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# MORE EXPLORATIONS ROUND NANDA DEVI

ERIC SHIPTON

*Evening Meeting of the Society, 22 February 1937*

MOUNTAINEERS will have been interested to learn that the Survey of India is now engaged on a new half-inch survey of the mountain regions of Kumaon and Garhwal. Previous surveys, as produced on the present $\frac{1}{4}$-inch sheets 53 N and 62 B, had been confined almost entirely to the populated and revenue-producing areas in or near to the great arterial valleys. Most of the glacier-covered country and the remoter valleys of these sheets are very sketchily drawn, in many places indeed so sketchily as to bear no resemblance whatever to the ground in question. Over much of the country too it has been found necessary to extend the primary triangulation. While engaged on this task in the Badrinath–Kedarnath range, Major Osmaston found that the whole trunk of the Gangotri Glacier was in fact several miles west of the position allotted to it on the map. I hope that now at last we shall have a final solution to the topographical problems which, as a result of the vague data recently brought back by various expeditions, have excited so much discussion.

The usual method employed for hill surveys in India is plane-tabling by Indians, who are each responsible for a section of the area. They work with remarkable speed and neatness, and under close supervision of their officers they produce very good work. But in the high Himalaya they are faced by unusual difficulties. Not being trained mountaineers they have great difficulty in moving their parties about in the glacier regions and in reaching suitable stations. Owing to the peculiar difficulties presented by the country round Nanda Devi it was decided to depart from the usual practice and to send Major Osmaston, who is in charge of these mountain surveys, to carry out a photographic survey of the basin drained by the Rishi Ganga. As I had made a reconnaissance of the region in 1934, the Survey Department invited me to accompany the party in order to assist Major Osmaston with the route and in the selection of suitable stations.

A Wild photo-theodolite and one hundred plates were taken as well as a

plane-table. I took with me the Watts-Leica photo-theodolite belonging to the Society, partly to supplement the main survey, and partly in order to give a further test to this novel instrument.

Six Sherpa porters were brought from Darjeeling, including Angtharkay. The name Sherpa has almost become generic for all porters engaged in Darjeeling. Actually one of these men, Gyalgen, came from two months' journey north of Lhasa.

We left Ranikhet on August 27. We had to take an unusual route to the Kuari Pass as one of the bridges on the Wan route had been carried away by floods. We had terribly bad weather all the way to Joshimath. The rains reached their climax on the night of August 29 and our camp was flooded out. Later we heard that 10 inches of rain had fallen in Mussoorie that night. The 29th was the day on which Nanda Devi was climbed.

We reached Joshimath on September 3 and left again on the 6th. On the 7th we camped at Lata, near the mouth of the Rishi Ganga. As we were sitting in camp a bearded and tattered figure appeared rushing down the steep path. This proved to be Peter Lloyd, the first of the returning Nanda Devi party. From him we heard of their splendid achievement. In my opinion the climbing of Nanda Devi is perhaps the finest mountaineering achievement which has yet been performed in the Himalaya; it is the first of the really difficult Himalayan giants to be conquered. This expedition was a model of what such an expedition should be: their party consisted exclusively of mountaineers; they avoided the great mistake which to my mind nearly all the major Himalayan expeditions since the war have made, and did not handicap themselves with a vast bulk of stores and superfluous personnel; each man was prepared to carry loads up to any height, and indeed all were called upon to do so during the most arduous part of the climb; above all, they avoided newspaper publicity. I was delighted to hear that Tilman had been one of those to reach the summit. He had done more than his share of the donkey work, having earlier in the year ascended the Rishi Nala and dumped provisions in the "basin" and then returned all the way to Ranikhet to organize the transport of the party. Later that evening Graham Brown turned up. The rest of the party we met on the cliff track to Durashi, except for Tilman and Houston, who had crossed a very difficult pass to Milam.

The passage of the Rishi gorge was now quite devoid of difficulty. There were cairns at every turn, a small but adequate path wound across the steep slopes, and any rock pitches were cleared of loose rock and earth. The monsoon was still active and we had a lot of bad weather. However when we reached the basin on September 16 the days were gloriously fine and the nights clear and frosty. The rivers were already fast sinking to their low autumn level and they presented us with no difficulties.

Osmaston decided to tackle the northern section of the basin first. I was keen to examine the ridges and valleys leading from the main basin up to the peaks bounding the western flanks of the Rhamani and Bagini glaciers, as we had not had the opportunity in 1934 of exploring this area. This I was able to do while Osmaston was mapping this part of the basin. The peaks in this vicinity are mostly composed of a beautiful pale granite, and soar to their

21,000 feet in clean curving lines, supported below by wonderfully carved ice flutings.

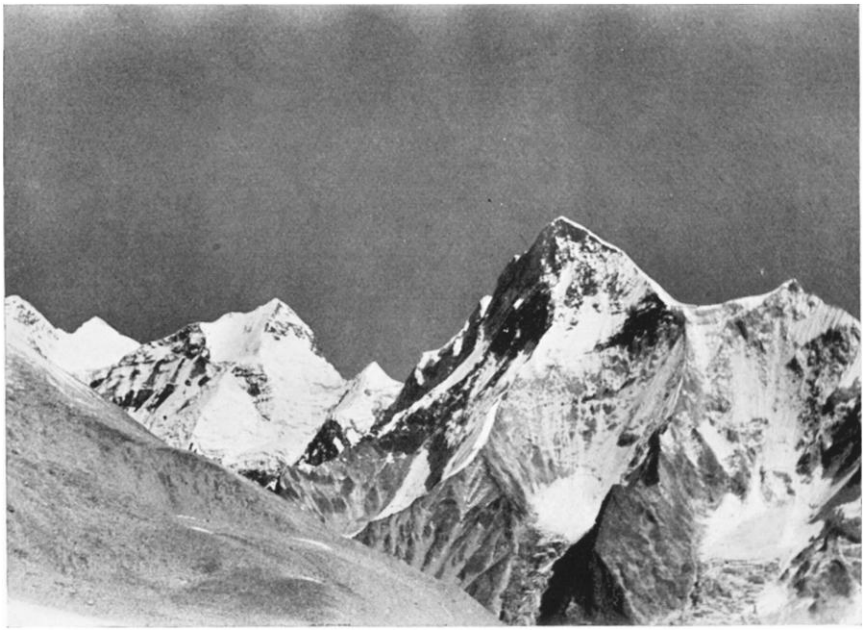
Tensing, one of our Sherpas, had developed some sort of fever in the Rishi Nala and every day for more than a fortnight he ran a very high temperature—often as much as 105°. Even when he had recovered he was no more than a passenger, as the fever left him very weak and thin. Owing to this we kept on two of the Lata men who had accompanied us into the basin. They worked splendidly and with a little training would be as good as the Sherpas. It is time that some one undertook the task of training the people of Garhwal as mountaineers. There is any amount of splendid material in the higher valleys. They have one tremendous disadvantage however and that is that their religion forbids them to eat either with Europeans or anything cooked or touched by Europeans, or by Indians of other castes. When a party is engaged in a long and difficult task this taboo would produce an impossible situation. With the Sherpas I am in the habit of eating out of the same dish and drinking out of the same mug and no one loses caste or feels embarrassed. Later in the year when we were employing some Dotial porters and the party ran short of food, the Dotials, who had finished their own food, allowed themselves to become feeble with hunger rather than eat the rice which we had been carrying in our rucksacks. Angtharkay always becomes infuriated by this prejudice, and taunts the victims unmercifully.

At the junction of the two great glaciers of the northern section we made a camp by the lake. We had brought a goat with us from Lata and at this camp we gave orders for it to be executed. It was a sad business as we had all become very attached to the animal. It had shared with us the fatigues of a long journey and the warmth and comfort of our caves and camp fires. It had been no easy task getting it up the gorge and Angtharkay who had been its keeper and principal helper was particularly distressed at the idea of killing it and had defended its life for some days with arguments for keeping it alive—the chief of these being that it might as well be made to carry its meat as far up the glacier as possible. That night however when eating fried liver and kidneys he had no regrets. The execution itself was performed by the two local men, who slashed open the belly and plucked out the heart before the animal had time to bleat.

