GLACIAL PHENOMENA ON THE YUN-NAN–TIBET FRONTIER.

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IN the following paper I shall endeavour to show that the ice is retreating progressively from east to west on the parallel ranges separating the southward-flowing rivers Yang-tze, Mekong, and Salween, on the Yun-nan–Tibet frontier, and that glaciation was once much more extensive on the easternmost of the ranges than it is at present; furthermore that this retreat is due, not to the rhythm of glacial and interglacial epochs, but to a diminution of rainfall, either regional or local.

Our first journeys then will be on the Mekong–Yang-tze divide, that is the parallel range separating the Mekong from the Yang-tze where those rivers flow due south close to one another. The range is very narrow, and from a commanding position to the west one can easily look right over it across the gorge of the Yang-tze beyond, and to the mountains beyond that again. South of latitude 28° the range is of moderate elevation, but about latitude 28°, longitude 99° occurs a nucleus of snowy peaks known as Pei-ma Shan in Chinese, the highest of which is probably between 19,000 and 20,000 feet. From the Mekong valley itself this group is invisible, but from the next range to the west (the Mekong–Salween divide) or from the road which connects the Mekong and Yang-tze valleys, passing east of the snowy peaks, it can be viewed in its entirety.

Viewed from the east the glaciers on what seems to be the highest peak are well seen, and are evidently shrunken glaciers, the biggest no longer reaching the valley it once occupied but clinging amœba-fashion to the mountain side and sending icy pseudopodia creeping down the cliffs. The surface is crevassed in a peculiar criss-cross fashion, as I saw through the glasses, but I did not actually reach the glacier (Fig. 1). Immediately below the peak at an altitude of about 15,000 feet is a flat grassy valley filled with glacier mud, which leads up to the pass on the extreme right of the figure over vast piles of angular boulders; and on either side of it open "hanging" valleys, one of which is seen in the foreground. At the head of this "hanging" valley nestles a tiny turquoise lake, and there is a second lake in the main valley below the small glacier on the right, from which the water pours in a cascade between stone portals and over the boulders into the valley below, where meandering through the meadow it soon reaches the fir trees and disappears in the forest.

Just above this lake is a broad flat sandy plain surrounded on three sides by steep mounds of large angular boulders, across which several small streams flow to the lake; the flat itself appears to be a silted-up basin.

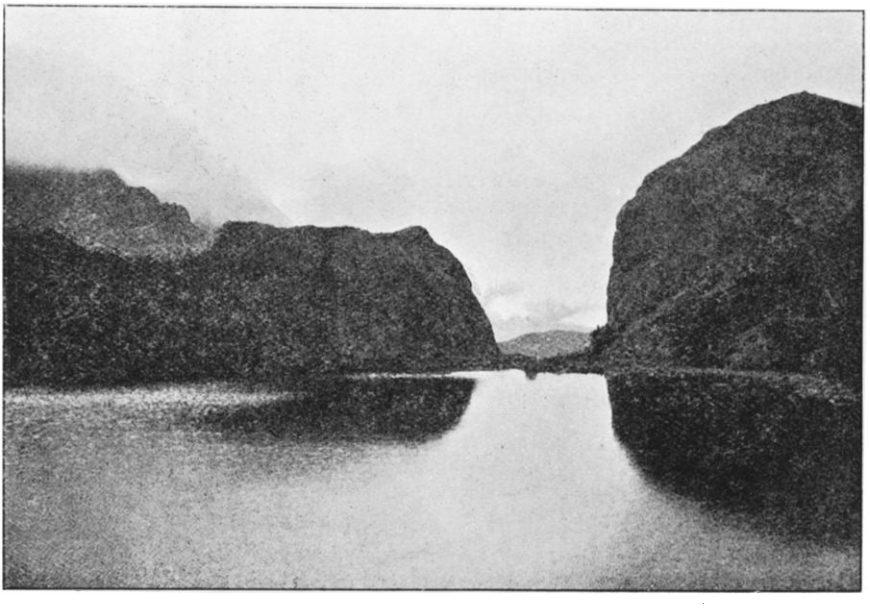
Climbing over the boulders, some of very large size, we found ourselves

on the small glacier which sweeps down from the high peak on the left, and has thrown a moraine (seen on the right) across the valley; the glacier, however, no longer reaches the moraine, which stretches down the valley as far as the little lake. It was here only a few score yards broad and at its termination almost concealed by rubbish. Keeping as close to the lateral moraine as possible, where there were few crevasses, we crossed it, and a sharp climb over confused piles of big boulders brought us to the pass at 17,000 feet.

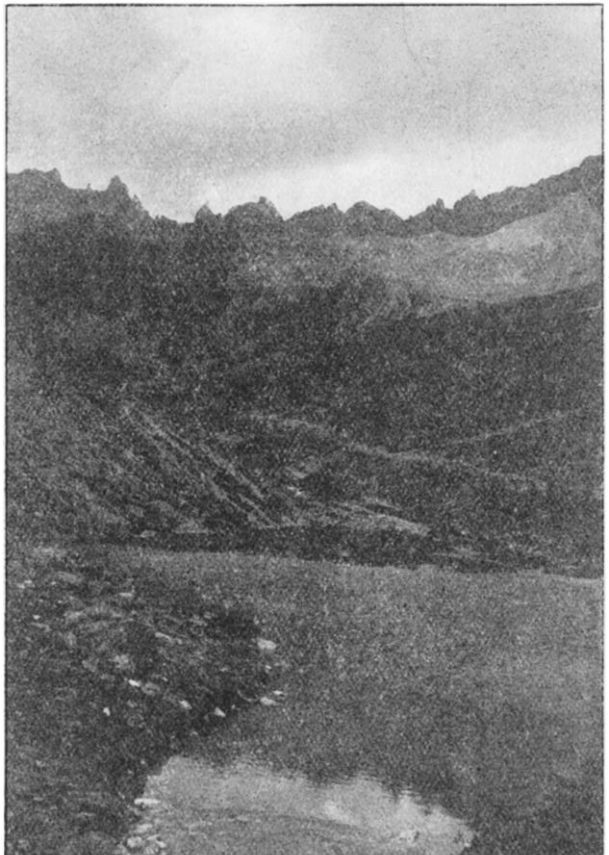
The descent on the west side was different, for there was no glacier in the valley nor even visible on the mountain above. We descended over the same confusion of boulders, amongst which we came upon small flat pockets of sand enclosed by steep slopes and shallow gullies dividing the boulders into vast mounds, till finally the valley fell away abruptly beneath us, and we were compelled to leave it and traverse along the side of the spur.

