some way be removed.

The snow that accumulates in the valleys gradually changes to granular snow ice, resembling the snow banks of late winter. This change is partly due to the pressure of the overlying mass, and partly to alternate melting and freezing during summer days and nights. The granular ice, called the *névé* (Figs. 246, 248), moves slowly down the steep valleys.

As the mass moves, pressure and further melting and freezing gradually change it to pure, clear ice. The supply from the snow field causes the ice to move down the valley, much as a river extends beyond the place where the rain fell. Such an ice tongue, occupying a valley, is called a *valley glacier* (Figs. 157, 181, 185, 247–251). In the Alps some of the glaciers are 10 to 15 miles long, extending 4000 or 5000 feet below the snow line. They end where the warmth is sufficient to completely melt the ice, and the terminus may be below the timber line, even in the zone where grain will grow.

The glacier moves down grade, behaving much as a mass of wax does when under pressure; that is, it moves as if it were slowly flowing. The most rapid motion is near the middle, though even here it does not usually move more than two feet a day. Every glacier carries rock fragments, some of which have fallen from the valley sides, while others have been obtained from its bed. These fragments, slowly dragged along, and pressed down by the weight of the ice, groove, striate, and scour the rocks over which the glacier moves. It may be compared to the work of sandpaper. By this scouring, known as *glacial erosion*, valleys are both deepened and broadened.

Bands of rock fragments, accumulated on the margin of the glacier, where they have fallen from the cliffs, are known as *lateral moraines* (Figs. 247, 249). Where two glaciers join, two lateral moraines unite, forming a *medial moraine* (Figs. 249, 250), near the middle of the glacier. The surface of the glacier melts in summer; but moraines protect the ice beneath from melting, and this causes them to stand up as ridges, often 50 feet or more above the surface of the glacier.

Although ice under steady pressure slowly flows, when subjected to a decided strain it breaks, forming cracks, or *crevasses* (Figs. 246, 248), in the glacier. Where the valley bottom is irregular, causing many strains in the moving ice, crevasses are especially abundant; and when the slope of the bottom is steep, the ice may become so crevassed that it is almost impossible to pass over it. Such a section is called an *ice fall*. Moraine fragments are constantly falling into these crevasses, some of them finding their way to the bottom of the glacier. Water from the melting ice also falls into crevasses, boring *pot holes* (p. 54) in the rock floor, and flowing in ice tunnels to the front of the glacier.

The rock fragments frozen in the bottom of a glacier are known as the *ground moraine*, and when a glacier disappears by melting this is left as a deposit on the valley bottom. To it are added the materials of the lateral and medial moraines, which slowly settle to the ground as the glacier melts.

At the end, or terminus, of a glacier, rock fragments are built into a *terminal moraine*. These fragments are brought by the ice and loosened as it melts, accumulating in irregular piles at the base of the glacier front. If the end of a glacier remains in one place for a long time, the terminal moraine hills may reach a height of 100 or 200 feet.

The water that falls into crevasses emerges as a stream from the ice front (Fig. 185), often from an *ice cave*. It is white with suspended sediment, or *rock flour*, supplied by the grinding up of rocks beneath the glacier. In summer, the volume of these glacier streams becomes so great that even pebbles are moved along. The clay is carried far down the valley, but the sand and pebbles are usually deposited on the valley bottom, gradually filling the valley. Over this deposit the stream flows in a branching, braided course, constantly depositing sediment and changing position (Fig. 251). Such *wash deposits* may reach a depth of over 100 feet.

Summary. — *Snow, derived from the snow field, accumulates in the valleys, changing to granular ice (névé), then to ice, which extends down the valley as an ice tongue or valley glacier. As it moves, it scours its bed, and carries rock fragments, both on its surface (lateral and medial moraines) and at its bottom (ground moraine). Both rock fragments and water descend to the bottom of glaciers through crevasses, caused by strains resulting from the ice motion. The rock fragments form a ground moraine and assist the ice in erosion; the water emerges from beneath the ice in streams, bearing rock flour, sand, and pebbles, which build extensive wash deposits. Terminal moraines are built at the ice front.*

100. Glaciers of Alaska. — Of the many Alaskan glaciers the best known is the immense *Muir glacier* (Figs. 253–255), which is fed by twenty glacier tributaries or more. These unite to form an ice tongue which advances down a broad valley and ends in the sea. Its front is a cliff, rising 200 feet above the water and extending 700 or 800 feet below. From it small icebergs frequently break off and float down the bay. The discharge of icebergs, added to melting, is causing the Muir glacier to steadily grow shorter.