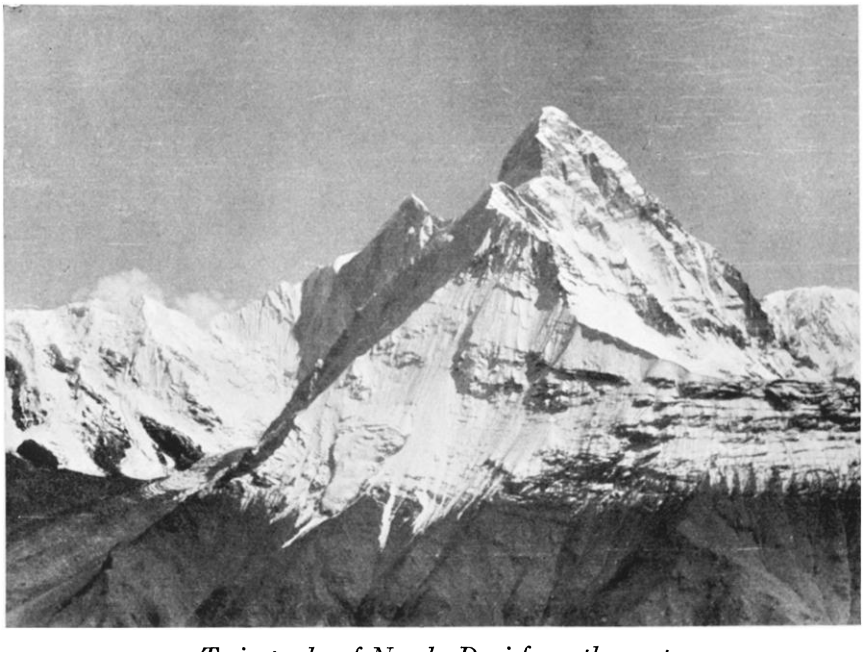
We crossed the Great North Glacier, which was a severe trial to Sen Tensing, who was now so weak that he found difficulty in walking. His temperature was still alarmingly high in the evenings, and we were beginning to get very worried about him. However in the large ablation valley on the other side of the glacier we made a base camp from which the remainder of the northern section could be reached. After a week's rest at this camp the fever left him. Angtharkay, Ang Dawa and I set out to climb a fine triangulated peak (21,770 feet) on the watershed overlooking the Milam Glacier. We camped at about 17,500 feet in a subsidiary valley and started before dawn the following day (September 23). We climbed up a steep and quite difficult ice ridge which involved a great deal of step cutting. The conditions were excellent however and the climb was pleasant and safe. Ang Dawa was quite the strongest of our six Sherpas: in fact he used to entertain us in camp with feats of strength. In the Rishi Nala too he had displayed considerable skill

on steep rocks and would run about over precipices without turning a hair. On this ice-ridge it was very surprising to see him crack up. He could not adjust his movements to the ground he was on and was terrified on steep snow slopes. He became exhausted early in the climb and a few hundred feet from the summit gave up the struggle. This delayed us a good deal and by the time Angtharkay and I reached the top the Milam glacier was filled with cloud and I did not get the view I had hoped for. We looked down on two gorge-like glacier valleys running eastward from the two cols on the watershed on either side of the peak. Lower down we could just discern their junction with the Milam glacier. It would be possible to cross either of these two cols and so to reach the Milam glacier from the Nanda Devi basin, though it would be a difficult undertaking with the loads it would be necessary to carry.

Though the peak we had climbed is the highest on that part of the watershed, in common with most of the great peaks of the Nanda Devi basin it has no name. With the new survey of the range a complete revision of the nomenclature of the district is being made. It is no easy task to decide on the most appropriate name for peaks and glaciers. Each group of villages has a different name for the same feature and they do not agree even upon the names of the great peaks which dominate the whole district. Thus all the peasants of the Dhaoli Valley, in the vicinity of the mouth of the Rishi Ganga, call Nanda Devi Nanda Ghunti and have never even heard of the former name. The peak known to us as Dunagiri is called by these people Tolmai Pahar, and it is only in the vicinity of the village of Dunagiri in the Bagini valley that one hears the name Dunagiri used for the mountain. On the other hand, the shepherds of the Rishi call the glacier which flows down from Changabang into the Rishi Nala the Bagini, whereas Bagini is the name given by the Dunagiri villagers to the great glacier in their valley. This state of affairs is found throughout the district—and indeed throughout all mountain districts I have travelled in, in Africa as well as the Himalayas. It is not surprising that it should be so. The peaks and glaciers are as yet of no economic value to the peasants, and to them only the grazing grounds, streams, and forests are worth naming. Thus the most prominent peak standing above a grazing ground would simply take the name of that grazing ground as indicating roughly its direction when seen from afar, while the shepherds on the opposite side of the peak call it after *their* nearest grazing ground. In this way the traveller is confronted by several peaks known by the same name and several different names given to each of the peaks. It seems to me that the best solution is for the pioneer travellers to adopt the pleasantest sounding of the various names, for geographers to accept their suggestions, and for subsequent travellers to refrain from discussion. In the case of uninhabited areas such as the Nanda Devi basin, none of the glaciers or lesser peaks has a local name and there are a great many 22,000 and 23,000 feet peaks which, though triangulated, cannot be seen clearly from the inhabited valleys, and remain unnamed. In these cases it is the duty of explorers to invent suitable names for all prominent features, and map producers should make an effort to adopt their suggestions. A tremendous amount of confusion and misunderstanding is caused by procrastination in this matter. We have produced a list of names

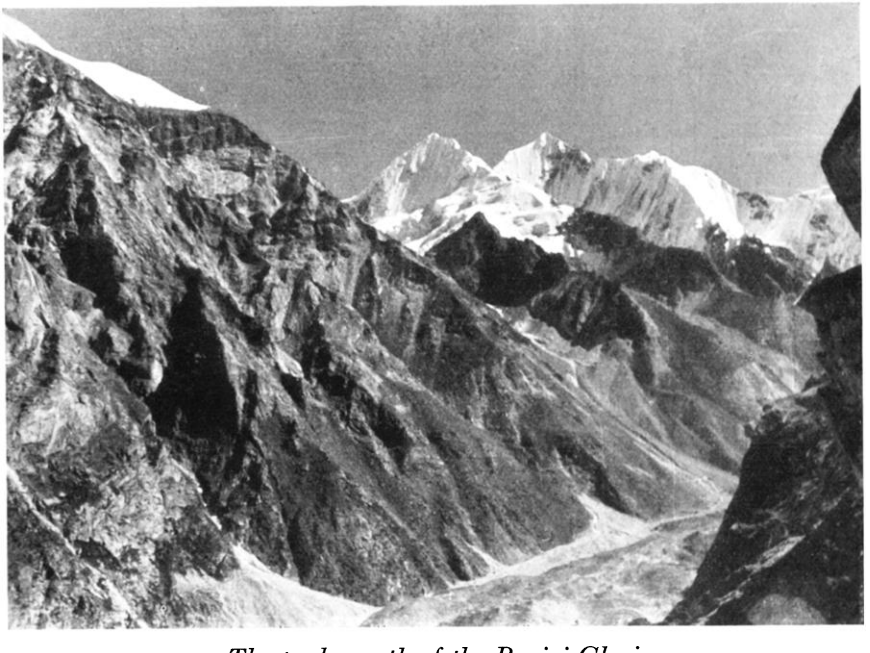


*Nanda Devi and the Bagini watershed*



*Twin peaks of Nanda Devi from the west*

*Dunagiri, Changabang, and Kalanka*



*The peaks north of the Bagini Glacier*

for peaks, glaciers and lakes of the Nanda Devi region which will be considered by the authorities when the map has been drawn.

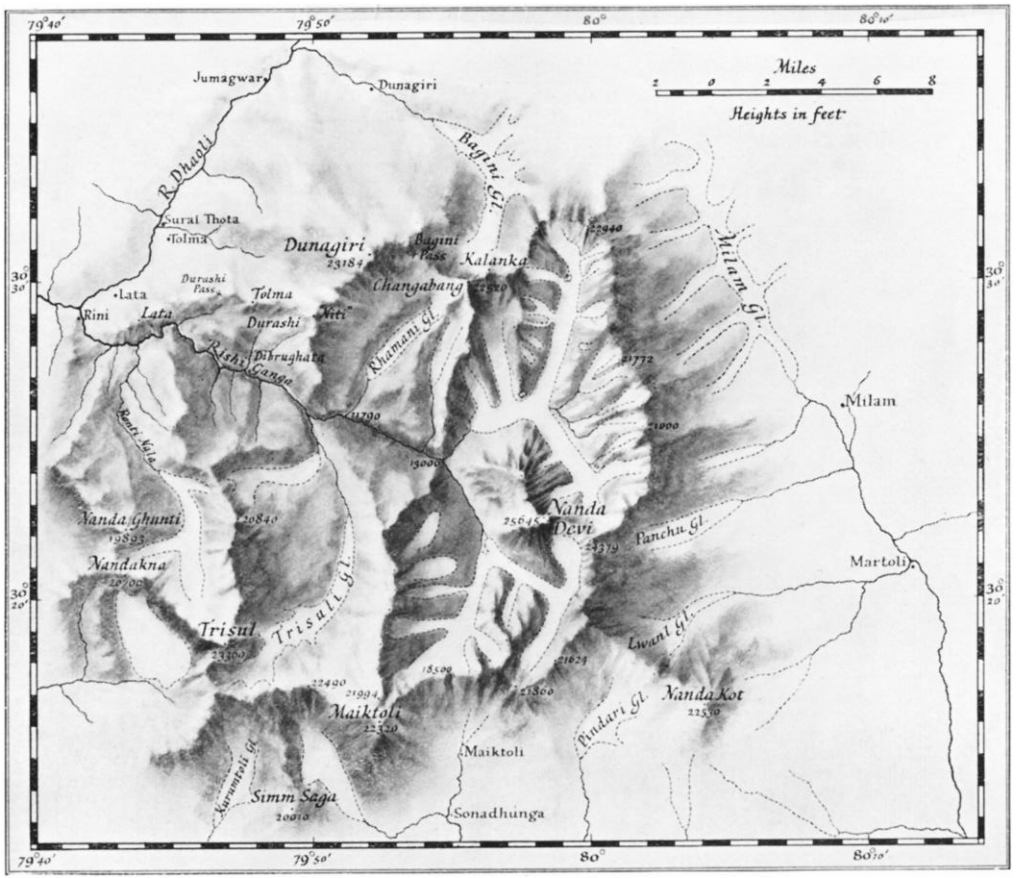
After accompanying Osmaston up the Great North Glacier (which will be given a more suitable name in due course) I returned to the lake, and from there went with Rinzing Bhotia up the Changabang glacier. The moraine which covers the greater part of the surface of the ice is made up of huge blocks of that remarkable white granite of which the cliffs of Changabang are composed. Half-way up we camped on the flat top of a glacier table. Except for the fact that the table might have collapsed, it made an excellent camp site. The weather turned bad, and that evening a good deal of snow fell. Starting before dawn the following day (September 27) we reached the head of the glacier which rises in a cirque of stupendous granite cliffs. We were making for a saddle at the foot of the southern ridge of Changabang which I hoped would offer a practicable route to the head of the Rhamani glacier. A gully in the granite slabs led us to the crest of the col without much difficulty, and from there we looked down on to the great snowfield which Dr. Longstaff had reached after crossing the Bagini Pass in 1907. We were separated from it however by a vertical wall of rock whose smooth face it was quite impossible to descend. Although by now most of the peaks were covered by cloud, the view was magnificent and I sat for an hour fascinated by the gigantic white cliffs of Changabang. The great snow dome of Dunagiri appeared now and then from across the Rhamani glacier but I did not get a view of the main mass of the mountain. We descended to our camp in the afternoon and thence, in heavily falling snow, down the glacier to the lake. We returned to the glacier junction camp the following day to find that Osmaston had been delayed by the bad weather and still had one more station to do in the northern section. He had been right up to the head of the Great North Glacier and had completed the survey of that valley and its tributaries.

