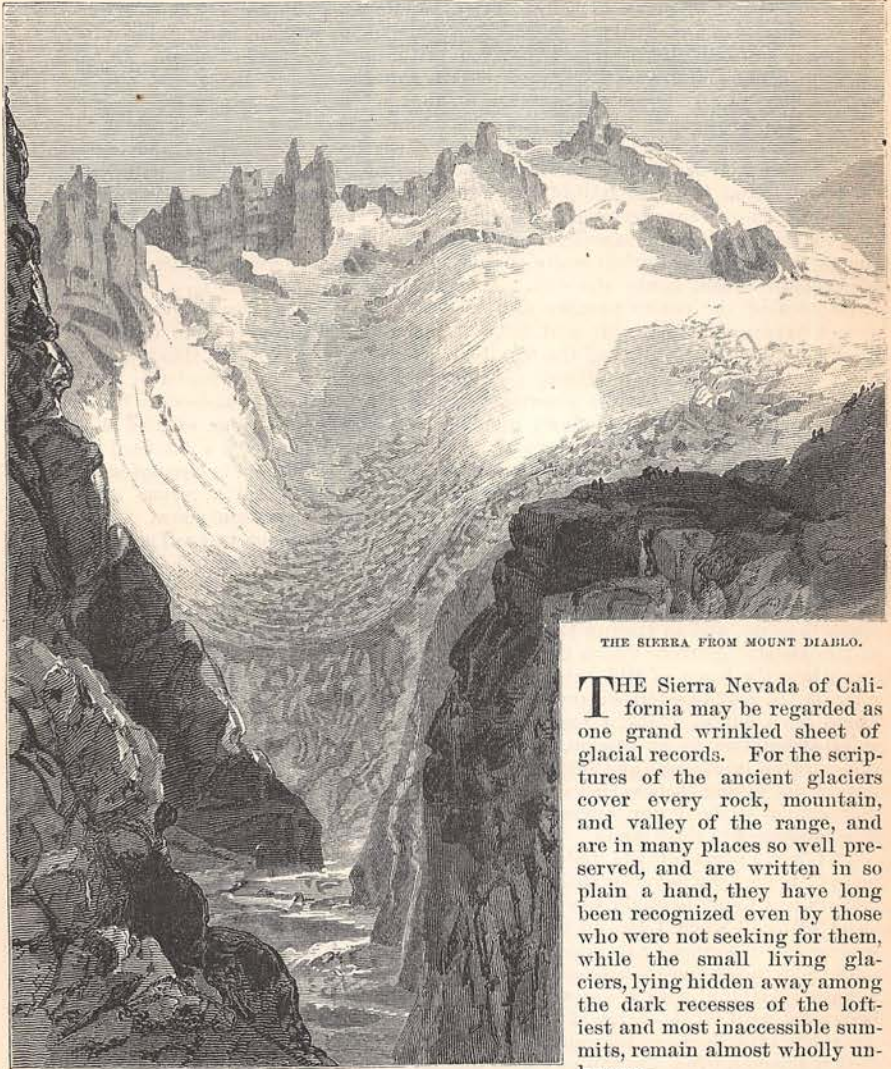


HARPER'S NEW MONTHLY MAGAZINE.

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LIVING GLACIERS OF CALIFORNIA.



THE SIERRA FROM MOUNT DIABLO.

THE Sierra Nevada of California may be regarded as one grand wrinkled sheet of glacial records. For the scriptures of the ancient glaciers cover every rock, mountain, and valley of the range, and are in many places so well preserved, and are written in so plain a hand, they have long been recognized even by those who were not seeking for them, while the small living glaciers, lying hidden away among the dark recesses of the loftiest and most inaccessible summits, remain almost wholly unknown.

Looking from the summit of Mount Diablo across the San Joaquin Valley, after the atmosphere has been washed with winter rains, the Sierra is beheld stretching along the plain in simple grandeur, like some immense wall, two and a half miles high, and colored almost as bright as a rainbow, in four horizontal bands—the lowest rose purple,

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Vol. LI.—No. 306.—51

the next higher dark purple, the next blue, and the topmost pearly white—all beautifully interblended, and varying in tone with the time of day and the advance of the seasons.

