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AN EXPLORATION OF THE NUN KUN MOUNTAIN GROUP AND ITS GLACIERS.

By William Hunter Workman, M.A., M.D., F.R.G.S.

(*From 'The Geographical Journal' for January*, 1908.)

Himalaya.
Kashmir
Map
Nieve Penitente

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THE Nun Kun mountain group is situated in Suru, Kashmir, between 33° 55′ and 34° 6′ lat. N., and 76° 2′ and 76° 13′ long. E. The massif to which this name is applied is comparatively small and compact, standing by itself in the midst of a network of mountains, occupying practically a square with a side of 11 miles. Two parallel spurs of the same fold, connected with the Nun Kun by narrow ridges, extend west to 75° 53′ long. E., enclosing a glacier 8 miles long. If the mountains forming the farther barriers of the glaciers of the group be included, the area would be considerably greater.

The highest central portion is guarded on all sides by a multitude of ragged precipitous spurs or buttresses, which run down from it to the surrounding valleys, the walls of which they help to form. On the north they overhang the Suru river in the Rangdum valley, where for 8 miles, with the opposite mountains, they enclose a gorge through which it flows. The summits of these external buttresses are mostly pointed or serrated, and attain heights of 18,000 to 20,000 feet.

The central part of the massif rises 2000 to 4000 feet, not only above its own lesser peaks, but above all others for scores of miles around, the nearest peak that exceeds it in height being Nanga Parbat, 120 miles north-west. East, west, and south, none of the vast multitude of mountains which it overlooks approach it in height. It stands alone, an elevated island of rock and ice, towering bold and sharp from an ocean of surrounding peaks. Although situated in a fairly well-known region, the valleys around it having for years been visited by sportsmen and somewhat by travellers, its height and its inaccessibility have rendered its upper parts hitherto secure from intrusion.

Sportsmen have occasionally entered the Shafat nala, the easiest avenue of approach, one having camped for some days in 1905 at the site of our base camp, 4 miles above the tongue of the Shafat glacier. In 1902 the Rev. C. E. Barton and Dr. A. Neve paid it a brief visit. They camped for a night near the same point, at an altitude of 14,900 feet, and the next day went up the Shafat glacier to a height estimated by them at about 18,000 feet, returning to a lower camp the same day. In 1903, Mr. Sillem, a Dutch traveller, visited the Shafat glacier. He is reported by Dr. Neve to have reached a height on it of 21,000 feet, but what he is said to have seen is rather indefinitely stated, and does not correspond to the topographical features at that height.

The object of the expedition of Mrs. F. Bullock Workman and myself in 1906 was the more thorough exploration of this region, particularly of

* Read at the Royal Geographical Society, November 25, 1907. Map, p. 43.

the upper unvisited portions. The chief village of the several composing what is called Suru, on the Suru river, three marches south of Kargil on the Leh route, and twelve from Srinagar, was selected as our base, this being the nearest village with a lambardar to the Nun Kun. The crops having failed the two preceding seasons in Suru and Ladakh, no supplies were obtainable there, so we were obliged to forward from Srinagar not only all supplies for our party, but also some 16,000 lbs. of grain for our coolies, to transport which required 243 coolies and 60 ponies. On June 24 we reached Suru, accompanied by the guide, Cyprien Savoye, six Italian porters, and five servants.

Just south of Suru, the Suru valley, which up to this point runs south from Kargil, makes a wide bend around the extremity of a high spur, and from Purkutse, the last village where any cultivation is seen, stretches east for 23 miles, under the name of the Upper Suru or Rangdum valley. It resembles Ladakh valleys, being mostly desert with some scanty vegetation. It cannot boast of a single tree, but the swampy land along the river is covered with bush-growth from 2 to 6 feet high. For 8 miles from Purkutse it consists of a gorge just wide enough for the passage of the here turbulent Suru river, directly over which, on the south, rise the frowning spires of the Nun Kun massif, 11,500 feet above, sending down a number of short glaciers, which do not reach the valley-bed, and a larger one, the Ganri, later to be described. It then opens out with an average width of about 1 mile to its end, where it expands into an amphitheatre, into which four valleys open.

On July 3 we reached Gulmatunga, one march above Purkutse, the site of a deserted village, on the north side of the unbridged Suru river, opposite which the Shafat nala, which was our first objective, enters the Rangdum. To reach this it was necessary to cross the river, which early in July is usually fordable at this point, but we found the water so high that the only way to get over was by swimming, as impossible a feat for our loaded caravan as flying would have been. The weather during the latter half of June had been fine and unusually warm. Since leaving Dras, at elevations from 10,000 to 12,000 feet, we had marched in such sun-maxima as 191°, 199°, 203°, 196°, 200°, 206°, 204·5°, and 205° Fahr. The great heat had melted the snow on the glaciers rapidly, and we had found all glacier-fed streams on our route greatly swollen and turbid, some of them being impassable after twelve o'clock. The Suru river was no exception. Its volume was much increased, and its mud-laden water of a dark slate colour. We camped, hoping to get across early in the morning, but the water did not fall sufficiently to make the river fordable. We were therefore obliged to follow it up for 16 miles to the hamlet of Tazi Tonzas, where it divides into several branches. Here, between 8 and 10 a.m., we made the passage of five small branches, and of the 200-feet-wide main branch, though the water of the last was waist-high and flowing with a rapid current, besides being

ice-cold, so that the men had to wade through it in squads, holding on to one another for security. We then descended the valley again, through swamps and over boulder-strewn tali, till the Shafat nala was reached after four days of extra marching.

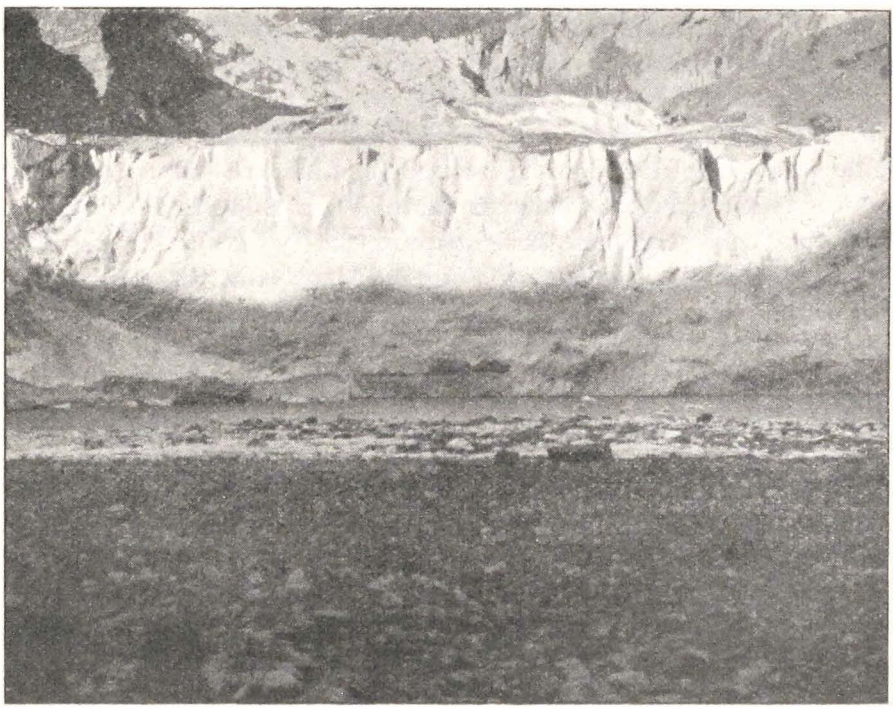
The Shafat nala runs from the Rangdum valley, a little west of south, straight away along the eastern edge of the Nun Kun for 9 miles to the base of an impressive snow mountain marked Z 1 on the Indian Survey map, seen through the nala from Gulmatunga towering above its upper end. The nala is enclosed on both sides by precipitous mountain-walls. For some distance above its mouth its bed consists of rolling hillocks, sparsely covered with vegetation. A large colony of marmots had appropriated these as a site for a subterranean city, and their burrows pierced the ground at short intervals in all directions. These marmots were evidently social in their habits, and exchanged frequent visits, as was shown by footpaths as distinct and well trodden as those made by man, running between the different burrows and forming a network over the whole surface. Were this place of sufficient importance to have a name, it might appropriately be called Marmotville. Beyond this for 2 miles the nala ascends gently in swampy meadows covered with grass and bushes resembling dwarf-willows, interspersed with stony reaches, and intersected by numerous swiftly flowing streams.

About 3 miles above the lower end of the nala the tongue of the Shafat glacier is met with, an irregular mass of ice stretching entirely across the nala, from 80 to 100 feet high, heavily covered with red granite detritus, which gives it the appearance of a large terminal moraine. The valley-bed immediately in front of it, though somewhat strewn with small stones, has no terminal moraines to indicate that, in recent times, the glacier has extended lower down than at present, to which fact the grass-covered alluvium existing almost at the edge of the tongue also testifies. Two good-sized streams issue, one on each side of the tongue, from deep gullies extending half a mile or more up the glacier. For the next 2 miles the glacier consists of a chaotic combination of high ridges, deep ravines with perpendicular walls, hillocks, and depressions, forming a labyrinth as difficult to traverse as could well be found. This part has no well-marked moraines, either lateral or median, though it is covered with an enormous amount of detritus. Its banks on both sides consist of steep mountain slopes greatly torn and eroded by ice and water.

The upper end of this portion ceases abruptly with a sharp sweep to the south-west, below which a lower surface of smooth white ice about half a mile wide begins, occupying the eastern side of the nala, and extending to the base of Z 1, 4 miles distant. This had few crevasses, but it was covered with small pockets, filled with crystal water, from a few inches to 2 feet in diameter, and from 6 inches to 2 feet deep, at the bottom of which lay either flat stones or a thin layer of silt, which, by

absorbing and transmitting the heat of the sun, had caused the ice beneath them to melt and form the pockets. Near the junction of the white ice with the lower portion were a number of glacial tables, some of them of large size, supported on ice pedestals from 3 to 6 feet high.