We descended the main glacier and crossed the rivers into the southern section. There I left Osmaston and went down the Rishi gorge to Dibrughata with Angtharkay and Sen Tensing, reaching there on October 3. We left again on October 4 and on the evening of the 5th reached a high pasture in the ablation valley of the Rhamani glacier. I was hoping to reconnoitre the south-west ridge of Dunagiri and, if time permitted, to make an attempt to climb the peak. On the 6th we went up a side glacier and camped on its moraine at about 17,000 feet. The following day we managed to reach a col nearly 20,000 feet high, connecting the south-west ridge of Dunagiri with a peak which on the old 1-inch maps bore the strange name "Niti No. 3." On the northern side of the col the ground fell away with tremendous steepness to the Tolma glen and we found ourselves looking straight down to Surai Tota in the Dhaoli valley. We turned right-handed and followed a narrow icy crest towards Dunagiri. Sen Tensing succeeded in dropping his ice-axe. We recovered it two days later, but its temporary loss produced a horrid feeling of insecurity for the whole party. Reaching a point where the ridge sweeps up with considerable steepness we pitched our tent under a great rock buttress. Later in the evening Angtharkay and I climbed several hundred feet further up the ridge to reconnoitre the route. We found that the going was over hard ice and that steps would have to be cut every foot of the way.

Our camp was in a superb position and commanded views from the great peaks of the Nanda Devi basin and the Trisul ranges to the mountains of Badrinath and Kamet. After a bitterly cold night we started before dawn, a very painful performance from which there was no relief until the sun appeared. We had left Sen Tensing behind in camp and Angtharkay and I took the labour of step-cutting in turns. It was very slow and tiring work, and when after some difficult climbing we reached the long, almost level ridge leading to the summit it was late in the day and we had not time to cut our way along the knife-edge crest to the top. The route however is quite feasible and, as far as I have been able to see, by far the best way of climbing this peak. We got to within 1000 feet of the top (23,184 feet).

We returned to the Rhamani glacier and camped at its head below the col which Rinzing and I had reached from the Nanda Devi basin. On October 10 we started to cross the Bagini Pass. I was rather confused by the topography at the head of the glacier. The western face of Changabang falls with its characteristic sweep of white granite to a col some 2500 feet below the summit. West of this the watershed ridge rises to a sharp conical peak, and then falls again to a long serrated granite ridge which nearly a mile further on abuts onto a peak (21,290 feet) of the great north-east ridge of Dunagiri. Between this peak and Dunagiri itself is another low depression which forms the watershed between the Rhamani and Dunagiri glaciers; this one however is almost inaccessible from this side. I was by no means certain which of these cols was the Bagini Pass which Dr. Longstaff had crossed in 1907 and as far as I know had not been crossed since. We chose the middle one and reached the crest of the serrated rock ridge at 12.30 on October 11, only to find that from where we stood there was no chance of descending on the northern side. We spent nearly the whole of the rest of the day moving ourselves and our loads along the knife-edged crest of the ridge before we could rope down into a gully through which a descent could be made. We were overtaken by dark when only about 200 or 300 feet down and had to construct a tiny platform on which to camp for the night. Early next morning we completed the descent of the rocks and ran down the snow-covered head of the Bagini glacier. The valley we were in was bounded on the east by a most magnificent wall of peaks, which form the north-western rim of the Nanda Devi basin on which we had stood two years previously. From lower down we could look up a small side glacier to the col under the western face of Changabang. I was extremely glad that we had not tried that route as it would have been almost impossible to descend from the col with our loads. The first crossing of the Bagini Pass must have been an anxious business; apart from the difficulty of the climbing Longstaff and his companions had no idea of where the pass would lead them, and even when they had negotiated the Rhamani valley they were still many days from habitation. We had none of these anxieties, and thus our passage was vastly easier.

The Sherpas were eager to reach fuel before nightfall, and we sped down the glacier without halting anywhere. Every step of the way was vastly interesting to me and I spent an absorbing day fitting in the topography of the Bagini glacier with our explorations of two years previously. We had magnificent views of the huge unnamed peaks of the Garhwal–Kumaon watershed.




*The Nanda Devi basin, based on a plane-table survey by E. E. Shipton and H. W. Tilman*

Immediately north of these peaks is the Girthi river which makes such a strange intrusion into this line of elevation. The sun had long set before we reached the first juniper on the southern side of the glacier and we were lucky enough to find a brook running down the ablation valley and soft turf on which to camp. The excitement of reaching juniper after some time on the higher glaciers never loses its force. In spite of the hardihood of this plant it is peculiarly sensitive to its position and at higher altitudes never grows on slopes with a northern aspect. For some miles that evening we had seen it growing on the opposite side of the glacier in tantalizing profusion, but it was not until the lateral moraine on our side became sufficiently large to produce a fertile south-facing slope that we came across any. The reverse is the case with rhododendron and birch, and at lower altitudes the aspect of one's camp is indicated by the different effect these woods have upon the food.

Next morning below the snout of the glacier we found a blaze of autumn colours. The bare, almost feathery branches of the birch woods contrasted with the brilliant green of rhododendron and juniper, and the whole valley was interlaced with vivid patches of red, flame, and copper. The glades were filled with long wavy grass the colour of ripe corn in the morning sunlight. In place of the raging torrents of muddy water which issue from Himalayan glaciers throughout the summer we found sparkling crystal streams. The air too had a sparkle of frost which enhanced the beauty of the autumn tints. Early in the day we reached the village of Dunagiri where we found all the population busily engaged in reaping their crops and storing the grain for the winter. The houses were decorated with huge yellow marrows and cucumbers. The whole valley seemed steeped in sunshine and the rich colourful ripeness of autumn hues.

The remainder of the day was spent basking in the sun outside one of the houses, chatting with the villagers who, to celebrate our arrival, indulged in a half-holiday. We were besieged with questions about our doings and the reasons for them; to these we gave the usual unsatisfactory answers, in return for which we received much interesting information about the valley and its people. It appears that in the autumn all the inhabitants descend as far as Karnaprayng and even further with their flocks, and the whole valley is deserted. All the farm produce is stored in the village for consumption during the following summer. The winter exodus takes place by slow degrees and was already in progress. The Sherpas spent a happy day trading old tins for food, and after some hours of hard bargaining had obtained, without spending a single *pice*, enough to keep us supplied for a week. The children in these villages are made to work from a very early age. In the evening I watched some tiny mites supervising with extraordinary skill the herding of enormous flocks into pens. There were innumerable lambs, each of which had to be placed by its mother. The children worked until long after nightfall settling the disputes and attending the bleated complaints of the sheep.

The following day I went up with Sen Tensing to investigate the so-called Dunagiri glacier and to reconnoitre the northern approaches of the peak. The glacier terminates in an immense wall of moraine debris which has been thrust into the birch forest high up the side of the main valley, a mile or

so below the snout of the Bagini glacier. It is very much alive and appears at the present time to be advancing; in former ages it must have flowed far down into the main Bagini valley. It rises, not at the foot of the peak of Dunagiri as I had expected, but in a rocky cirque culminating in a peak (21,290 feet) whose acquaintance I had made on the opposite side. The north face of Dunagiri itself was half hidden from view by this cirque, but from what I saw I should say that any route on this side would be a great deal more difficult than that which we had reconnoitred a week before. The best approach to the foot of the north face would probably be up the *nala* which joins the Dhaoli about 3 miles below Jumagwar. I do not know whether any one has been up this *nala*.