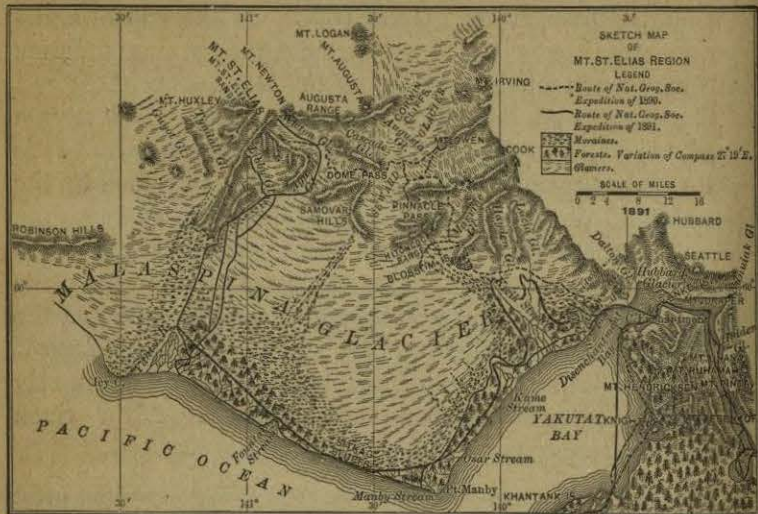

Fig. 252. — The Malaspina glacier.

Farther north is another large glacier, the *Malaspina* (Fig. 252), formed by the union of a number of valley glaciers that descend from the Mt. St. Elias range (Fig. 256). This glacier spreads out, fan-shaped, on a plain at the base of the mountains. For this reason it is called a *Piedmont* glacier (from *pied*, foot, and *mont*, mountain). It has a length of 60 or 70 miles and a breadth of 20 or 25 miles; and its movement is so slow that it is an almost stagnant, undulating ice plateau (Fig. 257).

Melting and evaporation have caused the rock fragments in the upper portion of the glacier to accumulate at the surface, especially near the lower end. These rock fragments form a rocky soil on the glacier, in which a forest is growing (Fig. 258).

Summary. — *Muir glacier, fed by over twenty tributary glaciers, ends in sea cliffs from which icebergs are discharged. Malaspina glacier, an almost stagnant ice plateau, is called a Piedmont glacier.*

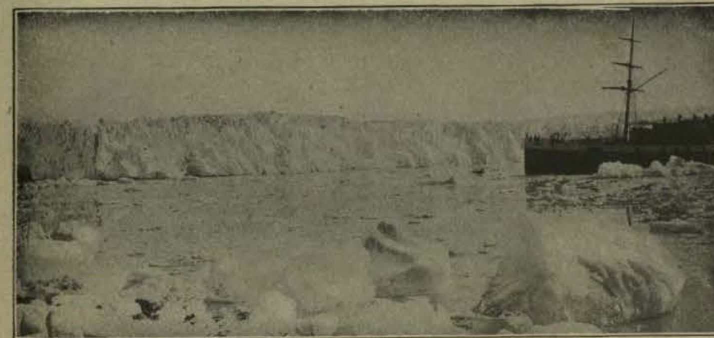
Fig. 253. — The sea front of Muir glacier, Alaska.


Fig. 254. — The end of Muir glacier.


Fig. 255. — The crevassed top of Muir glacier.

FIG. 256.—Mt. St. Elias, Alaska, from which valley glaciers descend to join the Malaspina glacier.

FIG. 257.—The surface of Malaspina glacier, Alaska.

FIG. 258.—Terminus of the Malaspina glacier on the land. This is an ice cliff covered with moraine soil, on the top of which a forest is growing.

101. Distribution of Valley Glaciers. — There are several hundred valley glaciers in Switzerland, and these serve as one of the attractions to tourists. There are also many in the Caucasus and Himalaya mountains, and in Norway, where some descend to the sea.

There are small glaciers in some of the high mountain valleys of Mexico (in the tropical zone) and of western United States. Toward the north glaciers increase in size and number, becoming especially large and abundant in western Canada and Alaska. Tourists are beginning to visit the Selkirk range of western Canada, which rivals Switzerland in the grandeur and beauty of its snow-capped mountains and its glaciers. The Muir glacier is also regularly visited by steamer.

The islands of the Arctic, such as Baffin Land, Iceland, and Spitzbergen, have innumerable valley glaciers, many of which descend to the sea. Glaciers are also abundant in New Zealand and the southern Andes.

