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WHY WE SHOULD MEASURE OUR GLACIERS*

By François E. Matthes

THE Sierra Club has recently joined a movement that is rapidly gaining impetus throughout the Pacific and Rocky Mountain States—a movement to secure annual measurements of the variations in length and volume of the glaciers in the United States, the purpose being to ascertain the nature and trend of these variations, which doubtless are caused by climatic fluctuations now in progress. A committee, under the chairmanship of Oliver Kehrlein, has been appointed to take part in this work, and the members of that committee are now making annual visits to the more important glaciers of the Sierra Nevada and Mount Shasta. The results obtained by them are forwarded to the Committee on Glaciers of the American Geophysical Union, which inaugurated this program of annual glacier measurements a few years ago and which constitutes the central agency for collecting, tabulating, and publishing the glacier data from all parts of the United States, including Alaska.

Among those who faithfully collaborate with the central committee in this far flung enterprise may be named the Research Committee of the Mazamas, which as early as 1928 began to make regular measurements to the fronts of certain glaciers on Mount Hood; the Park Naturalists of Yosemite, Mount Rainier, Glacier, and Rocky Mountain national parks; and the Superintendent of Mount McKinley National Park, Alaska. The National Park Service naturally plays a prominent part in this work, for the majority of the larger glaciers in the continental United States lie within its reservations. To this service, moreover, belongs the credit of having instituted the first systematic glacier measurements in the United States, namely those on the Nisqually Glacier on Mount Rainier. As a result there is now at hand a continuous and extremely valuable record covering the recession of that glacier for 16 years.

Space hardly permits mentioning individuals who are coöperating, but one there is whom I would not overlook—namely, our friend Bert Harwell, of Yosemite National Park. Not only has he organized and systematized in exemplary fashion the business of measuring glaciers in his official domain, but he has lifted it from a mere routine to a rite of almost dramatic interest to the people of California. And that is, indeed, a most fortunate circumstance, for the story which the glaciers are telling, slowly, mutely, through the years, may, for all we know, contain a fateful portent for the future.

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And that brings me to the question: Why is it important that we should measure our glaciers? What need is there of going to all of this trouble, and what purpose will be served by the results?

The answer is that glaciers are extremely sensitive to climatic fluctuations and register them more vividly than do streams, springs, lakes, or vegetation; and since we have so delicately, so daringly adjusted some of our great agricultural and engineering enterprises and their dependent industries to existing climatic conditions, it behooves us for the good of our complex American civilization to keep a close watch on climatic changes or fluctuations, however slight and transient, that may be taking place.

True, our meteorologists render efficient service with their accurate daily measurements of temperature, atmospheric pressure, precipitation, and humidity; and glaciers are after all very imperfect and complex meteorological instruments, varying among themselves by reason of differences in length and shape, in topographic situation, and exposure with respect to sun and wind, so that a number of local factors must be taken into account in the interpretation of each individual record. And the advances and recessions of their fronts or termini (I positively refuse to employ the inelegant term "snout") are but indirect effects of accessions of new snow on the one hand and of losses by melting and evaporation on the other. Nevertheless and notwithstanding all these disadvantages, glaciers offer supplementary information regarding climatic conditions that is not lightly to be disregarded.

An excellent illustration is afforded by the Nisqually Glacier on Mount Rainier. At the very time when the records of the national weather service, covering many decades, seemed to contain nothing bearing out the popular belief that perceptible climatic changes were actually in progress, or at least had taken place since times within the memory of the older generation, the Nisqually was melting back steadily at the very perceptible average rate of 60 feet per year. Indeed, since 1918, when the National Park Service began its annual measurements, the Nisqually has receded a total of 1081 feet. In

addition, it is known from reliable observations by the late James Longmire, the first white settler at the foot of the peak, that in 1885 the glacier reached down to the place now occupied by the highway bridge. And the descriptions of Lieutenant (later General) A. V. Kautz, who in 1857 made the first attempt to climb the peak, permit us to locate the position of the glacier's terminus at that early date, with a fair degree of accuracy, at a point 760 feet below the present site of the bridge. Accordingly it is reasonably certain that the Nisqually receded 760 feet from 1857 to 1885; 140 feet from 1885 to 1892; and 1310 feet from 1892 to 1918. Its total known recession prior to 1918 therefore was no less than 2210 feet, and in all, the glacier has been shortened 3291 feet, or nearly two-thirds of a mile, since it was first sighted by white men.

It is noteworthy, further, that the Nisqually's recession shows no signs of slowing up as the terminus reaches higher and higher elevations. On the contrary, it is proceeding now at more and more rapid rates. From 1857 to 1885 the recession took place at a mean rate of slightly over 27 feet per year; from 1885 to 1892 the mean rate was 20 feet per year; from 1892 to 1918 the mean rate was 50.4 feet per year; and since then the rate has increased to nearly 68 feet per year. The most rapid recession was observed in 1934, when it reached 155 feet. Three other large glaciers on Mount Rainier on which measurements were begun a few years ago—the Carbon, Emmons, and South Tahoma—show in the main comparable rates of recession, varying somewhat with their dimensions and orientations.

