QUATERNARY GLACIATION IN THE YANGTZE VALLEY*

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Eleven years ago when this society held its Third General Meeting I had the opportunity of calling your attention to certain strange deposits and topographical features that came under my notice in certain parts of North China. I showed you a number of striated boulders that could not be attributed to mere slickenside. Dr. J. G. Andersson who was then actively engaged in the hunting of archæological material throughout northern China was much alarmed by such unexpected occurrences. He had strong doubt as to the real value of the evidence that I was able to produce. He had every reason to doubt, and I admitted that his doubt was of a grave nature, when he approached me in a private conversation, in which he pointed out certain residual deposit in Chinghuangtao that could not have remained in its position had there been a sweep of glaciers. At the same time Dr. Andersson found difficulty to explain the origin of the striated boulders. Regarding the other field evidence which I gathered, he was of course not in the position to critisize.

The fragmentary evidence of glaciation in North China that had for a time stimulated my own imagination, had all the time to face the antithetical reminding of a vast deposit of loess. In spite of the possibility that glacial deposit might yet be discovered underneath the Malan loess in places where the topography favoured its preservation, the overwhelming evidence of arid climate has gradually shaken, if not shattered, I must confess, my earlier conviction. It seemed for a time that the idea was sadly miscarried. Some two years ago I took a party of students to the Lushan for field training. There again certain topographical features force themselves upon my notice. They demand an explanation in terms of stream erosion if glaciation is not to be admitted. Two years labouring in my own mind resulted however in a significant failure. There are certain features, as I shall show you later, that cannot possibly be assigned to the work of mountain streams. For tectonic and stratigraphical reasons I led my students in that occasion to the south-western foothills of the mountain

* Presidential address at the Tenth Annual Meeting.

where no glacial deposit was found. I was thus placed in an extremely unhappy position, either to produce substantial evidence for the hypothetical glacier or to ignore the topographical features that constantly demand a satisfactory explanation.

Last summer was a more fortunate season. I had an opportunity to revisit the noble mountain in the Yangtze Valley. For three weeks I was not hampered by the duty of a field instructor. I was therefore free to approach the problem from various angles. If glaciation is to be ultimately unearthed in this country, it is natural that the Lushan should be the place that eventually serves to give birth of that rather harassed and intimidated idea; for I know of no other region in this country that could have produced evidence so striking and conclusive.

Speaking from my own experience I think it safe to presume that few of us who are familiar with the extensive and successive deposition of loess in North China would feel inclined to admit Quaternary glaciation. And inasmuch as the phenomenon of glaciation involves so many important aspects of the palæontological, stratigraphical, archæological and geophysical problems, the whole sequence of observational facts must be treated with extreme care. As both reasoning and observation have compelled me to believe that this Quaternary glaciation is by no means of local nature, we cannot be too cautious in accepting the verdict which I now propose to pronounce. Under these circumstances I may be excused to present before you much of the details which from the point of view of a glacialist working in a known glaciated country, might be regarded as unnecessary and superfluous.

There is a certain advantage in discussing the whole sequence of the glacial phenomena in the order in which they happened to come under my notice. In that way you will find how certain observed facts dictate certain conclusion, and how that conclusion is borne out by further observation. Each step of procedure will thus serve not only for the extension of the field, but as a corroboration of the general result. I will lay more stress on the Lushan area partly because the work of searching the extinct glaciers in and around that mountain has been carried out to a rather advanced stage and partly because its natural advantage favours the proposition that it might be eventually taken as a type locality

for Quaternary glaciation in China. Certain types of deposit which might be mistaken as of lacustrine origin are there definitely traced to be connected with the boulder clay. This is a point of paramount importance in connection with any further search of the disappeared glaciers, for the topographical expression of the early glaciation rarely survives to the present day.

Topographic Evidence of Glaciation in the Lushan

Flat-bottomed Valleys. The two valleys that first struck me as being impossible to be due to stream erosion are those running respectively along the eastern and western sides of the Yuelunfêng. An excellent view of these valleys can be secured from the Nankang Pass.* The eastern one has a remarkably flat bottom when looked from a distance. Along its eastern side now runs a meagre stream. In rainy days numerous runnels flow down in an indefinite manner. The same is

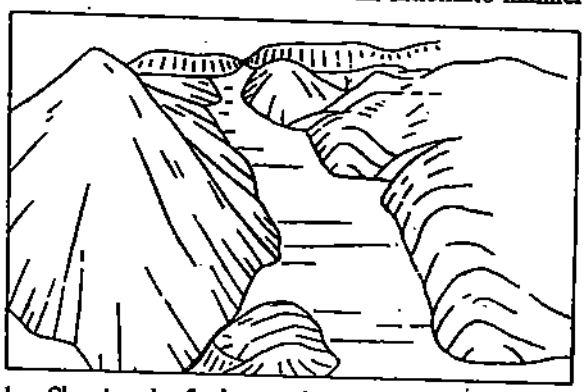

Fig. 1. Showing the flat-bottomed valley, east of the Yuelunfêng viewed from the Nankang Pass.

true with the western valley. The eastern one follows a straight course, while the western sweeps round the Yuelunfêng in its lower part. They are both tributary to the east and west valley immediately behind the Nankang Pass. The last-named is again a flat-bottomed one in its western part, but towards the eastern, or lower, part stream dissection has gone so far as to have cut it into a gully.

* The location of most of the localities mentioned in this paper is indicated in the accompanying sketch, p. 34, text-figure 2.

When examined more closely, we find that the bottoms of these valleys are all covered by a reddish, fine clay in which are strewn large and small chunks of rocks or sub-angular boulders usually with one or two faces planed and polished. Distinctly striated surface has however not been found though faint striæ are frequent on the polished surface.

At the place where the western valley sweeps a bend and joins the east and west one, there stands a deltoid platform consisting of boulder clay, some 20 m. higher than the rest of the valley-bottom (Pl. I. Fig. 1). In the eastern valley, too, we find on close examination that the flat-bottom is not entirely founded on a single inclined plane, but falls into two steps lengthwise. On the eastern foot of the Yuelunfêng the boulder clay forms a miniature terrace appreciably higher than the rest of the valley.

There are other features in the valley behind the Nankang Pass formed by boulder clay that seems to have undergone ice erosion as well as stream cutting since the time of its deposition. It is almost certain that these valleys were glaciated more than once. Whether the successive glaciers constitute different stages of a single period of glaciation or they belong to different glacial periods is a problem that requires further enquiry. The sharpness of the flat-bottomed valleys allures the imagination that the glaciers might have disappeared yesterday. The former interpretation would thus seem more probable. All these valleys are developed in an altitude of 900 to 1,100 m. above sea level.

The next system of flat-bottomed valleys is found in behind the famous Wulaofêng, or the Lion's Leap, and Chihlihchung. They are considerably broader than those already mentioned. The one immediately behind the Wulaofêng is in fact more an elongated névé than a valley. The Chihlihchung Valley covers a distance of about 4 km. terminating abruptly at the head of the Three Waterfalls. In these valleys tenacious red clays together with large and small boulders, chunks and detritus slabs of rocks abound. They are unstratified, closely packed, and are so thick and well set that the present streams have nowhere cut down to the bottom of this deposit. It is absolutely inconceivable that these materials could have been scree deposit from the mountain flanks. Along the length of the Chihlihchung Valley fans of more recent deposit are sent

down by lateral mountain torrents at two points. These fans intrude into the otherwise perfectly flat-bottomed valley in so striking a manner that one can hardly cast any doubt upon the erosional and depositional sequence.

At the point where the two valleys become confluent there is left a sharp ledge of bed-rock which is so remarkably abraded by the grinding ice-lobes from both sides that it vividly recalls the disposition of two glaciers (Pl. II, Fig. 1). The freshness of this feature forbids the assumption that there has been an elapse of any great length of time since the last glaciers left the place. This does not necessarily mean that the valleys were only recently glaciated; for in the Chihlih-chung Valley a minor flat-bottomed valley is carved out of the boulder clay. Here again we are to deal with successive stages of glaciation. The lowest reach of these valleys stands at an altitude of about 850 m. above sea level.

The Lotus Valley is again a flat-bottomed one. As usual, the floor of the valley is covered by clays and large chunks of transported rocks. The whole valley is in the shape of an elongated ellipse with an opening towards the north-east. Here and there the boulder clay is covered by a thin sheet of loessic loam which is remarkably free from boulders. At a number of points the present stream flows on the bed-rock. Obviously the valley is wide enough to form a glacier of its own. But essentially it must have served as a névé which nourished the glacier at a lower level.

The central and west valleys are both in fact flat-bottomed valleys. Red clay and large chunks of rocks are scattered all over these depressions. In the West Valley patches of the loessic loam sometimes cover the boulder clay and sometimes directly rest upon the bed-rock. Among the numerous large boulders there are two in the West Valley that deserve special mention. In a place not far removed from the church a flattish chunk of rock some 15 feet long, evidently came from the higher ridge, rests on another transported chunk of rock of even greater size. They together stand aloof, and form a spectacular view. No competent agency but a glacier could have piled them up in the fashion as they stand now.

