Glaciers.

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The life of a glacier is one eternity. See Boulder Dawson, Canadian Ice Age (1894); Bonney, Ice Work, Past and Present (1896); Kelkie, Great Ice Age (1895); Heim and Peuck, On the Ancient Glaciers of the Isar and Liuth (1886); Wright, Ice Age in North America (1890); Upham, Glacial Lake Agassiz (United States Geological Survey, Monograph XXV). See Boulder Clay; Columbian Formation; Diluvium, Champlain Stage; Drift; Drumlin; Till. Samuel Sanford, Engineering and Mining Journal.

Glacier, a small gray or bluebear (Ursus arctos) of the St. Elias Alps, Alaska. See Bears.

Glacier, a current of ice derived from snow. Water, changed into vapor by sun-heat and carried by the winds over frosty highlands, is crystallized into snow. Glaciers take their rise in regions which lie above the snow-line. Upon these regions, from their geographical position and elevation, the quantity of snow that falls exceeds the quantity melted and evaporated. The surplus, instead of accumulating indefinitely, is changed by the pressure of its weight into ice, which, though hard and apparently brittle and inflexible as glass, flows down toward the sea in beautiful swaying undulating lines, as if soft like honey or tar. Thus the overburdened regions above the snow-line are relieved and a continuous circulation is maintained—ocean water flying away through the form of vapor, but in returning creeping along the ground in the form of ice, grinding and crushing the rocks that lie in its way, and leaving a heavier track than anything else that moves on the face of the earth.

In general a glacier flows like a river, and drains off snow as a river drains off rain. At different places it moves at different rates, not only along its cross-sections, but along its length and from surface to bottom, as friction and the declivity of its bed varies. The velocity of the swiftest parts of the largest glaciers of the Alps is about from one foot to three feet per day; of the smallest, about as many inches. The lower central part of the Muir Glacier of Alaska flows about 10 feet a day. Some of the Greenland glaciers are said to flow much faster. Glacier motion, however slow, is continuous. It is less in winter than in summer, and slightly less in frosty nights than in warm and rainy days.

Crevasses—Though obedient to the laws of liquid motion in general, a glacier refuses to stretch, as is shown by its breaking sharply asunder at right angles to tension strains, thus forming the so-called transversal, longitudinal, marginal, and bergschrund crevasses. The first two are caused by unevenness of the channel, the marginal by differential motion, the bergschrund by the glacier flowing away from the motionless snow attached to the head of its basin. The last is of course a feature of all glaciers and appears in the middle of all glaciers flows faster than the sides; but large central areas, where the bed is regular in slope or slightly concave, are free from crevasses. The largest crevasses are several miles long, 1,000 feet deep or more, and 30 or 40 feet wide, though at first they are usually too narrow to admit a knife-blade. In some places all sorts of crevasses are interlaced, forming labyrinths of yawning gulls defying the skill and will of the bravest mountaineer who tries to hew a way through them.

Regelation.—The brittleness of ice, with its flowing motion, is partly explained by regelation. In 1850 Faraday discovered that when two pieces of thawing ice are placed together they freeze at the points of contact. Snow at a temperature of 32° F., stuffed into a mold and squeezed, becomes transparent ice. So also fragments of ice are pressed in a mold, crushed, and recongealed into a solid mass of the form of the mold, illustrating the breaking of glaciers and their regelation when from change of position the sides of the chasms, great or small, are pressed together.

Moraines.—The life of a glacier is one eternal grind. Its draining streams are always milky with rock mud rubbed off its bed, and separated from the large detached masses by the waters. Moraines, lateral, medial, and terminal, are the general detritus of a glacier and the weathered heights about it, drawn out and arranged by the ice currents, and located as their names indicate. The medial moraines, of which each glacier has one fewer than the number of its tributary glaciers, are formed by the union of two laterals at the confluence of the tributaries, and extend down the trunk in beautiful order. The terminal moraine is made up of parts of all the others. The moraine material, clay, sand, and boulders, of the great continental glaciers of the Ice Age, is often called drift. The detached rock masses, borne along by the ice currents and left in the terminal moraines, or if the glacier reaches the sea, dropped perhaps hundreds of miles away by icebergs, are called erratics.