The rose purple band, rising out of the yellow plain, is the foot-hill region, sparsely planted with oak and pine, the color in great measure depending upon argillaceous soils exposed in extensive openings among the trees; the dark purple is the region of the yellow and sugar pines; the blue is the cool middle region of the silver-firs; and the pearly band of summits is the Sierra Alps, composed of a vast wilderness of peaks, variously grouped, and segregated by stupendous cañons and swept with torrents and avalanches. Here are the homes of all the glaciers left alive in the Sierra Nevada. During the last five years I have discovered no less than sixty-five in that portion of the range embraced between latitudes $36^{\circ} 30'$ and 39° . They occur scattered throughout this vast region singly or in small groups, on the north sides of the loftiest peaks, sheltered beneath broad, frosty shadows. Over two-thirds of the entire number are contained between latitudes 37° and 38° , and form the highest fountains of the San Joaquin, Tuolumne, and Owens rivers.

The first Sierra glacier was discovered in October, 1871, in a wide, shadowy amphitheatre, comprehended by the bases of Red and Black mountains, two of the dominating summits of the Merced group. This group consists of the highest portion of a long crooked spur that straggles out from the main axis of the range in the direction of Yosemite Valley. At the time of my discovery I was engaged in exploring its *névé* amphitheatres, and in tracing the channels of the ancient glaciers which they poured down into the basin of Illilonette. Beginning on the northwestern extremity of the group with Mount Clark, I examined the chief tributaries in succession, their moraines, *roches moutonnées*, and shining glacial pavements, taking them as they came in regular course without any reference to the time consumed in their study.

The monuments of the tributary that poured its ice from between Red and Black mountains I found to be far the grandest of them all; and when I beheld its magnificent moraines ascending in majestic curves to the dark, mysterious solitudes at its head, I was exhilarated with the work that lay before me, as if on the verge of some great discovery. It was one of the golden days of Indian summer, when the sun melts all the roughness from the rockiest alpine landscapes. The path of the dead glacier shone as if washed with silver, the pines stood transfigured in the living light, poplar groves were masses of orange and yellow, and solidagoes were in full bloom, adding gold to gold.

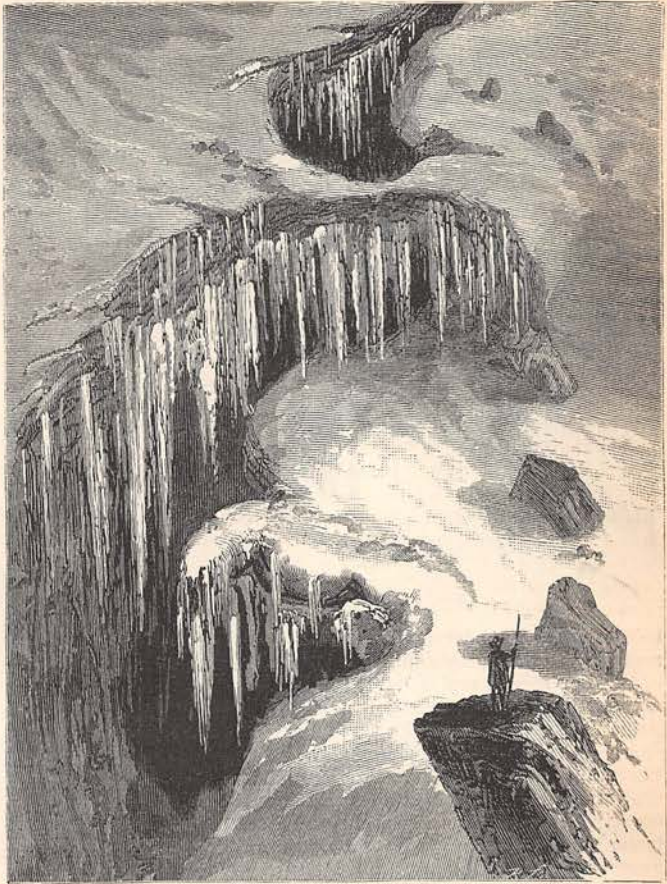
Pushing on over my glacial highway, I passed lake after lake set in solid basins of granite, and many a thicket and meadow watered by the stream; now clanking over naked rock where not a leaf tries to grow, now wading through plushy bogs knee-deep in yellow and purple sphagnum, or brushing through luxuriant garden patches among larkspurs eight feet high and lilies with thirty flowers on a single stalk. The main lateral moraines bounded the view on either side like artificial embankments, covered with a superb growth of silver-fir and pine, many specimens attaining a height of two hundred feet or more. But all this garden and forest luxuriance was speedily left behind. The trees were dwarfed. The gardens became exclusively alpine. Patches of the heathy bryanthus and cassiope began to appear, and arctic willows, pressed into flat close carpets with the weight of winter snow. The lakelets, which a few miles down the valley were so richly broided with meadows, had here, at an elevation of about 10,000 feet above the sea, only small mats of carex, leaving bare glaciated rocks around more than half their shores. Yet amidst all this alpine suppression the sturdy brown-barked mountain pine tossed his storm-beaten branches on ledges and buttresses of Red Mountain; some specimens over a hundred feet high and twenty-four feet in circumference, seemingly as fresh and vigorous as if made wholly of sunlight and snow.