Northwards of the Pei-ma Shan snowy group these features continually

1. PEI-MA SHAN, FROM RIDGE TO THE NORTH, ABOUT 17,000 feet. THE PASS IS SEEN ON THE RIGHT.

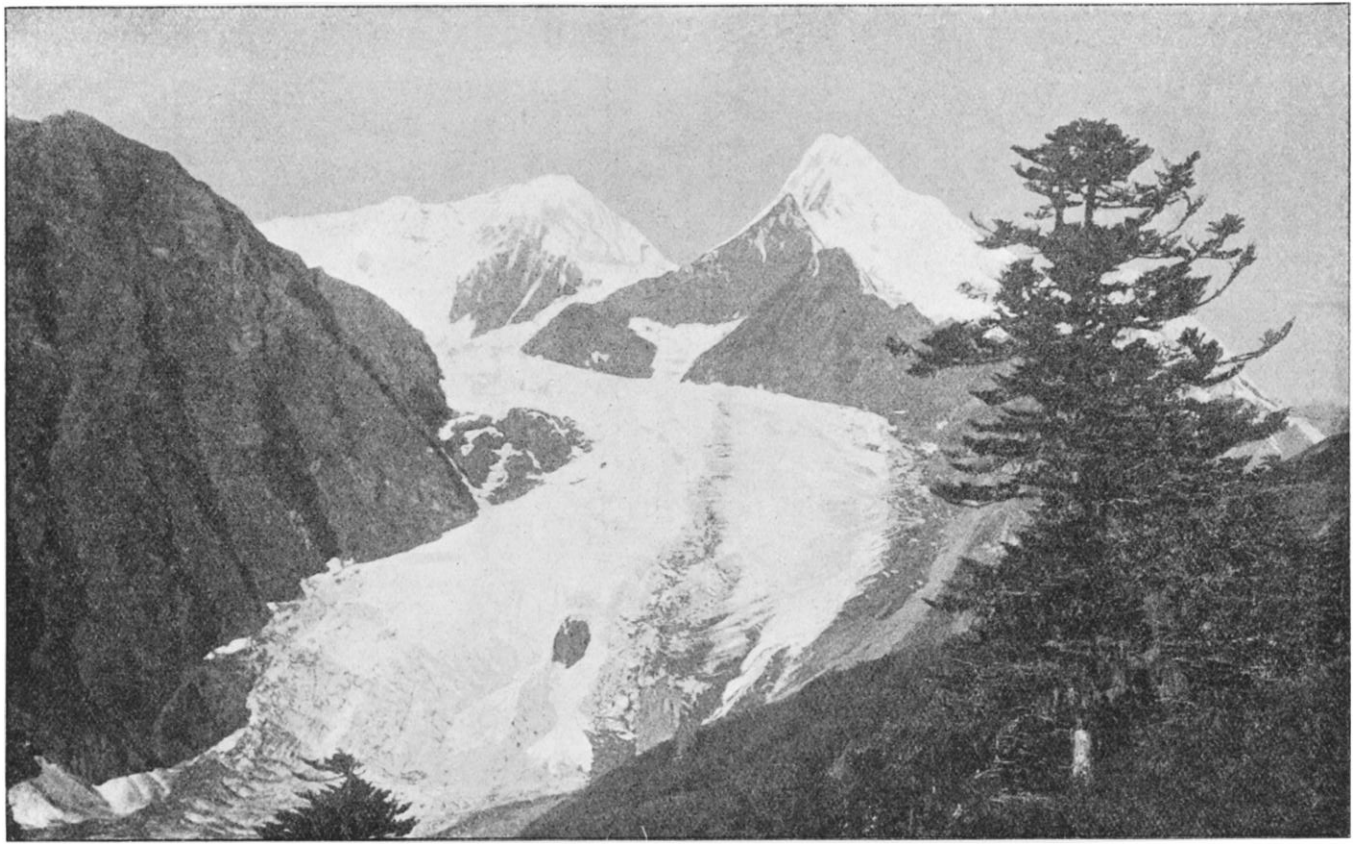


2. ROCK-BASIN ON THE MEKONG—YANG-TZE DIVIDE, 16,000 feet, LOOKING DOWN VALLEY. THE STREAM FROM THE LAKE FLOWS THROUGH THE GAP IN THE BASIN.