Summary. — *Valley glaciers exist in many parts of the world, even in the tropical zone. In cold climates they occupy low valleys, and even descend to the sea; in warm climates they are confined to the upper valleys of high mountains.*

102. Former Extension of Valley Glaciers. — It is well known that valley glaciers were formerly more extensive than at present. In fact, they once existed in places where now there are none. Nearly all Switzerland was once covered by an ice sheet, formed by the union of valley glaciers; there were many in the Rocky Mountains; and glaciers existed even in the Adirondacks and New England mountains.

The clear evidence of this former extension of glaciers is of various kinds, as follows: (1) rock fragments, called *erratics* (Fig. 259), often weighing tons, are found in the valleys. In many cases they are different from the rock near by, but are the same as rock found higher up the valley. They have apparently been brought by some powerful agent, like ice.

(2) The ledges in the valleys have been polished and scratched by the dragging of rock fragments over them

(Fig. 259), as if by ice. These scratches, or *striæ*, extend in the direction in which the erratic *bowlders* have been carried.

(3) Deposits like those now being made by glaciers occur in the valleys (Figs. 251, 260). These include lateral, medial, terminal, and ground moraines, the ground moraine making a thin sheet of mixed clay, pebbles, and bowlders, called *bowlder clay* or *till*. This till is unlike water deposits, being unassorted and unstratified; but it is like deposits from ice, which carries and drops large and small fragments with equal ease, and, therefore, side by side. In front of the terminal moraines, and sometimes mixed with them, are wash deposits of stratified gravels, like those now being laid down by the streams that issue from glaciers.

(4) The valleys also show signs of glacial erosion (Figs. 251, 259, 261, 262). The rocks of their sides and bottoms are polished by ice scouring, and the ledges are worn into smooth, rounded curves, known as *roches moutonnées* (sheep backs). This erosion has often broadened and deepened valleys (Fig. 261); and where they have been deepened a little more than elsewhere, *rock basins* have sometimes been formed, now occupied by lakes and ponds. In some cases the valleys have been deepened hundreds of feet; and in the region of former névé, broad deep amphitheaters, called *cirques*, have been formed.

Since the ice disappeared, side streams tributary to these ice-eroded valleys have not had time to cut their bottoms down to the level of the deepened main valleys. Their bottoms therefore stand above the level of the main valley, and they are accordingly called *hanging valleys* (Fig. 293). From them the streams tumble into the main valley as falls or rapids. These waterfalls add to the charm of the mountain scenery in Switzerland, Norway, Alaska, and other regions from which glaciers have departed.

Summary. — *Erratics, striæ, moraines, till, and wash deposits are among the evidences that valley glaciers were formerly more extensive, and even existed where now there are none. Evidences of ice erosion are also found, in the form of roches moutonnées, broadened and deepened valleys, rock basins, cirques, and hanging valleys.*

FIG. 259. — The top of a Swiss glacier, showing crevasses. Beyond it is a smoothed, scratched rock surface with erratic bowlders on it. The ice has left this surface so recently that vegetation has not had time to occupy it.

FIG. 260. — Moraines and moraine lakelets in a Rocky Mountain valley, in which a valley glacier formerly existed.

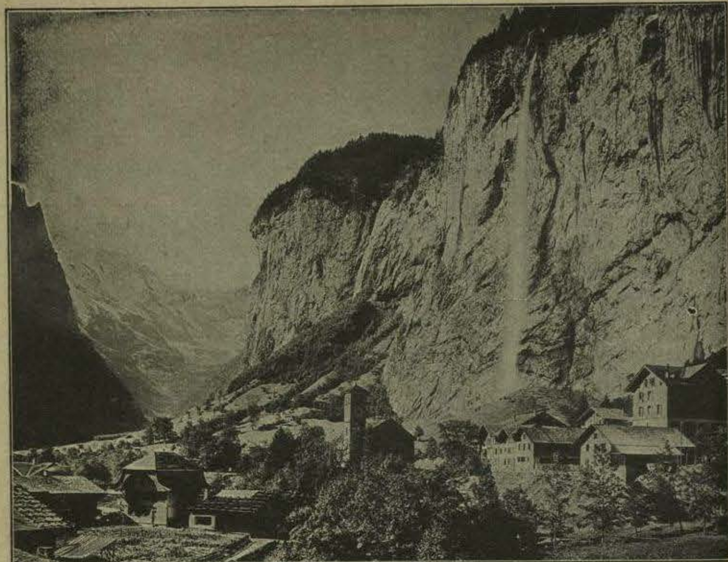

FIG. 261. — Lauterbrunnen valley and fall, Switzerland, a valley down which a glacier formerly extended, deepening it.