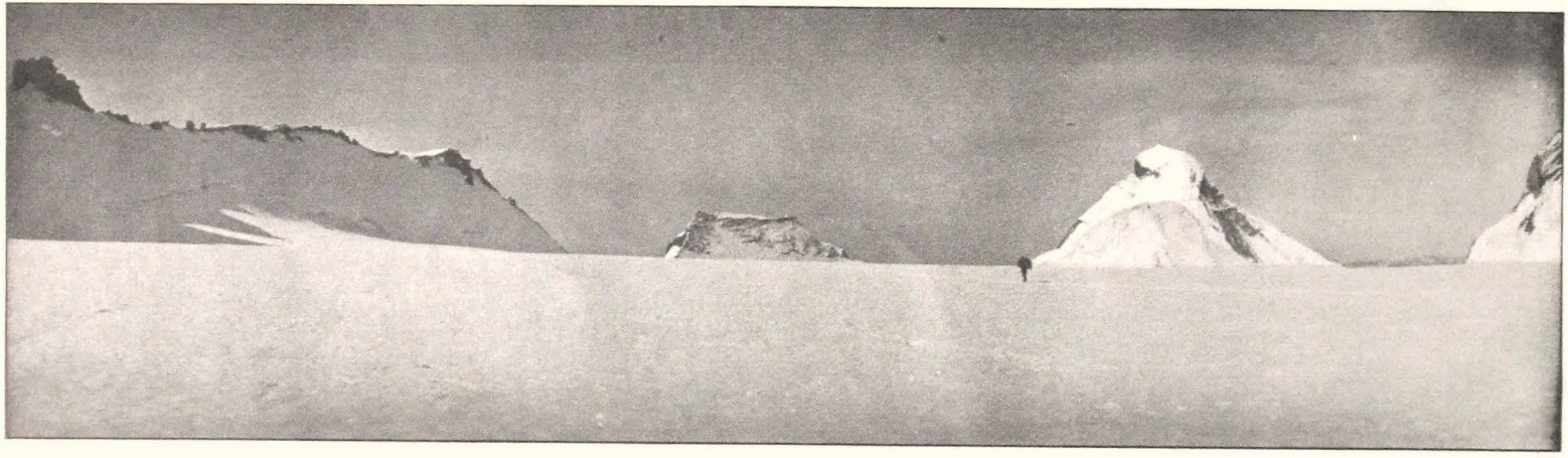
Adjoining the white ice on the west, but entirely distinct from it, both in character and origin, though equally a part of the glacier, runs another section parallel with and overtopping the white one by 60 to 80 feet. This section, about a quarter of a mile wide, fills the remainder of the glacial bed. It is greatly broken and crevassed, and thickly covered with reddish granite detritus. The final destination of this



SECTION OF PERPENDICULAR ICE-CLIFF, ABOUT 200 FEET HIGH, IN WHICH THE GANRI GLACIER, DESCENDING FROM THE NUN KUN, ENDS AT THE BANK OF THE SURU RIVER. PHOTO TAKEN AT 7 A.M.; LOWER PART IN SHADOW.

section affords an interesting example of the application of glacial force. On its west side, about 1 mile above the lower end of the white section, a branch glacier enters. This branch is short, not over 2½ miles in length, and perhaps half a mile wide, but, coming down from the sides of two peaks, one of them of over 23,000 feet, with a fall of 9000 feet, it presses with tremendous force upon the Shafat glacier. As a result, the red section is crowded bodily over to the east side of the glacial bed, cutting across the white section, forming a barrier to its further progress, and literally swallowing it up. The red portion then expands so as to fill the whole glacial bed, three-quarters of a mile wide, and forms the chaotic lowest 2 miles of the glacier already described.

Upper three miles of Shafat glacier descending from Nun Kun peaks on north (right) and Z 1 on south (left). The glacier is open on west, terminating at rock ridge on sky-line passing from Nun Kun to Z 1



South-west half of Nun Kun basin, as seen from its centre, showing highest peak, 23,447 feet, and three outlets. Right hand outlet forms one head of Ganri glacier, the other two feed the Fariabad glacier. We entered basin at point directly behind figure on surface. What appears to be a slope of highest peak is White Needle Peak directly in front of it.

The very abundant detritus brought down by the branch glacier is black. This crowds with the ice of the branch into the space from which the red section has been pushed, and can be traced downward for about a mile. Opposite the point of entrance, a large hillock of black material presses well into the red section rising high above the surrounding level. The eastern edge of the white section bears along a smaller black moraine, which is also swallowed up by the red portion at their point of contact.

Opposite Z 1 the Shafat glacier, which to this point ascends with a moderate gradient south 23° W., turns around the end of a spur from the Nun Kun, and pursues a course west 10° S. to a ridge 3 miles above, descending from the central one of the row of five southern Nun Kun peaks across the slope to meet an arête projecting from Z 1. This ridge rises only slightly above the glacial surface, but it forms a line of demarcation, on the north side, between the snows, which, coming from three of the Nun Kun peaks, feed the Shafat glacier, and those from the remaining two which fall to the Fariabad nala; and on the south, between those from the whole front of Z 1, and those from it west of the arête, which also fall to the Fariabad nala. The altitude of this ridge at a quarter of a mile from the wall of Z 1 is 16,911 feet. Thence it rises continuously till it ends in a peak of over 21,000 feet.

The reservoir of the Shafat glacier differs from those of the ordinary type, in that it is composed of two lateral parts or wings, over 2 miles distant from each other, the northern wing consisting of the slopes of the Nun Kun massif, and the southern of those of Z 1, the snows from both of which descend east of the boundary ridge into the intermediate depression, meeting near its middle line to form the glacier. The glacier is therefore destitute of a typical head or end basin enclosed by mountains on the west.

Its width just above the bend is about a mile, but below the ridge it widens to more than 2 miles, ascending sharply and greatly broken to the Nun Kun. The ice from the south or Z 1 wing is remarkably free from detritus, but that from the Nun Kun wing bears a considerable quantity in detached masses, which finally becomes concentrated in the red western section already described.

The glacier coming from the two remaining southern Nun Kun peaks, named by us the Fariabad glacier, descends from north to south across the upper end of and at right angles to the Shafat, contributing to the latter a small amount of ice through an opening in the dividing ridge near its centre.

We established a base camp on the spur around which the glacier turns, about 400 feet above the latter at an altitude of 15,100 feet. It commanded a view of a second tributary entering the Shafat from the east in an impressive ice-fall, and of the steep front of the splendid peak Z 1, over 22,000 feet in height, clad in a shaggy mail of ice, portions of

which every now and again broke away and plunged down to the glacier in resounding avalanches. After the Nun Kun massif Z 1 is the highest and most imposing mountain in the region.

While wood and supplies were being collected at this camp, we made reconnaissances of the ice-fall opposite, ascending the lower half of it, and of the higher parts of the Shafat glacier on both sides to heights of about 18,000 feet, from which an excellent idea of the glacier and its basin was obtained; but from no point could we see the conformation of the highest portion of the Nun Kun massif lying behind the five southern peaks crowning the wall above, nor could the relation of the

HILLOCK COMPOSED OF DETRITUS FORCED UP BY PRESSURE OF BRANCH GLACIER UPON SHAFAT GLACIER AT LINE OF CONTACT. BRANCH HAS A FALL OF SOME 9000 FEET. FIGURE OF SERVANT NEAR CENTRE OF HILLOCK GIVES IDEA OF SIZE OF LATTER.

highest western peak to its neighbours be determined, nor were the two northern peaks next in altitude to the highest visible, except the very apex of the north-easterly one from the ice-fall under Z 1.

Large portions of the *névé*-covered surface of the Shafat glacier, from 16,000 to 18,500 feet, were thickly strewn with *nieves penitentes*. This was the first time we had met with them in five seasons of Himalayan exploration, and I am not aware that their existence in Himalaya has been mentioned by any other observer. For a time they were regarded as peculiar to the Andes, having been observed only by explorers of that chain, until Hans Meyer, and after him C. Uhlig, discovered

them on Kilimandjaro. In the Andes they have been found from the equator to 35° 4′ lat. S., while those seen by us existed from 33° 57′ to 33° 59′ lat. N.

They varied in height from 8 inches to 3 feet, and had the shape of wedges or pyramids flattened at the sides with curling fluted crests, all turned in the same direction.

They were arranged in parallel lines running diagonally to the axis of the glacier, the long diameter of each nieve being parallel to the long diameters of others in the system and coincident with the direction of the lines. They were composed of granular snow, hard frozen in the morning, but softening more or less under the heat of the sun. No ice was found in them. The central portion of each, even when softened by the sun, was much denser than the outer surface or the surrounding *névé*, offering even in the smallest decided resistance to the thrust of an ice-axe, while the two latter could often be scraped away with the fingers. The *névé* on which they stood sloped at angles of 30° to 40°.

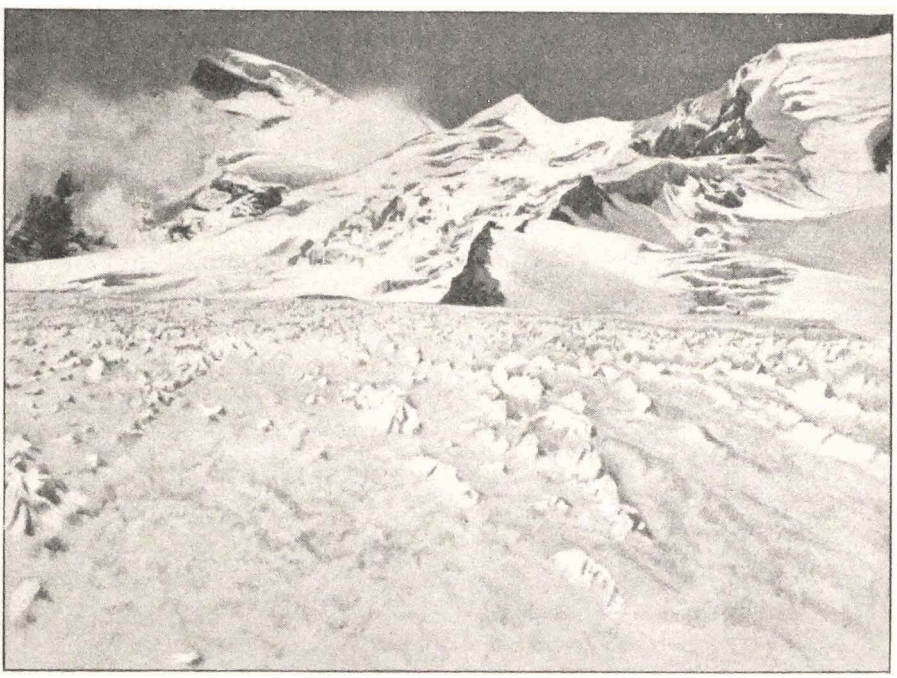
As this was the only one of many Himalayan glaciers we have explored presenting this phenomenon, attention was directed to the conditions obtaining on it as furnishing a clue to the mode of formation of the nieves. As already stated, this glacier is peculiar in that it is acephalous, being entirely open at its upper western end and fully exposed to the prevailing west winds, which sweep down its course with considerable force even in fair weather, and during storms must attain a high velocity. Another important condition not seen by us on other glaciers was the long-continued fine weather. During our Baltistan expeditions fine weather was the exception, almost daily snow-storms being the rule; but here, from early in June till our departure on August 9, the weather was continuously pleasant, only one slight squall being noted. In ascending the glacier, and on the mountains above, even to over 21,000 feet, no new snow was met with. To these two conditions the formation of the *nieves penitentes* here seen may be referred.

It is a matter of common observation that, when any object lies upon a glacier which protects the snow or ice beneath it from the sun's heat, or a condition exists that offers resistance to the same, the surrounding surface melts away, leaving an elevation of snow or ice in such place. When a rock rests on a glacier, a glacial table supported on an ice pedestal may result. Ice pyramids are sometimes seen capped with mud or fine detritus. When a portion of a glacial surface becomes more dense than that around it, the softer portions melt away, leaving the denser one standing as an upward projection.

This premised, the development of these nieves may be read as follows. During the winter and spring storms the wind, sweeping down the glacier, drifted the loose snow into waves and ridges. These, particularly the latter, were formed parallel to one another, with a direction more or less transverse to the axis of the glacier. The force of

the wind packed the snow composing the ridges, so that it became much denser than that in the hollows between them. Wind is the only natural force conceivable that could have caused ridges and wavy condensations of snow in the positions occupied by the nieves, upon fairly smooth slopes not exposed to avalanches and above the line of rain. This action of the wind being granted, it follows that the formation of waves and ridges of condensed snow was the first step in the process of development.

Then came the prolonged period of fine weather, when no new snow fell to cover the roughened glacial surface, when the latter was exposed



NIEVES PENITENTES ON SHAFAT GLACIER.

during the long days of June and July to the full action of the sun, burning with a heat of 170° to 206° Fahr. and over. As melting proceeded, the softer snow of the hollows yielded to a greater degree than the harder snow of the ridges, thus accentuating the difference of level between the two, and the ridges themselves were sculptured out, the densest and most resistant parts remaining as apices, till, finally, the flattened pyramids known as *nieves penitentes* were fully formed.