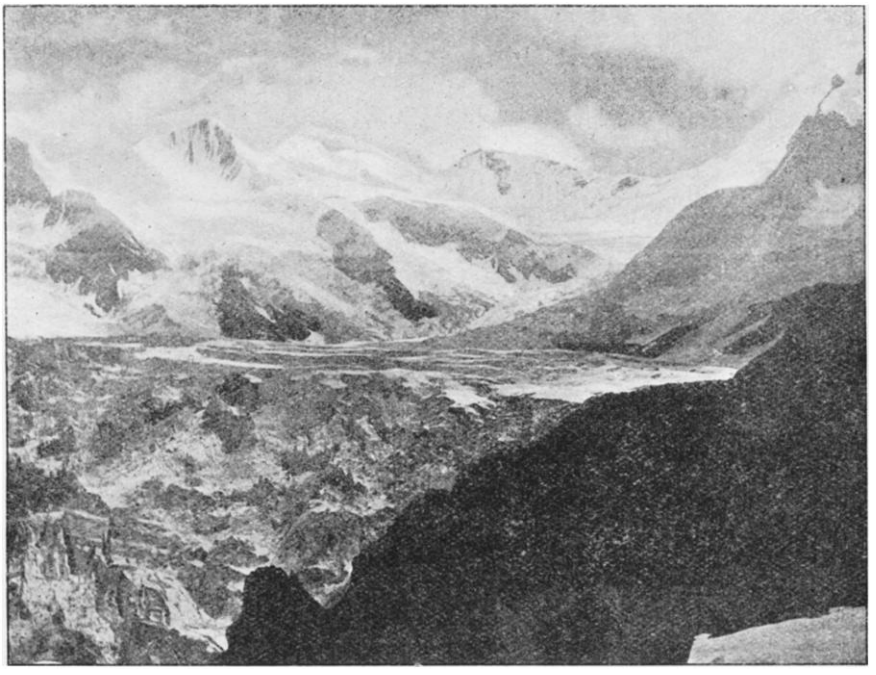


3. CREST OF THE MEKONG—YANG-TZE DIVIDE, WITH THE RUN-TSI LA (17,900 feet) TO THE LEFT. GLACIATED VALLEY WITH LAKE IN FOREGROUND.

4. ICE CATARACT AND NORTHERN PRECIPICE KA-GUR-PU GLACIER.



5. KA-GUR-PU GLACIER FROM CAMP AT 15,000 feet. NORTHERNMOST PEAK OF KA-GUR-PU RANGE.



6. KA-GUR-PU GLACIER AND SNOWFIELDS ABOVE THE ICEFALL, FROM THE HIGHEST POINT REACHED ON THE RIDGE, ABOUT 16,000 feet.

7. DOKER LA VALLEY, MEKONG—SALWEEN DIVIDE, 15,000 feet, LOOKING UP VALLEY. GRANITE WALL FROM BELOW CUT THROUGH BY STREAM FROM GLACIER.

reappear, though there are no more glaciers south of Adong (see sketch-map) and then only remnants. The side valleys, divided from one another by sharp ridges, the flanks of which present steep screes, always overhang the main valleys, and rise by a series of long steps—tread and riser—to the crest of the divide, the well-defined cirques being piled with great mounds of angular rock fragments. At the foot of the cirques and on the successive flats of the upper valleys are small lakes or pools, but these are not infrequently silted up. Some of them, such as that shown in Fig. 2, are of considerable depth, shelving rapidly. A peculiar feature about the uppermost of these lakelets is that they generally occur at the summit of a cliff which has been cut through, so that the stream at its exit from the lake is flanked by portals and then tumbles over boulders into the valley below (see Fig. 2 and compare Fig. 7). These scarped valleys are characteristic of this region; we shall find other instances when we come to the Mekong–Salween divide. Such breaches in the wall were—probably at least—started by the glacier, for it does not appear that the stream starting from rest in the lake would possess much erosive power.

In one side valley above Atun-tzu I found a very well preserved lateral moraine flanked on one side by boulders. Below in the main valley was a gigantic pile of big boulders shelving steeply down to a triangular lake; above, the moraine ended at the usual sandy flat—a silted-up lakelet, enclosed on two sides by gravel screes. Just above was the pass.

Roches moutonnées were conspicuous in the main valley at one point, and the valley also shows a typical **U**-shape without spurs in section. Besides the scarp shown in Fig. 2 this valley is again broken across by a cliff just above the village of Atun-tzu; over this cliff the stream pours, but there is no definite evidence that the glacier ever reached the village below. Supposing, however, that it reached the top of the cliff, as it must have done—for there is a lake occupying a valley below and to the north which has been ponded back by a moraine from this glacier—it must have been at least 5 miles in length.

Two other phenomena frequently noted on this range are (1) a peculiar tesselated arrangement of the stones, laid down like tiles in the level parts of the upper valleys, over which the stream, surrounded by boulder slopes, spreads out; (2) the frequency with which towers and pinnacles, generally of limestone, rise abruptly from the screes of gravel and earth crowning the highest spurs of the main divide. Frequently these wall-sided sharp-edged limestone rocks are of a most fantastic and striking form, and their isolation on the ridge of a gravel scree commands immediate attention.

We will now leave the Mekong–Yang-tze divide and investigate the snowy range of Ka-gur-pu on the Mekong–Salween divide to the west. Standing on the Mekong–Yang-tze divide and looking west we see the Ka-gur-pu range in its entirety, and are at once struck by two things: (1) The much greater amount of snow, and the consequent greater length of the glaciers which seem to come right down into the Mekong valley

after a very steep descent; (2) The different appearance of the peaks compared with those, snow clad and otherwise, on the Mekong–Yang-tze divide; for whereas the latter are mostly square-faced towers and buttresses, with abrupt **V**-shaped depressions between them so as to give a saw-edged outline against the sky (see Fig. 3), the former are all rounded or needle-pointed pyramids separated by more gently inclined **U**-shaped depressions. This latter difference may be ascribed partly to the difference of rainfall on the two divides, whereby the most westerly shows the curve of water-erosion while the Mekong–Yang-tze divide has for a long time been fashioned largely by dry denuding agents, particularly the action of a great range of temperature, both daily and seasonal; and partly to the effect of the different composition of the rocks themselves, the Mekong–Yang-tze divide being capped largely by limestone (though Pei-ma Shan itself is igneous), the Mekong–Salween divide by granite and metamorphosed igneous rock. Fig. 5 shows the northernmost peak of the Ka-gur-pu massif, and Fig. 3 the crest of the Mekong - Yang-tze divide and the Run-tsi La. When we come to examine the glaciers closer we find that they all, at least on the eastern flank, flow in deep gorges, and that they are all broken at one point by an icefall (see Fig. 4). Thus there is little room for lateral moraines (see Fig. 5) which often do not exist, and it may be necessary to fall back on other evidence as to whether the ice once filled the gorge to a higher level or not; also, if it did so, whether its subsidence is due to an actual diminution of the ice or to a continuous ploughing out of its bed.

