The Dam at Moraine Lake

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IN the first number of the *American Alpine Journal,* in an interesting article entitled "Climbs from the Fay Hut", Mr. Joel E. Fisher refers to an unusual condition of a cliff above the Fay Glacier where there are indications of an impending rock fall. He continues to say, "Before long, it will no doubt come away altogether and seek the valley, with a result similar to the so-called 'moraine' of Moraine Lake."

It is evident from this that Mr. Fisher does not believe in a glacial origin for the Moraine Lake dam and prefers to consider it a rock slide. With this opinion there are many people who not only agree but who have so expressed themselves from time to time, ever since the lake was named. The great majority of geologists, however, conclude that this formation is a true moraine and cannot possibly be a rock slide.

During a number of years previous to 1899, the writer made an extensive study of the glacial phenomena of the more accessible parts of the Canadian Rockies and published the results under the title "A Certain Type of Lake Formation in the Canadian Rocky Mountains," in the *Journal of Geology,* Vol. vii, 1899. In the same year, also, he gave the name to Moraine Lake, in the belief that the rock pile that dams the lake was a true moraine. It seems fitting therefore that he should restate at the present time the arguments that support this conclusion. This he will endeavor to do as clearly as possible and at the same time present fairly all the facts that point to a contrary interpretation.

First let us briefly examine the evidences of glacial action in the Valley of the Ten Peaks. The upper part of the valley is partly occupied by the Wenkchemna Glacier, which is of the piedmont type, formed by the amalgamation of several smaller ice streams descending from the mountains on the southeast side of the valley. Its heavy covering of rock debris retards melting and the movement of the ice is almost negligible. The glacier is about three miles wide and half a mile long. The motion of the ice, such as it is, must be described as more or less transversely across the valley rather than in the direction

of its axis. In some places there are evidences of a recent advance on the forest, where trees are partially buried and bent over by newly formed moraine. In addition to these unusual features, the stream that comes from this glacier is of crystal clearness, a circumstance almost unique in these mountains.

This glacier is, of course, a remnant of the much greater ice stream that filled the valley in the Ice Age, which terminated about nine or ten thousand years ago. It left lateral and ground moraine formations throughout the lower parts of the valley, and these have undergone practically no changes since, the forests having protected them from undue erosion.

The most conspicuous change that has taken place since the Ice Age is the formation of the immense talus slopes on the east side of the valley. They began to build up immediately after the retreat of the Pleistocene glaciers and have continued to the present with unabated activity, so much so, in fact, that it is dangerous to approach these slopes without using great care and vigilance against the frequently falling stones.

The only other formation of comparatively recent date is the pile of debris that partially, if not entirely, dams Moraine Lake. It is taken for granted that there are only two theories for its origin—a rock slide or a moraine. Moraines are so clearly understood that there is no need to describe them here beyond stating that they are usually sharp-ridged formations, more or less parallel to the sides and ends of glaciers. They often assume the form of a series of nearly parallel ridges owing to successive advances and retreats of the ice. They are composed of clay, gravel, cobbles, and boulders of large size, almost invariably arranged without any semblance of stratification. Many of the larger stones are striated and show evidences of glacial action.

Rock slides appear to be far less clearly understood. Catastrophic rock slides in which immense masses of material fall at one time are comparatively rare. The usual condition is a series of intermittent rock falls of a few stones, which, descending through many centuries, as a result of rain, frost and changes of temperature, build up piles of debris that rest against the sides of the mountains. These are known as talus slopes. They have a certain "angle of repose" which is the balance between gravity and friction, and which is always maintained in each and every part of a talus slope with very small variation. Moreover whether the entire mass of a talus slope falls at one time or

little by little through many centuries, the resulting slides will have the same angle of repose and the same profile under both conditions.

But a fact of supreme importance in this problem is that rock slides never go up hill and hence they do not and cannot make ridges or piles of debris higher than their course of descent. The motion of rock slides is always downward and outward, in a fan-like form, from their sources of origin. This statement, while opposed to popular conception, is based on both theory and fact and in the course of nearly forty years observation in the Canadian Rockies, the writer has never discovered an authentic rock slide that proved the contrary.

In other words rock slides, large or small, must not be considered as resembling in any way, or acting like, a liquid mass or even a semi-liquid mass, such as melting snow, which might ascend a slope for a short distance. Liquid masses are controlled by gravity, but rock slides are controlled principally by friction and are essentially inert and sluggish in their movements. The same laws controlled the disposition of the debris when the Campanile fell at Venice, as control the constantly moving slide on the west side of Cathedral Mountain or as controlled the overwhelming catastrophe in the upper Simpson Valley where in a few minutes a mass of rock, four miles long and hundreds of feet thick, obliterated a river and changed a landscape.

With these few ideas in mind, let us now carry our studies to Moraine Lake. Here we find a pile of debris about four hundred feet long, arranged in two parallel ridges running transversely across the valley. This pile rises sharply to about seventy feet above the surrounding country and probably one hundred feet above the lake bottom. It is separated by a more or less level space of about four hundred feet from either side of the valley.