The fact that the discrete pyramids, many of them with the ends of their elongated bases touching the similar ends of adjacent ones, stood in lines parallel to other lines, indicates (1) that they were formed out of pre-existing ridges or linear wavelets, and (2) that the condensation of snow in the ridges was not equally great at all points, but occurred in

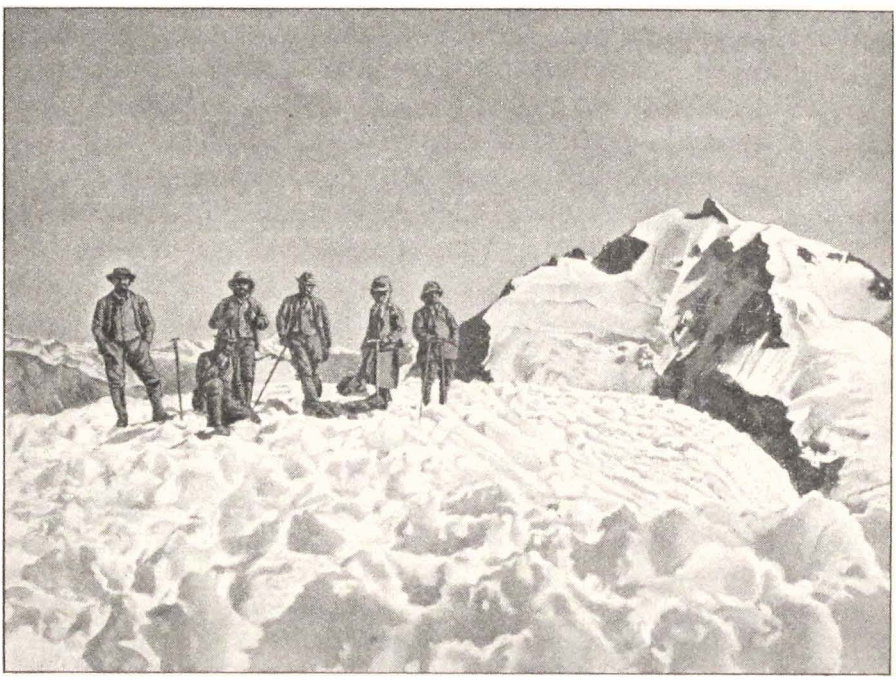
foci, the crests of which were a little distance apart, each crest, as melting proceeded, forming the apex of a nieve.

The glacier falls from west to east, east 10° N., and the line of union of its north and south slopes corresponds with its axis. The direction of the longer diameters of the nieves and of the lines of which they formed a part, was, on the north slopes, east 20° S., whilst that of those on the south slopes was north 45° E. The former cut the glacial axis at an angle of 30°, and the latter at one of 35°. The linear rows of nieves on the two slopes were thus inclined to one another at an angle of 65°. From this it appears that the direction of the primary ridges was determined by the direction of the slopes on which they were formed, the wind remaining constant to both. The apices of the nieves on both slopes curved over more or less, giving the pyramids a convex contour on one face and a concave one on the opposite. These, as well as the overhanging hoods, with which many of them were crowned, all pointed in the same direction, *i.e.* towards the east, down the glacier, away from the prevailing west wind, which never varied during the three weeks we were on this glacier. Both the curving apices and the hoods were probably due to the cornices formed by the wind along the crests of the primary ridges, which being denser offered greater resistance to the sun's heat than the snow immediately under them, and persisted as overhanging parts of the nieve. It may be noted that nieves were found only above the line where freezing occurs at night, *i.e.* above 16,000 feet, which circumstance may be a contributory factor to their development or modelling.

From the foregoing, the conclusion may be drawn that the formation of *nieves penitentes*, certainly of such as were here seen, depends on two conditions: (1) the existence of a strong wind blowing constantly from the same direction, driving the snow into wavelets and ridges usually parallel to one another, and condensing it into compact masses at foci a little removed from one another; and (2) a prolonged period of fine weather following, during which the softer portions are melted away by the sun's heat both direct and reflected, leaving the denser parts standing in the well-known shapes. In stormy seasons the ridges, after being formed, would be protected from the sun's action by new snow under which they would be buried, and no nieves would be developed.

Six miles west of the upper end of the Shafat glacier stands a hitherto unnamed summit of 19,080 feet, called by us Mount Nieves Penitentes, and 2 miles north of it another of 20,571 feet, D 41. First ascents of both of these were made by us. The last 300 feet in altitude of the rounded top of the former as well as others of its upper surfaces were thickly covered with *nieves penitentes* of the same character as but larger than those on the Shafat glacier. Above 19,000 feet the final slants of D 41 rise at angles of 60° to 70°. These, facing south, but fully exposed to the west wind, bristled in every part quite to the summit, with

nieves rising one above another in unbroken succession. These were the largest of all, rose from an ice basis, and themselves consisted of ice. In connection with the statement of Prof. Hauthal, that *nieves penitentes* in the Andes occur exclusively in sheltered places, it is interesting to note that those observed by us at three different points in Himalaya occurred on surfaces fully exposed to wind, that the higher and more exposed the surface the larger were the nieves, and that the largest, most perfectly developed, and apparently the most durable of all, were found at the highest altitude, from 19,000 to 20,571 feet, where the wind would naturally be the strongest. On the Barmal glacier, springing from the



SUMMIT OF MOUNT NIEVES PENITENTES, 19,080 FEET, COVERED WITH NIEVES PENITENTES. D 41 IN BACKGROUND, 2 MILES TO NORTH.

two last-mentioned peaks and a wall connecting them and protected by precipitous mountains, and in the Nun Kun basin at an altitude of 21,000 feet, covered with snow and also much enclosed, no nieves were seen. Sir Martin Conway, from his observations of *nieves penitentes* on Aconcagua (see 'Aconcagua and Terra del Fuego'), concludes they are carved by solar radiation out of old avalanche beds, wind having nothing to do with their origin. Nieves formed in this manner would be found only on circumscribed areas in positions, which avalanche beds might occupy, and not widely distributed over glacial surfaces and on mountain-sides and tops, as in case of those seen by us, where there could be no question of avalanche beds. The conditions under which nieves have been observed have evidently differed somewhat in different places.

Prof. Hauthal also regards the sun as the sole agent in the formation of nieves. This hypothesis fails to explain satisfactorily the parallelism of the lines in which the nieves stand, as well as the implied selective power of the sun in melting away some portions of a glacial surface and leaving others intact, both of which can be accounted for by the known action of wind in causing parallel wavelets and ridges and condensing the snow in them.

Gussfeldt, one of the early observers of Andean nieves, is one of the few who recognize the agency of wind in the first stage of their development, but he does not mention the causation by it of foci of condensation that offer resistance to the sun's heat, which I regard as an essential factor in the process.

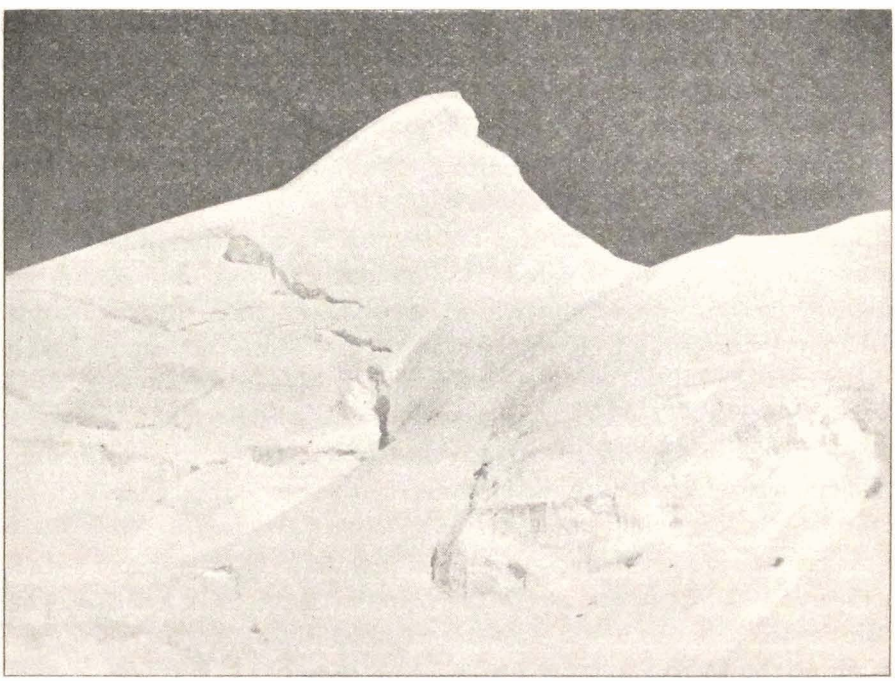
While the conclusions above stated appear to me to be the only ones consistent with existing conditions that will explain the formation of the nieves observed by me, I am quite willing to grant that condensation of snow in foci may, in certain cases, be caused by other agents than wind.*

The experience of four previous expeditions having demonstrated that coolies cannot be depended on to go much above points where rocks exist for shelter at night and water is to be had, the plan was adopted, with a view to exploring the higher parts of the Nun Kun, of taking out trained European porters to carry light camp outfit to altitudes above those which can be reached by coolies. Six porters besides the guide, who also agreed to carry a load when necessary, were judged sufficient for our purpose, and this number had accordingly been brought with us.

A reconnaissance disclosed a rock promontory projecting into the ice about 2500 feet above our base camp, with screes beneath it, where coolies could pass the night; and about 2200 feet above that, among the icefalls at the base of a snow-needle, a small sloping snow-plateau, which the coolies, by starting early from their night bivouac, could reach in time to return to the latter the same day. This was the highest point at which they would be available. Basing our plan of attack on the upper portion of the massif on the existence of these two *pieds à terre*, a good supply of wood and food was forwarded to the promontory, and two days later four porters with coolies were sent ahead with their own and our extra outfit, with orders to remain over night at the promontory, move up next morning with the coolies to the plateau, and make a second camp there, sending the coolies back to us. From here they were to push on and establish a third camp with extra Mummery tents at the highest available point, and then return to and await us at the second camp.

* For some further details, see *Zeitschrift für Gletscherkunde*, Band ii. Heft i., July, 1907, p. 22.

On July 25, Mrs. Bullock Workman, myself, Savoye, and two porters, with fifteen coolies, followed, climbing at first over great moraine masses, and later over tumbled and crevassed slopes of ice and snow lying between the giant rock-ribs descending from the peaks above. We saw many *nieves penitentes*, some of them of large size. We camped on snow just above the base of the promontory at an elevation of 17,657 feet. The minimum night temperature was 17° Fahr. The next morning we continued on up still wilder ice-slopes, steep and fatiguing, greatly broken, and seamed with wide blue chasms lined with icicles, to the second camp, where the four porters were waiting. This camp stood at



WHITE NEEDLE PEAK, ONE OF THE ENCLOSING BARRIERS OF THE NUN KUN BASIN; ALTITUDE ABOUT 21,800 FEET. NOTE PROFILE ON RIGHT OF APEX. THREE BLACK DOTS IN CENTRE ARE PORTERS DESCENDING SLOPE.