But below the lowest glacier there existed unmistakable evidence of the previous extension of the ice. The snout of the glacier itself sloped gradually down in a long pointed tongue marked by a few lateral crevasses pointing down-stream. Here the surface of the glacier was smooth and undulating, convex from side to side, sloping gradually down from above, and presented no difficulties. There was very little moraine stuff on its surface but sections near the snout presented a curious honey-comb structure, the walls between the pit-marks being defined by dirt lines. Not far above the snout the cliff, seen on the right in Fig. 4, rises sheer from the glacier and is traversed at some height above the glacier by a path. The smooth undulating surface at the snout does not extend far up the valley; big longitudinal crevasses soon appear, and the sound of stones falling into the chasms both from the cliff on the right and from the surface of the ice, mingled with the splash of water, is continually heard. A little higher up we find a stormy sea of ice at the foot of the fall. The sound of the séracs falling over this precipice from above in the silence of the night is most awesome. During the winter a regular army of ice pillars seem to rise up and crowd to the brink of the precipice, and towards the end of June they begin to fall, so that by the end of August the ice cataract presents quite a different appearance, the dirtier surface ice being streaked and powdered with the frozen spume of the shattered séracs which leave long trails in their wake.

It is to be noted in Fig. 4 that the north flank of the gorge, *i.e.* the side facing south, is a more or less sheer precipice, while the north-facing side is less steep. But this is not always the case for in Fig. 5 it is just the reverse. All the streams flowing to the glacier (Fig. 4) from the precipice side leap 100 feet or more over the cliff—that is, the valleys are "hanging" valleys just as they are on the Mekong–Yang-tze divide. On the other less precipitous side, facing north and therefore less exposed to sunshine, these "hanging" valleys may be seen in process of formation as the ice-level drops.

At this present time the glacier ends at an altitude of roughly 9000 feet above sea-level (by aneroid). In the valley below the icefoot are great mounds of stones, some of them scratched, which have been spread out by the streams, and lower down the valley terraces have been cut out of the rubble. From the glacier foot to the Mekong is a distance of about 2 miles as the torrent flows, and whether the glacier ever reached the Mekong or not and actually flowed in that gorge is an interesting question; but there can be no doubt that it once reached at least a mile further down the valley and that it is still retreating.

I have already said that the cliff seen on the right in Fig. 4 begins a little above the glacier snout. From the end of this cliff, and stretching down the glacier valley for half a mile beyond the snout is a lateral moraine, its summit and far side covered with trees, while the flank facing the glazier is almost bare below or dotted with plants trying to establish themselves. The summit of the moraine is 350 feet above the glacier-level and shows a sort of step structure, as though there had been periodic fluctuations in the retreat of the ice. The lower step is not very clearly defined and may be due to local causes, but the upper one is conspicuous and marks the lower limit of trees on the moraine, including *Ailanthus*, willow, poplar, maple, oak, *Hippophæ*, etc. This part of the moraine is composed of big boulders, while below the step or ledge the material is finer—gravel with small scratched stones. Here small bushes of *Hippophæ*, with species of *Rubus*, *Senecio*, and one or two grasses were noted.

This very well preserved moraine extends, as I have said, about half a mile beyond the present icefoot, after which come terraces and cliffs of gravel; but there are rocks below this which have been smoothed and scored by the ice, as well as marks on the cliff where the path is now cut above the moraine which must be due to the same agency. When I asked the Tibetans if the ice had not retreated they said that forty or fifty years ago it extended further down the valley.

Across the valley, on the north-facing flank, are indications of a subsidence in the ice-level, a bare wall of rock or earth not yet occupied by plants intervening between the ice and the forest above. This is all there is in the way of a lateral moraine, most of the rubbish which falls from the cliffs on either side being engulfed in the longitudinal crevasses,

or in the chasm between the ice and the containing wall (see Fig. 5 in text).

One more point in connection with this glacier. At an altitude of about 10,000 feet we came upon an open more or less level bay in the cliff, and here, on the very brink of the precipice, was another portion of moraine, also covered with trees. Though not more than 50 yards long, its extraordinary position on the edge of the cliff 150 or 200 feet above the glacier made it a very conspicuous object. It was wedged in between two lengths of vertical cliff, much as the short stretch of moraine

SECTION ACROSS GLACIER FOOT, KA-GUR-PU.

(MEKONG-SALWEEN DIVIDE)

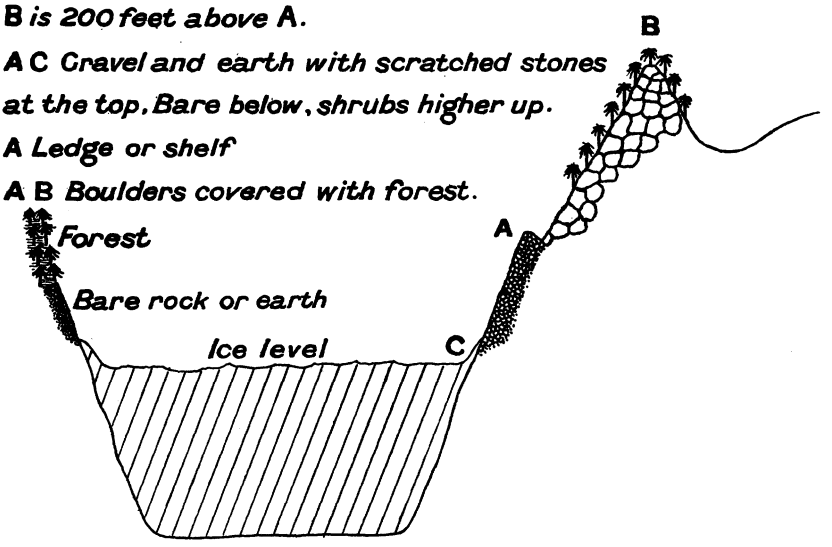
The section is not drawn to scale and the slopes are exaggerated.

