ART. IX.—*Glaciation of the Mountains of Japan*;* by N. YAMASAKI.

Glaciation, which played so important a role in the development of the topography of parts of Europe and America, is as yet known only in a few places in eastern Asia. In China proper there are only a few evidences of glaciation. Loczy notes its existence on the great snowy mountains on the western boundary of the Province of Szechuan. He also observed moraines on an eroded plateau in the same mountains, but at an elevation below the extremities of the present glaciers. We have no further information as to the existence of glaciers in any of the other high mountains of that mighty country, save the discovery of tillite of great geologic age near the Yangtze Gorge by Willis and Blackwelder. There is scarcely a report of the existence of glaciation farther north, in the Amur Region, the Littoral Province, Kamtschatka or in Siberia.

It is only recently that the question of glaciation in Japan has attracted the attention of scientists and been discussed by them. Forty years ago the Hida Mountains, a lofty chain in Middle Japan, had already been visited by a score of foreign alpinists. Among them, Atkinson reports that the snow of the snowfield on Mount Hakusan and Mount Tateyama near the coast of the Japan Sea is hard enough to be called ice. Kinch, who crossed the famous Harinoki Pass, described three or four snowbeds and miniature glaciers. Divers also observed in the same region some snowfields with the characteristic appearance of glaciers. John Milne, then professor at Tokyo, compiled their observations and came to the conclusion that at an elevation of about 5,000 feet in middle Japan and at 4,000 feet a little farther north, near the coast of the Japan Sea, there are fields of permanent snow, which are sometimes so firmly consolidated as to form small glaciers. He further proved the possibility of Pleistocene glaciation in Japan on the ground of climatological and biological data. He also reported the presence of "roches moutonnées" on Gassan, a high, dormant volcano

* Read at the First Pan-Pacific Scientific Conference at Honolulu, August, 1920.

in North Japan, but later observers are doubtful of their character.

Since that time no further investigations were reported, not even from Milne, until recently some of our geographers took up the subject again. I have always been of the opinion that there may be some traces of glaciers in our mountains, especially the lofty ones of Middle Japan, for there are several peaks 3,000 meters or more in height, which have snow during nearly all of the year in consequence of the heavy precipitation that results from the oceanic climate. The winter snowfall is greater than that of the European Alps. Moreover the temperature does not differ greatly from that of the Alps. So believing the possibility of the existence of glacial features in our lofty mountains, I have visited them several times to investigate the question more thoroughly. Fortunately I made the discovery of topographic forms characteristic of glaciated mountains with the supporting evidence of moraines and striæ which show the former existence of an ice covering in these mountains.

Now let us consider the topography of Middle Japan. In the center of the main island of Japan, where the two principal mountain arcs of North Japan and South Japan meet, the terrestrial configuration attains its greatest complexity. Several mountains, both tectonic and volcanic, stand side by side and upon one another. Indeed the renowned volcanic chain of Fuji, with its numerous gigantic cones, traverses the island and occupies the depression zone between the precipitous scarps of the two principal arcs. Especially esteemed for their prominent features are the mountains that lie on the western side of the Fuji chain and form the northern extremity of the southern arc of the cordillera of our archipelago. Their culminating peaks are 3,000 meters in elevation, or even more. The ridges are sharp and ragged, forming sometimes pointed needles, pinnacles, or steep rocky walls facing gorges a thousand meters deep. These scenes are of truly Alpine character, and some years ago these mountains were given the popular name of "The Japanese Alps." There are three principal mountains, namely Akaishi, Kiso and Hida, which run parallel to each other and trend southwest to north-northeast. Of these, Hida is the highest and most characteristic. It forms the eastern

margin of Hida Plateau and falls abruptly to the rift valleys of Matsumotodairai and Himekawa with precipitous fault scarps. The most gigantic and imposing view that it presents attracts many alpinists every summer from all parts of the country. Yarigataka or Spear Peak, often called the Japanese Matterhorn, Shiroumadake, Hodakayama, Kurodake, Yakushidake, and Tateyama are the best known peaks. Besides them, Ontake, Norikuradake and Yuodake are eminent volcanic cones and lie in the southern part of this mountain. Hari-nokitoge is noted as the highest mountain pass in Japan.

Climatologically treated, there is at present no mountain in Japan from the central chain of the Island of Sakhalin on the north to the backbone of Formosa in the south (nearly 4,000 meters high) which rises above the snowline. Even the beautiful snow-clad cone of Fuji, 3,778 meters high, loses its white cap in midsummer, leaving only small patches or streaks of snow on the shaded side of the crater or in the radial valleys. The same is true of the northern part of the Japanese Alps. The annual precipitation in this region is as high as 2,500 millimeters, owing to the great winter snowfall. Not on the mountain itself, but on the plains or hills at the foot of its northern slopes, the snow is so deep that small village houses are entirely buried in it. On the ridges and flanks of the mountains there are many patches of snow even in midsummer. These, however, gradually melt away before the next snowfall—by the end of October at the latest. But it is not infrequently observed that rather large snowfields, often a few meters deep, last through the year in shaded valleys or below cliffs. Most of these snowfields consist merely of snow, but in some cases, as I have observed in Shiroumadake, for example, the snow is consolidated partly to translucent ice near its base. One might give the names "puny glaciers" or "miniature glaciers" to such ice masses.

The climatic conditions in these mountains are not far different from those of certain other regions where glaciers are found at present. We have no meteorological stations on any peak of the Japanese Alps, but if we compare the temperatures of three meteorological stations in the towns of Takayama, Matsumoto, and Nagano near the mountains, with that of Vienna at the foot of

the European Alps, we can prepare the following table in which temperatures are reduced to sea-level.