I regretted leaving our friends of the Bagini valley and their charming village; their hospitality and kindness matched their beautiful surroundings. Further down the valley the autumn tints were even lovelier than they had been near the glacier. I spent nine months in the Himalaya last year and at no time did I see such a wealth of lovely things as during this October; even flowers were not wholly lacking and occasionally in some well-watered glen we would come across drifts of primulas defying the rule of the seasons. In my opinion there is no better time to travel in Garhwal than the autumn; the days are cool, the nights not too cold, snow conditions are good (except high up on north-facing slopes), and the weather is usually fine. An added advantage is that, with the newly reaped crops, it is very easy to live off the country. In the forest we came upon several small encampments of peasants, busily engaged in collecting the stones of wild apricots, from the kernels of which they make oil. Further down the Bagini torrent enters the main Dhaoli valley through a fine canyon which is not the least impressive feature of the very beautiful valley down which we had come. Two more marches took us to Joshimath where we rested for two days. I had been there only a couple of hours when Professor Heim arrived, and I was delighted to be able to spend the two days in his company. They had just completed a tremendous season of geological work in the vicinity of the Almora–Tibet frontier.

I left Joshimath with the two Sherpas and three Mana porters on October 18. Half-way to Tapoban I met Osmaston returning from his work in the Nanda Devi basin. The excellent weather of the last three weeks had enabled him to complete the survey of the southern section a great deal sooner than we had expected, and he had been supported in the Rishi Nala by Fazal Ali, probably the most competent of his plane-tablers. Fazal Ali had surveyed the Trisuli Nala at a remarkable speed, averaging nearly 5 square miles a day, which is fast going for such difficult country. He was now working in the Rhamani Nala, and later completed the mapping of the lower part of the Rishi gorge. Only one section of the outer basin remained; this was the valley running north from glaciers between Trisul and Nanda Ghunti. It had been decided therefore that I should make a survey of this area with the Watts-Leica photo-theodolite, with the dual object of rounding off the Nanda Devi survey and of trying out this instrument in an independent survey. Osmaston went off up to Badrinath with the object of inspecting his surveyors in that district. Most unfortunately one of his camp officers had died in the Arwa valley, and

although Captain Crone had gone up to deal with the situation, much reorganization was required.

We camped our first night out of Joshimath at Rini which is situated at the mouth of the Rishi Nala. The following day we enlisted the help of a local man to show us the best way to the highest pastures in a valley we were making for, and to help me in naming some of the prominent features. Dr. Longstaff has referred to this valley as the Rinti Nala, though the name used by the people of this district is more like Ronti. We followed the main gorge for a while by a path which has been very cleverly engineered by the peasants, but soon the going became difficult and we turned right-handed and climbed up over steep, heavily forested slopes past another tiny village basking happily in its rich, self-contained isolation. Higher up, the Rini man introduced us to a variety of wild fruits which grew in the forest, some of which were new to the Sherpas. The commonest of these resembled a crab apple on the outside, though its internal construction and taste were more like those of a persimmon. All through the forest there was a wonderful profusion of autumn colours. We put up plenty of Monal pheasants which sailed over our heads, screeching noisily. During the two days we were going through this forest we must have seen nearly a hundred of these birds. Even in this remote valley they were very wild and very rarely gave us a chance to get near to them.

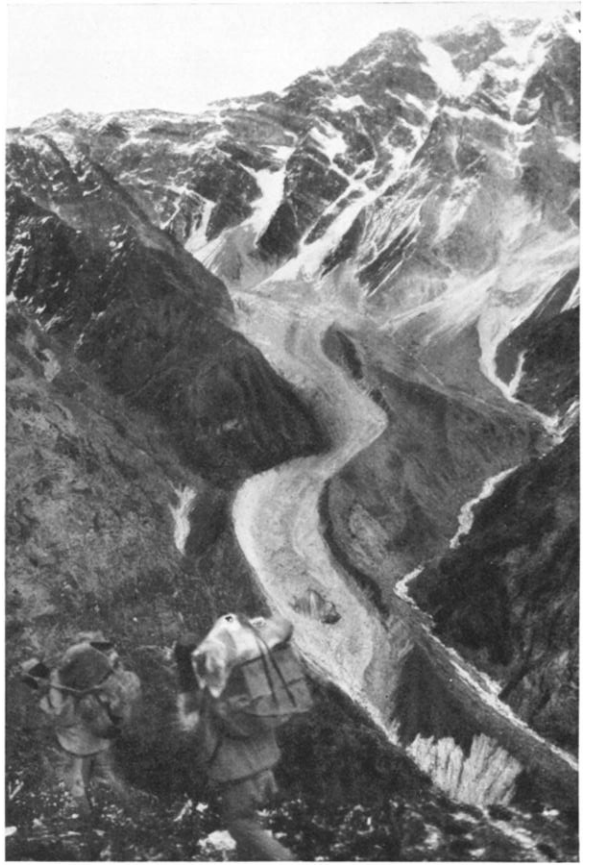
We entered the Ronti valley several thousand feet above its floor, and on October 20 camped in a cave high up on the side of the *nala* and commanding a magnificent view of the surrounding country. The lower section of the valley in which we found ourselves is bounded on the east by huge precipices which culminate in a line of jagged aiguilles; but the western slopes are gentle and well wooded and frequented by shepherds from the villages in the neighbourhood of Rini. Their grazing ground was pointed out to me by the Rini man who called it Chamba Kharak. This part of the valley is enclosed by a great ice-covered wall which forms the eastern ridge of a peak (19,893 feet). Round the eastern end of this wall the valley runs up through a narrow gorge to a large glacier basin which forms its upper section. Through this gorge we could see the tongue of the glacier protruding. There has been a good deal of confusion regarding this peak (19,893 feet) and its southern neighbour (20,700 feet), which is such a prominent feature seen from Ranikhet and Almora. The present map labels the former Nanda Ghunti and the latter Nandakna. Dr. Longstaff however has always referred to the higher peak as Nanda Ghunti, and certainly that is what it is called by the inhabitants of the valleys to the south-west of the range. We found that the Rini villagers refer to the northerly peak as Ronti, and I hope that these two names will be adopted on the new map.

One of the Mana porters had been with Tilman's party and entertained us in the evenings by voluble descriptions of their adventures in the Rishi gorge during the monsoon. I was amused to find that these men had nicknamed Tilman "Balu Sahib" (*Balu* meaning a bear) owing to the speed with which he moves over steep forested ground. On reaching the Ronti Nala I discharged the local men and set to work with the two Sherpas on the survey. But the weather broke and we were confined to our cave for three days. A good deal of snow fell and it began to look as if winter conditions would

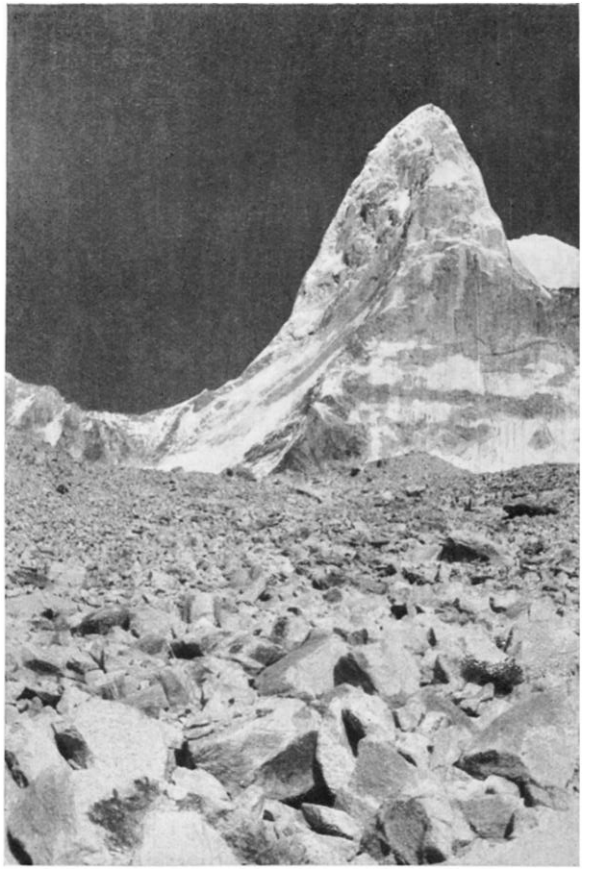
prevent any further work. Also I was afraid that our food supply would run too short to allow us to attempt to cross the pass over the watershed. However we had brought another sheep with us and occupied ourselves concocting fancy meat dishes. The morning of October 24 was fine, and by starting before dawn we managed to reach a high spur in time to take a round of angles and photographs before the mists rose out of the valleys and swamped the view. The dawn views were magnificent and showed nearly all the great peaks of this section of the range like islands washed by an ocean of flame-coloured cloud. In the afternoon we humped our heavy loads over to Chamba Kharak, from which I was able to do another station. We repeated this procedure every day until five stations had been completed in the lower section of the *nala*. As the view was invariably obscured by nine o'clock each morning it was difficult to put the stations sufficiently high, and we had to do twice as many as would have been otherwise necessary. The great advantage of this method of photo-survey over plane-tabling is the very short time that it is necessary to occupy a station. Plane-tabling in the conditions which we were experiencing would have been almost impossible. The photo-theodolite which I was using weighs 18 lbs. including stand and cases; it is extremely simple and convenient to use; and if it is found possible to plot with sufficient accuracy from the tiny photographs, it will bring photographic survey within the scope of even the most lightly equipped parties. Moreover the use of roll films instead of plates makes it much easier to bring back the results intact. The film is held flat while being exposed by means of a pressure glass in the back of the camera.