19,900 feet on a small sloping surface at the base of a ragged wall, from which at intervals great icicles were broken away by the wind and hurled down in dangerous proximity to the tents. Two hundred feet distant below the camp a wide bergschrund yawned. The coolies marched well to this point, though some of them were sick at the last, and nearly all complained of headache. They were allowed to return to the lower camp on arrival. The minimum temperature here was also 17° Fahr. On our return it was 10° Fahr. The wind blew down upon us in strong gusts the whole night, shaking the tents so that we feared we should be carried down into the bergschrund. This, with the altitude, the effect of which all felt decidedly, effectually prevented sleep.

From here the whole party of nine started upward together. The only possible route led up the steep face of the ice-wall, and above it involved the traverse of a long, sharply inclined, curving ice-slope covered with snow. Had the passage of our caravan started an avalanche, as we feared might occur, we should have been carried down over the wall into an abyss of unknown depth running along its whole base. Two weeks later, when the snow had melted or become converted into ice, this slope would have been too dangerous to attempt. Its top lies at an altitude of about 21,000 feet, at the base of a beautiful snow-needle some 800 feet higher, which crowns the extremity of a short arête projecting from the highest Nun Kun peak. Up to this point we had seen nothing of the massif except the slopes facing the Shafat glacier. On reaching the crest we found we were standing, not on a col between the first and second of a line of peaks, as the Survey map and previous statements had led us to expect, but just above the brow of a glacier emerging from a great oblong snow-plateau or basin, about 3 by 1½ miles, enclosed by six great and one smaller peak, the highest of which, 23,447 feet, rises up by itself steeply from the plateau unconnected by cols with any of the others. Descending into this basin, we reached the third snow camp, which had been established at an altitude of 20,632 feet. The minimum temperature here was 4° Fahr.

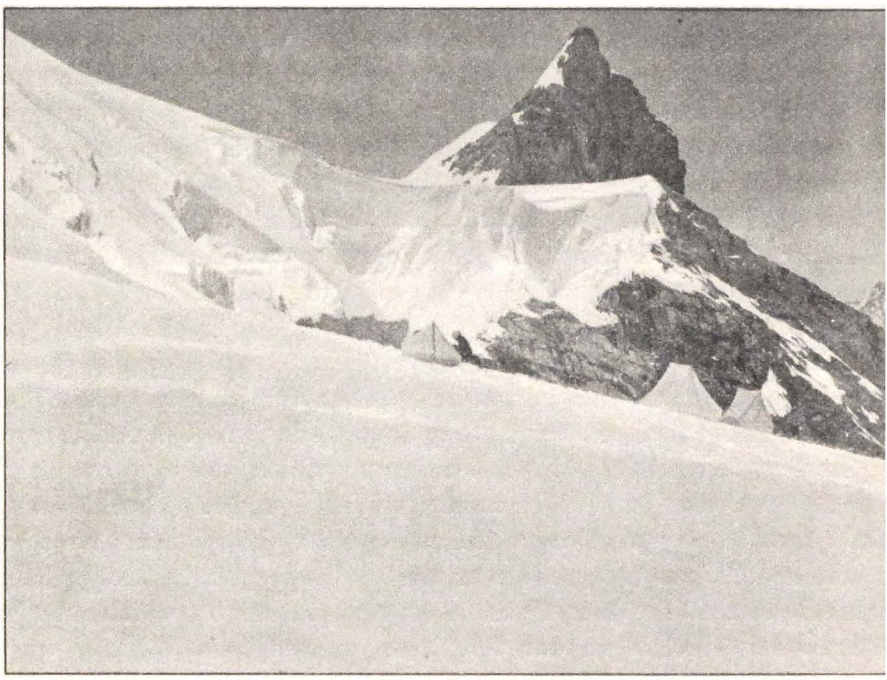
Reconnaissance from this and the preceding camp showed the ascent of the highest peak to be impracticable from this plateau, certainly for our party, as it could be assailed only at one point, above which it would be necessary to camp, the arêtes leading to which are so steep that no loaded porter could probably surmount them, and, if passable at all, would tax the powers of an unloaded expert to the utmost. We therefore moved the camp the next morning 3 miles farther to the upper end of the plateau, at the base of the peak next in height, which promised better conditions. Here our fourth snow camp was pitched at an altitude of 21,300 feet. The porters could only bring half the necessary kit at one time, so they and the guide descended to the third camp for the rest, intending to return that afternoon. But a dense mist after midday and the softening of the snow by the great heat prevented their return, so that Mrs. Bullock Workman and myself were left to pass the night alone in the almost terrifying silence and loneliness of this untrodden solitude of snow.

We did not sleep. As I have found before under similar circumstances, the absolute silence that reigned during the watches of the night, in the absence of sleep, proved almost as nerve-wearing as an excess of noise. In such a situation one has the feeling of having completely lost touch with the material world, and the imagination, uncontrolled by the suggestions of ordinary sounds, runs riot among fancies and possibilities neither wholly pleasing nor reassuring.

The afternoon was windless and oppressively hot. The sun shone

through the drifting mist with a sickly light, but with a heat that se the mercury in the solar thermometer up to 193° Fahr. at 2 o'clock, a to 142° Fahr. at 3.30 o'clock. The heat was equally unbearable with and without the tents, and all the harder to endure because of the mis which, while shutting out all view of the world around, shut in t heat, so that it became a palpable entity penetrating to every pa of the system with depressing effect. At sunset the temperature f to freezing, and an hour later to 10° Fahr., reaching a minimum −4° before morning, a difference of 197°.

At daylight, Savoye and two porters arrived, their faces blue wi



SECOND SNOW-CAMP (WHITE NEEDLE CAMP) AT 19,900 FEET (AIRY, 20,251 FEET AT BASE OF ICE-WALL BENEATH WHITE NEEDLE PEAK. ROCK PEAK, ONE SOUTHERN ENCLOSING PEAKS OF NUN KUN BASIN, IS 1½ MILE EAST OF T CAMP.

cold and their moustaches covered with ice. Having drawn on o frozen boots, we set out with them to ascend the steep ice-covered fla of the mountain above, its lower half broken into ice-falls, where almo every step had to be cut. At an altitude of 22,720 feet, as the mis which almost daily obscured the mountain-tops towards noon we gathering, I stopped with one porter to photograph, while the lat were yet visible, and Mrs. Bullock Workman went on with the oth two to complete the ascent, attaining an altitude of 23,300 feet. Ca was reached at 7 p.m. The temperature fell that night to −6° Fahr.

I have stated the altitude of our highest camp as 21,300 feet. Th

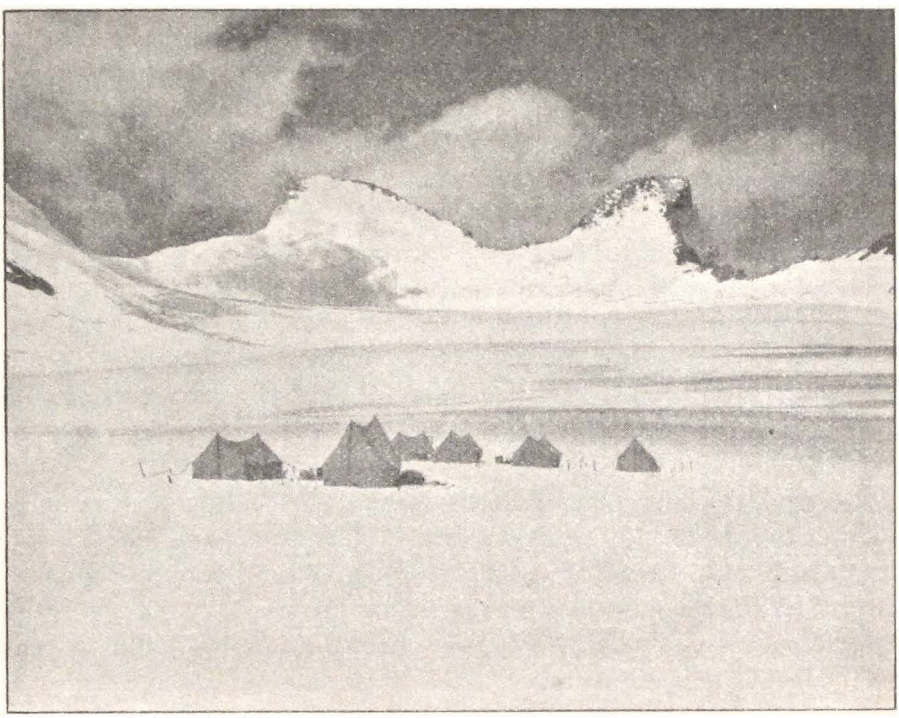
was measured by hypsometric readings compared with simultaneous ones at the lower Government station of Dras, 34 miles distant, where readings were taken for us three times daily during our absence. The same readings, calculated by Airy's table, make its altitude 21,600 feet. The variation being so great, and Airy's table differing from others in placing sea-level at 31 inches and giving relatively higher altitudes for very low pressures, the results of calculations by it have not been used. If Airy's table can claim greater accuracy than the older tables, then the altitude in question must be regarded as 21,600 feet. In either case this camp is of importance practically, as I hope presently to show, as representing, I believe, the highest point to which, up to date, November, 1907, tents have been taken and occupied, and the highest measured point at which mountaineers have passed the night. Two parties have recently claimed to have bivouacked in the open without tents at greater altitudes, Mr. Reginald Rankin on his descent from Aconcagua being overtaken by darkness at an elevation he states as 22,000 feet, and Dr. Longstaff, with guide and porter, under similar circumstances, having spent a night in the snow at what he "thinks" was 23,000 feet. From their published accounts it appears that in neither case was the altitude mentioned determined by any kind of measurement.

It has been asserted several times within the past year that Mr. W. H. Johnson, in the employ of the Indian Survey, camped in 1865 in the Kiún Lún at an altitude of 22,000 feet. I have been unable to find, in Mr. Johnson's account of his work in the 'Synoptical,' Vol. 7, of the Indian Survey, and in the *Journal* of the Royal Geographical Society, any mention of such a camp. If any camp, which Mr. Johnson thought approached this altitude, was made, it must have been on the peak E 61, the only peak in the region exceeding 22,000 feet, which was measured in 1862 by a Survey employé and its height given as 23,890 feet. This measurement was unchecked, and the details of it were so meagre that the Survey did not endorse it, expressly stating that, for reasons given, they considered it too high—as I have been credibly informed, probably 1000 feet or more too high. Any camp, therefore, that Mr. Johnson may have made on this mountain, the altitude of which he would naturally estimate with reference to the assigned height of the mountain itself, would have to be lowered by the same amount, which would bring it in any case below the altitude of our recent highest camps.

In order to place mountaineering on a scientific basis, among other things, the necessity of the measurement of altitudes reached, by one of the methods recognized as fairly reliable, is obvious, since such measurement alone defines with approximate exactness the height at which observed altitude phenomena may occur, and without it observations lose an important part of their value. In this connection I would call your attention to some of the subjective experiences, particularly at

night, of the nine Europeans engaged on this occasion, not merely in high climbing, but in carrying loads, making and occupying camps measured at 19,900, 20,632, and 21,300 feet (by Airy's table 20,251, 21,093, and 21,600 feet).