Flat-bottomed valleys covered by boulder clay are in fact found all over the northern part of the mountain. They vary in size and in gradient. At certain

places clay may predominate, but more often large and small boulders pave the valley. To name a few others I might point out the one on the south-eastern side of Yupeiting leading down to the Incense Mills, another from the south-western part of Luling to the Emerald Grotto, a third from Mongmachang running north-westward and several others stretching northward from below Lienhuaan. They are not limited to any particular altitude. Some, for instance, the Hsuelihpo Valley, reach the foot of the mountain.

U-shaped Valleys. Closely associated with the flat-bottomed valleys, are the U-shaped ones. Some of these are already classed as flat-bottomed, but they merge in fact into the U-shaped type. I will name only two typical examples so as to fullfil this category of glacial features. The one is found above Niuerhcheng and below the Poyang Ridge or Tayueshan. This valley is carved out of the north-western wing of the Tayueshan Anticline. It follows therefore the strike of that part of the mountain, namely, NE-SW. The valley is divided into two parts by a watershed immediately above the Hankow Gorge. The north-eastern part leads to another U-shaped valley to be described below; and the south-western part suddenly terminates at the strange depression of Luling. Boulder clays now and then covered by loam are widespread all along this valley (Pl. III, Figs. 1,2).

The other U-valley affords one of the most impressive sights of all the glacial features in the mountain. I noted this wonderful feature two years ago, but resisted to believe in its glacial origin largely because of its tectonic control. Facts have however proved my first impression to be correct.* This valley starts from Hsiaotienchih, past Wangchiapo and runs towards the E.N.E. down to the foot of the mountain with a rather uniform slope and a regularly U-shaped cross-section all along its length. High mountains stand on both sides of the valley. It is formed in a syncline of the hard Tayueshan Grit and the soft Kuniuling Series which latter is almost completely scooped off (Pl. IV, Fig. 1).

Boulder clay occurs in abundance along the mountain slopes on both sides as well as in the bottom of the valley. In the very bottom the broad curve is planed down to a flat bed on which are spread clays and boulders (Pl. IV,

* Mr. Y. Y. Lee of the Research Institute of Geology, Academia Sinica, has independently arrived at the same conclusion.

Fig. 2). There is hardly any question that a lobe of ice of relatively recent date has abraded its path to form that bed in descending the valley. Standing by the side of the flat bed is a deltoid plateau consisting of boulder clay on which are built a large number of thatched huts. The surface of this isolated mass is not on the same level, but follows the general inclination of the valley. It is therefore evident that the valley was glaciated on a much grander scale before the diminutive glaciers appeared in the scene. The lower level of the valley-bottom is deeply incised by the mountain stream from above Wangchiapo, or the Paradize Pool, showing the depth of post glacial erosion. To this interesting fact useful reference will be made later.

Hanging Valleys. When traced along their course the flat-bottomed valleys in the northern part of the Lushan are seldom accordant. They often hang to some peculiar depression or to another valley which runs in a different direction. A typical example of this type of feature is well illustrated in Pl. II, Fig. 2. The Lotus Valley of which mention is already made hangs to the great U-valley below Hsiaotienchih. The valleys on both sides of the south-western part of the Tayueshan hang to the Luling depression which itself suddenly descends, with a fairly powerful stream, to the lower reach of the Central Valley. Instances of this kind are too numerous to be placed on the record. A few examples as these ought to suffice the categorical requirement.

Cirques and Corries. Strictly speaking a cirque is a funnel-shaped hollow formed on the flank of the glaciated mountain. There are features of this description found in the Lushan; but they appear to be of quite recent date, and its origin is still problematic. If I may use the term in a little extended sense, then a large group of topographic phenomena must naturally fall into this category. I would first of all refer to the circular depression immediately behind the Tiehchuanfêng (Pl. VI, Fig. 1). This quaint hollow space in the mountain has a diameter at its top of well over 500 m. and a depth of about 60 m. A single outlet runs towards the north-west leading to the top of a precipitous cliff which stands some 850 m. high. Along that outlet there is only a meagre stream which dwindles to ramifying seepages as is traced to the interior of the depression. It is obviously absurd to assume that an isolated hollow of that extraordinary shape has been carved out by the agency of rain water or deserted streams. Moreover

such an assumption cannot afford any explanation of the deposit of boulder clay which we now find in the depression.

Equally remarkable is the depression of Luling. Here the hollow is even of larger size. U-shaped and flat-bottomed valleys suddenly drop into this basin as they come from the north-east. A minor stream runs down to the basin from Huenmenkou on the eastern side, and a smooth but steep slope extends up to the lofty peaks of the Taiyifêng and Kiuchihfêng on the south-east. There is a ridge running along its north-western side formed by the Niuerhcheng Sandstone. A notch is cut into this ridge, through which the basin finds its only outlet at Kiaoluchiao. It will be thus realized that if not for this outlet, there will be no way to drain out the water that poured down from the surrounding mountains into this basin.

Large boulders and huge chunks of rocks from the high peaks, sometimes 30 feet across, are found everywhere in and around the basin. They are always associated with a fine, tenacious reddish clay. These materials are not uniformly spread in the basin, but occur either in pockets, or to form smooth slopes on their own account. In the former case we might offer the explanation that they were mere scree deposit, but in the latter the transporting agency must be found either in water or ice. It is beyond comprehension that streams flowing down the glacis could have had the force of carrying such mighty blocks of rocks in so large a quantity, and could have at the same time produced such a fine clay.

A swimming pool is now founded on the bottom of the depression. On the eastern side of the pool stands a snubbed hill-spur which presents a nearly vertical front facing the basin. It is obvious that the front of the hill-spur could not have been produced by stream action. Nor is there any fault from which it might have resulted. All the prominent features in and around the basin indicate, in fact, the scouring and scooping action of glaciers which became confluent at Luling.

Although the place is situated in an altitude of about 900 m., it supports an exuberent arboreous flora. Being shielded from the north wind, the mountain inhabitants find a comfortable resort in this depression during the winter season. Such is the present climatic condition in the basin. Towards the end of the fourth century A.D. when the famous general Huan-chung was appoint-

ed the governor of Kiangchow, he sent a man out of his own curiosity, to explore the Lushan. At that time the mountain was of course a breeding place for fairy tales. His explorer, so it is said, found a lake "on top of the mountain" several hundreds of maos in area being surrounded by a thick growth of mulberry trees*. It is on the record of several ancient books of varying authority that there was a lake on top of the mountain.§ Accepting these accounts, I see no other place throughout the mountain but Luling that can have been a possible site of a lake of that size. It would thus seem that the notch through which the basin is now drained, either in those early days had not yet been cut down to the base level of the basin or was still blocked up by moraine. The latter is judged to be more probable.

Besides these two large ones, there are numerous minor depressions which head the flat-bottomed valleys. Each of these depressions must have been a gathering ground of snow, a firn or a miniature névé. They are too shallow to deserve the name cirque and too small to be called a true névé. The fact however remains that the glaciers were essentially nourished by them. These features being generally developed at the head the valleys, they are but slightly disturbed by subsequent stream erosion.

Snow Slopes and Névé. Numerous slopes with a remarkably smooth contour are found in and around the northern part of the mountain. They are as a rule here and there blanketed by the red clay, slabs and boulders. The most prominent of these slopes is the one which forms the northern flank of the Kiuchihfêng and Shiangsiaofeng. Boulder clay is particularly widespread in this slope. The several glaciers which descended the northern flank of the mountain must have been fed by this large collecting field. The back slope of the Wulaofêng and the slope below the Nankang Pass are all significant examples of the same kind.

In a broad sense the whole area of the northern part of the mountain forms a huge névé. There are however certain differentiating features. Some of the flattish high ground obviously favoured the accumulation of snow.

* 'Shu-yi-chih' (述異記)

§ 'Lieh-sien-chuan' (列仙傳); 'Sin-yang-chih' (潯陽記); 'Kuang-chou-chih' (廣州記).

Others facing north or north-east may have accelerated precipitation. The evidence is strong, as will be seen later, that the north and north-east winds were probably largely instrumental to the heavy precipitation. The highest ridge in the northern part of the mountain is the Tayueshan sometimes called the Poyang Ridge. This anticlinal mountain has a peculiar flattish top which is here and there covered by a reddish clay. The latter in turn is sometimes covered by loam. It is this ridge that must have served as the principal névé in the north-eastern part of the mountain.

On the north-western flank of the Tayueshan two connected longitudinal valleys are developed in between the Tayueshan Grit and the Niuerhcheng Sandstone. The north-eastern one leads to the large U-valley of Wangchiapo of which mention is already made; and the south-western one terminates at Luling (Pl. III, Figs. 1,2). The watershed of these two valleys is situated in above the Hankow Gorge. It is not the bedded rock but red clay with boulders that forms the divide. In the watershed one finds a flat area which presents every appearance of a small névé so often associated with modern mountain glaciers. I will not occupy any more time on these features, for their evidential value is only of subsidiary order.

Glacial Deposit on the Lushan.