The most striking features of large glaciers are the median moraines, the lakes and sluggish streams on its surface, the wild ice catacorants corresponding to the cascades and rapids of rivers, and the discharging frontal wall, with its icebergs upheaving, sinking, and roaring amid eternal thunder. Glaciers vary widely in size and form; they may be classified as follows:

(a) Continental glaciers, of which only two now exist, the Greenland and South Polar ice caps.

(b) Glaciers of the first order, which are more or less river-like, flow into the sea, and terminate in berg-discharging ice cliffs.

(c) Glaciers of the second order, which approach the sea, but do not enter it, and of course do not discharge icebergs, waste from melting and evaporation equaling the snow supply.

(d) Glaciers of the third order, residual branches of those of the second, separated and made independent by the melting away of the trunks to which they belonged. Nearly all the glaciers of the world are now of this order.

Distribution of Glaciers.—Most of the glaciers of North America are distributed along the mountain ranges of the Pacific coast between lat. 36° 30' and 36°. About 65 small residual glaciers a mile or less long still linger on the Sierra Nevada of California between lat. 36° 30' and 38°, at an elevation of 11,000 to 12,000 feet above sea-level. Groups of larger glaciers drain the snow-fields of Mount Shasta and the high volcanic mountains of the Cascade Range in Oregon and Washington. From ice-crowned Mount Rainier, 14,600 feet high, eight glaciers, 5 to 10 miles long, descend into the forests to within 3,600 and 4,000 feet of sea-level. The
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broad, lofty mountain chain extending along the coast of British Columbia and southeastern Alaska is generally ice-laden; the upper branches of the main canions are occupied by glaciers, which gradually increase in size and descend, lower, up to the highest and snowiest region of Alaska between lat. 56° and 61°, where a considerable number flow into arms of the sea. This is the region of greatest glacial abundance on the continent. To the north of lat. 61° the glaciers gradually diminish in size and descend to about lat. 63° or 65°. Beyond this, to the north end of the continent, few if any glaciers now exist, the ground being comparatively low and the snowfall light.

Glaciers of the third order, a mile or two to 15 or 20 miles long, fill the upper canions and hollows of the highest region in countless thousands. The large glaciers of the second order number about 100. They are distributed along the coast from the mouth of the Stikine River to Cook Inlet and the Alaska Peninsula, pouring their majestic floods from far-reaching mountains. The expanded fan-shaped ends of many of this order are from two to four or five miles wide. The largest among these are the Malaspina Glacier, the Miles, Yakutat, Grand Plateau, Crillon, and La Pèrouse, fronting the sea along the St. Elias and Fairweather mountains. The Malaspina is the largest of them all, being about 20 miles long and 65 or 70 miles wide,—a grand undulating ice prairie sloping gently from the base of the St. Elias Mountains, and separated from the sea by a girdle of forested moraines five to six miles wide, except at Icy Cape, where it presents bluffs of pure ice that are being undermined by the waves. The La Pèrouse also presents ice bluffs to the open ocean, which at high tide are wave-washed, and small bergs are occasionally detached; but far the greater number terminate a mile or two from the tide line, back of moraines in rather low-spreading crevasse-gashed bays, over which one may easily climb.

The great glaciers of the first order flowing out into deep ocean water and discharging fleets of icebergs number about 31. One, the southmost, extends to 60° 30', 4 into branches of Holkam Bay, 1 into Takit Fiord, 9 into the Glacier Bay fiords, 2 into Lituya Bay at the base of Mount Fairweather, 3 into Disenchantment Bay, and 11 into the wild fiords of Prince William Sound the northmost being a little above the 61st parallel.

The scenery of these fords is of the grandest description. From wall to wall they are encumbered, often jambed with icebergs, which by the most active glaciers are discharged at intervals of a few minutes with thundering roaring that may be heard 5 or 10 miles away, proclaiming the restless work and power of these mighty crystal rivers, in striking contrast with the dead silence of those of the second order, though they also, except at their decaying ends, are ceaselessly flowing and grinding.