Evening came on just as I got fairly within the portal of the grand fountain amphitheatre. I found it to be about a mile wide in the middle, and a little less than two miles long. Crumbling spurs and battlements of Red Mountain inclose it on the north, the sombre, rudely sculptured precipices of Black Mountain on the south, and a hacked and splintery *col* curves around from mountain to mountain at the head, shutting it in on the east.

I chose a camping ground for the night down on the brink of a glacier lake, where a thicket of Williamson spruce sheltered me from the night wind. After making a tin-cupful of tea, I sat by my camp fire, reflecting on the grandeur and significance of the glacial records I had seen, and speculating on the developments of the morrow. As the night advanced, the mighty rocks of my mountain mansion seemed to come nearer. The starry sky stretched across from wall to wall like a ceiling, and fitted closely down into all the spiky irregularities of the summits. After a long fireside rest and a glance at my field-notes, I cut a few pine tassels for a bed, and fell into the clear death-like sleep that always comes to the tired mountaineer.

Early next morning I set out to trace the ancient ice current back to its farthest re-

cesses, filled with that inexpressible joy experienced by every explorer in nature's untrodden wilds. The mountain voices were still as in the hush of evening; the wind scarce stirred the branches of the mountain pine; the sun was up, but it was yet too cold for the birds and marmots—only the stream, cascading from pool to pool, seemed wholly awake and doing. Yet the spirit of the opening, blooming day called to action. The sunbeams came streaming gloriously through jagged openings of the *col*, glancing on ice-burnished pavements, and lighting the mirror surface of the lake, while every sunward rock and pinnacle burned white on the edges, like melting iron in a furnace. I passed round the north shore of the lake, and then followed the guidance



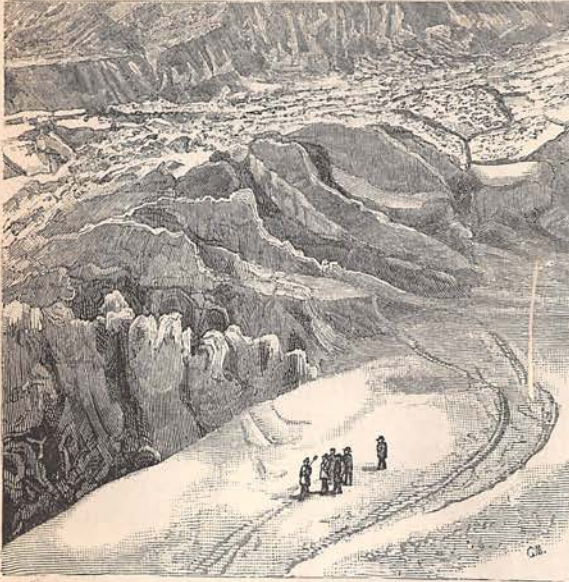
THE BERGSCHRUND OF BLACK MOUNTAIN GLACIER.