Boulder Clays. In connection with the description of the various topographic features I have frequently mentioned a red clay with boulders. This material was at first thought to be the ordinary weathered debris of the bed-rock. Close examination however showed that the clay was much too fine and too tenacious to be regarded as disintegrated scree. The pebbles and slabs of stones found in it are usually well set in the more or less consolidated clay. When excavated by small streams it generally presents a glossy surface, rather tardy to admit the cutting of running water. The slabs and sub-angular boulders are often rubbed and polished in one or two faces. A few are clearly marked by striæ. Pl. V, Fig. 2 shows an example of the striated boulders. Neither the boulders nor the clay occur in layers or in any laminated manner. Their arrangement is entirely tumultuous.

Some of the artificial excavations, e.g. the one behind Chinhaikuan, show that the boulder clays are not all of the same nature. One can distinguish

a lower layer in which the material is fairly well set and brilliantly red in colour, and an upper layer in which the slabs of stones are quite loose, and the sandy clay is tinted with a reddish brown colour. The latter is in turn covered by a loessic loam. As the boulder clays are distributed in a drifting manner, it is not always possible to differentiate these two layers.

The thickness of the boulder clays varies to a considerable extent. In the depressions and some of the valleys they have not yet disclosed the floor on which they rest. At certain places they are well over 10 m. in thickness, at others only a few feet thick. Sometimes a veneer of this material is left on the mountain flank. While they spread far and wide in the northern part of the mountain, no trace of it is found in the southern part. The boundary is located on the southern side of the elevated basin of Niangtienpin.

When the nature of these boulder clays is considered in conjunction with the various topographic features it seems obvious that we are here dealing with rubble moraines.

Boulder Slopes. In descending the mountain from Kuling to Tunglin, a tumultuous heap of large, angular boulders was found at some distance to the north of the road reposing on the slope of Shangyuanpan. They lie at an altitude of about 520 m. When I first sighted these riffraff stones, I was struck with the impression of a ruined village that was entirely built by stone masonry. There was no notable amount of boulders above or below. That heap lies perfectly isolated. Gravity alone or gravity plus running water could not have accomplished the feat.

Nor is this the only instance of strange stone-heaps. The old road which descends from Kuling to Lienhuatung runs across, at an altitute of about 700 m., several strips of boulder bed which follows down the mountain slope for a distance and then disappear. The boulders or blocks vary in size ranging from several feet to more than 8 feet across. Nearly all of them are perfectly angular showing no sign whatsoever of being rolled in water, nor could they have fallen down from the remote peaks in that extraordinary fashion. For the lack of a better name I would call these heaps of stones the boulder slopes (Pl. VI, Fig. 2).

The only feasible explanation for such strange accumulation of boulders as I can offer is that they fell at first on the surface of a lobe of ice which carried them down to a certain altitude where the ice began to decay. The angular blocks were therefore left stranded. This explanation leads to the necessary inference that post glacial erosion has not yet had sufficient time as to have completely removed the piled up blocks. If a large number of this kind of deposit be found along the flanks of the mountain, we might be able to determine the snow-lines at different stages of the last period of glaciation.

It seems that we have had a sufficient number of examples of the kind of evidence in hand as to warrant ice action in the Lushan itself. At this stage we might pose for a moment, and ponder over what this ice action might mean. Is it not possible that, in view of the high altitude of the mountain, the accumulation of snow in the winter season might have produced local glaciers either in the historic times or even in the present day?

There are numerous facts which decide an answer in the negative. (1) The mountain is not really of great height; the highest peak, the Hanyangfêng, reaches only to a little above 1,400 m. Some of the glaciated valleys, as I have already mentioned, descend right down to the foot of the mountain. (2) Historical records from the fourth century onward show that in the depressed parts of the mountain where we find boulder clays, tall trees flourished from age to age. (3) The mountain inhabitants can testify that during the winter season the accumulation of loose snow even in the depressed part rarely exceeds 20 feet, considerably less in the higher slopes. It never flows in the form of compacted ice. (4) The highest peak, the Hanyangfêng, is located in the southern part of the mountain. In the winter season today that part of the mountain is often snow-clad as is the northern part. No trace of boulder clay is however found in the southern part. (5) Within the northern part of the mountain where the boulder clays abound, there are valleys which are entirely free from such a deposit. The two valleys on the north-eastern and south-western sides of the snubbed hill at Luling affords a significant example. The south-western valley is almost filled up by clays and boulder, but in the north-eastern one the bed-rock is freely exposed. The latter, therefore, must have been incised by the stream coming from Huenmenkou in post glacial times. (6) The boulder clays are often covered by a loessic

loam which is remarkably uniform in composition, and free from rock fragments. This very loam is widespread in the Yangtze Valley, and its constituents are precisely of the same nature as the Siashu Loam in the Nanking Hills.§ Formerly we referred this loam to the Pliocene. Now I have strong reason to place it in the equivalent position of the Malan loess in the north. It is thus evident that the boulder clays cannot be of very recent date.

These statements, convincing as they are, carry an air, as one might say, of a forced argument. We shall not feel satisfied unless we can actually demonstrate the existence of moraine beyond the mountain proper. Evidence of that kind will be final. And that is available.

Moraines in the Environs of the Lushan

Evidences both erosional and depositional have led us to conclude that the Lushan was glaciated in a relatively recent geological time. If the glacial action was on a large scale as it appears to be from the indications so far discussed, it would be inevitable that we should find glacial deposits somewhere on or near the foot of the mountain. As I mentioned before no such deposit was found in the foothills to the south-west. I therefore decided to follow the great U-valley of Wangchiapo on the north-east down to its mouth, and chase every suggestive trace to the shore of the Poyang Lake if such is available. As a pleasant surprise, a cliff of boulder clay was found by the side of a vigorous stream which had just arrived at the foot of the mountain. Most of the boulders are several feet across, only slightly worn, and are promiscuously set in a loose matrix of a reddish and rather sandy clay. There are more boulders than clay. None of these materials show any layered effect (See Pl. VII, Fig. 1).

The cliff is some 35 m. high. Above the cliff stretches out a terrace. And above the terrace looms a foothill which is connected with the main mountain. That foothill, known under the name Changling, or the Long Hill, is likewise covered by boulder clay. Here, then, we have some evidence that the boulder clays were not all formed in a single period.

Still more surprising is the vast extension of red clays beyond the cliff just mentioned. They spread out far and wide over hills and valleys. The whole

§ Lee, J. S. and Chu, S., A geological Guide to the Lungtan District, Geol. Inst. Academia Sinica, 1932, p. 13,19.

area beyond the mouth of the U-valley is covered simply by a mass of red. As we follow down the main stream along which are founded numerous water mills, we find drifting boulder clays all along the valley side (Pl. VII, Fig. 2). They form two successive terraces: the lower one is about 10 m. high and the upper 50 m. The clays become ever finer and more tenacious, and its red colour becomes increasingly bright. At the same time boulders became less numerous. In certain places the deposit is almost a pure, brilliantly red clay, though a careful search in it never fails to find boulders.

The surface of the boulder clays is not on the same level. Sometimes it curves down to form rather broad and shallow valleys or plains, and sometimes it rises to fashion lowly plateaus, irregular in shape and smooth in contour. Between a pair of gentle valleys always stands a loaf of hummocky hill, like a half buried cylinder, with one or both of its ends tapering down to the plain (Pl. VIII, Fig. 1). The size of these hills usually varies from one third of a kilometre to 4 kilometres in length, and one fifth of a kilometre to less than half a kilometre in width. Each lobe of these hills is remarkably uniform in height. Some rises to 25 m. above the intervening valley, and some to 35 m. They are either entirely formed by the boulder clay, or have a nucleus of bed-rock underneath. Above the boulder clay a mantle of loessic loam may or may not be present.

The smaller lobes are undoubtedly to be attributed to drumlins. But the long ones, which elsewhere in the environs of the Lushan, attain such a length that they can hardly be justly described under that name, though genetically they may be of the same nature. I would therefore propose to apply the local name, *loong*, to those long bodies of boulder clay irrespective of the presence or absence of a nucleus of bed-rock. It should perhaps be noted that the word loong (壟) has been often misused by the country folk. Ideographical investigation shows that originally it refers to a special type of hill but not to the valley. These loongs and drumlins together with the low-lying boulder clays spread out like a fan in the plain between the mouth of the U-valley of Wangchiapo and the shore of the Poyang Lake.

Not being satisfied with this single example of the continuous relation between glacial erosion and deposition, it was further resolved to trace other suspected valleys from the higher reaches of the mountain to its foot and beyond.

The road from Kuling to Tunglin running along the north-western flank of the mountain was selected for the next trial. This road follows the south-western side of a valley which starts from an altitude of about 520 m. The upper part of the valley has almost a perfectly flat bottom and a smooth slope. Lower down, where the present stream has acquired some force, the flat bed of boulder clay is partly incised into a gully in which the red boulder clay is well exposed. In the lower reaches of the stream the gully is well over 65 feet in depth. On approaching the foot of the mountain boulder clay is not only found in the valley but everywhere on the slope in which the road runs. Large and small boulders occur in quantity being always mixed with a tenacious red clay. Most of the boulders are planed, polished and scrutched on one or two faces. They seem to diminish in number as are traced away from the foot of the mountain.