On the afternoon of October 27, in a heavy snowstorm, we made our way through the bottle-necked gorge which lies between the lower and the upper sections of the Ronti Nala. We were climbing on the moraine-covered ice of the glacier which squeezes itself through the gorge. Our great difficulty was to find any water, as at this time of the year all the glacier pools are hard frozen day and night and we could not afford the fuel necessary to melt ice at this stage, being then above the limits of juniper. I was surprised to find Monal pheasant far up the glacier. Up there they seemed extraordinarily reluctant to embark on their gliding downward flight and we got so close to them as to tempt the Sherpas to chase them with a fusilade of stones. Although the Sherpas threw with great accuracy, the birds seemed to have a cunning knack of hopping over the missiles, and we failed to replenish our larder in this way.

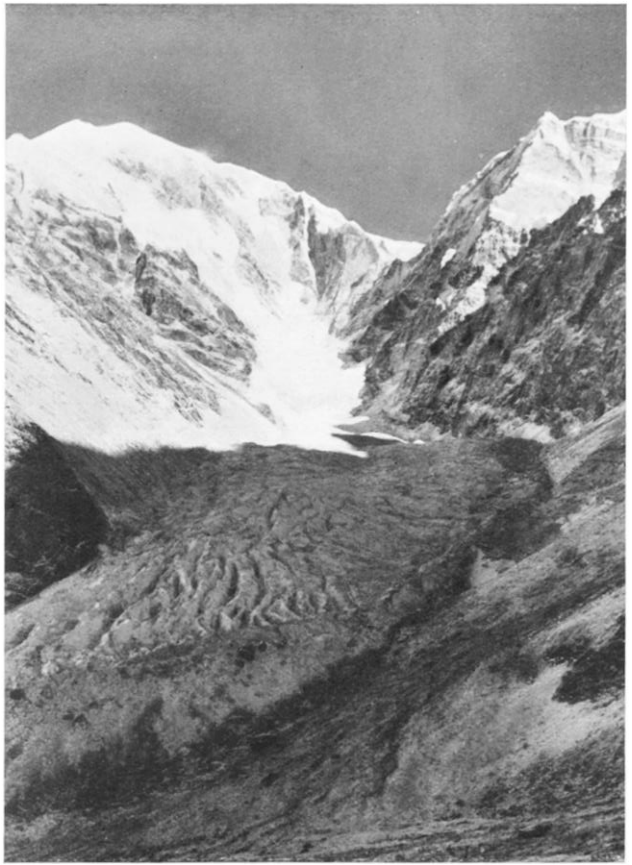
Fortunately the next day the weather became finer and we were able to make the best use of the short time in the upper glacier basin. We found it to be divided into three sections. Firstly, there was a large ice-stream coming down from the saddle between Nanda Ghunti and Nandakna. This saddle must lead to the headwaters of the Birch Ganga. I was very tempted to visit it but could not spare the time. Next there is a small tributary glacier rising under the western ridge of Nandakna; at the head of this is the saddle reached by Longstaff and Ruttledge from the other side. Thirdly, what is probably the main glacier flows under the ice-terraced cliffs of the north ridge of Trisul. Although the upper part of this was out of sight, I decided, when the survey was finished, to look for a way across the watershed in this direction.



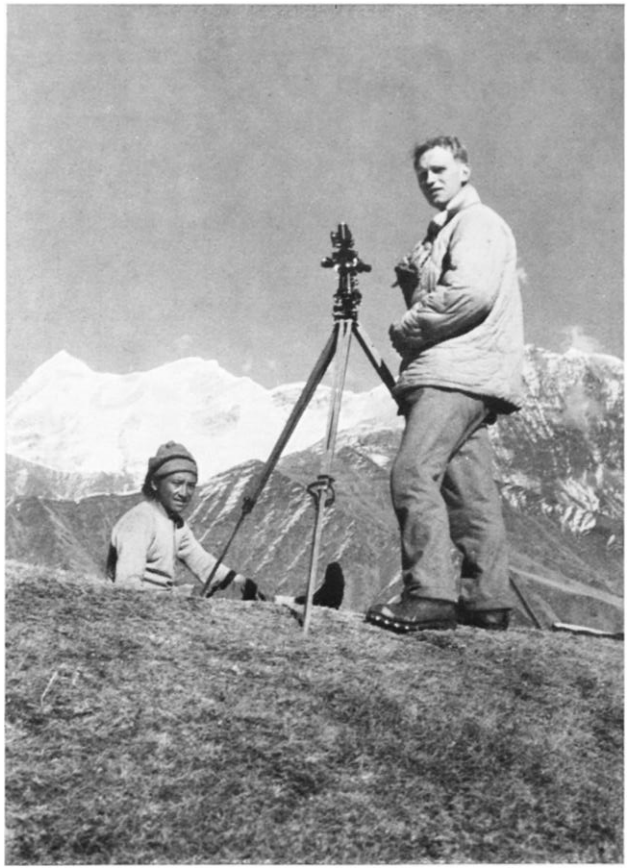
*The Kurumtoli Glacier*



*Changabang from the Rhamani Glacier*



*Head of the Kurumtoli Glacier*



*Shipton, and Angtharkay, with the Watts-Leica photo-theodolite*

It proved to be the right line and we encountered no difficulties whatever. Our last camp and station were on the saddle itself and commanded glorious views on both sides of the range. The glaciers on the southern side are very small and we were soon back in heavily forested country. In the upper part of the Nandagini we saw large herds of game. Near the entrance to the Nandagini gorge, where we camped, we found signs of the visit of the surveyor who had been working in this area. In spite of this we found it quite difficult to follow his track in the jungle. Sen Tensing became separated from us, and Angtharkay and I retraced our steps for a long way in search of him. Instead of him we found a good path, which we concluded he must have been following. It was not however until late in the evening that we found him. He had not struck the path and had been struggling along some hundreds of feet below it. Angtharkay and I told him, untruthfully, that we had found a village in the afternoon and had been sitting there imbibing milk and baked potatoes. Angtharkay told him to go back to get food for himself from the mythical village. However I thought that was carrying the joke too far and stopped him.

From Sutol we crossed the Wan Pass to Gwaldam; and later from Wan we crossed into the valley of what, on the existing map, is called the Kurumtoli glacier which Dr. Longstaff explored in 1905. He calls it the Keil glacier. In this region I did several photographic stations, which were intended to supplement the work of the plane-tabler who had not had time to complete his work in this part.

On my way to Bombay I went to Dehra Dun where I met Osmaston and Captain Crone, whom I had seen previously at Joshimath. Osmaston's photographs had come out well except for a certain amount of fogging round the edges. Crone calibrated the camera I had been using and appeared to think that there would be no difficulty in plotting the data I had brought back. He is working on it now and I am anxiously awaiting his report on the work of this very handy little instrument.

## DISCUSSION

Before the paper the CHAIRMAN (Dr. T. G. LONGSTAFF) said: Owing to the regrettable absence of the President through illness it falls to my lot to introduce the lecturer this evening, though I expect most of you know him well already.

Mr. Shipton is a very experienced mountaineer. He learnt his trade in the Alps, which are still by far the best school. In 1929 he climbed Mount Kenya with Wynn Harris. In 1930 he made with Tilman a very fine traverse of Mount Kenya by a new route, a very memorable expedition. In 1931 he was a member of the successful expedition to Kamet in Garhwal. In 1932 he was in Ruwenzori. In 1933 he reached 28,000 feet on Mount Everest. In 1934, with Tilman and only three Sherpas, he succeeded in effecting the first entrance into the inner sanctuary of Nanda Devi, having forced the upper gorge of the Rishiganga which had previously defeated all comers. In addition to that, they made two exceptionally difficult glacier passes, one over the main range to the south of Nanda Devi and the other over the main water-parting of the Badrinath group. In 1935 Shipton led the so-called reconnaissance expedition to Mount Everest, during the course of which his party climbed twenty-six peaks of over 20,000

feet, which is more than all the other 20,000-footers that have ever been climbed in the Himalaya put together.

In 1936 he accompanied the Mount Everest Expedition. The monsoon arrived too early and it was not possible to do anything. Therefore in the autumn, through the courtesy of Brigadier Couchman, he got leave to accompany Major Osmaston, who had been detailed by the Survey of India to make a map of the basin of the Nanda Devi and the gorges of the Rishi. And now, without telling you more about the paper, I will ask Mr. Shipton to read it.

*Mr. Shipton then read the paper printed above, and a discussion followed.*

The CHAIRMAN: I think Colonel Lewis, Surveyor-General designate of the Survey of India, is here to-night. If so, I would like him to come on to the platform to tell us something about the country, because the inception of the new survey is due to him; and, furthermore, it is due to his interest that Mr. Shipton was able to accompany Major Osmaston.

Colonel C. G. LEWIS: Two years ago the Survey of India decided to start the survey of the Tehri-Garhwal and Kumaon Himalaya between the Punjab and Nepal borders. The existing maps, over fifty years old, are quite inadequate for present-day needs, and in addition it was decided to increase the scale from $^1/_4$ inch to $^1/_2$ inch to the mile. In the first season we finished the area drained by the Bhagirathi River in Tehri State.