A B C Ancient moraine, A is 150 feet above the ice level at C and B is 200 feet above A.

A C Gravel and earth with scratched stones at the top. Bare below, shrubs higher up.

A Ledge or shelf

A B Boulders covered with forest.



seen in Fig. 5 is, only instead of being down by the ice it was a long way above it.

This settles the question of whether the ice-level in the gorge has subsided owing to a diminution in volume or to the ploughing out of its bed. We have seen that the ice-level must have sunk between 200 and 300 feet in the gorge, for the summit of the moraine previously described is 300 feet above the glacier. But this moraine also extends half a mile down the valley beyond the present icefoot, and there are smoothed and scratched rocks half a mile beyond that. Evidently, then, the glacier itself has shrunk and it has all the appearance of a glacier in retreat.

Coming now to the glacier shown in Fig. 5. The foot of this glacier was inaccessible, but from the ridge whence the photograph was taken I

reached the moraine seen on the right. It is only a few hundred yards in length and of inconsiderable height. The ice no longer reaches it and a second moraine is being formed below.

The precipitous part of the ice-fall is well shown in the left-hand corner of the photograph, where two exposures of rock in the bed of the glacier are shown, though the whole visible length is steep. This glacier is not so long as the one previously described and ends about 10,000 feet above sea-level.

Fig. 6 is a view of the same glacier just above the beginning of the fall, taken from further up the ridge. Long transverse crevasses begin to appear as the ice approaches the brink.

We will now go to the other end of the Ka-gur-pu group and examine a valley from which the ice has retreated much further. Here at the southern end of the range is a valley—the Doker La valley, which instead of running steeply down from the crest of the watershed at right angles to the Mekong gorge, has been cut for some distance more or less parallel to the latter and to the divide itself before breaking through it at right angles.

Near what at first sight appears to be the head of the valley it opens out from a narrow gorge through which the stream tumbles and roars over large boulders to a comparatively broad meadow where the now divided stream rattles over a sandy bed. In this meadow are three colossal blocks of stone possibly not inferior in size to the olivine boulder above the Mattmark Lake in the Saas valley. Two of them are of granite and might possibly have fallen from the granite cliffs immediately above, though this is very unlikely. The third, an older block than the others—for its angular corners are worn smooth by weathering and it is completely overgrown with vegetation instead of only its summit being covered—is not of granite, and cannot therefore have fallen from the cliffs above; indeed, it cannot have been carried down the valley for less than a mile, which was as far as I explored in that direction, finding it hemmed in by granite cliffs thus far. Above this meadow over which hangs the lateral valley leading to the pass (Doker La), the main valley again narrows down and apparently comes to an end about a mile beyond in a granite wall (see Fig. 7) just below which is another enormous granite boulder. Over this granite wall a stream pours from the valley above, a continuation of the main valley, at the head of which is a small glacier, the southernmost glacier of the Ka-gur-pu range. But the stream has also cut through the cliff, as seen on the right of Fig. 7, and at the top of the cliff one might expect to find a small lake, only it is as a matter of fact silted up.

Looking down valley from this cliff (which I surmounted by means of the gulley on the right) to the meadow we see a broadly **U**-shaped valley walled in by sheer granite precipices, slit in turn by narrow gullies and dotted with these enormous boulders. The meadow is a sandy plain, another silted-up lake, and it is evident that the glacier the snout of

which at present reaches to within about a quarter of a mile of the cliff, once stretched down beyond the meadow; it has in fact retreated a couple of miles.

To what height it may have filled the valley we have the height of the cliff and also the height of the "hanging" valley above the meadow to show, presuming that the ice was once level with the floor of the latter valley; there are also visible on the granite precipices in some places deeply scored marks which may have been caused by ice-action. The height of the granite wall in Fig. 7 is about 400 feet, and the height of the "hanging" valley above the meadow is not less than twice that amount; and since it is evident that this valley presents very much the appearance that would be presented by the valley in Fig. 3 were the ice to disappear, we may fairly conjecture that the ice in the Doker La valley was not less than 200 feet deep, a depth which would barely cover the precipice. Some allowance must be made for the subsequent erosion of the valley by water after the retreat of the ice, and perhaps the ice never filled the lower part of the valley to a height level with the top of the wall; but we have already referred to a moraine 350 feet above the present ice-level, so that 200 feet in this case is likely to be a conservative estimate.