As on the north-eastern side, here again the country is covered by a sweep of the red material. Hillocks of hummocky contour surround the Tunglin Village. They are some 60 m. high running along the foot of the mountain instead of radiating away from it. Further north-west, a huge fan of red clay with scattered boulders spreads out in the north-westerly direction. In the red country some five lobes of loongs radiate out towards the marshy ground. The longest of these covers a distance of well over 6 km.

Turning now towards the south-west, we find endless deposit of boulder clays along the main road from Tunglin to Tungyuan. Sometimes they form drumlins and sometimes long lobes of hills generally some 30 m. high. As a rule, they assume a north-western trend, that is, they run in a direction perpendicular to the foot of the high mountain from which they issue forth. In certain places, for instance, in the neighbourhood of Kinkiachao, a loong formed by numerous boulders and a subsidiary quantity of clay places itself upon a field of red clay with few boulders. The latter clay is scarlet red, and fairly well set. It is obviously different from the brownish red and rather loose clays associated with numerous boulders. The loong with numerous boulders near Kinkiachao is therefore judged to be the ground moraine of a glacier of more recent date.

All along the north-western flank of the mountain there is a sloping terrace some 250 m. high on the average. On this terrace there appears to be

little boulder clay except at those places where it is traversed by glaciated valleys. Usually the boulder clay appears below this terrace lapping over the foot of the mountain. The boulders are not uniformly distributed in the clay. They may be abundant in one place and exceedingly rare in others. Some of the clays are extremely tenacious and almost dark red. It contains patches, bloches and streaks of white giving it a mosaic appearance (Pl. IX, Fig. 1). The more rectangular bloches simulate the appearance of thoroughly weathered large crystals of felspar. In this clay boulders are especially rare, though never absent. A clay of the same kind also occurs below the Wangchiapo Valley. There, it likewise forms a part of the moraine.

On the north-western side of the mountain the boulder clay is traced to the village of Tungyuan. South of that village no trace of it has been found. In its place we find abundant loam capping the hill-top. The north-western boundary of the red clay with boulders appears to be marked by the railway. Beyond that line Silurian sandstones and shales are freely exposed in places covered by loam.

Now we come to deal with northern slope of the mountain and the country beyond. Very little boulder clay can be seen along the main road from Kuling to Lienhuatung except in the foothills. From above Lienhuatung to the city of Kiukiang the motor road travels in the red clay country. The red clay is often buried under the loam. Boulders become less and less in number as the clay advances farther away from the mountain. In several places, e.g. near Hsinchao, boulders with a sandy loam form a roundish mount being surrounded by a red clay obviously of older date. In the red clay boulders and slabs of the Lushan rocks are never wanting, though at times extremely rare.

At Kiukiang and all along the southern bank of the Yangtze River the clay is often exceedingly pure, vividly red, forming here and there cliffs of notable height. This red material can be traced to the Village of Hsinkang, some 11 km. below Kiukiang. Beyond this point it suddenly disappears. I have not yet explored the whole region occupied by boulder clay on the northern side of the mountain. But judging from the established points and the distant view from the higher parts of the mountain, the whole sheet of the deposit forms a huge

fan which has a radius of no less than 12 km. Within this red fan drumlins and loongs radiate out in the usual form as to characterize the movement of mountain glaciers. As the clay is undercut by the Yangtze its original extension must be greater than is visible in the present day.

Finally a few words must be said of the moraines found on the south-eastern side of the mountain. Looking towards the south-east from the Nankang Pass the observer cannot fail to be impressed by a broad stretch of mountain slope suddenly receding from its usual front so as to form a gigantic gap or an embayment. The promontory on the left-hand side embodies the precipitous cliffs ranging from the Hinkuefêng to the Lungchihshan, and that on the right-hand side comprises the rugged heights of Wukueipao, Chihsienfêng and Wuyuefêng. The noble peaks of the Kiuchihfêng, Taiyifêng and the Nanking Ridge are all arranged in a nearly E.-W. trend, and descend to the embayment with a sharp slope. All along this slope highly inclined beds of loose angular boulders and patches of boulder clay occur here and there. The latter becomes abundant in the neighbourhood of Taiyitsun, a village located at an altitude of about 600 m., nearly half-way between the Taiyifêng and Kuanyinchao.

Lower down, in the neighbourhood of Peihuchao, a peculiar, semi-circular hollow is carved out of the Tayueshan Grit. The hollow is lined with boulder clay. From this point on, the boulder clay occurs in a continuous sheet blanketing the eastern slope of a V-shaped valley through which pours down an active stream. A patch of boulder clay is found on the south-eastern side of the Hinkueifêng lying at a considerably higher altitude. This patch of boulder clay is apparently a remnant of older deposit. The younger boulder clay follows the valley down to the village of Matuchen. Thence forward it is dissected by the stream. A few isolated patches and lobes of boulder clay standing some 15 to 20 m. high are still left in the valley.

Apart from these patches which are entrenched in a valley there is little boulder clay to be seen in the region where the large gap merges into the open plain. A line can be drawn from the vicinity of the White Deer Grotto past Lohanlin and then on to the north-eastern corner of the Yuchinshan showing the boundary of an area in which boulder clay is only limited to the valley and the lee side of the higher hills. East of this line, boulder clay indiscriminately

covers the high and low grounds. Sometimes it forms a roundish mount, e.g. the Tingshan, nearly 140 m. higher than the lake, and sometimes it forms a rolling plain as is seen around the city of Nankang. The former exemplifies a typical kame, and the latter appears to be a fan-shaped drift deposited in a later date. More often however the red country is marked by long lobes of hills in the form of drumlins and loongs. The longest of these hill-ranges starts from the Tapaishan, and extends eastwards to the shore of the lake. The distance covered is no less than 6 km. The whole hill possesses a hummocky contour scoring an altitude at the Tapaishan of 160 m. above the lake, sagging slightly in its middle portion, and rising again to the height of 130 m. by the lake shore. When I first sighted this hill-range from the Lion's Leap, I had the impression that it might be an esker (Pl. VIII, Fig. 2). Closer examination shows however that it is composed of unstratified boulder clay with a nucleus of granite in its western part, and numerous large boulders in its eastern extremity. The boulders are all derived from the Lushan. They are often as large as 8 to 10 feet across. Is it possible that natural agency other than the glacier could have conveyed boulders of such a large size over a distance of 6 km. in an essentially level ground? Moreover, the boulders are not only found in the clay, but are piled up on top of the hill which stands 130 m. higher than the lake.

On carefully weighing the evidences in the field it must be reiterated that the difficulty in formulating explanations to account for the various topographical features as well as certain types of deposit under the assumptions of torrential wash, landslides, river floods, piedmont fanning, colluvial or residual filling etc. seems to be enormously greater than that involving glacial action. To my limited knowledge and power of imagination this difficulty is almost insurmountable if ice action is to be ruled out.

Distribution of the Successive Glaciers in the Lushan Area.

In discussing the glacial evidence on the top of the noble mountain we have already recognized two different stages of glacial erosion and deposition. In tracing the boulder clays in the plains around the mountain we have also established the fact that they are not all formed in a single period of glaciation. From the data so far available we can recognize at least two but more probably

three successive periods or stages of glaciation in the Lushan area. They are separated by interglacial periods of different length of time.

For the first period of glaciation which is the most extensive and lasted the longest I propose the name Poyang. It is during this period that the extensive sheet of red boulder clay and most of the drumlins, loongs and the large kames were formed. Little or none of the topographical features produced by the large glaciers of this period has survived on the top of the mountain. The glaciers may have descended the embayment-like gap in front of the Taiyifêng and Nankang Ridge, the Wangchiapo Valley as well as the northern and north-western flanks of the mountain. No erosional trace however, except those on large scale, are recognizable in the present day. Judging from the enormous volume of material that they had brought down from the mountain, they must have indiscriminately buried all the minor features that were developed on the mountain in pre-glacial times.

There were probably four large glaciers that came down from the mountain during the Poyang glacial period. One from its north-western flank, another from the northern side, a third from the north-east along the great U-valley of Wangchiapo and its neighbouring mountain slopes, and the fourth from the precipitous cliffs of the Wulaofêng, Taiyifêng, Kiuchihfêng etc. No glacier of any size seems to have developed in the southern part of the mountain, for in the south-western foothills and the adjoining plains no boulder clay has been found.