Only one of the party—a porter—suffered from mountain sickness. Although complaining of headache and weakness at the third camp (20,632 feet), he started to go to the fourth with a light load of instruments, but was unable to keep up with the rest of us and soon fell behind, showing unmistakable signs of mountain sickness. Before



THIRD SNOW-CAMP (CAMP ITALIA) AT 20,632 FEET (AIRY, 21,093 FEET) NEAR SOUTH-WEST END OF NUN KUN BASIN, EXTENDING NORTH-EAST OF CAMP TO TWO OTHER ENCIRCLING PEAKS 3 MILES DISTANT. ONE AT LEFT IS PINNACLE PEAK, 23,300 FEET, ASCENDED JULY 29, 1907.

reaching an altitude of 21,000 feet, though naturally a strong and healthy man, he collapsed entirely and became helpless. He complained of loss of sensation in his hands. His woollen mittens being drawn off, his fingers were found white and stiff, and, if not already frostbitten, on the point of becoming so. Vigorous rubbing and pounding of his hands finally restored circulation, when he was sent down to the third camp. The fact that his hands, even when protected by thick woollen mittens, were brought by the cold to the verge of frostbite, while my own, without any covering, were comfortably warm, shows how profoundly the circulation and vitality are prostrated by mountain sickness, and how

dangerous it is for one suffering from this malady to be exposed to the cold of high altitudes.

At the second camp, 19,900 feet, and above, three suffered with severe headache, pain in back and lower limbs, especially at night, and a fourth with headache at night; while three were troubled with cough without discoverable pharyngitis or bronchitis, which promptly disappeared in two cases on descending to the base camp, but persisted for a week in the third. These symptoms did not incapacitate any one, except the porter who was ill, from accomplishing the daily work.

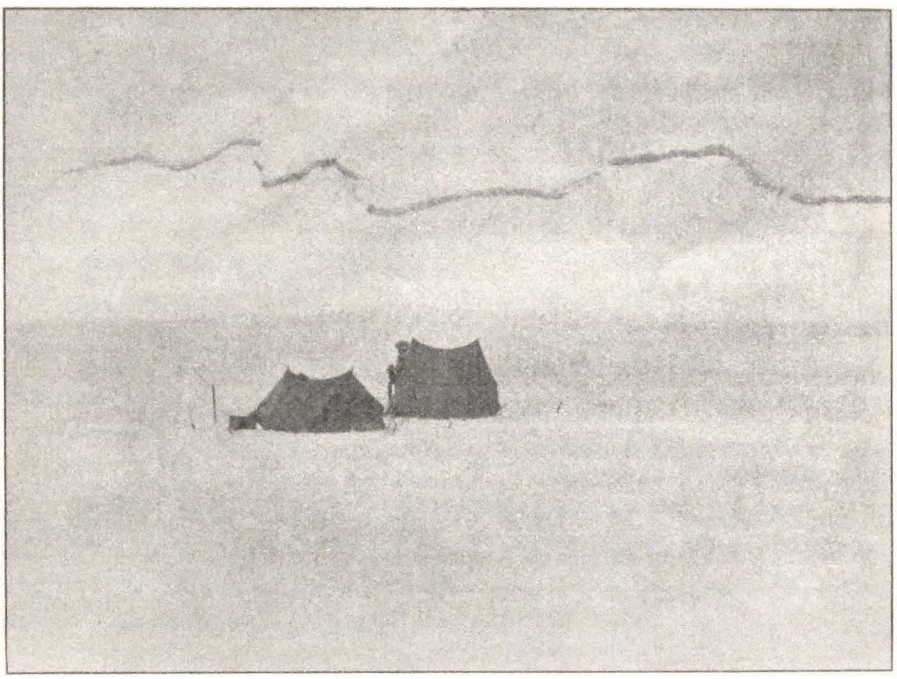
Every one, as was to be expected, felt the effect of altitude on the respiration, though some to a greater extent than others. This, as usual, manifested itself by shortness of breath and panting on slight exertion. In the erect position, when resting, the respiratory disturbance was not so noticeable, being marked only on movement, but at night on lying down it became more urgent, being accompanied by a feeling of oppression, for the relief of which a number of deep inspirations were necessary. The frequent repetition of these wearied the respiratory muscles and even became painful. This constant gasping for breath interfered with sleep, no matter how tired one might be, and if, at last, after a long period of prostrating wakefulness, one did doze for a moment, one would immediately start up with frantic efforts to obtain sufficient oxygen to relieve the stifling sensation which threatened to terminate one's existence. During the five nights at our three highest camps no one obtained more than a few snatches of sleep, and four, of whom I was one, practically none at all. Those nights are not easily forgotten, when one lay sleepless on the snow, in the cold, and silence, and darkness, struggling for breath, and counting the slowly dragging hours with a feeling that the strain could not be endured till daylight. It is scarcely necessary to say that even the strongest could not hold out for long against the depressing influence of loss of sleep, combined with the lowering of vital energy due to the scarcity of oxygen at these high altitudes. We were conscious of a distinct decline in strength on the last two days, and after six consecutive days of hard work and five sleepless nights every one felt an irresistible desire to relieve the tension by a descent to a lower level.

I have elsewhere, in connection with our highest camp in the Chogo Lungma region, at 19,358 feet, where five Europeans were affected in a similar manner during two nights, suggested the possibility that, in attempts on the highest Himalayan summits, where camps would have to be made at from 23,000 to over 27,000 feet, insomnia alone might prevent success.* This corroborative experience of nine active mountaineers at camps approximately 550, 1300, and 2000 feet higher than that above mentioned, at all of which respiratory disturbance and

* See *The Alpine Journal*, August, 1905, p. 14.

insomnia were distinctly more pronounced, being most marked at the highest, appears to me now to justify the opinion that insomnia will be found to be an adverse factor in high mountain work no less formidable than cold, deficiency of oxygen, and weather, and much more so than mountain sickness, inasmuch as it appears likely to affect a larger number of climbers.

Our primus stoves and hypsometer lamps felt the altitude quite as much as we. The alcohol in the lighting cups of the former would not burn until the cups had been heated by the application of half a dozen burning matches, and the petroleum gas issuing from the burners was



FOURTH SNOW-CAMP (CAMP AMERICA) AT 21,300 FEET (AIRY, 21,600 FEET) AT BASE OF PINNACLE PEAK. ITS DESOLATE SITUATION IS APPARENT.

only partially consumed when saucepans were placed at the ordinary distance above the latter, the rest escaping in smoky ill-smelling fumes. To insure complete combustion it was necessary to give the flame its full height, so that the air could have access to it from every point. With this precaution petroleum in a primus stove makes a more efficient fuel and generates a much greater heat at high altitudes than alcohol used in any apparatus I have seen. The wicks of the hypsometer lamps were also lighted with difficulty, two or three matches in succession being required, and when they were lighted, placing the lamps in the metal jackets promptly extinguished the flame. Having had the same experience previously, we had had the burning-tubes replaced by new ones of double the diameter, but this did not help the matter. The ordinary

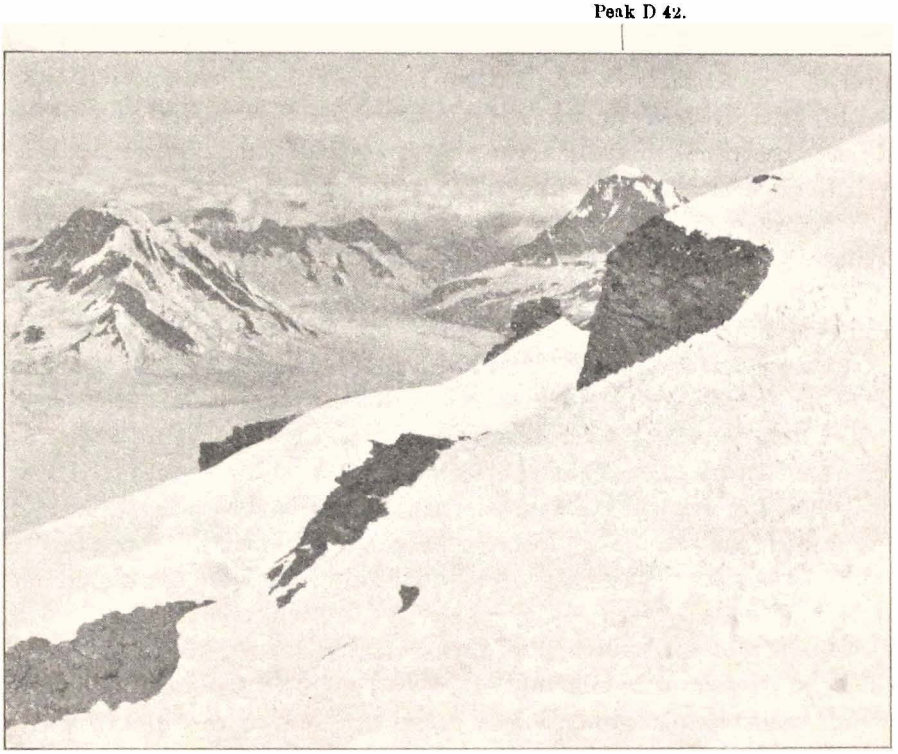
jacket does not admit sufficient oxygen to insure combustion at high altitudes. The lower half of the jacket, at least, should be made of wire-gauze so as to admit all the air possible.

We found the low temperature, $-4°$ and $-6°$ Fahr., and even that of 17° and 10° Fahr. with strong wind, trying, at night. Arctic explorers endure temperatures much lower than these without difficulty, but their work lies near sea-level, where the atmospheric pressure is more than double that at 21,000 feet, and they can encase themselves in furs without suffering from the weight. There the air also contains sufficient oxygen to enable them to breathe freely under any degree of exertion, and to sleep soundly, thus sustaining the bodily heat and vital forces at a normal limit, so that they can offer a maximum power of resistance to cold. But at high altitudes, where vitality has been lowered by hard work, loss of sleep, and deficient oxygenation, where only a closely calculated minimum of clothing and bedding can be carried, an amount really insufficient to protect one against cold, a temperature of zero means a good deal more than it does to the Arctic explorer. The mountaineer at high altitudes is called upon to endure Arctic conditions without the means of protection available to the Arctic explorer. All our party, in addition to flannel-lined Mummery tents, with ground-sheets sewn in, were provided with rubber ground-sheets and well-padded eider sleeping-sacks, enclosed in outer ones of camel-hair or army blankets; but these were inadequate to prevent us, even when wearing our thickest clothing besides, from feeling the cold sensibly at night at the second camp, and to a much greater degree at the two highest camps. Two thousand feet higher, where the cold would be considerably greater, we should probably have suffered more severely.

An effect of altitude upon the mind, which was noticeable here, as it has been elsewhere above 18,000 or 19,000 feet, deserves mention. Owing, perhaps, to a general loss of energy and to the disturbance of respiration and circulation incident to even moderate exertion, a mental condition of irresolution and disinclination to effort supervenes. The simplest actions assume formidable proportions, and even photography, which one recognizes as of the highest importance and which at ordinary altitudes is not a difficult process, becomes a bugbear; while the ascent of a peak, a really arduous undertaking at high altitudes, looms up as an almost impossible proposition. One has, therefore, often to call the will into play to its utmost power to force one's self to carry out what has been proposed. Those who are destined to raise the mountaineering altitude record much higher than it now stands will undoubtedly be persons of strong will and self-control.

Another point of interest is, that the guide and porters were able to carry loads of 40 lbs. to an altitude of 21,300 feet. The gradients, except that of the ice-wall above the second camp, were not steep, and the last

two marches upward were only about three hours; but to carry loads of 40 lbs. up inclines of 25° to 35° in snow ankle-deep, at that altitude, requires strength and endurance. How much higher they could have gone, or up how much sharper slopes, I will not venture an opinion. Savoye expressed grave doubts whether they could carry the same loads up much steeper gradients than were encountered, for at altitudes like these the difficulty of carrying a given load increases enormously with a comparatively slight increase in gradient. These men were certainly more efficient than coolies, and with their aid we were able to make two camps at altitudes which could not have been reached with coolies.