of the stream back into the recesses of the amphitheatre. It led me past a chain of small lakelets set on bare granite benches, and connected by cascades and falls. The scenery became more rigidly arctic. The last dwarf pine was left far below, and the stream was bordered with icicles. As the sun advanced, rocks were loosened on shattered portions of the walls, and came bounding down gullies and *coulairs* in smoky, spattering avalanches, echoing wildly from crag to crag.

The main lateral moraines, that stretch so formally from the huge jaws of the amphitheatre out into the middle of the Illilouette basin, are continued upward in straggled masses along the amphitheatre walls, while separate stones, thousands of tons in weight, are left stranded here and there out in the middle of the main channel. Here, also, I observed a series of small, well-characterized, frontal moraines, ranged in regular order along the south wall of the amphitheatre, the shape and size of each moraine corresponding with the shapes and sizes of

the daily shadows cast by different portions of the walls. This correspondence between moraines and shadows afterward became plain.

Tracing the stream back to the last of its chain of lakelets, I noticed a fine gray mud covering the stones on the bottom, excepting where the force of the entering and out-flowing currents prevented its settling. On examination it proved to be wholly mineral in composition, and resembled the mud worn from a fine-grit grindstone. I at once suspected its glacial origin, for the stream which carried it came gurgling out of the base of a raw, fresh-looking moraine, which seemed to be in process of formation at that very moment. Not a plant, lichen, or weather-stain was any where visible upon its rough, unsettled surface. It is from sixty to over a hundred feet in height, and comes plunging down in front at an angle of thirty-eight degrees, which is the very steepest at which this moraine material will lie. Climbing the moraine in front was, therefore, no easy undertaking. The slightest



MOUNT SHASTA GLACIER.

touch loosened ponderous blocks, that went rumbling to the bottom, followed by a train of smaller stones and sand. Picking my way with the utmost caution, I at length gained the top, and beheld a small but well-characterized glacier swooping down from the sombre precipices of Black Mountain to the terminal moraine in a finely graduated curve. The solid ice appeared on all the lower portions of the glacier, though it was gray with dirt and stones imbedded in its surface. Farther up, the ice disappeared beneath coarsely granulated snow.

The surface of the glacier was still further characterized by dirt bands and the outcropping edges of blue veins that swept across from side to side in beautiful concentric curves, showing the laminated structure of the mass of the glacier ice. At the head of the glacier, where the *névé* joined the mountain, it was traversed by a huge yawning *Bergschrund*, in some places twelve or fourteen feet wide, and bridged at intervals by the remains of snow avalanches. Creeping along the edge of the *Schrund*, holding on with benumbed fingers, I discovered clear sections where the bedded and ribbon structure was beautifully illustrated. The surface snow, though every where sprinkled with stones shot down from the cliffs above, was in some places almost pure white, gradually

becoming crystalline, and changing to porous whitish ice of different shades, and this again changing at a depth of twenty or thirty feet to bluer ice, some of the ribbon-like bands of which were nearly pure and solid, and blended with the paler bands in the most gradual and exquisite manner imaginable, reminding one of the way that color bands come together in a rainbow.