The movement of these glaciers is well shown by the radiating drumlins and loongs which are indicated on the diagram (Fig. 2). The north-western glacier pushed forward to the north-west. Only its southern part perhaps tended to flow northward. One can detect this tendency by the trend of the hill range of Peichangling. The northern lobe of ice achieved the longest reach, and spread out like a huge fan from the neighbourhood of Taipinkung, Lienhuatung and Yaochiashan. The city of Kiukiang was at that time under a thick cover of this glacier. This northern lobe of ice is separated from the north-eastern one by the north-eastern prolongation of the Lushan, which might have behaved as a subsidiary névé. Of this, no corroborative data are however yet available. The lower course of the Wangchiapo Valley runs nearly W.-E. But the axis

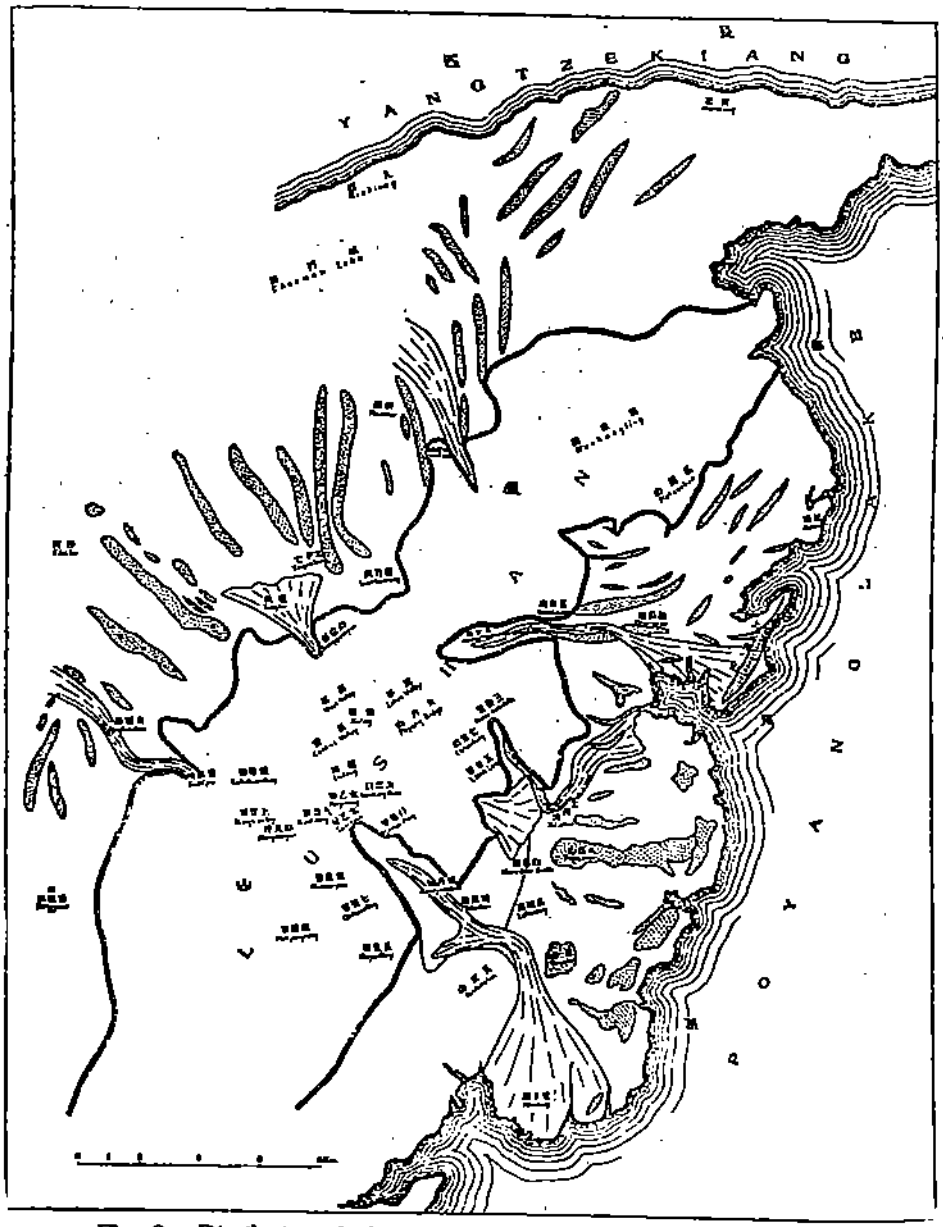

Fig. 2. Distribution of glaciers in the Lushan area. Stippled area: loongs and drumlins formed by moraines of the Poyang Period; stroken; younger boulder clays deposited during the Kinchin and Tulu Periods.

of the north-eastern glacier did not follow this direction. The numerous drumlins and loongs clearly indicate that it flew north-eastward to beyond the shore of the present lake. The southern part the ice front probably stood along the hill-ranges of Kutang and Shangchinshan. These hills are distinctly transverse in their arrangement, and in them occur numerous small pebbles in association with the boulder clay. They may represent fragmentary remains of the frontal moraine (Pl. IX, Fig. 2).

The south-eastern glacier seems to have displaved a considerable force, partly because it descended from precipitous cliffs. As distinguished from the behavior of the other glaciers, this ice lobe showed powerful scooping action in the foot of the mountain. Masses of granite, gneiss and schist are laid bare in the region of Matuling and the White Deer Grotto. We may well compare this region with what is generally called the "central basin" in connection with the development of mountain glaciers. This scoured area is ideally followed further away from the mountain, by the "drumlin zone" in which we actually find drumlins, loongs and kames. The very outline of the land in this part of the country is indeed highly suggestive of the shape of the departed glacier.

The next recognizable period is the one represented by the patches and lobes of deposit occurring in the neighbourhood of Kuanyinchao or Kinchin. As already said, these patches of moraine are sunk in a valley which is carved out of older moraine and the bed-rock on which the latter must have at a time formed a cover. The surface of the older moraine, as judged from the Tingshan kame and its fragmentary remains on the south-eastern side of the Hinkueifêng, stands well over 100 m. higher than the younger moraine. A prolonged period of erosion must have elapsed before the deposition of the younger moraine. The later period of glaciation might be named the Kinchin period, and the glacier that came down from the Taiyifêng past Kuanyinchao during this period the Kuan-yinchao glacier.

The extension of the Kuanyinchao glacier can be traced by the moraine that it deposited. From Taiyitsun down to the neighbourhood of Matuchen the moraine is more or less continuous. Beyond the narrow between the Fong-huangshan and Yuchinshan the young moraine has already been dissected and eroded to such an extent that it is no longer possible to trace its extension with

certainty, I have assumed that the Kuanyinchao glacier flew southward mainly because of the fact that over the Nankang Plain the boulder clay assumes a uniformly low level and that its colour is deep red. The latter fact suggests the presence of reworked boulder clay.

The Kuanyinchao glacier is only of a restricted size as compared with the glaciers of the Poyang period. The amount of moraine that it produced indicates also a much shorter period of glaciation than the Poyang. On the northern and north-western sides of the mountain we have found younger moraines among the old. Whether those younger moraines are to be referred to the Kinchin period or to a still later stage is a problem that requires further investigation.

Boulder clays distinctly younger than the Kuanyinchao deposit were found at several places beyond the foot of the mountain. A typical example of these young deposits occurs near Tuluchen. The glacier which was responsible for the formation of this suspected moraine evidently came down from the mountain through the precipitous cañon which is renowned for the presence of the Three Waterfalls. It will be remembered that at the head of these waterfalls there is a typical U-valley known under the name Chihlihchung. As soon as the young glacier emerged from the canon, it swept round towards the north-east grinding its path through a body of young granite, leaving numerous large boulders and a reddish brown clay all along its way. This bed of boulder clay is somewhat elevated forming a perfectly smooth slope. On the north-western side it banks against the granite, and on the south-eastern side against the loam. The latter seems to have suffered glacial erosion. Here the question arises: Was there a period of glaciation in post-Malan time or was the loam deposited in an interglacial period? With the meagre data in hand these questions must be left for future enquiry.

The boulder clay just referred to form a perfectly flat surface at any transverse section. Longitudinally the boulder bed shows an inclination of 3½ to 4°. In tracing downward, it is found that the clay becomes more and more dominant until we come to Tushanpo where there is left a hummocky heap of exceedingly brilliant red clay which probably marks the front of the diminutive

glacier. A relaxed stream now winds through the glacis cutting a channel of no more than 15 feet in depth. It is indeed astonishing that there could have been glaciation of so recent a date. The evidence is however distinctly against the hypothesis that these materials were brought down by former mountain streams. Tentatively, I propose to name this last stage of glaciation the Tulu stage. As yet we cannot regard this hypothetical glacier as representative of a period, for it might be the final phase of the Kinchin glaciation if it did actually exist.

Nor is the inferred Tuluchen glacier the only one to represent the final stage of glaciation in the surrounding plain of the Lushan. Another recent valley probably of glacial origin comes down from the great U-valley of Wang-chiapo. It passes Wutihmiao, Wuchiateng, and then cuts through a long drumlin in the neighbourhood of Okungpao. Thence the loose boulder clay spreads out in the form of a fan, and finally disappears at the lake shore. If not for its continuous relation with certain flat-bottomed valleys on top of the mountain and the boulder clay that forms its floor one might regard this valley, at least in its lower part, as a flood plain of the mountain stream.

Some of the topographic features which are still so fresh and vivid as to indicate recent glacial action in the higher parts of the mountain are best attributed to the result of this final stage of glaciation. There is hardly any question that this final glaciation when established, will even prove to be of more restricted extent than the Kinchin stage. At the same time it would be too hasty to pass any judgment on account of the limited thickness of the boulder clay that it produced; for we do not know how much of that material has been eroded away during post glacial times.