VIEW DOWN BARMAL GLACIER FROM POINT ABOUT 20,000 FEET HIGH ON D 41. SLOPE IN FOREGROUND COVERED WITH NIEVES PENITENTES.

The question to what height trained mountaineers will be able to carry outfit requisite to camping must be left to the future to decide. With the various obstacles to high climbing more accentuated in proportion to altitude, it seems certain that loads will have to be reduced as altitude increases, until a limit will at last be reached where not enough can be carried to support life and protect the mountaineer against cold and weather. That limit is likely, I fancy, to be found considerably below heights at which camps will have to be made to render the highest summits accessible.

One of the most interesting features of the Nun Kun is the plateau, or snow-basin, where we camped, which, enclosed by its circlet of seven

glittering peaks, sits like a diadem on the brow of the lofty massif which it crowns. Its surface is undulating, being depressed in the centre, but rising towards the bases of the peaks, where it shades off into the mountain slopes. The altitude of its highest part, which is at the north-east end beneath the second highest peak, is 21,600 feet. Thence it slopes away to the south-west to about 20,300 feet at the Ganri outlet under the highest peak. Its shape is oblong, its long diameter running north-east and south-west being 3 to 3½ miles, and its conjugate diameter about 1½ mile. The peaks rise sharply from it, and descend more sharply, largely in perpendicular precipices, on the outer side. The four north-east peaks are connected by rock and snow saddles. The other three, including the highest at the south-west end, stand alone, rising directly from level ice. Around the bases of these three the basin has four outlets, by which its snows escape to form the ultimate source of the three principal glaciers of the massif, one stream descending north-west between the highest peak and the one next north-east to make one head of the Ganri glacier, two others to the south to feed the short but broad Fariabad glacier, and the fourth also to the south, to contribute to the north reservoir of the Shafat glacier. It is very unusual for three glaciers to originate in a single basin.

The Ganri glacier has two reservoirs, or heads, the larger one drawing its snows from the whole north-west side of the highest Nun Kun peak, from the north slope of an arête running from the latter to the Barmal ridge (an arête of D 41), and from the north-east face of D 41, which unite in a converging snow-field 3 miles wide at its upper part, with a fall from about 19,000 to 17,000 feet. The second head descends from the Nun Kun basin, leaving the latter at an altitude of about 20,300 feet. The two come together at the end of a rock arête of the highest Nun Kun, just above the entrance to a gorge enclosed on both sides by ragged mountains descending steeply to the Rangdum valley. The upper end of the gorge appears to be at an altitude of about 17,000 feet. From this point the glacier, crowding into the gorge in a greatly narrowed stream, tumbles more than 5000 feet in a continuous line of seracs to near its termination 8 miles below its sources.

The most remarkable feature of this glacier, and one seldom seen in purely mountain glaciers, is its tongue, which ends abruptly at the river-bank, like that of a polar glacier extending to tide-water, in a perpendicular ice-precipice about 600 feet long and 200 high. Its successive layers, as they separate themselves, fall in miniature icebergs into the current, by which they are carried away and strewn along the river-banks below. The river washes the base of the whole front of the tongue, apparently cutting under its lower edge somewhat; but the depth to which it can undermine the ice must be slight, as the latter does not project appreciably into the river, but breaks off at the edge of the bank. Here a river not many feet in depth is seen to produce

the same effect upon a massive glacial tongue as is produced by the deeper waters of the polar oceans upon glacial tongues that push into them.

West of the tongue, and separated from it by a considerable interval, a giant lateral moraine, over 200 feet high, and towering above it by more than 100 feet, extends entirely across the valley, and similarly a shorter lateral moraine projects on its east side. These moraines, together with the boulder-masses piled up in the space between them, show that the glacier was formerly much longer, wider, and thicker than at present, covering the whole width of the valley and impinging against the opposite mountain walls. The amount of detritus brought down to build these moraines and boulder-masses was enormous. At present the glacier, as seen both from above and below, appears remarkably clean and free from detritus.

The third or Fariabad glacier, beginning in the two southern outlets above mentioned of the basin, and reinforced by snows from the external slopes of the two western peaks, descends rapidly in a confused mass of ice-falls, caverns, crevasses, and seracs, directly south to the side of the Z 1 glacier above the opening of the Fariabad nala. It is separated from the Shafat glacier on the east by the ridge before mentioned, and is bounded on the west by a large spur from the highest Nun Kun, descending to the Fariabad opening. Its length is 4 and its width 2 miles. It is a most dangerous glacier to venture on.

The three principal Nun Kun glaciers are not very long, being respectively only 9, 8, and 4 miles in length, but, springing from heights of from 22,000 to over 23,000 feet, and falling 10,000 to 11,000 feet in these short distances, they possess great potential energy, developing ice-falls, ice-precipices, and seracs as large and high, crevasses and abysses as wide and profound, ridges and ravines as pronounced, and moraines as gigantic, as those found on glaciers of far greater size and length.

We decided next to try to complete the circuit of the Nun Kun. Reconnaissance showed that no passage to the west from the top of the Shafat glacier at a high level existed, the way being barred by the spur descending from the highest Nun Kun to the Fariabad opening, followed by a succession of arêtes, snow-basins, and precipices; but if we could get down over the Fariabad glacier, or over a sharp rock-spur of Z 1, to the Fariabad opening lying 4000 feet directly below, we might find a way by a nala that was seen to ascend north-west from the last, and to end in a great amphitheatre of ice and snow, at the top of which a saddle might be found. This would be a matter of pure pioneering, as the survey map was of no assistance,* and *none* of our coolies knew

* Those who are at all acquainted with the history of the Indian Survey know that its work in the northern part of Kashmir territory was, and under the circumstances had to be, more in the nature of a reconnaissance than of a finished survey, salient points being fixed and intermediate details, which could not be seen, being

anything of the proposed route. Success was by no means certain, but we determined to try it.

We accordingly cut loose from our base camp on August 9, with fifty coolies carrying a minimum of lightest outfit and nine days' supplies, sending all other luggage back to Suru in charge of a Gurkha and shikari by way of the Rangdum valley. We ascended the Shafat glacier, crossed the ridge above it, and descended the east edge of the Fariabad glacier till it plunged down so steeply and became so broken that it was no longer available. We then crossed to the rock-spur of Z 1 at an altitude of about 16,000 feet, and descended with considerable difficulty its precipitous greatly broken face, covered with loose rocks and *débris* for some 2000 feet to the Z 1 glacier, which, falling from the top of the mountain in a very steep ice-fall, fills the Z 1 nala almost to its junction with the Fariabad nala. A short distance above the tongue of this glacier the tongue of the Fariabad glacier, coming down from the Nun Kun in a great broken ice-wall, ends abruptly at its edge without any terminal moraine. The tongue of the Z 1 glacier ends in a steeply falling front of discoloured ice, 300 feet or more in height, with a sharply defined curving contour thickly seamed with longitudinal crevasses. Here, also, there is no terminal moraine, though the nala-bed below is sprinkled quite thickly with *débris*.

Glaciers do not by any means always form terminal moraines. As to this fact, there is no difference of opinion among glaciologists, in whatever manner they may account for the formation of such moraines. The one hypothesis, that terminal moraines result from the gathering up and pushing along of the subglacial ground-moraine material, and even, as some hold, of the ploughing up of the terrain beneath the ground-moraine by an advancing tongue, and to a less extent by a stationary one, so as to form a wall at its end, fails to account for the cases where no terminal moraine results, even under the most favourable conditions of active advance. It also ignores or minimizes the part which moraine material carried by the tongue must play in the process of moraine building. It is evident that no moraine would be formed by a tongue in retreat.

The other hypothesis, that such moraines are wholly due to the deposition and excretion of the material lying in and upon the tongue, presupposes the co-operation of two factors: (1) that a glacial tongue should carry a considerable quantity of detritus, and (2) that its front should remain stationary long enough for the detritus to be deposited in sufficient quantity to form a moraine, *i.e.* the ice from above must advance to the terminal line as fast as the ice there melts and discharges its detritus upon that already deposited, till the process is completed. By this

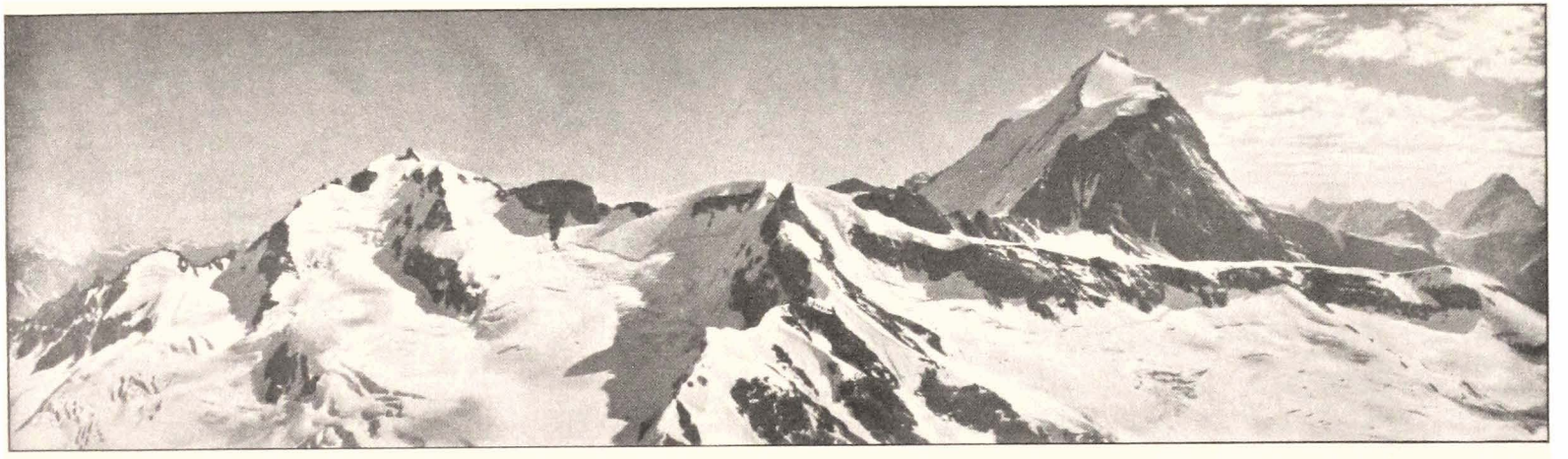
filled in on the resulting map by inference. It is, therefore, no discourtesy towards the Survey for those exploring the hitherto unvisited intermediate parts to mention the absence or inaccuracy of topographical details on the map.

hypothesis, if a tongue carries no moraine material, no moraine should be formed under any conditions of advance or retreat. This fails, in its turn, to account for those cases where glacial tongues bearing no observable moraine-material have been found to be bounded by high and large terminal moraines. If the end of a tongue recedes faster than the ice above it advances, no moraine results, its detritus being spread more or less evenly over the denuded surface without accumulating at any one point.