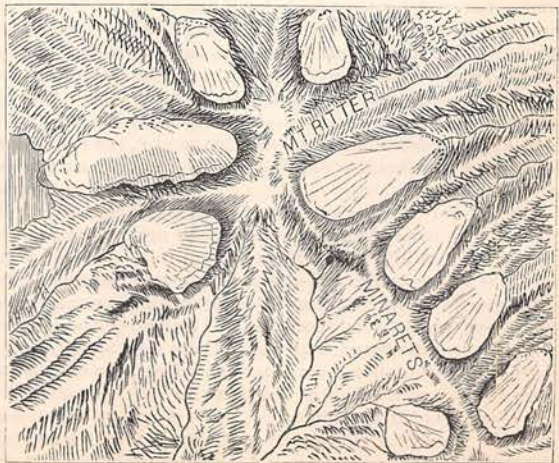
A series of rugged zig-zags enabled me to make my way down into the weird ice world of the *Schrund*. Its chambered hollows were hung with a multitude of clustered icicles, amidst which thin subdued light pulsed and shimmered with indescribable loveliness. Water dripped and tinkled overhead, and from far below there came strange solemn murmurs from cur-

rents that were feeling their way among veins and fissures on the bottom.

Ice creations of this kind are perfectly enchanting, notwithstanding one feels so entirely out of place in their pure fountain beauty. I was soon uncomfortably cold in my shirt sleeves, and the leaning wall of the *Schrund* seemed ready to engulf me. Yet it was hard to leave the delicious music of the water, and still more the intense loveliness of the light.

Coming again to the surface of the glacier, I noticed blocks of every size setting out on their downward journey to be built into the terminal moraine.

The noon sun gave birth to a multitude



GLACIER OF MOUNT RITTER.

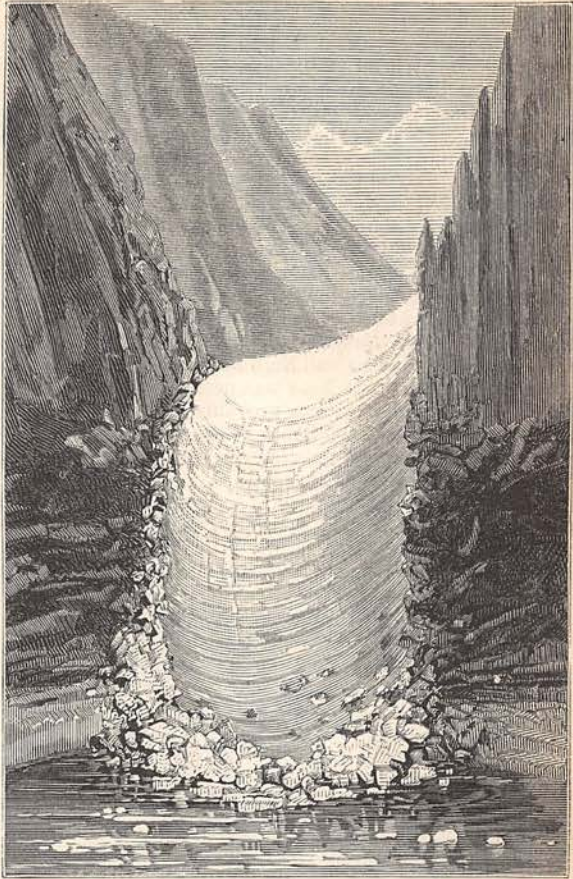
of sweet-voiced rills that ran gracefully down the glacier, curling and swirling in their shining channels, and cutting clear sections in which the structure of the ice was beautifully revealed.

The series of frontal moraines I had observed in the morning extending along the base of the south wall of the amphitheatre corresponds in every particular with the moraines of this active glacier; and the causes of all that is special in their forms and order of distribution with reference to shadows now plainly unfolded themselves. When those climatic changes came on that broke up the main glacier that once filled the amphitheatre from wall to wall, a series of residual glaciers was left in the cliff shadows, under whose protection they lingered until they formed the frontal moraines we are studying. But as the seasons became warmer, or the snow supply became less abundant, they died in succession, all excepting the one we have just examined, and the causes of its longer life are sufficiently apparent in the greater extent of snow basin it drains and in its more perfect shelter from the sun. How much longer this little glacier will live will, of course, depend upon climate and the changes slowly effected in the form and exposure of its basin.

Soon after this discovery I made excursions to the ice wombs situated on the head cañons of the Tuolumne and San Joaquin, and discovered that what at first sight and from a distance resemble extensive snow-fields are really active glaciers, still grinding the rocks over which they flow, and thus completing the sculpture of the summits so grandly blocked out by their giant predecessors.