The conclusion would thus seem inevitable that the Lushan area was glaciated at least twice but more probably three times in the Quaternary Period. The oldest of these glaciations is the Poyang which is the longest in duration. The Poyang was followed by an interglacial period during which genial but probably rather arid climate prevailed. Then came the Kinchin glaciation. Lobes of ice were sent down from the mountain along several valleys which were carved out of the old moraine. Another interglacial period followed; but this time it did not last so long as the previous one. It was soon succeeded by the

Tulu glaciation. During this last glaciation only diminutive glaciers came down to the plain, although the high mountain was undoubtedly under the grip of severe cold. This last glaciation was an ephemeral episode as compared with the Poyang. It lasted probably only for a few thousands of years. Since that time loess-formation and rain-wash characterized the climate. There may have been fluctuation of temperature and the amount of precipitation, but never again glaciers were developed.

A glance at the accompanying diagram (Fig. 2) will show that even in the Poyang period the southern part of the mountain was not glaciated. The long stretch of drumlins and loongs on the northern side of the mountain clearly indicates that the farthest extension of the ice sheet is restricted to that side. The inference is therefore natural that it was the snow-laden northern or north-eastern wind that was chiefly responsible for the production of the mountain glaciers. That the greatest U-valley is located in the north-eastern part of the mountain is also a fact in support of this deduction.

Dates of Glaciation

The youngest strata on which the oldest moraine rests is a red sandstone of early or middle Tertiary age. This red sandstone is occasionally exposed on the shore of the lake. A broad stretch of this sandstone is uncovered in the valley on the southern side of the Tapaishan. The very nature of the moraines together with the fact that the drumlins are but very slightly dissected forbids any assumption that they were formed in pre-Pleistocene time.

It happens that the mountain provides an opportunity for us to determine the number of years that have elapsed since the close of the last glacial period. It will be recalled that the U-valley of Wangchiapo has a secondary flat glacis in its bottom. The glacis is deeply incised by the mountain stream. Careful leveling below Wangchiapo shows that from the bottom of the stream cutting to the bottom of the U-valley which is still covered by boulder clay of one to two metres thick, there is a vertical distance of 76 m. This is taken to be the amount of stream erosion in post glacial times.*

* An arid climate is believed to have prevailed during the interglacial periods. Otherwise, the drumlins formed in the Poyang period of glaciation could not have escaped stream dissection and erosion. The valley is thus not likely to have been cut down by streams to any notable depth before the last stage of glaciation.

At Kinchin on the southern slope of the mountain, a stone bridge was built in the year 1014 A.D. across a stream of a similar strength as that at Wangchiapo. This is the famous Kuanyinchao. On coming down from the mountain through a relatively open valley the water suddenly finds itself being restrained below the bridge. Consequently it concentrates its force of incision at that point. A deep pool in the form of a huge pot-hole is now found under the bridge. Measurement shows that a depth of a little over 6 m. of a gneissoid granite has been removed through stream erosion from underneath the foundation stone of the bridge since it was built. Immediately below the pool the valley shows two distinct stages of erosion. The upper part is fairly open, but the lower part forms a gorge with almost vertical walls on both sides. It is beyond question that the gorge has been brought about by the locking of the water after the construction of the bridge. The gorge measures 5.2 m. deep. This is the total amount of erosion due to an entrenched mountain stream over a period of 920 years. The rate of erosion is therefore about 56 cm. per century at Kuanyinchao.

Now the rock at Wangchiapo is a hard grit apparently of comparable resistivity as the gneissoid granite at Kuanyinchao. The depth of post-glacial erosion would therefore give us an estimate of 13,600 years. On the growth of the Muota delta in Lake Lucerne Heim estimates the period elapsed since the Bühlstadium, that is the maximum of the Würm glaciation in the Alps, to be about 16,000 years. Lucerne and Lushan are separated by a vast stretch of continent, and the methods of estimation are entirely different. Yet the figures arrived at are singularly of the same order. It would thus seem acceptable to correlate the last period of glaciation in the Lushan area with the Würm in the Alps.

Glacial Indications in Other Parts of the Yangtze Valley

Some of the loongs and kames in the neighbourhood of the Lushan reach a height of over 130 m. above the lake. The shapes of these hills and the nature of the material that forms them prove that they are sub-glacial deposits. It will be thus realized that the older glaciers might be hundreds of feet thick. Such a thickness of ice spreading out in the plain must necessarily involve an

arctic temperature. It is beyond imagination that an arctic climate could have been a local phenomenon. We would therefore expect to find glacial evidence elsewhere in the Yangtze Valley.

Near the city of Nanchang which is situated at the southern end of the Poyang Lake, a mountain range, called the West Mountain, rises to a height of about 700 m. On top of the foothills of this mountain red clays with boulders are widespread. Mr. Wang-yu who went there to investigate the nature of the recent formations came back with the report that all the red clay hills exhibit a hummocky topography like a "basket of eggs." Mr. Wang further asserts that he had seen boulders with grooved and striated surfaces. Evidence of this kind seems to be strong enough to warrant glaciation.

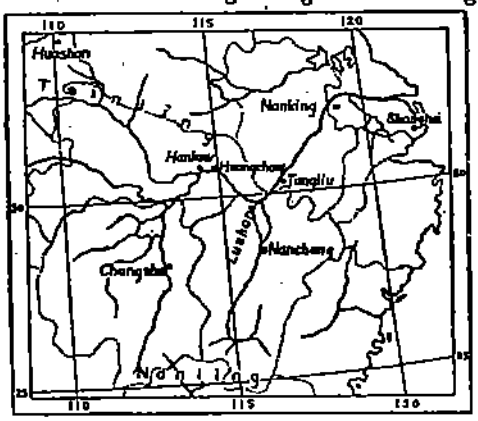

Fig. 3. A sketch map of the Yangtze Valley.

If we follow the Great River down from the mouth of the Poyang Lake we find, for a long distance, no boulder clay by the side of the river. But as we arrive at Tungliu, a place some 70 miles away from Kiukiang, boulder clays are again widely exposed all along the southern bank. They form numerous hummocky hills, usually some 30 to 40 m. high. Boulders are sometimes numerous and sometimes exceedingly scarce. When present they are always tumultuously mixed in the unstratified clay. Associated with the boulder clay are now and then found gravel beds. When the high mountains in the hinterland recede from the river, then these gravel beds are developed on the southern bank, and form miniature cliffs. When the river approaches the mountains,

then boulder clays appear. Thus it is highly probable that the gravels are really of glaceo-fluviatile origin. They represent the outwash apron.

Even in the neighbourhood of Nanking signs of glaciation are not wanting. On the southern side of the Purple Mountain long lobes of whale-backed hills run almost perpendicularly to the general strike of the mountain. On top of these hills we find, below a mantle of loam, sometimes a fine red clay and sometimes red clays mixed with slabs of stones and boulders. Among these materials now and then occur large, angular blocks of the conglomerate which forms the highest ridge of the Purple Mountain. The present topography of the mountain does not favour the assumption that they were brought to their present resting place by the sole agency of gravity. A possible glacial action is therefore not excluded.

On the northern side of the Chihsiashan, near Nanking, Mr. S. Chu observed an unstratified, mottled clay with sub-angular boulders derived from the hill. The clay, according to Mr. Chu, is exactly of the same nature as the mottled clay of the Lushan area. This deposit is entrenched in a miniature valley which obviously afforded protection from erosion. On this boulder clay rests a mantle of loam. If the implications of the problem of glaciation in the Nanking area be fully explored some light may eventually be thrown upon the mythical origin of the post Yuhuatai* or its associated gravels. In passing, I may mention that the suspected red clays, gravels and boulders occur also on the northern side of the river. They are spread here and there in the low ground up to the northern side of Mingkuang. Are these all residual or purely river deposits?

Now let us consider the indications available in the upper part of the Yangtze Valley. I will first of all call your attention to the district of Huangchow where there are things which have puzzled me for more than a quarter of a century. When I had the pleasure of chanting the Four Classics I well remember that I used to play the game of hide-and-seek in behind a gigantic boulder which is called by our villagers the "meteorite". That meteorite is

* Barbour, G. B. Geomorphology of the Nanking Area: Contr. Nat. Res. Inst, Geol. No. 3. 1933, pp. 94-98 and 111.

in fact a block of gneiss so thoroughly weathered that its mineral constituents are almost beyond recognition. No gneiss of that kind is known in that country, nor is it likely to occur *in situ*. It must have arrived from the Tsinling Range. Drifting clays usually with gravels but few boulders occur far and wide in that country. They attain a considerable thickness in the north-eastern suburbs of the city of Huangchow. I would not definitely say, as yet, that these are all moraines. Any explanation that can satisfactorily account for their origin would be of great value.

In central and southern Hunan a mottled red clay is widely distributed. It contains white patches and bloches precisely in the same manner as those occurring in the moraines near the Lushan. With this clay are now and then associated gravel beds. This clay is traced to as far as the Nanling Range. There is as yet no positive evidence to show that these materials are of glacial origin, but they certainly invite further enquiry along that line.