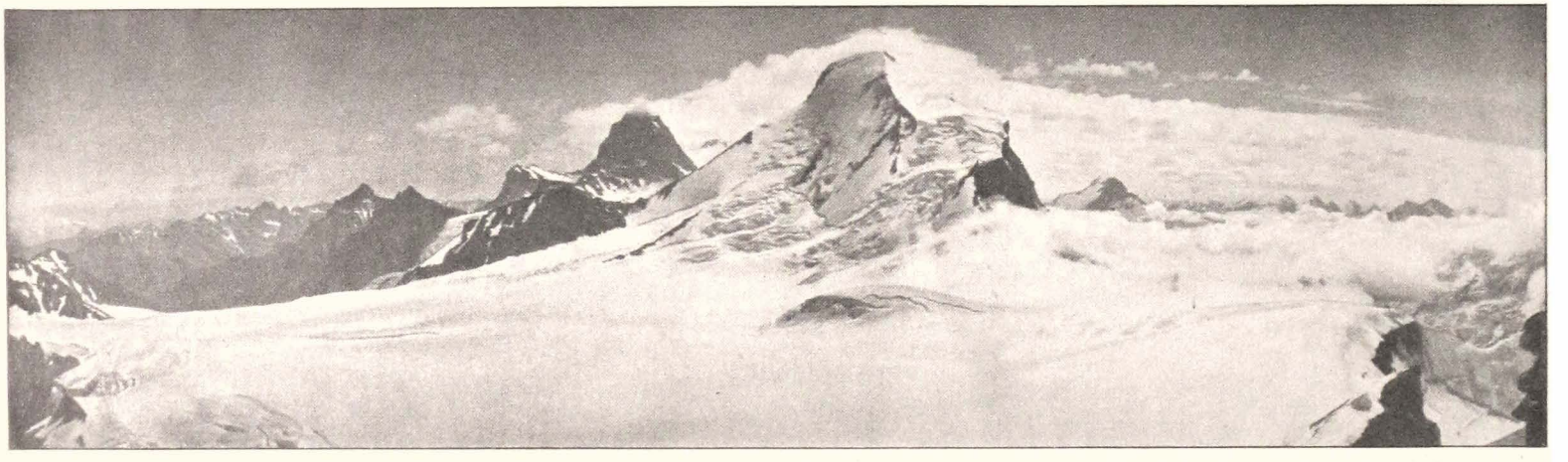
The tongues of the two glaciers above mentioned, at present, furnish examples of the absence of one of these factors in each case. The Fariabad tongue bears no detritus to speak of, and has no deposit at its end. That of Z 1 has been receding constantly and rather rapidly for some time, and, though carrying considerable *débris*, has left it evenly distributed over the nala-bed in front of it, not having paused long enough at any one point to build an elevation that might be called a moraine. Half a mile farther down the nala are some larger *débris*-deposits overgrown with vegetation, which might be regarded as terminal moraines.

The successive terminal moraines often found in front of glaciers, with intervals between them little or not all strewn with detritus, show that the same glacier, according to the presence of both these factors or to the absence of one or both, may build terminal moraines at one time and fail to do so at another. The smoothness of many such intervals would indicate that, during a period of recession, the respective tongue carried but little detritus. In Himalaya, glaciers may recede for considerable distances without leaving behind *débris* of any size, as in case of the Chogo Lungma tongue, cited in a paper read by myself before this Society (see *Geog. Journal*, March, 1905, p. 251), which has retreated 1184 feet in forty-two years, leaving a smooth river-bed below it. Observed facts appear to show that there is truth in both the above hypotheses, and it is not improbable that many moraines are formed by the combined action of both the methods they suggest. In 1902 and 1903, when I saw the tongue of the Tippur glacier, near that of the Chogo Lungma, it was adding to its large terminal moraine at a rapid rate by the deposit upon the latter of detritus from its upper surface.

From the Fariabad opening we followed up the nala leading north-west (North-West Nala). About a mile above the former, west of the rock-spur from the highest Nun Kun, a glacier from the base of that peak reaches the north side of the nala in an ice-fall, but does not penetrate it. Two miles above this, a glacier, descending from the mountains on the south, fills the nala for another mile. Two hundred feet in front of its tongue is a high terminal moraine composed entirely of fine brown sand with ice still beneath it. This appears as if it might have been formed by the ploughing up of the nala-bed by the glacial tongue during an advance. The sand has protected the ice on which



Panorama from summit of Mt. Nieves Penitentes, 19,080 feet. Peak on left is D 41, 20,571 feet. Barmal Ridge runs from it to lower edge of picture in centre. These two enclose northern half of head of Barmal glacier. Peak on right is highest Nun Kun, the snows around which are turned by the ridge running from it to centre of Barmal Ridge, and by latter into the Ganri glacier on north and, as seen in foreground, into the north-west nala on south. Peak at extreme right is Z 1.



Panorama from summit of D 41, 20,571 feet, showing two heads of Ganri glacier, the larger in foreground coming from highest Nun Kun, the Barmal Ridge and D 41, the smaller descending from Nun Kun basin between highest peak and one next north of it (on left). Arête from highest peak to Barmal Ridge concealed by cloud. Part of west face of Barmal Ridge at extreme right.

it rests from the sun's heat, while the uncovered ice behind it has melted entirely away. Higher up another glacial tongue enters the nala from the south, on which are two picturesque lakes. After ascending the steep glacial amphitheatre in which the nala ends, we came to a snow col at 17,347 feet, south of Nieves Penitentes peak, and east of the head of the Bara Zaj Nai nala, to which most dangerous-looking ice-slopes descend. We named this North-West col.

The only practicable passage from here appeared to be towards Mount Nieves Penitentes. A gentle descent of half an hour brought us to its base. Here we were overtaken by a dense mist. Having fortunately taken bearings before it set in, we pushed up an ascending snow-slope in the mist between an ice-fall and a bergschrund, and finally reached a rock-arête rising above the snow close under the western angle of Mount Nieves Penitentes at an altitude of 17,260 feet. This our coolies, who arrived two hours later, and who up to this point could give us no information, recognized and called the Barmal la. Here we camped four nights. The Barmal la commands a view of the head and of much of the course of the Barmal glacier, a large and handsome sheet of ice springing from the slopes of Nieves Penitentes peak and of D 41, 2 miles north, and from a high rock-wall connecting them, which we named the Barmal ridge. It runs westward for 8 miles, walled in on each side by a line of jagged peaks, and ends among green slopes south-east of a mountain-cirque enclosing the reservoir of a branch of the Bhot Kol glacier. The width of the Barmal glacier near its origin is about 2 miles, but it soon narrows to 1 mile, maintaining this width for over 5 miles. This glacier is not on the Survey map. It has, however, evidently been long known to the natives, who often cross it with yaks in going between Tongul and the Bara Zaj Nai, and also the Fariabad nala. Local tradition credits one European with having visited it many years ago. In 1902, Rev. C. E. Barton and Dr. A. Neve, ascending from Tongul, crossed it to the Bara Zaj Nai nala at a point about 5 miles west of the highest Nun Kun. In 1904, Dr. Neve reports having crossed it again at the same point, and having climbed on the side of D 41 to a height stated as 19,200 feet.

On two successive days we made first ascents of Mount Nieves Penitentes, 19,080 feet, and D 41, 20,571 feet, from the summits of which we obtained not only comprehensive views of the surrounding region, but unobstructed views of the western end of the Nun Kun massif, of the two reservoirs of the Ganri glacier, and to the west the full sweep of the Barmal glacier to its end 8 miles beyond.

In the February 1903 *Alpine Journal*, Dr. Neve shows a photograph of a section of the Barmal glacier taken from the pass to the Bara Zaj Nai, which he designates as "the Great Western Glacier of Nun Kun." He further states in his 'Tourist's Guide to Kashmir,' 6th edit., 1905, p. 122, that Mr. Barton and he, in 1902, "discovered that the Bhot Kol

glacier comes all the way from the Nun Kun peak." Also in the February 1905 *Alpine Journal*, p. 350, he speaks of the Barmal glacier as "the upper Bhot Kol glacier." From these quotations it is evident that he supposes the Barmal to be identical with the Bhot Kol glacier, and that its ultimate source is the highest Nun Kun peak.

I cannot agree with him in either of these suppositions. As regards the first, it may be said, having been over the same ground, and having also traversed the Bhot Kol glacier from end to end, I found no evidence that the two glaciers are identical. The lower end of the Barmal glacier, where Dr. Neve supposes the connection to be, is separated from the Bhot Kol by mountains and ridges from 17,000 to 19,000 feet in height. As regards the second supposition, from the summits of Mount Nieves Penitentes and D 41, the south-west and north-west faces of the great pyramid of the highest Nun Kun are seen to be separated by a sharp rock-arête, broken at one place, running down the pyramid from its apex to its base on the high plateau, where the arête is lowest. Thence it passes directly west, rising as it goes, and joins the Barmal ridge at its highest central point, about 19,000 feet.

This arête and the Barmal ridge turn all the snows coming from the Nun Kun peak, and those of the plateau between this and the Barmal ridge, into the west reservoir of the Ganri glacier on the north, and towards the North-West nala on the south side, and, as can be seen from these photographs, not a particle of snow from the Nun Kun can enter the Barmal glacier. Had Dr. Neve climbed sufficiently high on D 41 to fully overlook the Barmal ridge, he would have seen the impossibility of this supposition.

The ascent of Mount Nieves Penitentes and of D 41 was by no means easy. Both are peaks of the very first order. One slope of the former, requiring three-quarters of an hour to climb, was steeper than could be measured by the scale of Abney's level, being apparently 70° or 72°. The last 1500 feet of D 41 was also difficult, consisting of ice-slants varying from 60° to 70°. Fortunately these were wholly covered, as stated, with *nieves penitentes*, forming a precipitous giant stairway of ice, by which we were able to scale it in safety. Had its surface been smooth, the undertaking would have been much more difficult, more fatiguing, and highly dangerous. Half an hour after the top was reached a thick mist swept up from the Barmal glacier and enveloped us, shutting out all landmarks. This was accompanied by an icy wind, which congealed the breath into icicles on our moustaches and covered our clothing with feathery fringes. Recognizing the danger both of remaining and of descending, we preferred to attempt the latter, and succeeded in getting down in two parties invisible to each other, by following the slight spoor made in ascending. Previous to departure a stone cairn was built on the summit and notes of the ascent placed in it.

The Barmal la stands perhaps 600 feet above the Barmal glacier, at the top of a very steep ice-wall cleft by two bergschrunds, to ascend or descend which requires a good knowledge of ice-craft. Our coolies were powerless to negotiate it alone, which fact prevented many of them from deserting during the four days we camped there, and even the guide and porters would not venture on it unroped. Two rock-cairns stand on the summit of the la. By whom they were made we could not learn. No records were found in them, and I know of no account of any European having visited this place. As it is practically certain that natives could not reach it from the Barmal glacier unless the ice-wall were greatly changed, it may be surmised that some party, having come up to it from the south side, mistaking it for a snow-pass somewhat farther west, and having found the descent to the Barmal glacier barred by the ice-wall, built these cairns as a beacon by which the place might in future be avoided. The existence of other cairns on ledges to the south, indicating the way to the other pass, supports this view. Half or three-quarters of a mile west lies the snow-pass referred to, accessible by easy snow-slopes, leading from the Barmal glacier to the Bara Zaj Nai. It is over this pass that the natives take their yak-caravans from Tongul, and this was the pass used by Dr. Neve, also under the name of the Barmal la.

The Sentik la is a depression about a mile distant from D 41, in the ridge leading west from it. Over this pass lies the way from the Barmal glacier to Tongul, the nearest village in the Suru valley. Below the pass the Sentik glacier, about 3 miles long, coming from the north side of D 41 and neighbouring mountains, and receiving two ice-falls from the west reservoir of the Ganri glacier, descends north to the head of a very steep nala, enclosed on both sides by jagged rock-peaks, below which slopes and ridges fall away to Tongul, a short march from Suru. By this route we returned to the latter village, having covered over 90 miles of rough country in completing the first circuit of the Nun Kun, besides many more in exploration and ascents.