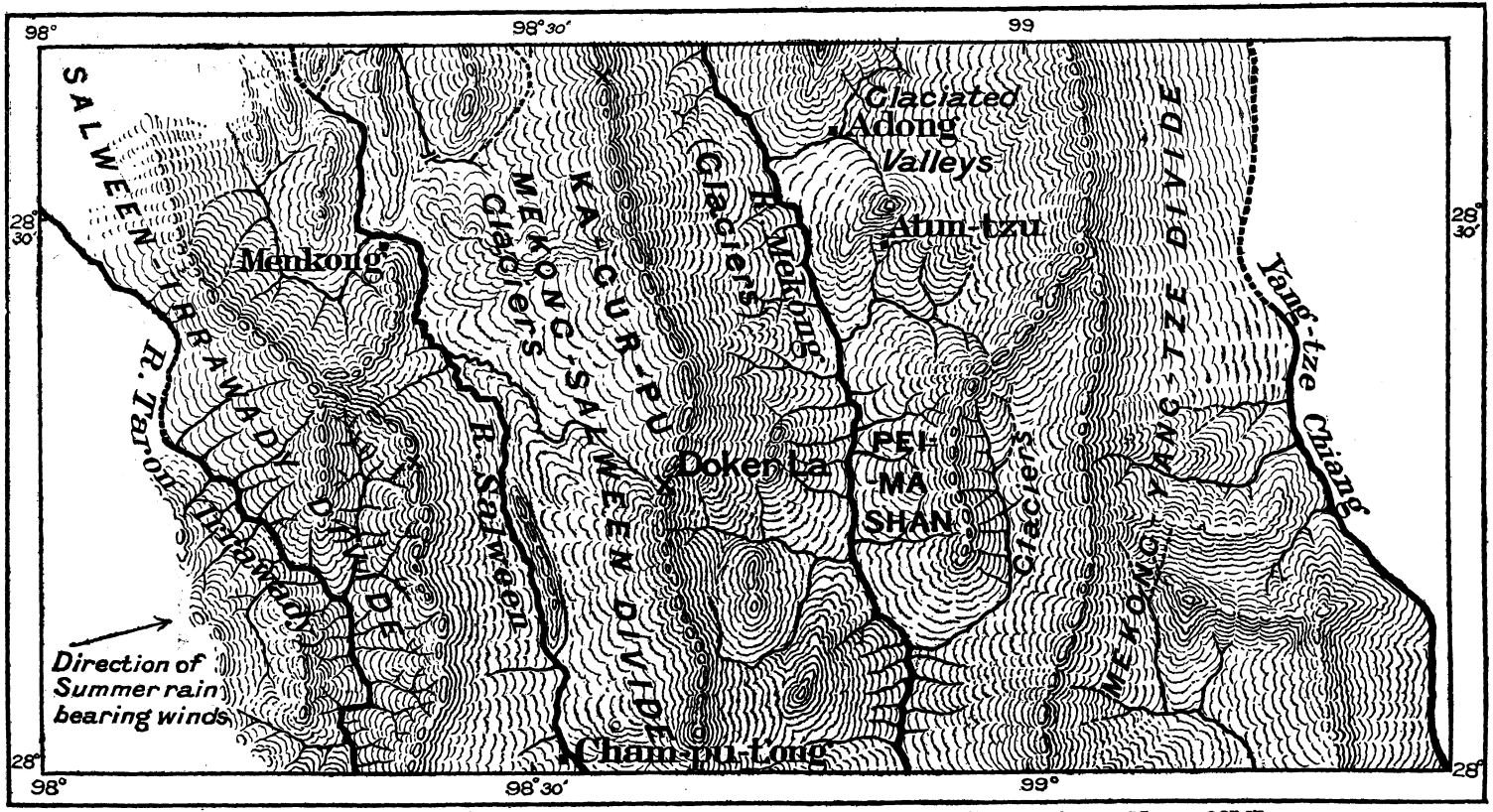
Comparing Fig. 7 with Fig. 2 it is to be noted that we have exactly the same structure on both divides, namely the valley broken by a cliff which has been cut through. We see the same thing again in Figs. 4 and 5, the cliffs in these cases being under ice. Fig. 2, of course, is taken from above and shows the rock basin filled with water; from below it looks exactly like Fig. 7 except that the water nowhere pours over the cliff, though as the lake gets gradually silted up it will no doubt do so in the future.

How these broken valleys were formed in the first instance one can only conjecture at present, and it is perhaps beside the present inquiry.

Thus the evidence for the previous extension of the glaciers on the Mekong–Yang-tze and Mekong–Salween divides is conclusive, and there is very good reason to believe, both directly from the evidence and indirectly from the lower snow-line and heavier rainfall on the Mekong–Salween divide, that the glaciers of the former range have retreated furthest. I saw no unmistakably glaciated valley on the Mekong–Salween divide which was not still occupied, at least at its head, by a glacier, and of the three glaciers visited no one had retreated more than 2 miles, or at least had left definite proofs of having done so.

It is otherwise in the case of the Mekong–Yang-tze divide. The main valley above the village of Atun-tzu must have been occupied by a glacier quite 5 miles in length, of which not a trace now remains even in the five lateral valleys or on a peak 19,000 feet high at its head. On Pei-ma Shan there are indications of ice-action in valleys no longer occupied by glaciers, while the smaller glacier shown on the right in Fig. 1 has retreated at least 3 miles. Moreover the Pei-ma Shan glaciers do not

SKETCH MAP SHOWING DISTRIBUTION OF GLACIERS ON THE YÜN-NAN TIBET FRONTIER



Scale 1:750.000 or 1 Inch=11·84 Statute Miles 5 0 5 10 15 20 Miles

descend below 16,000 feet, whereas those of the Ka-gur-pu descend to at least 10,000 feet, though there can be no appreciable difference in the altitudes of the two ranges.

Coming now to the Salween–Irrawady divide, I can judge only by analogy and by indirect evidence, not having climbed the range in this latitude. I have, however, climbed it on the north-eastern frontier, at Hpimaw (lat. 26°), and conclude from the alpine flora discovered at 12,000 feet (which is very similar to that found in the Mekong–Salween divide 2000 feet higher and 100 miles to the north), from the amount of snow still unmelted at 12,000–13,000 feet in July, and from the low altitude (7000 feet) to which snow descends in winter, that the glaciers have not retreated and are not in process of doing so. The same conclusion is certainly strengthened by the views of the snow-peaks on the Salween–Irrawady divide I have obtained from the Mekong–Salween divide in December and June, as well as by the rainfall throughout the Burmese hinterland, and the altitude to which snow descends in the upper Salween Valley in winter—about 10,000 feet.

I must confess the final proof is wanting, and I shall not feel happy on the subject till I have examined the glaciers on the Salween–Irrawady divide between the villages of Cham-pu-t'ong and Menkong in the Salween Valley. Nevertheless I have shown reason to believe, and am myself morally convinced, that the glaciers on these three parallel ranges have retreated progressively from east to west on a scale that might be expressed by the numbers 2, 1, 0. Furthermore, it is significant that north of the Ka-gur-pu range the glaciers have retreated to a greater extent, and the Mekong–Salween divide resembles the Mekong–Yang-tze divide in all respects. Of one thing there can be no doubt. The Salween Valley here is a climatic barrier or dividing line of first-class importance. West of the Salween are the rain-sodden, largely evergreen jungles of the Burmese hinterland, including many species common to southern Burma, where are found the tiger, elephant, rhinoceros, sambhur, and barking deer, besides hornbills. East of the Salween are the north temperate, deciduous, and coniferous forests of Western China, with the Himalayan bear, leopard, wolf, etc.* Were a comprehensive comparison of the fauna on the two sides of the dividing line to be drawn up it would be found that amongst the lower orders (*e.g.* insects) many species were confined to one side or the other.