From the evidences discussed here it seems hardly possible to doubt a widespread Pleistocene glaciation in the lower and central Yangtze Valley§. The glaciers were, of course, of the Alpine type. Mountains that attained a height of more than 500 m. were probably rarely exempted from glacial action, at least that of the Poyang Period. Only in places where a plain is surrounded by high mountains a semblance of the Piedmont type of glacier may have developed. If an intermontane basin has an opening to the north-east, then the condition would even be more favourable. When it was announced that I had the pretentious hope that the Lushan might eventually be made a type locality of Quaternary glaciation in China, I meant to convey the idea that we are henceforth to deal with mountain glaciers if the subject is to be pursued.

Problems Arising from Glaciation in the Yangtze Valley

If we accept glaciation in the Yangtze Valley as we are compelled to, what then of the northern part of the country? It is unnecessary to repeat the

§ While the present paper is in press Mr. T. Y. Yü reports a scattered occurrence of boulder clay on the southern side of the eastern Tsinling Range over a stretch of country of more than 100 miles.

evidence that I had gathered eleven years ago.† Your attention is here invited to a fresh case not of my own observation but of my colleague Prof. C. Y. Hsieh. According to Prof. Hsieh there are numerous strange features in the Huashan, southern Shensi, which might be well accounted for by ice action. He has kindly showed me a series of photographs taken in the mountain. Among them there are one or two which undoubtedly indicate the presence of cirques.*

Even in the neighbourhood of this city, the Western Hills of Peking, I have frequently noted peculiar topographic forms that can hardly be considered as the work of stream erosion or any destructive agency of nature other than ice. Evidence is however too meagre to justify any positive statement at present.

Over the other side of the Yellow Sea, the question of possible glaciation has been now and then discussed—so I was informed—by Japanese geologists. Years ago, a casual note by the late Yamazaki was published in the American Journal of Science discussing glacial features that have been preserved in the high mountains in Japan. It is to be regretted that I cannot, for the moment, give you the exact reference. Nor am I in the position to discuss such matter.

It is immaterial whether or not these isolated cases will be eventually substantiated. The evidence seems strong that glacial conditions did prevail in the Yangtze Valley during the Pleistocene time, and that they prevailed repeatedly in the latitude of 29° 30′-37′ that being the latitudinal position of the Lushan. In the North American Continent Pleistocene glaciers extended down to the latitude of 38°. In Europe they are restricted to even higher latitude. This part of our Asiatic Continent hitherto considered to have enjoyed a genial climate in the days when Europe and North America were under the grip of polar severity now proves to be similarly affected by a sweep of cold. And in the matter of latitudinal extension of lowland glaciers our Asiatic Continent has actually broken the records of all continents of the globe.§

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† Lee, J. S., Recent Ice Action in N. China, Geol. Mag. Vol. LIX, No. 691, Jan. 1922, pp. 14-21.

* Dr. E. T. Nystrōm informs the writer that he had actually observed end moraine a few kilometers north of the Huashan at an altitude of about 200 m.

§ The writer is indebted to Dr. E. Norin for his valuable information regarding Quaternary glaciation in India.

In view of these newly established facts, would it still be necessary to move the early Quaternary poles to such a position as is so ardently advocated by Köppen and Wegener? What could have been the koleidoscopic changes that were wrought upon the floras and migratory faunas of this country during the glacial and interglacial periods? How our Palæolithic ancestors were chased and spared by the advancing and retreating glaciers? These are among the more pressing problems of profound scientific interest that demand an immediate solution. I do not pretend to discuss these involved questions this evening, but merely raise them for your own consideration in your special fields.

Explanation of

Plate I.

Plate I

Fig. 1. A cirque-like depression on the eastern side of Huenmenkou (橫門口) and south-western side of Yuelunfêng (月輪峯). In the northern part of this depression is a deltoid platform composed of boulder clay suggesting a fan. Its steep front indicates however that it was once a more extended deposit. A flat-bottomed valley runs along the eastern side of the platform indicating two stages of glaciation. The road leading to the small house on the right crosses the platform as well as the valley. All along this road boulder clays are well exposed. (p. 18).

Fig. 2. A natural dam of boulder clay built across the E.-W. valley behind the Nankang Pass. This dam is now cut across by a stream flowing eastward. Formerly it probably served as a bank of a glacial lake.

Fig. 1

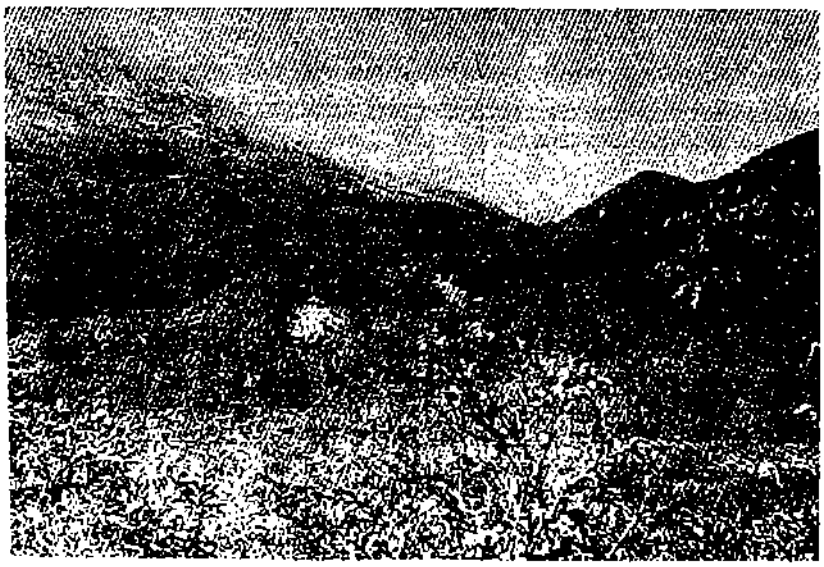

Fig. 2

Explanation of

Plate II.

Plate II

Fig. 1. The flat-bottomed valley of Chihlihchung becoming confluent with another flat-bottomed valley behind the Lion's Leap. Between these two valleys there is left a sharp ledge of rock suggesting confluential abrasion of two glaciers; viewed from the Lion's Leap. (p. 19).

Fig. 2. A typical hanging valley developed in the north-eastern part of the Lushan.

Fig. 1

Fig. 2

Explanation of Plate III.

PLATE III

Fig. 1. Two U-valleys terminating abruptly at the Luling depression (廬林). The U-valley on the left is named Tachaochang (大校場) following the strike of the Poyang Ridge on its eastern and the ridge of the Niuercheng Sandstone on its western side. Boulder clay abounds in this valley leading up to a névé above the Hankow Gorge. (p. 20).

Fig. 2. Another aspect of the same U-valleys as shown in Fig. 1.

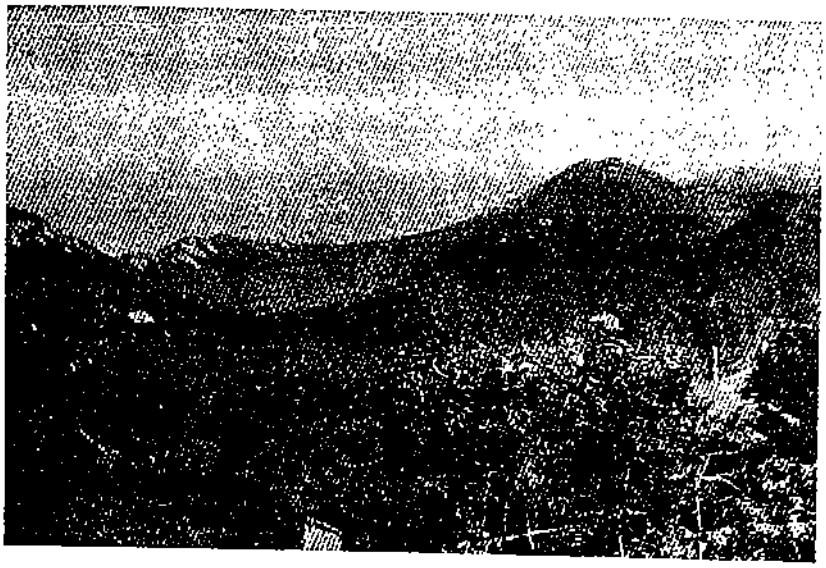

Fig. 1

Fig. 2

Explanation of

Plate IV.

PLATE IV

Fig. 1. The U-valley of Wangchiapo, sometimes called the Takutang Valley (大沽塘谷), looking eastward from below Hsiaotienchih (小天池). The gap in the bottom of the valley is believed to be due to stream cutting in post glacial times. (p. 20 and p. 38).

Fig. 2. A closer view of the bottom of the Wangchiapo Valley showing a perfectly flat valley paved by clays and boulders, subsequently generated.