FIG. 262. — A view on the Grimsel Pass, Switzerland, showing a smoothed rock valley with little lakes. This was formerly occupied by a glacier which has now entirely disappeared, leaving scoured rock sides and moraine deposits as proof of its former existence.

103. The Greenland Ice Sheet. — The island of Greenland is mountainous, not greatly unlike northern New England and Scotland. Near the coast there is a fringe of peninsulas and islands on which there are scattered Eskimo settlements. The mountain valleys have valley glaciers, and small ice caps exist on some of the larger islands and peninsulas.

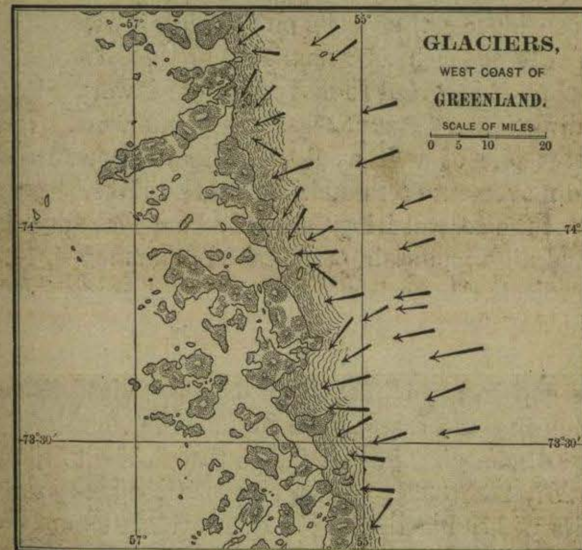

FIG. 263. — A map of the region around the Cornell glacier where Figs. 264, 265, and 271 were taken (near the long peninsula at the top). The arrows show the general movement of the ice, outward from the interior, but turning down into the valleys, and ending in tongues in the bays and fiords.

Back of the fringe of coast land is a great waste of ice and snow, with an area of about 500,000 square miles, more than ten times the area of New York State. This enormous ice cap is sometimes called the Greenland glacier; but it is so large, and, in a number of ways, so different from what is commonly called a glacier, that the term *ice sheet* is a better name. *An ice sheet is a mass of ice, covering and moving over a large area of land, hill and valley alike.*

In the interior, a part of which Peary has crossed, the elevation is 8000 to 10,000 feet, and the temperature never rises above the freezing point. The surface is, therefore, always covered with loose, dry snow. Nearer the coast, where the elevation is less, the warmth of the summer sun melts the snow, leaving an ice surface quite like that of valley glaciers.

The continued fall of snow on the high interior of Greenland has caused such an accumulation that, changed to ice by pressure, it is forced to move slowly outward (Fig. 263) in all directions, — north, east, south, and west. It moves as a great pile of wax would, and in its slow, irresistible outward movement crosses hill and valley alike.

Back of the coastal fringe the only land that appears is an occasional high mountain peak, called a *nunatak* (Fig. 264), which projects like an island above the sea of ice. Near the coast the ice extends down the valleys, often reaching the sea (Figs. 263, 264). At the head of fiords these valley tongues end in sea cliffs 200 or 300 feet high (Fig. 265), advancing in some cases at the rate of from 50 to 75 feet a day, and discharging huge icebergs that float into the Arctic (Figs. 267, 268, 339). Most of these tongues are only a few miles wide; but the largest of all, the Humboldt glacier of north Greenland, is 60 miles wide. Their surface is broken by crevasses, quite unlike the smooth, unbroken ice plateau of the interior.

Unlike that of valley glaciers, the surface of the ice sheet is quite free from rock fragments, excepting where nunataks supply materials for a medial moraine, or, near the end of a valley tongue, where cliffs rise from the ice margin. Near the bottom, however, there is much rock material, which has been worn from the land. In transporting this load of rock fragments at its base, the ice sheet scours its bed and does much work of erosion.

Melting near the margin causes streams and even ponds

FIG. 264. — A view of the Greenland ice sheet, showing its vast expanse, its extension into the fiord valleys, and a nunatak rising above its surface. This is a view of the Cornell glacier, one of the large valley tongues of the Greenland ice sheet.

FIG. 265. — Front of the Cornell glacier (Fig. 264), where it advances into the fiord. From it huge icebergs are frequently discharged.