Glacier Bay is the icest of the inlets which fringe the coast. Both to the north and south of it the glaciers pour in from the central and northwestern snow-fed, and of course give birth to fewer icebergs. Of its nine glaciers of the first order, the Muir is the largest. It is about 50 miles long, the main trunk below the confluence of the principal tributaries is about 25 miles wide, and probably about 1,500 feet deep. The berg-discharging part of the sea-wall is less than two miles wide, rises above the water to a height of 250 to 300 feet, and sinks to a depth of about 700 feet.

The grandest of the Prince William Sound glaciers are the Columbia, Barry, Harvard, Yale, and Harriman. Some of the smallest of the noble company descend flowery mountain-sides in the wildest and most imposing scenery.

Residual glaciers from a mile to 10 or 12 miles long, including neve, are distributed throughout the Rocky Mountain ranges from lat. 43° to 53°. The greater number lie between 50° and 52° 30' at the heads of the Saskatchewan, Athabasca, and Columbia rivers. The largest groups are magnificent rags and patches of an ancient ice-sheet, some of them covering an area of 40 to nearly 100 square miles, and sending down river-like glaciers six to eight miles long.

Glaciers of the third order abound on the Alps, the Pyrenees, the Caucasus, the Scandinavian Peninsula, the Andes, the lofty snow ranges of Asia, and on the mountains of New Zealand.

More than 1,000 with an area of about 1,200 square miles, have been surveyed and named in the Alps. The largest are river-like, 10 to 15 miles long, descend into the forests, and terminate at an elevation of 4,000 to 6,000 feet. Most of the smaller ones are like masses of pure snow, and terminate about 2,000 feet higher.

The Caucasus is perhaps about as heavily ice-laden as the Alps. Few of its glaciers are known to descend much lower than 6,000 and 7,000 feet. Those of the Pyrenees are comparatively small.

Many of the glaciers of Norway pour grandly down from extensive neve fields to within 1,000 feet of the sea-level. A few approach the shore and may rank as glaciers of the second order, while one, the only one in Europe of the first order, discharges into Jokul Fiord, near the 70th parallel. Between the larger glaciers flowing toward the heads of the fiords there are many hanging and cascading glaciers, ranged along the brows of plateaus, some of which pour over precipices in separated cascades, some like that of glaciers discharging into the sea. At the foot of the cliffs the battered fragments are welded, and thus these wild ice-streams, after their plunge through the air, are made whole again, and flow quietly on their way as re-generated glaciers, the space between their upper and lower parts being only a wider kind of crevasse.

The low-descending New Zealand glaciers almost rival those of the Alps in size, while their beauty is greatly enhanced by the rich vegetation through which they flow.

The glaciers of South America are distributed almost along the whole extent of the Andes. According to Whymper those under the equator attain their greatest size on the snow-laden, storm-beaten summits of Antisana, Cayambe, and Chimborazo. On Cayambe, 12 glaciers of considerable size were counted, flowing from the center of the snowy mountain descending to about 15,000 feet above sea-level. To the south of lat. 46° many approach the sea.

On the lofty mountain chains of Asia, especially the snowy Himalaya, Karakoram, Hindoo-
Kush, Kuen-Lun, and Thian-Shan, thousands of little known residual glaciers still exist. The largest which have been explored are the magnificient Biafo and Baltoro Karakoram glaciers, 30 and 55 miles long, descending to about 11,500 and 12,000 feet.

Excepting Australia, which seems to have lost all its glaciers, Africa is glacially the poorest of the continents. Its only known glaciers are those of the two great snowy mountains, Kenya and Kilimanjara, near the equator.

The Arctic islands—Jan Mayen, Nova Zembla, Spitzbergen, Franz-Joseph Land, and many others—are heavily ice-laden. Their largest glaciers are broad sheets discharging magnificent bergs into the frozen sea.