It might be argued, perhaps, that this rapid and continued recession of the glaciers on Mount Rainier is occassioned not by a climatic change but by a gradual rekindling of the volcanic fires beneath the peak. If that were true, however, the glaciers on Mount Rainier would constitute an exceptional, isolated case, but the fact is that the glaciers on the Rocky Mountains, notably in Glacier National Park, where volcanic action is wholly absent, also are rapidly melting back, and appear to have done so for several decades. The recessions of those glaciers, it is true, are on a much smaller scale than those of the glaciers on Mount Rainier, but they are roughly proportionate to the size of the ice bodies concerned.

Comparison of recent photographs with those which I took in 1900 and 1901, while mapping that region, show plainly the reductions in length and thickness which the Blackfoot and Sperry

glaciers have suffered: they reveal the sadly emaciated appearance of the Grinnell Glacier, which formerly filled its ampitheater quite snugly; and they advertise conspicuously the complete disappearance of the glacieret that clung so spectacularly just below the summit of Going-to-the-Sun. Altogether it is evident that Glacier National Park now is not nearly so beglaciered and besnowed as it was at the beginning of this century.

The Sierra Nevada, too, has lost much of its snow and ice during the past 50 years. Photographs taken by the late Professor I. C. Russell in 1883 show, for instance, that the front of the Lyell Glacier then was fully 300 feet nearer to the terminal moraine than it now is; likewise that the Dana Glacier extended at least 100 feet farther out towards its terminal moraine than it does at present. But these figures do not adequately express the real magnitude of the changes that have taken place in these ice bodies. Both of them have been greatly reduced in thickness and consequently in volume. For the Lyell Glacier this reduction is difficult to estimate, but for the Dana Glacier, which is relatively circumscribed, comparisons with the aid of Professor Russell's photograph have led Assistant Park Naturalist M. E. Beatty to estimate that the loss may amount to fully one-third of the total mass, as it existed in 1883. This is a far greater loss, proportionately, than that which the Nisqually Glacier has suffered in the same interval.

There is ample evidence, further, that a host of small cirque glaciers have vanished from the range during relatively recent times. The little glacier under Merced Peak which John Muir discovered to his surprise and joy, in 1871, is a typical example. It is, in fact, the one which gives us the clue to the disappearance of all of the others. It was no mere snow bank but a real though small residual glacier, composed of laminated ice and rent by crevasses due to its gravitational movement, as Muir clearly perceived, yet all that now remains in its empty cirque, as Mr. Harwell can testify, is the terminal moraine that was built up at its front. Now there are throughout the High Sierra scores, if not hundreds, of empty cirques that contain short moraine loops of the same fresh, unweathered type. To mind come at once the small cirque to the south of Fletcher Lake, which is shut in by a marvellously perfect moraine wall, and the larger cirque at the head of Fletcher Creek, which contains a longer but less conspicuous moraine loop; for these were among the

first to attract my attention in the Yosemite National Park, back in 1913. There is no need to enumerate other examples, for features of this kind must be familiar to all who have mountaineered in the High Sierra. Suffice it to say that there is little doubt in my mind, after several years of intensive study of glacial moraines in the Sierra Nevada, that every one of those cirques contained a small glacier some fifty or sixty years ago, or to put it more broadly, during the nineteenth century.

In this connection it would be a real satisfaction to learn the approximate date of the disappearance of Muir's little glacier. Does any member of the Sierra Club perchance possess first hand information concerning it?

This much is certain in any event that the fresh, unweathered moraines in question do not date back to the glacial epoch. Their age is to be measured not in thousands and tens of thousands of years but in decades and centuries. For that matter, the massive moraine loops that encircle the Lyell, Maclure, Dana, Darwin, and Palisade glaciers belong to the same category. They differ from those in the empty cirques only in that the glaciers by which they were built still lie within them, though greatly shrunken in size. These glaciers have survived because they were the most favorably situated for the amassment of snow as well as for its conservation; they are the last remaining ones of a great array of dazzling ice bodies that adorned the Sierra Nevada during early historic times.

In the Alps of Switzerland and Savoy it has been found possible to date some of the more recent moraines; for there mountain communities have existed for many centuries, and in their archives occur descriptions of the specific glacial advances by which these moraines were laid down. In fact, by assiduous research of this kind Paul Mougin, of the *Département d'Eaux et Forêts* (Department of Water Resources and Forests), succeeded in reconstructing from authentic documentary evidence the oscillations of the glaciers on the French side of the Mont Blanc chain as far back as 1580. As a result it is definitely known that the glaciers in the Alps were relatively small prior to the 16th century; that they then increased considerably in length and volume, and maintained their great size, except for minor oscillations, up to the middle of the 19th century. After that a general recession set in which was checked by a minor re-advance from 1875 to 1898. The later details of this desultory recession,

which has been more pronounced in some parts of Europe than in others, and in places even offset by slight advances, may be gleaned from the reports of the International Glacier Commission, which systematically gathered these data from 1894 to the beginning of the World War; also from the reports of its successor, the *Commission Glaciologique,* which was appointed by the International Geodetic and Geophysical Union in 1927.