Station	Elevation, above sea-level, meters	Temperature, Annual, C.	January Temperature	July Temperature
Takayama	561.4	10.0°	—2.3°	21.8°
Matsumoto ...	582.1	10.1°	—2.1°	22.0°
Nagano	420.4	10.9°	—1.5°	22.9°
Average ...	521.3	10.3°	—2.0°	22.2°
Vienna	170.0	10.0°	—1.6°	22.5°

The temperatures at the four stations are nearly equal to each other, while the elevations of the Japanese stations are greater than the elevation of the Vienna station. Dachstein, near Vienna, in the northern Limestone Alps, has its snow-line below 3,000 meters elevation, and Hohe Tauern in the Central Alps is covered with permanent snow at an elevation of 2,860 meters. Of course, snowfall and glaciation are influenced by not only temperature but also by other controlling conditions such as the amount of precipitation, the humidity, the direction of the prevailing winds, and topographic features. If we consider only temperature, we find that the snow-line for the Japanese Alps would be only a few hundred meters above their summits, so that with a fall of only a few degrees in temperature the snow-line would be depressed to these peaks. The precipitation would be sufficient to make snowfields and glaciers.

In the course of a close examination of the topography of the mountains we found various characteristic forms of ridges and valleys due to glacial processes. The most distinctive feature is the occurrence of cirques or kar at the valley heads near the crests. Along the crest of the central range of the Japanese Alps proper or the Hida Mountain, from the gigantic needle of Yarigatake to the renowned peak of Shiroumadake, we find this particular type of topography. Again, nearly a dozen cirques lie side by side on the ridges of Yakushidake and Tateyama, to the west of the former, and between them is the deep gorge of Kurobe. If we stand on a prominent peak, such as Tateyama, it is not difficult to find a score of cirques on the surrounding mountains. Some of them, and the valleys below them as well, are often covered with snow patches in midsummer days. Weathering and erosion

have not as yet altered the forms greatly, and they are still fresh and well preserved. Where many cirques lie close together, as in Kurotake and Yakushidake, characteristic comb-ridges are formed between them.

The most important and peculiar feature of these cirques is that their floors are all of about the same height above sea-level, as shown in the following table:

	Meters.
Goro	2550
Mitsu	2600
Harinoki	2500
Nakanomata	2550
Kurotake	2500-2600
Yakushi	2600
Renge	2500
Tateyama	2500-2600

In short, the cirque floors range from 2,500 to 2,600 meters in elevation, and average 2,550 meters. What is the significance of this regularity? Perhaps there is no better explanation than a former lower altitude of the snow-line. Above this level the lofty ridges of the Japanese Alps were once covered with permanent snow, and just below there were hanging glaciers here and there along the flanks of the ranges. Of course these glaciers were not so large or extensive as those which existed in the European Alps during the last ice age. We have not yet found any morainal landscape at the foot of the mountains. There are neither terminal moraines nor glacial lakes at the lower extremities of the mountain valleys. The glaciers must have terminated at a little higher elevation. Perhaps certain exceedingly deep incisions in the upper parts of the valleys are due to glacial erosion. Other indications of glaciation that have been noted are the striations on the rock blocks of Shirouma and the moraines in several places, especially the peculiar moraine mounds in a high valley basin of Kamikochi near the famous peaks of Yarigatake and Hodakayama, which were recently discovered by the late Professor Ozeki.

There is no question at present as to the glacial origin of the peculiar features of our lofty mountains, and it remains only to discuss when this glaciation took place. We have not come to any satisfactory conclusions on this

question as yet. The correlation of that period with the ice age of Europe and America is too difficult with our present knowledge. We have not yet found any glacial or glacio-fluviatile strata of diluvial age of undoubted extension. Most of the Tertiary and post-Tertiary strata that have been studied to date consist of marine or brackish water formations, and our paleontologists are eagerly endeavoring to determine the climatic conditions of that epoch with especial reference to their fossil faunas. Their opinions are as yet in disagreement. According to Prof. Yokoyama of Tokyo University, who has studied especially the formations of Tertiary and later ages in the approaches of the Bay of Tokyo, the climate of Middle Japan in the Pliocene was colder and then became warmer in the diluvium than at present. So he denied the evidence of an ice age in our diluvium. On the other hand Professor Yabe, of the University of Sendai, holds that at the end of the Tertiary the climate of Japan became gradually colder and reached the minimum temperature in the ice age, after which it became somewhat warmer but again colder until it attained the temperature of the present.

Summing up briefly what I have mentioned here, the lofty mountains in Middle Japan in 36° north latitude were once covered by permanent snow and bore glaciers. Their existence is clearly proved only by the characteristic cirque topography with the corroborating evidence of moraines and striae. The floor of many cirques are nearly at a uniform elevation, 2,550 meters, which marks the former snow line. The glaciers were hanging glaciers and not of great extent and were located near the summits of the ridges. No glacial or glacio-fluviatile deposits have been discovered as yet that would allow of exact determination of the date of the glaciation. In short, the glaciated area of Japan is limited to a small district of high elevation, in great contrast to the vast extent of the glaciated areas of America and Europe. The lack of traces of glaciation in eastern Asia, even in high latitudes, will also deserve further research. How and when did the ice age occur in our country? How is it related to that of other regions? Other equally important subjects for investigation are the direct cause of the change of climate, and its influences on topography and the distribution of

fauna and flora. Of course it is not our aim to attack the problem of glaciation and subordinate questions from only the geographical point of view. Help from geology, paleontology, astronomy, climatology, biology and all allied sciences must be cordially accepted. Especially necessary are actual observations and comparative study of the data. To such research, I am sure, this Conference will give the best opportunities, and I beg you, gentlemen, to kindly help me with your valuable suggestions as to the present subject.