That these residual glaciers are wearing the rocks on which they flow is shown by the fact that all the streams rushing out from beneath them are turbid with finely ground rock mud. They all present solid ice snouts creeping out from beneath their fountain snows, and all are carrying down stones that have fallen upon them, to be at length deposited in moraines.

All the specific crevasses of glaciers are also exhibited by them—marginal, transversal, and the jagged-edged *Bergschrund*. In



END OF THE NORTH RITTER GLACIER DESCENDING INTO GLACIER LAKE.

some transversal crevasses, as, for example, near the middle of the eastern branch of the Lyell Glacier, sections of blue ice eighty to a hundred feet deep occur, while the differential motion is manifested in the curves of the dirt bands and of the blue veins and moraines, not a single glacial attribute being either wanting or obscure. But notwithstanding the plainness and completeness of the proof, some of my friends who never take much trouble to investigate for themselves continued to regard my observations and deductions with distrust. I therefore determined to fix stakes in one of the more accessible of the glaciers, and measure their displacement, with a view to making the ordinary demonstration of true glacial movement, while subserving other desirable objects at the same time. The Maclure Glacier, situated on the north side of the mountain of that name, seemed best fitted for my purposes, and, with the assistance of my friend Galen Clark, I planted five stakes in it on the 21st of August, 1872, guarding against their being melted out by sinking

them to a depth of five feet. Four of them were extended across the glacier in a straight line, beginning on the east side about halfway between the head and foot of the glacier, and terminating near the middle of the current. Stake No. 1 was placed about twenty-five yards from the side of the glacier; No. 2, ninety-four yards; No. 3, one hundred and fifty-two yards; No. 4, two hundred and twenty-five yards. No. 5 was placed up the glacier about midway between the *Bergschrund* and No. 4. On the 6th of October, or forty-six days after being planted, I found the displacement of stake No. 1 to be eleven inches, No. 2 to be eighteen inches, No. 3 to be thirty-four inches, No. 4 to be forty-seven inches, and No. 5 to be forty-six inches. As stake No. 4 was near the middle of the current, it was probably not far from the point of maximum velocity—forty-seven inches in forty-six days, or about one inch per twenty-four hours.

On setting out from Yosemite Valley to fix stakes in the Maclure Glacier, I invi-

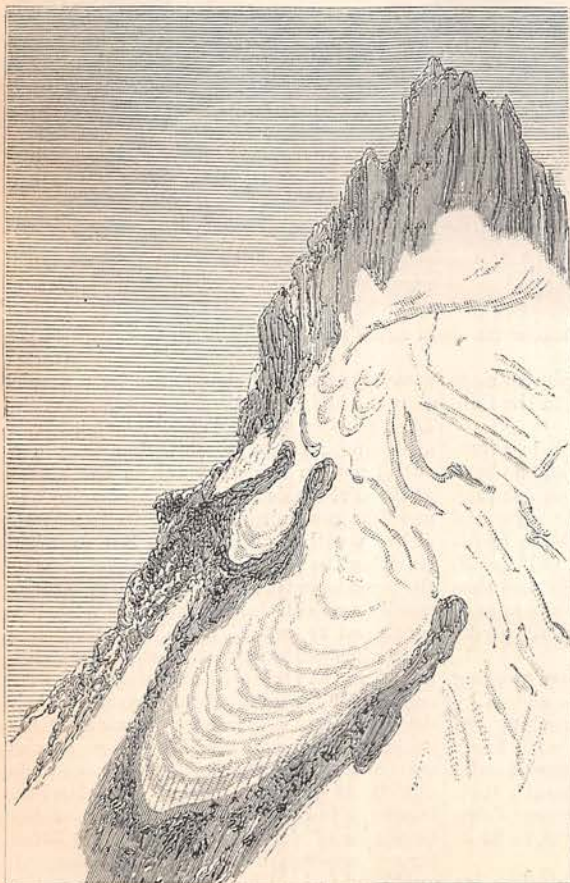
ted Professor Joseph Leconte to accompany me. He had already given in his adhesion to my glacial theory for the formation of Yosemite Valley, and I was anxious to direct attention to other erosive effects of the ancient glaciers in the formation of mountains, ridges, lake basins, etc., as well as to point out some of the newly discovered glaciers.