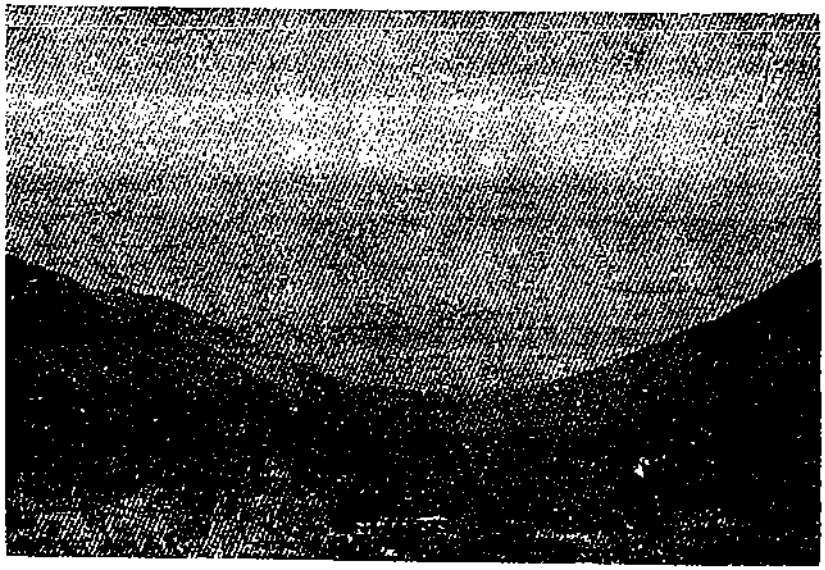

Fig. 1

Fig. 2

Explanation of

Plate V.

Plate V

Fig. 1. Typical boulder clay developed in and around the Lushan. This particular photograph is taken in the plain on the eastern side of the mountain, not far from the shore of the Poyang Lake.

Fig. 2. A typical striated boulder with the striated surface almost perfectly flat and other faces uneven or slightly curved. The edges between the neighbouring faces are more or less rounded. Bedding planes are not clearly developed in this boulder. Faint lamination runs oblique to the striated surface with its trace almost perpendicular to the principal set of striæ. There are two sets of striæ on the planed surface nearly perpendicular to each other. Slickenside is definitely excluded. Natural size of the striated surface: about 21 × 12 cm. This particular specimen was found in the Tachiaochang Valley where no landslide is topographically possible. Similarly striated boulders frequently occur in the boulder clays, but seldom the striæ are so well developed as in this specimen.

Fig. 1

Fig. 2

Explanation of

Plate VI.

PLATE VI

Fig. 1. The Tiehchuanfêng (鐵船峯) cirque, viewed from the top of the Shangsiaofêng. (p. 21).

Fig. 2. A slope in the northern part of the mountain covered by strips of loose boulders which sometimes attain a considerable size. These are believed to have been left stranded by decaying ice. (p. 25).

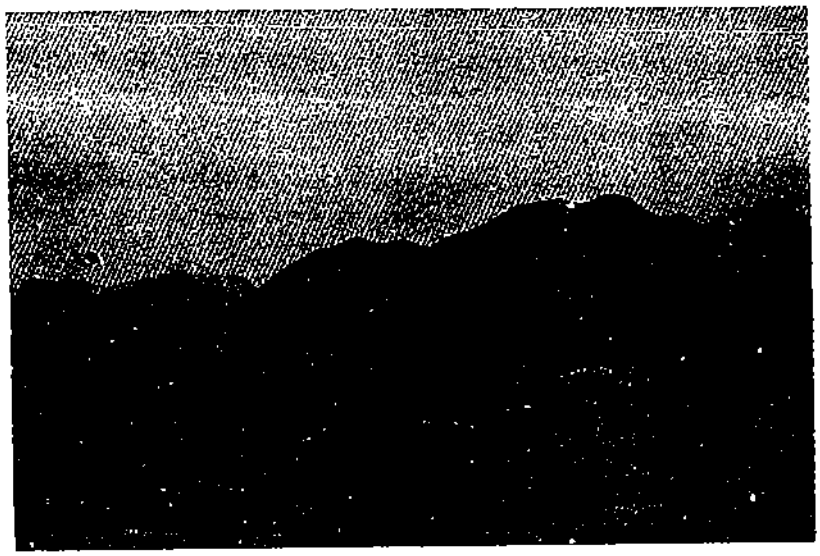

Fig. 1

Fig. 2

Explanation of

Plate VII.

PLATE VII

Fig. 1. A coarse boulder clay with an admixture of sands and numerous boulders entirely devoid of any trace of stratification; at the mouth of the Wangchiapo Valley, below the Changling (長嶺). (p. 27).

Fig. 2. Below the locality shown in Fig. 1, an exposure of boulder clay reveals two successive stages of deposition separated by an irregular surface. Note that the boulder clays in this exposure are of finer texture than the preceding one. (p. 28).

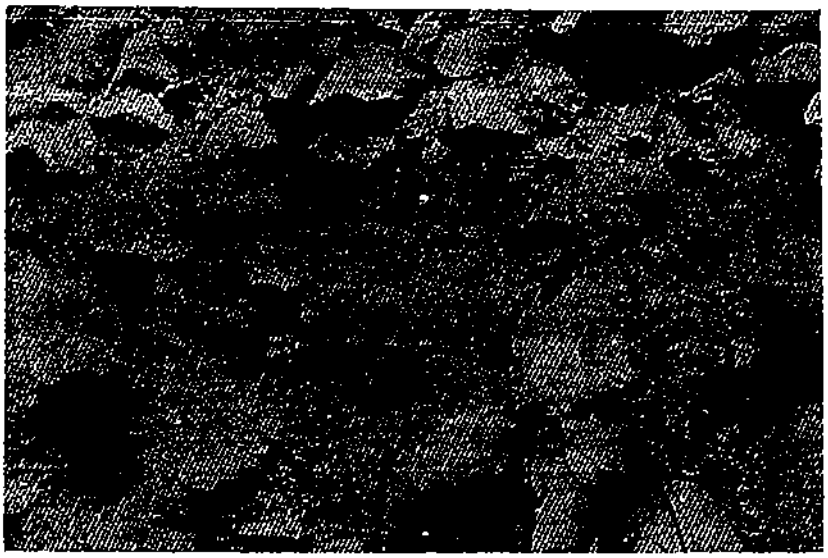

Fig. 1

Fig. 2

Explanation of

Plate VIII.

PLATE VIII

Fig. 1. A typical drumlin entirely composed of boulder clay about half a kilometre long and ¼ of a kilometre wide, near the Matsushan. Drumlins of this type abound in the plain on the eastern side of the Lushan. (p. 28).

Fig. 2. The low-lying hill-lobe seen through the gap of the Lion's Leap is the loong of the Tapaishan (大排山) and Changling extending to the shore of the Poyang Lake. Gigantic boulders together with boulder clays form the bulk of the hill. (p. 32).

Fig. 1

Fig. 2

Explanation of

Plate IX.

PLATE IX

Fig. 1. A tenacious red clay, unstratified, with numerous white bloches and streaks and large and small sub-angular boulders indiscriminately scattered in it. In places the clay becomes predominant and boulders rather rare; occurring in all parts of the Lushan area. (p. 30).

Fig. 2. Boulder clays of the Shangchinshan, on the lake-shore. Here the boulders are generally of smaller size, very abundant, but still unstratified. Sometimes the boulders are of so fine a grade as to merit the name gravel. In front of the large boulder on which the writer sits, is exposed a hardened layer of a bluish clay apparently due to the invasion of the lake water. This suggests an interlude of genial climate. (p. 33).

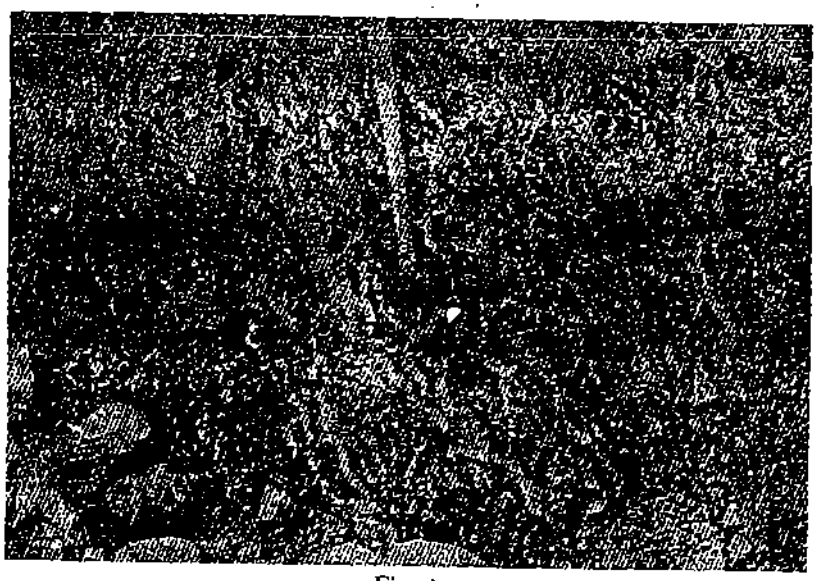

Fig. 1

Fig. 2