Last year, when we came to Kumaon, the problem of getting into the Nanda Devi sanctuary immediately presented itself. Some of our Indian surveyors who have had several seasons of training and experience in Chitral and Gilgit have become experts in the technique of alpine surveys but are quite untrained in mountaineering. It was unlikely that a surveyor by himself with local transport would succeed in penetrating into the sanctuary and unfair to ask him to make the attempt. It was therefore decided that Major Osmaston himself would have to do the survey, and at this juncture we found that Shipton was at a loose end. The Surveyor-General, Brigadier Couchman, was only too glad to avail himself of his help. The results, as you have just heard, were most satisfactory and successful.

I should like to say that the Survey of India has been considering for some years the question of names in uninhabited mountain regions. The situation was becoming almost intolerable. Last year the principle was adopted of selecting invented names given by explorers or by our own parties during the course of survey, so that names may now be given to peaks, passes, and glaciers which hitherto have been nameless.

I take this opportunity of thanking Mr. Shipton, on behalf of the Survey of India, for the great help he gave us last year in the survey of the Nanda Devi sanctuary.

The CHAIRMAN: Professor Graham Brown was with the British-American party which climbed Nanda Devi in 1936. We shall be very glad to hear something about that expedition, which was just prior to Mr. Shipton's.

Professor T. GRAHAM BROWN: In the summer of 1936 a party of eight of us—I wish there had been nine—started off into the Nanda Devi basin in order to climb that great mountain. I say I wish there had been nine because I wished to have Mr. Shipton with us on that particular occasion. His engagement with Everest delayed him and he was not able to join us. Had he done so he would not have been able to take part in this wonderful expedition that we have heard about to-night, and I am not quite sure whether we would not have been the chief losers in the long run.

We went up into the Nanda Devi basin, eight of us, seven climbers and one

not a climber, though through no fault of his own. There were four Americans, C. S. Houston, A. B. Emmons, Adams Carter, and W. F. Loomis; the four British were N. E. Odell, W. H. Tilman, Peter Lloyd, and myself. We set to work in that wonderful gorge, and I would like to say that, when going up there, it really seemed marvellous to me that Mr. Tilman and Mr. Shipton had been able to find a way up in 1934: a grand piece of work in itself.

We were a small party, travelling light, and travelling in the monsoon. We travelled in the monsoon because our summer holidays happened to coincide with it, and there was very little other time in which this particular party could have gone to the Himalaya. We came to Nanda Devi and then our Sherpas unfortunately went sick. We had six of them. One Sherpa paid one visit above Camp II, two Sherpas got to Camp II, and the rest did not get farther than the Base Camp or Camp I. We had altogether six camps on the mountain, so that I can say almost the whole of the work above Camp I, and the whole of the work above Camp II, was done by the seven British and Americans.

The final climb was made by Odell and Tilman, and nobody deserved it better than Tilman himself. He was a grand man: his first exploration had been in 1934, and he had done what Mr. Shipton, rather humorously I think, called the donkey work. We got to the top and it was a very gratifying thing because we felt that we were a small party, climbing cheaply and simply, climbing at quite the wrong part of the year, and climbing quite a decent bit of mountain. We hope it will be an encouragement to other small parties to tackle the same sort of mountain in the same way.

The CHAIRMAN: I will ask the Secretary to tell us something about the photo-theodolite. We are always at daggers-drawn, the Secretary and I, over this. I have always averred that it is absurdly heavy and cumbersome, especially the theodolite stand. I prefer light camera legs, wobbling in the wind, which can be carried in a rucksack. Now it seems to me, from what Shipton and Tilman have said, that if we can have a photo-theodolite of Leica type portability it will be an instrument which will give us the advantages of the too-heavy photo-theodolite, and we shall now be able to congratulate the designers on evolving something really suitable for use in the field. I ask Mr. Hinks to tell us something of the instrument.

Mr. HINKS: I am anxious to say something about the instrument which Mr. Shipton has dignified by the name of the Watts-Leica photo-theodolite; it is not so terrifying or so complicated an instrument as it sounds. It was in fact improvised here in the Society in the space of three days before the Mount Everest reconnaissance of 1935. We had an old 3-inch mountain theodolite which had been in the possession of the Society for about twenty years; we secured a second- or third-hand Leica camera for about £7 and had calibration marks put in, and had a cradle made to carry the camera on top of the theodolite, the whole idea being that the instrument should be as light as possible. To turn on the film for the next exposure you just take the camera out of its cradle, replacing it in its geometrical bearing without sensibly deranging the theodolite. It is what we used to call, in elementary wireless days, a "hook-up," but with a certain merit about it, as was proved in the Mount Everest region in 1935 and as Mr. Shipton proved around Nanda Devi in 1936. We are looking forward to having the instrument re-designed this year so that it may go out to the Himalaya again. It is hoped that in the course of time it will be improved without being made any heavier, and that it may be quite useful.

The CHAIRMAN: We have had a very delightful lecture this evening. I know the country fairly well. I was there in 1905 and in 1907, and again, for a short time, with Hugh Ruttledge and his wife in 1927.

What strikes me most is the speed with which Shipton moved. He always went with two Sherpas only. When I was in these parts thirty years ago no natives were accustomed to climbing above the snow, and as first-comers who go to any district must be careful not to offend the natives in any way, so as not to make it more difficult for those who follow them, we could not take natives high in those early days. I climbed with the two Brocherels of Courmayeur, the home of the great Italian guides who have covered themselves with honour in Europe, Asia, Africa, and America. There were just the three of us, and we used to go away for days at a time into the blue. Shipton reverts to the earlier practice: he goes off alone with two Sherpas, carrying everything on their own backs. It is impossible for any but the smallest parties to cover such an amount of ground.

In 1907, when I was beaten in the Rishi gorge, I had to go straight at it after climbing Trisul. I had one day. We climbed up the northern wall for nearly 3000 feet and could not see any way along. We saw that we could get along the south wall, but we had no time to try it. Even so I am exceedingly surprised at the success of Major Osmaston in getting delicate survey instruments undamaged along that route. I should think that Colonel Lewis was speaking with all sincerity when he said that the success of this expedition was probably in considerable part due to Shipton being with them, for he was able to show the way.

As to the ground he covered in the Ronti valley, I have looked that up in my notebook and I find I spelt the word *Rönti*, but when I got home I said to myself, "Now, how would the English pronounce that?" So I wrote it *Rinti* and, as Shipton has said, that is wrong.

I hope there will be an endeavour to preserve the name Nanda Ghunti, which means the Goddess Nanda in her bridal veil, Nanda being the bride of Shiva, whose abode is on Trisul. If you can keep Nanda Ghunti for the south peak and Ronti for the north peak I think it would be an admirable solution. Between those two peaks, Trisul, the Trident of Shiva, and Nanda Ghunti, the goddess in the bridal veil, there is a serpent 100 yards long who eats all who come near the bride and her bridal veil. And, that you may know it is so, I was told that at the mouth of the *nala* there is a pile of slippers belonging to the men the serpent has eaten.

I look forward to the publication of the new map of the Nanda Devi basin with the greatest interest, tinged with a slight anxiety that my own map of thirty years ago may turn out to be too many miles out for what remains of my reputation.

I ask you to express your appreciation of Shipton's interesting lecture in the usual manner.

# THE MEDICAL AND PHYSIOLOGICAL ASPECTS OF THE MOUNT EVEREST EXPEDITIONS

DR. C. B. WARREN

*Afternoon Meeting of the Society, 10 May 1937*

*Introduction*

THE climbing of Mount Everest calls forth physiological adjustments in the human body which are of great interest for the practical bearing which they have upon the success or failure of the venture. It is coming to be realized that the climbing of the mountain is almost as much a physiological problem as a mountaineering feat. Does deterioration in the physical condition set in when a certain altitude has been reached, despite the fact that acclimatization may still be going on? Is it possible to climb to 29,002 feet without using oxygen? These are problems which concern particularly the ascent of a high mountain. But perhaps it is worth remembering that the study of high-altitude physiology is beginning to have other practical applications in these days of aeroplanes and ever-increasing travel by air.

Since the main object of the expedition to Mount Everest in 1936 was to climb the mountain and no provision was made for scientific work to be done as a side line, only very simple observations could be made. These nevertheless may be worth recording since it is seldom that opportunities for collecting data at altitudes over 20,000 feet present themselves.

*Mountain-sickness*

It has long been known that people may be overcome by unpleasant symptoms on going rapidly to a great altitude. The malady is known as mountain-sickness. A person suffering from mountain-sickness complains of a variety of symptoms, some of the commoner of which are difficulty with the breathing, giddiness, headache, and a feeling of nausea which may end in vomiting. And many a mountaineer must at some period of his career have fallen a victim to this bogey of the sport. The condition is due to lack of oxygen as a result of breathing the rarefied atmosphere at high altitudes. It is often acute in onset, and affects only those who ascend rapidly before they have had time to get used to the heights. Thus speed of ascent and lack of acclimatization appear to be the essential factors for its production, though severe exercise will often precipitate the attack. The acclimatized person does not suffer from the acute form of mountain-sickness, though on going higher than the altitude to which he is acclimatized he may feel the effects in other ways.