Shortly after his return to Oakland he prepared a paper "On some of the Ancient Glaciers of the Sierra," which was read before the California Academy of Sciences, and afterward published in the *American Journal of Science and Arts*, in which he says, "Here, then" (on Mount Lyell), "we have now existing not a true glacier, perhaps, certainly not a typical glacier (since there is no true glacier ice visible, but only snow and *névé*, and certainly no protrusion of an icy tongue beyond the snow-field), yet nevertheless in some sense a glacier."

The above is an example of the rashness sometimes evinced by scientific observers in allowing themselves to decide upon imperfect data. Professor Leconte had never before seen a glacier of any kind, and did nothing more by way of investigation of this one than to spend a few minutes on the terminal moraine. Yet this, it seems, was deemed sufficient to enable him to decide "certainly" concerning it. Now the Lyell Glacier, which Professor Leconte approached, but did not set foot upon, was at the time of his visit (August 19) still covered with winter snow. Had his visit been delayed a few weeks he would have observed the required "icy tongue protruding from beneath the *névé*," because by this time the sun melted the covering of snow, and, according to his own chosen definition, the glacier suddenly became changed to a typical one.

As to the statement, "there is no true glacier ice visible," it is only necessary to observe that though there was none visible from the moraine where he was seated, there were many fine sections of "true glacier ice" visible in marginal and transversal crevasses, had he taken the pains to reach them.

Great vagueness prevails concerning the essential



GLACIER ON THE NORTHEAST SIDE OF MOUNT RITTER, SHOWING PROTRUDING ICE TONGUE AND A WEB-WORK OF CREVASSES.



RUSH CREEK GLACIER, ON THE EASTERN SLOPE OF THE SIERRA, NORTH OF MOUNT RITTEL.

characteristics of glaciers. The icy snout creeping down out of the *névé* fountains is not available for all glaciers at all seasons, because in years of extraordinary snow-fall the whole surface of some slow-flowing glaciers remains covered during the whole year, and would accordingly be classified as true glaciers one season, *névé* fields another; and, as we have seen, the Lyell Glacier, though not typical in August, became typical in September.

A glacier is a current of ice derived from snow. Complete glaciers of the first order take their rise on the mountains, and descend into the sea, just as all complete rivers of the first order do. In North Greenland the snow supply and general climatic conditions are such that its glaciers pour directly into the ocean, and so undoubtedly did those of the Pacific slope during the flush times of the glacial epoch; but now the world is so warm and the snow crop so scanty, nearly all the glaciers left alive have melted to mere hints of their former selves. The Lyell Glacier is now less than a mile

long; yet, setting out from the frontal moraine, we may trace its former course on grooved and polished surfaces and by immense cañons and moraines a distance of more than forty miles.

The glaciers of Switzerland are in a like decaying condition as compared with their former grandeur; so also are those of Norway, Asia, and South America. They have come to resemble the short rivers of the eastern slope of the Sierra that flow out into the hot plains and are dried up. According to the Schlagintweit brothers, the glaciers of Switzerland melt at an average elevation above the level of the sea of 7414 feet. The glacier of Grindelwald melts at less than 4000 feet; that of the Aar at about 6000. The Himalaya glacier, in which the Ganges takes its rise, does not, according to Captain Hodgson, descend below 12,914 feet. The average elevation at which the glaciers of the Sierra melt is not far from 11,000 feet above sea-level. The Whitney Glacier, discovered by Clarence King, is situated on the north side of Mount Shasta, and descends

to 9500 feet above the sea, which is the lowest point reached by any glacier within the limits of California. Mount Shasta, however, is an isolated volcanic cone, and can not in any sense be regarded as a portion of the Sierra. Mount Whitney, situated near the southern extremity of the Sierra, although the highest mountain in the range (nearly 15,000 feet), does not give birth to a single glacier. Small patches of perpetual snow and ice occur on its northern slopes, but they are shallow, and give no evidence of glacial motion. Its sides, however, are still brilliantly polished by vanished glaciers that once descended into the main trunk glacier of Kern Valley on the west and to the Owens River on the east.