There is, of course, no hope that we shall ever be able to trace the oscillations of the American glaciers back as far and as accurately as those of the French and Swiss glaciers have been traced, because of the recency of the settlement of this country. Kautz's observation on the terminus of the Nisqually Glacier, in 1857, appears to be the earliest bit of information that we have concerning any glacier in the continental United States.[1] For the Sierra glaciers our data do not go farther back than those of Professor Russell in 1883. It is truly unfortunate that the Spanish and American pioneers, who had so much energy and enterprise, did not explore the mountains far enough to get in sight of the glaciers. Their interests, however, lay elsewhere.

Nevertheless, in the Sierra Nevada at least two significant facts concerning the past oscillations of the glaciers can be learned from the character and disposition of their moraines. And these two facts afford us an enlightening perspective on the climatic fluctuations that have occurred during recent centuries.

In the first place it is patent to the trained eye of a glaciologist that the short moraine loops in the cirques of the High Sierra are very much younger than the youngest moraines of the ice age. They constitute a series by themselves unconnected by any transitional forms with the moraines of glacial times, and there is therefore good reason to believe that they belong to an epoch that was separated from the ice age by a considerable interval. What happened in that interval? Did the glaciers of the ice age die away altogether, so that the Sierra Nevada was divested of all ice? Yes, as I interpret the glacial record, that is precisely what happened. And after that warm interval the climate again turned cooler and a new generation of cirque glaciers was born. The Lyell, Maclure, Dana, and others are the last of that later generation.

[1] The Committee on Glaciers would greatly appreciate being informed of any other early data on the state of glaciers in this country or Alaska that may be known to the readers of the SIERRA CLUB BULLETIN.

There is, I should add, nothing particularly heterodox in this idea of an interval of warm climate—warmer than now prevails—following the ice age. Such a warm interval has long been recognized by European glaciologists, and there is abundant proof of it throughout the northern hemisphere. To mention but two bits of evidence of special interest to Americans: The Norsemen who centuries before Columbus made his voyage of discovery settled upon the shores of Greenland, there found thriving forests, where now the barren ground is permanently frozen. This is proved by the fact that their graves, now encased in frozen soil, are pierced by the roots of trees that have long since ceased to grow in Greenland. And to come closer home: High up on the southwest slope of Mount Hood the Mazamas in 1931 discovered the remains of a forest of tall, straight trees that lie buried beneath a recent moraine of the Zigzag Glacier. That forest, though not composed of timber line trees, had flourished at a level somewhat higher than the present timber line and then was overwhelmed by the glacier, which more recently has retreated up the mountain side. Evidently at a time not so very remote the timberline on Mount Hood was about a thousand feet higher than it now is.

The other fact that is evident from a study of the moraine loops in the Sierra cirques is that they are the product of a long series of small glacial advances that were all approximately of the same general magnitude. In many of the cirques the glacial advances were so nearly equal that the terminal moraines were piled against and upon one another until there resulted a single embankment that now seems disproportionally big for the small glacier that built it. In other cirques, however, the glacial advances differed somewhat in extent and the terminal moraines lie more or less spread out in consequence, so that many of them can be counted. Most instructive in this respect is the beautifully rhythmic series of moraines in the cirque south of Kuna Peak. They lie closely pressed against one another, yet with moats between the crests, all repeating the same curves and angles that outline the lobes of the ancient ice front. How many moraines there are in the series I cannot say, as they were partly covered by fresh snow when I saw them in 1916; but I should judge that there may readily be a dozen or more. I certainly hope that before long someone will visit that cirque and make a complete and accurate count.

There can be no doubt that these moraines in the Kuna cirque record a rhythmic series of climatic pulsations of gradually diminishing intensity. How many years or decades are represented by each moraine crest, how many centuries by the entire series, is still a matter of guess, but in any event they show us that such a series of moderate climatic pulsations has been in progress for a long time and has led right up to the present. If it continues, all well and good, for such moderate climatic pulsations will work no hardship on us. They probably correspond to the recurrent waves in the climatic curve that are indicated by the rings in the Big Trees. If, on the other hand, there should come a decided departure from this mild see-saw in our climate, then we might indeed suffer. Which way fate lies, our annual glacier measurements will tell, and possibly even may foretell, in the course of time. Let us therefore continue them faithfully, assured that our efforts are really worth while, and will yield results of economic as well as scientific value to posterity.