Let us assume that this is indeed a true rock slide that has fallen from the mountains on the southeast. The time of this fall might have been as long ago as immediately after the ice retreat, or as recently as three or four hundred years ago, as shown by the maximum age of the trees growing on it and rock splitting. If we select the earlier date, we must remember that then there were no talus slopes, all ground moraine and other debris having been swept out of the valley or smoothed off by the glaciers. The southeast side of the valley was like part of a canyon with a high, precipitous cliff, rising out of a nearly level, valley floor. This cliff was about ten or twelve hundred feet from the present location of the rock pile. In order to picture the rock fall we must imagine it to have descended the

precipice, and, upon reaching the valley, instead of resting there as would be expected, to have moved across the plain for about a fifth of a mile and then piled itself up neatly seventy-five or a hundred feet high without leaving behind a connecting ridge, or even a single rock to give evidence of whence it came.

On the other hand, if we assume that the slide is of quite recent date, when the talus slopes were almost as fully developed as at present. then the slide would have had the advantage of riding in part, over the talus slopes, and thus arriving several hundred feet nearer to its goal. However, we should again expect a long connecting ridge of material similar to the formation itself, to reach out from the talus slope and clearly indicate where this slide came from. No such ridge exists and where one should be expected there is a gap seventy feet deep and four or five hundred feet wide.

The reader is at liberty to premise any intermediate date for the occurrence of this rock slide with varying difficulties, but they are in all cases insurmountable. In other words this rock mass if a slide, violates all the known laws of such formations: in location, in profile and in origin, no less than in the arrangement of the ridge across the valley in the direction of motion of the theoretical slide. It seems fair to say, therefore, that the theory of a rock slide for this formation is untenable.

There is only one other assumption for the origin of this formation, namely, that it is a true moraine. From our knowledge of moraines, we see at once that the formation fulfills every apparent condition of a moraine, in its location in the valley, in profile, and in the direction in which its moraine-like ridges run. It is exactly where a moraine should be expected to be found in relation to the valley and its surroundings. Having satisfied ourselves of this, let us seek final and conclusive proof in the internal structure of the formation. Now, we are astounded to find that there is here no evidence of glacial origin, such as striated stones, gravel and clay. On the contrary the pile is composed of sharp-edged rocks, quartzites and shales of all sizes up to immense blocks weighing many tons, mixed with earth and sand. Actually we have here a pile of debris that could not possibly have arrived at its present location as a rock slide, yet with the internal structure of a rock slide and the outward form and position of a moraine. Is there any way to reconcile these divergent facts?

Fortunately we have a most probable cause for this unusual formation. There are evidences all through the Canadian Rockies of considerable earthquake activity at periods that are comparatively recent. One of these earthquakes may have occurred at a time when the Wenkchemna Glacier still extended as far as the present location of Moraine Lake and may have dislodged part of a rock wall at an unknown distance up the valley. The resulting debris, falling on the glacier, may have been transported and deposited intact as a moraine. As the mass of material was very thick it would have protected the underlying ice from melting, and, riding on the surface of the glacier would have arrived without the usual evidences of glacial erosion.

In 1904 Dr. William H. Sherzer made an investigation and later a report on the Victoria and Wenkchemna Glaciers in Alberta, and the Yoho, Asulkan and Illecillewaet Glaciers in British Columbia for the Smithsonian Institution. On pages 69 and 70 of this most interesting monograph Dr. Sherzer writes as follows: "Moraine Lake. This lake has had a different history from that of Lake Louise in that it is apparently not a rock basin and so attains no great depth. It is, however, like Lake Louise in that it has a morainic dam across its foot, although in the case of Moraine Lake the dam is of a different type. This consists of a sharply defined heap of rock debris about four hundred feet long, placed at right angles to the main axis of the valley. The ridge increases in height rather gradually toward the west and attains a height of about 70 feet, ending abruptly, as steeply as the debris will stand and with no trace of any continuance across the valley. This is so unusual a feature for a terminal moraine that many are disposed to consider the mass as a rock slide from the adjoining mountain face. . . . The writer is disposed to accept the view of Wilcox, who gave the name to the lake, that we have here a moraine. It is, however, not of the bear-den type found farther up the valley, but very much older than the most ancient of the two. Its general lack of vegetation may be due to the scarcity of suitable soil, although it does support a sparse growth of timber. The unusual features of the mass, considered as a moraine will be understood when the unusual nature of the glacier that formed it is considered. This represents the position of the front of the easternmost ice stream, of the ancient piedmont Wenkchemna during a prolonged period of the halt."

In view of the apparent facts above mentioned and the opinion of so eminent a geologist as Dr. Scherzer it seems fair to place the burden of proof on those who hold the rock slide theory and ask them to show when and how this formation arrived at such a remarkable position as it now occupies and also to explain why this moraine-like ridge should have a profile unlike any other rock slide, so far as known, in the mountains.