Mount Ritter, about 13,300 feet in height, still nourishes five glaciers, which, though small, are exceedingly well characterized, and differ in no particular from those of Switzerland excepting in degree. The finest of the five is on the north side, and flows at first in a northerly direction, then curves toward the west, and descends into a small blue glacier lake, whose banks around more than half its circumference are buried beneath perpetual snow. The outcropping edges of "the blue veins" are presented on the lower portion of this glacier, sweeping across the snout in fine concentric curves, scarcely marred by the rocky *débris* with which the glacier is laden. This beautiful glacier forms one of the highest sources of the North Fork of the San Joaquin.

Another of the Ritter glaciers, situated on the northeastern slopes of the mountain, is drained by a branch of Rush Creek, which flows into Mono Lake on the east side of the range. All the sixty-five Sierra glaciers that I have observed are a survival of the best fed and most favorably situated.

The Sierra granite is admirably fitted for the reception and preservation of glacial records, and from these it is plain that the Sierra ice once covered the whole range continuously as one sheet, which gradually broke up into individual glaciers, and these again into small residual glaciers arranged with reference to shadows. These last were very numerous; several thousand existed on the western flank alone, differing in no way from those that still linger in the highest and coolest fountains.

All the glaciers of California occur upon the north sides of mountains, and flow northward; or if they flow in an easterly or westerly direction, they are contained between protecting ridges trending in the same direction.

Furthermore, because the main axis of the Sierra extends in a north-northwesterly direction, the east side of the range is longer in shadow, and the greater number of the glaciers that occur along the immediate axis are on the east side.

The transformation of snow into glacier ice varies as to place and rapidity with the climate and with the form of the basin in which the fountain snow is collected. In the Sierra there is no definite snow-line, and therefore no fields of fountain snow extending to determinate elevations above the glaciers for the true glacier ice gradually to merge into. The change, therefore, of snow to flowing ice is more abrupt in the Sierra Nevada than in the Alps or in any mountain range possessed of perpetual snow not dependent upon shadows.

The whole number of active glaciers in the Alps is, according to the Schlagintweit brothers, 1100, of which one hundred may be regarded as primary. The total surface of snow, *névé*, and ice is estimated at 1177 square miles, or an average area of about one square mile per glacier. Some of the Sierra glaciers are as large; as, for example, the Lyell, North Ritter, and several that are nameless on the head of the South and Middle forks of the San Joaquin.

The main cause that has prevented the earlier discovery of Sierra Nevada glaciers is simply the want of explorations in the regions where they occur. The labors of the State Geological Survey in this connection amounted to a slight reconnaissance, while the common tourist, ascending the range only as far as Yosemite Valley, sees no portion of the true Alps containing the glaciers excepting a few peak clusters in the distance.

In the Swiss Alps carriage roads approach within a few hundred yards of some of the low-descending glaciers, while the comparative remoteness and inaccessibility of the Sierra glaciers may be inferred from the fact that, during the prosecution of my own explorations in five summers, I never met a single human being, not even an Indian or a hunter.

THE FILLET.

Love has a fillet on his eyes;
 He sees not with the eyes of men;
 Whom his fine issues touch despise
 The censures of indifferent men.
 There is in love an inward sight,
 That nor in wit nor wisdom lies;
 He walks in everlasting light,
 Despite the fillet on his eyes.

If I love you, and you love me,
 'Tis for substantial reasons, sweet—
 For something other than we see,
 That satisfies, though incomplete;
 Or, if not satisfies, is yet
 Not mutable, where so much dies;
 Who love, as we, do not regret
 There is a fillet on Love's eyes!

R. H. STODDARD