It was during the earlier stages of the march to Mount Everest that acute mountain-sickness was met with. These marches brought us rapidly and steeply from the plains of India on to the high Tibetan tableland and involved an ascent of 16,000 feet within the first 70 miles. During the reconnaissance in 1935 we all suffered more or less severely from mountain-sickness on reaching Tangu at 12,000 feet, and again two or three days later when crossing the Kongra La. But in 1936 these early stages were taken more slowly, with the result that after a week's stay in the bungalow at Tangu the party went

over the pass two days later without serious consequences. Last year however the one time in the course of the expedition at which acute mountain-sickness with vomiting did occur was at Tangu on the outward journey. On that occasion the symptoms consisted of severe headache with dislike of the light, nausea and vomiting, and came on a short time after Smythe's return from a climb which he had done near the bungalow. Once the pass is crossed the route to the mountain runs for some 200 miles through comparatively level country, but all the time at altitudes greater than 13,000 feet. Throughout this part of the journey there is thus plenty of time for acclimatization to take place. Long before we had reached the Base Camp at 16,600 feet we had ceased to be breathless on the slightest exertion, and our headaches had passed away. Indeed we arrived at the Base Camp in high spirits and feeling as well as at sea-level.

*Alterations in the breathing and the respiratory system*

One of the most obvious changes associated with life at high altitudes is the difficulty with the breathing. This is most marked when the ascent has been rapid and acclimatization has not occurred; and still more so I think in those who are not accustomed to making mountain ascents. In 1936 most of us noticed breathlessness for the first time on reaching Tangu at 12,800 feet, and this persisted during the crossing of the 16,000-foot Kongra La and for several days thereafter. But in the course of the march to the mountain we became so well acclimatized that no discomfort with the breathing was noticeable at the Base Camp at 16,600 feet except when taking fairly strenuous exercise.

The nature of the difficulty with the breathing requires consideration. There was no marked alteration in the *rate* of respiration when at rest, but on the slightest exertion it increased out of all proportion to the amount of exercise taken. Then from time to time one would have to make a forced expiration followed by a long deep inspiration in order to get enough oxygen. Except during exercise there was no obvious alteration in the *depth* of the respiratory movements, though perhaps experiments with a spirometer might have detected a change. Alteration in the respiratory rhythm known as "Cheyne-Stokes" breathing was frequently observed during sleep. The altitudes at which this change of rhythm appeared were extremely variable even in the same individual. In one person it was present once at 9000 feet and again later at 21,200 feet. Illness often seems to predispose to it. Wakefulness at night time is sometimes occasioned by the breathing at high altitudes, particularly on going up to a new camp for the first time. Soon after getting off to sleep one wakes up suddenly with a slight feeling of suffocation and has to take one or two long deep breaths in order to get relief. The explanation of this is that during sleep the breathing becomes shallow and the lungs are not properly ventilated. As a result the carbon dioxide which is being formed in the body all the time cannot be got rid of in the breath and it therefore accumulates in the blood. If carbon dioxide accumulates in the blood and in the lungs the breathing is powerfully stimulated and there is a feeling of suffocation. By placing a high pillow beneath the shoulders at night the weight of the body is lifted off the chest and the respiratory movements remain

unhampered. This is often just enough to get rid of the wakefulness. I discovered the trick when climbing in the Garhwal Himalayas and have proved its value since then. The fact that discomfort with the breathing becomes less noticeable as one acclimatizes suggests that a mechanism has been brought into play whereby the breathing can be maintained at the new level without conscious effort.

A characteristic which has been described as peculiar to the native peoples who dwell permanently at high altitudes is the shape of the chest. This is deeper and of greater capacity than that of persons living at sea-level. A greater capacity of the chest, so long as the lungs are healthy and the ribs mobile, would mean that a greater area of the lung was exposed to aeration. In order to see if our own lungs increased their capacity as we went higher we measured the *vital capacity*. To do this the subject is instructed to take in as

*Vital Capacity of the Lungs.*

| | Lachen 8,800 ft. | Base Camp 16,600 ft. | Camp I 17,700 ft. | Camp III 21,200 ft. | Base Camp 16,600 ft. | Tengkye Dz. 13,800 ft. |
|---|---|---|---|---|---|---|
| *Individual* | 23.3.36 | 29.4.36 | 5.5.36 | 26.5.36 | 16.6.36 | 27.6.36 |
| C.W. | 4.3 | 4.3 | 4.0 | 4.1 | 4.1 | 4.3 |
| E.K. | 4.0 | 3.8 | 4.0 | 3.9 | 4.0 | 4.2 |
| E.W. | 4.3 | 4.6 | 4.8 | 5.0 | 5.0 | 5.2 |
| E.S. | 4.6 | 4.8 | 5.0 | 5.0 | 5.5 | 5.6 |
| F.S. | — | 3.7 | 3.7 | 3.8 | 4.1 | — |
| P.O. | 4.0 | 4.4 | 4.1 | — | 4.4 | 4.5 |
| C.J.M. | — | 4.0 | 4.2 | — | 4.8 | 4.6 |
| H.R. | 4.3 | 5.0 | 4.9 | 5.1 | 5.3 | 5.4 |
| N.H. | 3.5 | 4.2 | 4.0 | — | — | 4.6 |
| P.W.H. | 3.5 | 4.1 | 4.6 | 4.6 | — | 4.3 |

*Fig. 1.*

much air as possible in a single breath. When the chest seems full to bursting point he is made to blow out the air into a gas meter until he can expel no more. The volume of gas expelled is measured by the meter. In some members the vital capacity had increased at the end of the expedition by as much as 27 per cent., but in others the increase was less marked. This improvement in the vital capacity appears to be one of the ways in which acclimatization can be assisted. But it must be remembered that training alone will produce some change, since in athletes the vital capacity is found to be greater than normal. The test is employed by physicians for assessing the soundness of the lungs. It was one of the many tests to which we were subjected by the Royal Air Force Central Medical Board before going out with the expedition. For various reasons no measurements of the chests of the natives living in Tibet were made. The vital capacity test is unsuitable for this purpose since its performance depends for accuracy upon the intelligent co-operation of the subject, and it is difficult to explain how it should be done in a foreign

language. We did however from time to time have occasion to examine medically most of our porters, many of whom were Tibetans and hillmen. When making these examinations I noticed that the heart sounds were often difficult to hear, and not only that but the normal area of cardiac dullness was reduced in extent, which would suggest that there was in these people some change in the lungs.

A condition known as clubbing of the fingers is frequently associated with states in which oxygenation of the blood is defective. Barcroft observed clubbing of the fingers in the dwellers at high altitudes in the Peruvian Andes. We noticed no such thing in the Tibetans or in our porters.

From all Everest expeditions there have been reports of altitude sore throats, and both in 1935 and 1936 almost every member of the party suffered. From the point of view of keeping the climbers fit for their task the problem of their prevention is important. Several theories of the cause of the condition have been put forward. Hingston thought that they were due to the rapid breathing of cold dry air. Greene suggested that they were due to an infection picked up from the dust of age-old camps during the journey through Tibet. I think that the following explanation is possible. Normally the throat and nose contain bacteria which are harmless, the normal buccal flora. But by breathing the unusually dry air of the north side of the mountain through the mouth instead of the nose—for when you are panting for breath mouth-breathing is the rule—the breath is not moistened by passage through the nose. The result is that the cells lining the upper respiratory passages over which it passes become dried up. In this state they are liable to invasion by the normal buccal flora. In several cases we noticed that the throats were actually ulcerated, and in 1933 Greene observed the same thing. With Shipton the infection spread to his larynx so that he lost his voice and could only issue orders to the porters at Camp III in a hoarse whisper. There was a noticeable improvement in the altitude throats as soon as the moisture-laden monsoon clouds began to pour over the passes from the south on to the East Rongbuk Glacier. When climbing in Garhwal on the southern slopes of the Himalaya these sore throats were not nearly such a common feature of life at high altitudes. The application of liquid paraffin with a spray so as to form a protective film over the throat was tried and found to be inadequate treatment. I can only suggest that an improved mask of the Matthews' respirator type should be used when taking exercise high up. With this mask the moisture in the expired air is condensed on a pad of copper gauze, and then with inspiration the air taken in is moistened and warmed by passage through the gauze. If properly designed the respirator could be worn without there being any obstruction to the breathing.

*The heart and circulation*

In 1936, as no one was exposed to the strain of going really high, dilated hearts were not to be expected. Only once was the whole party examined for heart-strain and that was after coming down from Camp III for the first time. On that occasion there were no dilated hearts. Apparently they were a feature of previous expeditions, and Hingston said that in 1924 all the climbers who had been to high camps showed evidence of them. Their absence in

1936 is due to the fact that no one had a chance of going higher than 23,000 feet.

Irregularities in the cardiac rhythm have been reported, but were not an outstanding feature in 1936. Once when going up to Camp III at a time when I had a sore throat I noticed that my heart was making extra beats at irregular intervals, but this was the only time at which an irregularity in the heart beat was noticed.

The pulse rate was examined particularly with a view to noting alterations in the basal rate. The rates both sitting and standing were also recorded at various altitudes. A large number of determinations were made but the following table (Fig. 2) records only a few of these for illustration. The features in the case recorded are: that there is no increase in the basal rate until 20,000 feet is reached; there is some increase in the sitting rate and a very definite increase in the standing rate as height is gained. These observations are in agreement with the findings of Hingston in 1924.