But it is on Greenland and the South Polar lands that glacier ice reaches its grandest development. Excepting a narrow interrupted strip around its shores, Greenland lies buried beneath a continuous mantle of ice thousands of feet in thickness, through which only the tops of its highest peaks, called "nunataks," protrude. From this ice-cap huge glaciers pour into the sea, discharging icebergs of enormous dimensions, some of which sail into the Atlantic thousands of miles from home.

Still greater is the South Polar ice-cap, probably over two miles in thickness. The sea front of some of the glacier currents it pours forth are from 100 to over 400 miles wide, from which flat-topped island-like icebergs 5 to 10 miles long are discharged. Here the great cosmical winter of the Glacial Period still exists in severe, serene grandeur.

Greater Extension of Glaciers.—That a great part of the earth in both the northern and southern hemispheres, now warm and fruitful, was recently covered by flowing, grinding ice, is well known. Over the eastern half of North America from the Arctic regions to lat. 40° or lower, moraines and beds of moraine material variously modified, grooved, scored, and polished surfaces, with other characteristic traces of glacial action, are displayed in wonderful abundance and uniformity.

Along the mountain ranges of the west side of the continent they extend still farther south. The broad Rocky Mountain chain and the plains along its flanks abound in glacial traces on a grand scale. On the Sierra Nevada polished and striated rock surfaces the most evanescent of glacier inscriptions may still be found as far south as lat. 36°; while a degree or two farther north, at an elevation of 7,000 to 8,000 feet above the sea, there are broad glacier pavements in so perfect a state of preservation that they reflect the sunbeams like glass and attract the attention of every observer.

Over the miles of part of Oregon, Washington, British Columbia, and the Arctic and sub-Arctic regions about Bering Sea and northwestern Alaska, the rocks in general are less resisting, and the weathering they have been subjected to is more destructive. Therefore the support of the inscriptions is less clear in these northern regions than in California.

But in all glaciated regions there are other monuments of ice action which endure for tens of thousands of years after the simpler traces we have been considering have vanished. These are the sculpture and configuration of the land, in general,—the cañons, valleys, fiords, mountains, ridges, and roches moutonnées, the forms, trends, and correlations of which are specifically glacial and almost imperishable. These also, it is true, suffer incessant waste, being constantly written upon by the elements. But because they are so colossal in size and peculiar in form and arrangement they continue to stand out clear and telling through every after-inscription, showing how great the ancient glaciers must have been, and how great are the geographical and topographical changes they have produced. On the Atlantic coast, where man is busiest, even in the parks and gardens of New York, glaciated rocks shine and call attention to the story of the Ice Period; and in orchards growing on moraine soil around the town of Victoria on the west side of the continent, fruitful boughs drop apples and peaches on the edges of glacier pavements, while the harbor rocks are still bright notwithstanding the centuries of wave-action they have been subject to. Thus striking for the works of ice must play beside the works of man; yesterday in nature's chronology our continent now so fertile was a dreary wilderness of ice. No tale of fairytale is so exciting to the imagination as the story of the works and ways of snow-crystals having their origin in glaciers of ages past to sculpturing by other agents from their white tents on the highlands to develop earth's beauty, make beds of fertile food-soil, basins for lakes, valleys for rivers; to separate continents and sculpture their shores into countless islands, bays, sounds, and fringing fiords, then vanishing like clouds.

This change from icy darkness and death to life and light was slow as we count time, and is still going on wherever glaciers exist. The great winter of the Glacial Period is giving place to a great summer before which all the world is wasting away,—the Polar ice-caps, as well as the small shrinking remnants. All are shorter, narrower, shallower than they once were. The world is growing warmer, the snow-supply diminishing. But in these changes these elements we must bear in mind that the same sunshine that wastes glaciers nourishes them. In the formation of glaciers an enormous amount of sun heat is required to produce the vapor for the snow of which they are made. For the structure and phenomena of glaciers Agassiz has written, "Gla­ciele;" J. D. Forbes, "Travels in the Alps;" and "Norway and Its Glaciers;" Tyndall, "Glaciers of the Alps."