August 18 and 19 were very warm days at Suru, the sun burning with unusual fervour. We had found during the summer, as during those of 1902 and 1903, sun maxima of 200° to 206° Fahr. at high altitudes to be not at all uncommon, but had never known them to attain the figures reached on these days. On the 18th, at 1 p.m., the sun thermometer registered 206°, and, at 1.15, 212° Fahr. As this last figure seemed incredible, the instrument, which was so hot that it could scarcely be touched by the hand, was raised to the vertical position and shaken, but the mercury did not fall. At 1.25 it reached 216°. This was not only an unusually high maximum, but it occurred at an unusually late hour, most maxima I have observed occurring at or before 1 o'clock.

On the 19th, at 12.30 p.m., the thermometer registered 196°. At

12.45, 213°. At 1, through a thin film of cloud, 217°, not falling when placed vertical, and at 1.5, 219° Fahr. The altitude of Suru is 10,850 feet. As sun-temperatures increase in proportion to altitude, what must the temperatures on these days have been at over 20,000 feet?" * On these, as on other occasions when I have noted high temperatures, the maxima showed themselves in sudden waves or flashes of heat lasting a few moments and then subsiding. It may also be noted that, as on the 18th, some of the highest temperatures have occurred when the sky was covered with thin cirrho-stratus clouds.

Before the paper, the PRESIDENT: The lecturer of the evening, Dr. Hunter Workman, is going to address us on his last expedition with Mrs. Bullock Workman, his wife, in the Himalayas. I regret that Mrs. Workman has not been able to be here to-night, as we hoped she would have been, because she is engaged in something almost more arduous than climbing 23,000 feet. She is delivering thirty lectures in thirty-seven days, starting from Munich and going by Vienna up to Dresden, Berlin, Hamburg. I need not introduce Dr. Workman to you, because he and Mrs. Workman are old friends of our Society. It is about eight or nine years since they started on their explorations in the Himalayas. Dr. Workman delivered an address here about three years ago on his journey from Srinagar to the sources of the Chogo Lungma glacier. They then returned to the Himalayas, and in the following year Mrs. Bullock Workman gave us a very interesting address on the earliest exploration ever made of the Hoh Lumba and Sosbon glaciers. To-night, after fresh travels and always on new ground, we are to hear from Dr. Workman an account of their joint ascents in the Nun Kun group. I shall not enter into the difficult question as to what traveller has ascended the greatest height above sea-level. We have Dr. Longstaff here, and I believe there is only a matter of about 10 feet between them, him and Dr. and Mrs. Workman; but I will remind you that all of these explorers are not merely trying how high they can climb. Careful observations are taken of glaciation and in other scientific directions, so that their ascents have real scientific value.

After the paper, Sir THOMAS HOLDICH: I am rather glad of this opportunity of expressing my admiration for the consistency and the determination and the ability with which a long record of observations has been taken by Dr. Hunter Workman and his gallant wife—if he will allow me the expression—under circumstances of extreme difficulty. I have had some slight acquaintance with the difficulties and the disabilities which beset the taking of observations in very high altitudes in the Himalayas, and I can only liken it to the conditions under which a man might find himself if he was at sea in very stormy weather, and very sea-sick, and was asked suddenly to make records of the height of the waves and the strength of the winds: he would find that it took a great deal of resolution and determination to effect his purpose. It is indeed a most difficult proposition.

There are some of the phenomena to which Dr. Hunter Workman has referred which I had the opportunity of observing, to a certain extent, when I was in the Andes. He referred to the *nieves penitentes*. Now, although I saw nothing of *nieves penitentes* in the highest altitudes of the Andes, yet I did observe distinctly the same results, induced probably by the same causes, on the surface of the wide plains which intervene between the Andes and the Atlantic, as I was crossing in winter;

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* See the *Geographical Journal*, March, 1905, p. 260.

and I was convinced that the cause of the formation which Dr. Hunter Workman puts forward is correct, namely wind-action. I know of no part of the world in which the wind is more persistent from a certain quarter than it is on the western slopes of the Andes and across the intervening plains between the Andes and the Atlantic. The *nieves penitentes* of the Pampas were most obviously caused by wind. As regards his criticism of the Survey maps, I have very little to say. I can only explain to you, as he must be very well aware, that it is not, and never can be, one of the primary objects of the Survey Department of India to make detailed maps of regions so inaccessible and so remote as those which Dr. Hunter Workman has visited. All I can certainly promise is that the department which is responsible for those maps will receive with the greatest thankfulness any corrections or recommendations that explorers of the type of Dr. Hunter Workman, who take observations carefully and consistently, may possibly give to them.

You must know, for it has been frequently discussed in this hall, the difficulty that exists in determining altitudes at such great heights as those with which Dr. Hunter Workman has been dealing. Barometric observations are notoriously uncertain, and amongst them we must include hypsometric observations, that is, observations obtained by the boiling-point of water, to which Dr. Workman has referred; all are equally affected by variations in atmospheric conditions. There is no doubt that the most certain way of determining the heights of remote and inaccessible peaks is by a process of triangulation, where the angles are actually measured and heights reduced by mathematical processes. But all the same, it must be admitted—and will be admitted by any mathematician—that even so there are uncertainties when it comes to dealing with such enormous altitudes as those of the Himalayan peaks. We do not know exactly, and at present there is no means of determining, what the exact effect of refraction may be in those altitudes; and the result of variation when applied as correction to those observed trigonometrical altitudes may be very considerable. For instance, I may mention that we are still in doubt as to the exact height of the highest mountain in the world, Mount Everest. But we are pretty certain that whatever the correction may be that has to be eventually applied when we are more certain than we are at present of the value of refraction, it will not diminish that height. On the contrary, Mount Everest will probably prove to be some hundred feet or so higher than we at present reckon it. But when we come to the mountains which approach Mount Everest nearest in height, K_2, which is situated in the north-west of the Himalayas, and that grand peak Kinchinjunga, opposite Darjiling, we are not at present sure which is the highest. We know which is the highest peak in the world, but we do not know the second highest. It may prove—personally, I think it will so prove—that K_2 (a peak with which Dr. Hunter Workman is well acquainted), which has always been considered to be the second highest, will prove to be third, and Kinchinjunga will have the honour of ranking second.

However that may be, we must all of us accord our unmitigated admiration to the exploits of a lady who has succeeded in exploring such inaccessible altitudes as Mrs. Bullock Workman has done. My admiration for her achievements is unlimited, and I think that, even if it is impossible to say, amongst some four or five people who have ascended higher than any people in the world, which individual amongst them has actually achieved the proud position of getting highest, still we must agree that amongst those few Mrs. Bullock Workman certainly takes a prominent place. Under which circumstances, it is possible that it may be suggested to you, as it has been to me, that it is almost time that a great society like this ranked ladies and men together on precisely the same plane of geographical research. I won't pursue that subject any further; but if any

movement hereafter should ever take place which would allow ladies as Associates of the Royal Geographical Society to receive the same official recognition as men receive, all I can say is that such a movement would have no warmer supporter than myself.

Dr. T. G. LONGSTAFF : I congratulate Dr. and Mrs. Workman very heartily on the great feat they have performed. I should think that Mrs. Workman's record for altitude will never be beaten by any other lady but herself, and any one who knows what climbing at high altitudes means must appreciate the extraordinary degree of fortitude and perseverance with which she is gifted. This ascent of a peak of 23,300 feet by a lady must always rank as one of the most wonderful mountaineering exploits on record. Dr. Workman deserves the thanks of all of us for his self-sacrifice in devoting himself to photography, the results of which have given us such pleasure this evening, instead of completing the ascent, although, of course, he climbed higher than the summit of this peak in 1903.

I must also congratulate my friend Cyprien Savoye and the six Courmayeur porters on the successful accomplishment of a very arduous enterprise. One of the essentials for still higher ascents will be that the man—or lady—who makes the final climb must not be tired out by several days of load-carrying just beforehand ; and this plan of having a good supply of the very best professional Alpine porters will no doubt be necessary. In my opinion, not even the Gurkha, with all his pluck, has quite the same stamina for this sort of work as the Alpine peasant, though I, for one, prefer his company.

Dr. Workman has mentioned my name in connection with the greatest altitude at which travellers have encamped, but is not correct in what he has said about me, as he will see if he reads the account of my Tibetan experiences in 1905 in the *Alpine Journal* (vol. **23**, pp. 202–228). If he had read my account, he must have noticed my reference to W. H. Johnson. This gentleman, who belonged to the staff of the G.T.S. of India, and was also a Fellow of this Society, spent a night at over 22,000 feet in the Kuen Lun when surveying beyond the Changchenmo in 1864 (*J.R.G.S.*, **37**, pp. 1–47 ; and *Proc. R.G.S.*, **11**, pp. 6–14). But the question of records does not in any way detract from the wonderful feat of endurance performed by Dr. Workman and his wife in spending a night at well over 21,000 feet, after they had already spent three consecutive nights at great altitudes.

Though Dr. Workman does not exaggerate the unpleasant symptoms experienced by most people at high altitudes—indeed, he rather makes light of them—I cannot agree with him as to the improbability of the ascent of the highest mountains on the globe, provided always that a relatively easy route exists which is not barred by "questions of high imperial policy." On the Tibetan side of Everest the snow-line probably lies above rather than below 19,000 feet. The rest must be climbed in two days, and this cannot at present be said to be an impossible performance, because both Graham's party and my own, on the final day of the ascent of the two highest mountains that have yet been climbed, were able to ascend nearly 6000 feet and get back to camp for the night. Although I believe that personally I could not climb as high as the summit of Everest, I am equally sure that there are others who can. I wish I was as sure that Englishmen will be permitted to make the attempt.

Dr. Workman's observations on the existence and formation of *nieve penitentes* and on the relative absence of terminal moraines in this part of the Himalaya, are most interesting and valuable. But in reference to the latter, it seems to me that the action of streams and landslips combine to modify such structures in the Himalaya to a much greater extent than in the Alps or Caucacus, and I have

several times been puzzled to know whether I was standing on a terminal moraine or not.

The mountaineering obstacles to the success of Dr. and Mrs. Workman's expedition have been great; the extreme steepness of the snow-slopes we have seen on the screen to-night must have frequently subjected them to serious risks from avalanches. I think that the difficulties, and indeed the actual hardships, that are involved in taking photographs and observations at high altitudes, are realized by very few, either of the general public or scientific geographers, and I again congratulate them most heartily on what they have done, and I hope that they will be thoroughly successful in the expedition which I hear they are undertaking next year, and that Mrs. Workman will raise her own record still higher.

Dr. HUNTER WORKMAN: In regard to the ease with which Mount Everest can be climbed, granting that any one might climb 7000 feet on Mount Everest, from 16,000 feet to 23,000 feet, I think the next 6000, from 23,000 to 29,000, would be a much more difficult affair, because the air is very much more rare the higher you go, and I doubt whether anybody could breathe and undergo the physical strain necessary to climb that last 6000 feet, even if he had the strength. With regard to the suggestion of mountaineers having their camps prepared for them by porters, the question is whether porters could do the work. For reasons given in the paper, I doubt it. As a matter of fact, if the ascent of Mount Everest should be attempted, it is more than likely that its gradients and the natural obstacles would be found to be such as would preclude the possibility of climbing 7000 or 6000 feet in a single day, and a succession of camps would have to be made under the disadvantageous conditions I have mentioned.

The PRESIDENT: In thanking Dr. Hunter Workman for his paper, I need not, I think, say anything more than Sir Thomas Holdich and Dr. Longstaff have said concerning our admiration for the work of himself and Mrs. Workman. I would only ask Dr. Workman to convey this to Mrs. Workman on our behalf.

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