Now this retreat of the glaciers must be due either to a general increase of temperature or to a diminution of rainfall. If it were due to the former there is no reason why the glaciers of the Mekong–Yang-tze divide should have retreated further than those of the Mekong–Salween divide, or,

* Gill mentions tigers in Western Szechuan, and it is a well-known fact that tigers are common in certain cold countries, *e.g.* Manchuria. The Himalayan bear and the leopard certainly occur in the Burmese hinterland ; the few animals mentioned must be taken rather as typical of the two regions.

presumably, those of the Mekong–Salween divide further than those of the Salween–Irrawaddy divide, which perhaps are not in a condition of retreat at all. It is therefore evident that there has been a diminishing rainfall on these mountains which may be regional or local in each case.

Now the climate throughout the Burmese hinterland, at least as far east as the Salween Valley, is a modified monsoon climate. The dry season is shortened by the winter rains, but the heavy summer rainfall is dependent on the south-west winds which continue to blow till after January. It would be necessary, then, to postulate a diminution of the monsoon itself if we are to account for the retreat of the ice by a regional diminution of rainfall.

Much more natural is it to suspect a local diminution of rainfall on each range, the greatest diminution occurring on the easternmost range, which is furthest from the source of supply owing to the intervention of rain-screens in the west. For the strength and humidity of the monsoon is dependent on forces which cannot have been materially altered within recent geological time, at any rate on the main distribution of continental land and water, the heat of the sun, and the rotation of the Earth, for example.

We are therefore justified in believing (1) that the Mekong–Yang-tze divide once had a heavier rainfall than it has at present and was correspondingly glacial; (2) that the rainfall has been cut off from the west by the intervention of rain-screens, namely, the Mekong–Salween and Salween–Irrawady divides (this conclusion is supported by botanical evidence based on the distribution of alpines on these ranges, and perhaps by the parallel ranges west of them again), and the same is the case, though to a lesser degree, with the Mekong–Salween divide, screened by the Salween–Irrawady divide.

From these considerations it follows that the oldest range is furthest east, the newer in the west, and hence that the pressure, if pressure and not a tension-strain ruckled up these parallel folds, acted from the west.

Before the paper the PRESIDENT said: The author of this afternoon's paper, "Glacial Phenomena on the Yun-nan–Tibet Frontier," is well known to us for his previous contributions to the geography of the interesting regions on the borders of Burma and China. He cannot be here this afternoon to read his paper in person, for he is at present on military service in Burma. In his absence I will ask the Secretary to read the paper.

(*The foregoing paper was then read and a discussion followed.*)

Dr. J. W. EVANS: I must congratulate Mr. Ward on a brilliant piece of work in a difficult country and on an interesting account of the glacial phenomena in the area, illustrated by many typical photographs. The retreat in the glaciers must be due to variation in the rainfall; but we should adopt an attitude of reserve as to the explanation that this is to be attributed to a rise of the mountain ranges between the river valleys. Glaciers adapt themselves rapidly to variations in the precipitation. The effects are visible in a few years, and

at the utmost thirty or forty years will show the full effect of any change of climate. We cannot accept the supposition that these mountain ranges have risen appreciably in the course of the last half-century until the rise is confirmed by actual survey. There must, I imagine, be another explanation of the change of climate. Perhaps the south-west monsoon winds have become feebler, or there were formerly winds from the north-east which brought the moisture from that direction. Such variations are apt to occur in cycles. There is no doubt that many regions of the Earth would be highly glaciated if there were a comparatively small increase of snowfall; for example, the northern part of Ontario. Any one who descends a mine in that region is struck by the extreme cold at moderate depths below the surface, and frequently icicles may be found hanging from the roofs or walls of the workings. If there were enough snowfall the whole country would be glaciated.

One of the chief interests of the present paper is that it describes important glaciers in Eastern Asia. North of this region there are mountain ranges having no apparent glaciation, past or present. Some indeed have said that the extensive glaciation of the Pleistocene never extended to Eastern Asia. If this were so, it was probably because the snowfall was insufficient.

The author doubts whether the notches he describes on the tops of cliffs have been initiated by the streams that flow through them, because these had already traversed lakes, so that they contained no material to assist erosion; but in the Andes, at altitudes where it freezes hard at night and thaws by day, every stream is marked by the shattering of rock by frost, and erosion is consequently very active.

The PRESIDENT: About twenty-five years ago our Alpine Club started a Committee of Investigation which developed into the International Commission on Glaciers. This Commission has already published much material, and will doubtless welcome Mr. Ward's contribution. I think there are several points of importance in his paper. First, there is the geographical fact that such large glaciers exist so far east in Asia. It will certainly be news to many of us. Secondly, there is the suggestion that the diminution of snow and ice on the eastern of the three ranges investigated is due to the uprising of the western range. On this point I confess a profound scepticism. I do not see any proof of a local retreat of glaciers in excess of that which has taken place in historical times over the whole of Europe and the old world, or of oscillations exceeding those recorded in the last few centuries. There is abundant evidence that about 1855 there was a maximum of glacial extension in Europe, and since then there has been a marked retreat of the ice. The Lower Grindelwald Glacier has now retreated high up its valley and left bare an old quarry with cut blocks of marble. The same marble is found in old houses of the seventeenth century in Bern, and its origin had been a mystery until the present retreat of the glacier. Hence it is clear that the advance of the last century in Europe had been preceded by similar oscillations, and it seems reasonable to account for the diminution in the Tibetan glaciers by causes affecting generally the northern hemisphere.

We can find in the Italian Alps, in the Adamello district, most of the features which Mr. Ward so well describes in these distant ranges—the alternating steps and flats, each step in the valleys causing an icefall or a waterfall, and each flat being occupied either by a tarn in the process of being filled up by the pounded stuff borne down by the glacier stream, or presenting the level floor left when that process has been completed. With regard to the clean-cut narrow clefts by which the streams cut into the ice-smoothed and furrowed

barriers which often contain the flats, I have a theory which is, I believe, capable of illustration by well-known features in the Bernese Alps. The examples I refer to are the clefts below the Eiger and Lower Grindewald Glaciers, and that by which the Aar penetrates the Kirchet above Meiringen. These sharp gorges were probably made by streams flowing under the glacier at a time of its greater extension, and these streams, being laden to an excessive degree with grit, were able to cut very narrow clean clefts through the rock. The walls of these clefts, protected from sub-aerial denudation by the glacier itself, have remained sharp and perpendicular.

We may hope that these mountains may in time become a place of resort for Englishmen stationed in Upper Burma. The scenery obviously is of great beauty, and the botanist as well as the geologist should find abundant interest. We shall send our thanks to Mr. Ward for his paper, and express the hope that he will continue his explorations.

Prof. J. W. GREGORY sent the following notes for the discussion :—

Mr. Kingdon Ward's account of the glaciation of Western Yun-nan is a very valuable contribution to the geography of the district, and three of his conclusions are of wide general interest. Firstly, he adds another to the cases in which the variation of glaciers is a local effect, for he has given conclusive evidence of glacial recession on the eastern mountains of this region while the western glaciers have remained undiminished. It is unfortunate that Mr. Ward's evidence is least definite regarding the non-diminution of the glaciers on the Salween–Irrawady divide ; for in many cases in which it has been claimed that there has been no recession of tropical or sub-tropical glaciers the claim has subsequently been disproved. Mr. Ward's negative conclusion is adopted for the region with which his acquaintance is least.

A second interesting contribution is his account of the striking biological differences on the two sides of the Salween valley. All fresh evidence of such differences in adjacent parts of a continuous land are useful, for they help to remove some of the inconsistencies between the biological and geological evidence as to the history of the Malay Archipelago and the isolation of Australia.

Mr. Ward's interesting suggestion that the diminution of the eastern glaciers of this district is due to an increased elevation of the mountains to the west would require very clear evidence in its support. There has probably been much more recent movement, both of elevation and depression, of the Earth's surface than many English geographers are disposed to admit. I have no *a priori* objection to his conclusion ; and if Mr. Ward regards this change as one which has been slowly progressing since prehistoric times his suggestion may be valid. For there probably have been important earth-movements to the east of the Bay of Bengal in Pleistocene times ; and, as Mr. Ward refers to the moraines as tree-covered, he may regard them as of considerable age. Moreover, his description of the Sierra-like crest of the Yang-tze–Mekong divide indicates either that the summits were not ice-covered or that the glaciation was so remote that the limestones have since been weathered into pinnacles. If, however, Mr. Ward considers that the retreat of the glaciers during the past fifty years is due to earth-movements during that time or even during the immediately preceding centuries, he will want stronger evidence in support of his conclusion than is likely to be forthcoming from a district of which our knowledge is so limited.

The advance and retreat of glaciers is very variable owing to local changes in precipitation, the exact cause of which may be indeterminable even in well-

known districts. One Alpine glacier may advance while its neighbours are receding ; and this difference must be due to some local accident in precipitation and not to the formation of wind screens by earth-movements in the Alps.

Mr. Ward's evidence seems to me conclusive that the different behaviour between the eastern and western glaciers of his district is due to a local variation in precipitation, but the explanation may be meteorological and not tectonic. His paper is very suggestive and a useful contribution to the physical geography of Yun-nan.

THE RETURN OF SIR ERNEST SHACKLETON.

Hugh Robert Mill, D.Sc.

NEWS has been received of the safe return of Sir Ernest Shackleton to the Falkland Islands on May 31, after the most adventurous journey in the records of Antarctic exploration. The *Daily Chronicle* of June 2 published a long account of the expedition forwarded by wireless telegraphy from Port Stanley, and to this we are indebted for the following condensed summary.

The *Endurance*, with Sir Ernest Shackleton and the party who hoped to cross the Antarctic continent, left South Georgia on 6 December 1914, and met heavy pack-ice two days later off the Sandwich group, entering the pack in 58° 40′ S., 18° W. The ship pushed her way southwards through the ice for about 1000 miles, sighting Coats Land on 10 January 1915. Very heavy ice was encountered, and 200 miles of new coast-line was discovered and named the Caird Coast. Great glaciers were observed discharging from this land. The season proved abnormally cold, summer conditions not occurring. In the middle of February the ship was beset and never got free again. It was impossible either to land or to return, and the party prepared to winter in the ship. The winter was comparatively mild for the latitude, the lowest temperature being 35° below zero Fahr.; but the usual blizzards were experienced in full force. The *Endurance* first drifted to the south-west, her extreme southerly position being 77° S. in 35° W. She remained immovably locked in the pack, and then drifted in a zigzag course through the Weddell Sea in a generally north-westerly direction. The menace of ice-pressure became serious in June, the mid-winter month, and increased in July, when all preparations were made for leaving the ship in case of need. On one occasion in a terrific pressure the ship was hove bodily out on the ice, but stood the strain; but in September she was badly nipped, and this happened again more than once early in October, causing much damage to the hull. At this time she was drifting over the position assigned to Morrell's New South Greenland, and got a sounding in 1900 fathoms. On 27 October 1915, in 69° 5′ S., 51° 32′ W., a very intense "screwing" of the pack under pressure burst the ship's sides in and tore out her stern-post and rudder-post, while water entered and extinguished the fires. The boats,