The basal rate is the number of beats per minute of the pulse when taken the

*Pulse-rate of one individual.*

| *Altitude* | *Basal* | *Sitting* | *Standing* |
|---|---|---|---|
| 8,800 ft. | 63 | 66 | 81 |
| 15,000 " | 63 | 71 | 85 |
| 16,600 " | 63 | 71 | 89 |
| 20,000 " | 67 | 92 | 102 |
| 21,200 " | 73 | 92 | 114 |
| 21,000 " (three weeks later) | 70 | 90 | 102 |

*Fig. 2*

first thing in the morning with the subject lying quietly in bed. Under normal circumstances the frequency remains very constant for each individual. Any effort such as turning over in bed will send the rate up. Fig. 3 shows the basal pulse rates of eight members of the party at different times during the expedition. In every case except one the rate remained unaltered below 20,000 feet. But in the case of Kempson his rate was constant only below 17,700 feet. In two members of the party the basal pulse frequency remained constant even at 21,200 feet. In six out of eight members of the expedition then the heart was working at an increased rate even under conditions of complete rest whenever they went above Camp I at 17,700 feet. And this happened not only on their first visits to Camps II and III but also during subsequent visits when it was known that they were better acclimatized. Perhaps it is significant that 20,000 feet corresponds roughly to the altitude at which we noticed other signs of deterioration, such as loss of weight and lack of appetite.

It is well known that on going to a high altitude there is an increase in the number of red corpuscles per unit volume of blood and a corresponding rise

in haemoglobin content. Now since the oxygen required by the body for purposes of life and respiration is carried to the tissues by the haemoglobin

*Basal-pulse Rates of Different Individuals*

| Place | Altitude | C.W. | P.W.H. | E.W. | P.O. | E.K. | J.L.G. | E.S. | H.R. |
|---|---|---|---|---|---|---|---|---|---|
| Gangtok | 6,000′ | 62 | – | – | – | – | – | – | – |
| Lachen | 8,800′ | 63 | 63 | – | – | 58 | 48 | 71 | 61 |
| Tangu | 12,800′ | 62 | – | 63 | – | – | 52 | 70 | – |
| Kampa Dzong | 15,000′ | 63 | – | – | – | 65 | – | 70 | – |
| Tengkye Dzong | 13,600′ | 62 | – | – | – | 62 | – | – | – |
| Base Camp | 16,600′ | 63 | – | – | 58 | 64 | – | – | – |
| Camp I | 17,700′ | 63 | – | 58 | – | 82 | 48 | – | 56 |
| Camp II | 20,000′ | 67 | 66 | 83 | 64 | 88 | – | – | – |
| Camp III | 21,200′ | 73 | 66 | 83 | 64 | 102 | 64 | 64 | 56 |
| Camp I | 17,700′ | 61 | 64 | – | – | 67 | 51 | – | 55 |
| Camp II | 20,000′ | 69 | – | – | – | 89 | 68 | – | – |
| Camp III | 21,200′ | 70 | – | – | – | 90 | – | – | – |
| Camp I | 17,700′ | 62 | – | – | – | – | – | – | – |
| Camp II | 20,000′ | 65 | – | – | – | 84 | – | – | – |
| Camp III | 21,200′ | 72 | – | – | – | – | – | – | – |
| Tengkye Dzong | 13,600′ | 64 | – | – | – | – | – | – | – |
| Lachung | 8,800′ | 55 | – | – | – | – | – | – | – |
| Tong | 4,800′ | 54 | – | – | – | – | – | – | – |

*Fig. 3*

which is present in the corpuscles, an increase in this pigment will enable more oxygen to be transported. The changes in the blood have always been

| Date | Altitude (feet) | Corpuscles per cu.mm. |
|---|---|---|
| April 10 | 700 | 4,480,000 |
| May 12 | 4,390 | 5,240,000 |
| May 21 | 8,000 | 6,040,000 |
| May 28 | 10,000 | 6,624,000 |
| May 30 | 11,960 | 6,760,000 |
| June 1 | 12,400 | 6,800,000 |
| June 21 | 13,300 | 7,525,000 |
| June 23 | 15,600 | 7,840,000 |
| June 26 | 16,900 | 7,640,000 |
| July 27 | 18,200 | 8,320,000 |

*Fig. 4*

regarded as one of the most important factors determining acclimatization. Blood counts have frequently been made at altitudes up to 15,000 feet, and

Hingston quotes a few figures from altitudes higher than this on the Pamir plateau (see Fig. 4). So far as I know counts were not made during Everest expeditions until 1936. It should be mentioned however that Kellas was able to make a count on his own blood at a camp at 20,000 feet before and immediately after ascending Pauhunri (23,180 feet). Fig. 5 shows the number of red corpuscles per cubic millimetre of blood and the percentage of haemoglobin in one member of the 1936 Everest Expedition. The normal figures at sea-level should be: 5,000,000 red cells per cubic millimetre, and 100 per cent. of haemoglobin. It will be seen that there is a progressive

*Blood-count and Haemoglobin of one individual.*

| Date | Place | Altitude | R.B.C. | Hb% |
|---|---|---|---|---|
| 14.3.36 | Gangtok | 6,000′ | 4,710,000 | 93 |
| 25.3.36 | Lachen | 8,800′ | 4,950,000 | 96 |
| 29.3.36 | Tangu | 12,800′ | 4,885,000 | 96 |
| 6.4.36 | Kampa Dzong | 15,000′ | 5,110,000 | 99 |
| 11.4.36 | Tengkye Dzong | 13,800′ | 5,420,000 | 105 |
| 21.4.36 | Shekkar Dzong | 14,000′ | 5,850,000 | 116 |
| 5.5.36 | Camp I | 17,700′ | 6,090,000 | 120 |
| 15.5.36 | Camp III | 21,200′ | 6,550,000 | 129 |
| 16.6.36 | Base Camp | 16,600′ | 6,800,000 | 134 |
| 27.6.36 | Tengkye Dzong | 13,800′ | 6,710,000 | 129 |
| 22.7.36 | Bombay | S.L. | 6,770,000 | 134 |
| 17.8.36 | London | S.L. | 6,550,000 | 129 |

*Fig. 5*

increase both in the number of corpuscles and in the percentage of haemoglobin present as height is gained. It will also be noticed that the figures have not returned to normal even three weeks after reaching sea-level again. Seven weeks later they were normal.

Fig. 6 shows the percentage increase in the haemoglobin of different members of the party as they went above 6000 feet. From these figures the individual variations in response to altitude can be seen, and they can be briefly summarized as follows:

1. The maximum increase in the Hb. content of the blood of any individual was 48 per cent.; three out of the eight members attained this figure: they were E. W., F. S., and J. M. (In the case of J. M. his polycythaemia was twice interrupted by attacks of malarial fever.)
2. The average maximum increase was 36 per cent.

3. In the cases of E. W., E. E. S., and to a less extent E. K., the percentage increase had become marked at the time of reaching Kampa Dzong (15,000 feet). In the remaining five it was delayed until Tengkye Dzong.
4. In the case of E. E. S. his Hb. level appeared to respond more rapidly than the others to changes in altitude.

The changes in the blood appear to follow closely the stages in our ascent, as can be seen from the chart (Fig. 7), where there are two steep rises in the red cell and haemoglobin curves at a time when there have been two periods of steep ascent. On the same chart another series of figures have been plotted, representing changes in the reaction of the urine.

The deep breathing which becomes necessary on going high in order to keep up the oxygen tension in the lungs results in carbon dioxide being washed

*Percentage increase in Haemoglobin*

| Place | Altitude | C.W. | E.W. | E.E.S. | E.K. | J.L.G. | N.H. | F.S. | J.M. |
|---|---|---|---|---|---|---|---|---|---|
| Gangtok | 6,000′ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lachen | 8,800′ | 3 | - | 9 | - | - | 0 | - | - |
| Tangu | 12,800′ | 3 | 3 | 9 | - | - | - | - | 2 |
| Kampa Dzong | 15,000′ | 3 | 25 | 25 | 17 | - | - | - | - |
| Tengkye Dzong | 13,800′ | 13 | - | - | 17 | - | 9 | - | 5 |
| Shekkar Dzong | 14,000′ | 25 | - | - | - | - | 17 | - | - |
| Base Camp | 16,600′ | - | - | - | 21 | 21 | - | 33 | 43 |
| Camp I | 17,700′ | 29 | 29 | 39 | - | - | - | - | 38 |
| Camp III | 21,200′ | 39 | 44 | 39 | 34 | 40 | - | 48 | - |
| Base Camp | 16,600′ | 44 | - | - | - | - | - | 48 | - |
| Tengkye Dzong | 13,800′ | 39 | - | 28 | - | - | 21 | - | 48 |
| S.S. Mooltan | S.L. | 44 | 48 | 35 | - | 40 | - | - | 38 |

*Fig. 6*

out of the lungs. But carbon dioxide is an acid gas and its loss from the body tends to leave the blood more alkaline. In order to compensate for this tendency towards alkalosis the kidney excretes more alkali and the reaction of the blood is restored to normal. Since it is difficult to estimate directly these changes in the reaction of the blood an indirect method of doing so was sought. This was by estimating the reaction of the excretion from the kidneys. In Fig. 7 an upward deflection in the curve indicates an increase in the *p*H or alkalinity of the urine. Two peaks of alkalinity are present. Each one appears at a period of rapid ascent and precedes a rise in the blood and haemoglobin curves. The exact interpretation of these findings is at present difficult and debatable. But it can be said that there appears to be a tendency towards alkalosis at a time when the ascent is rapid and before the blood count has adapted itself to the new level.

Blueness of the face and lips and lividity of the fingers were noticed at the

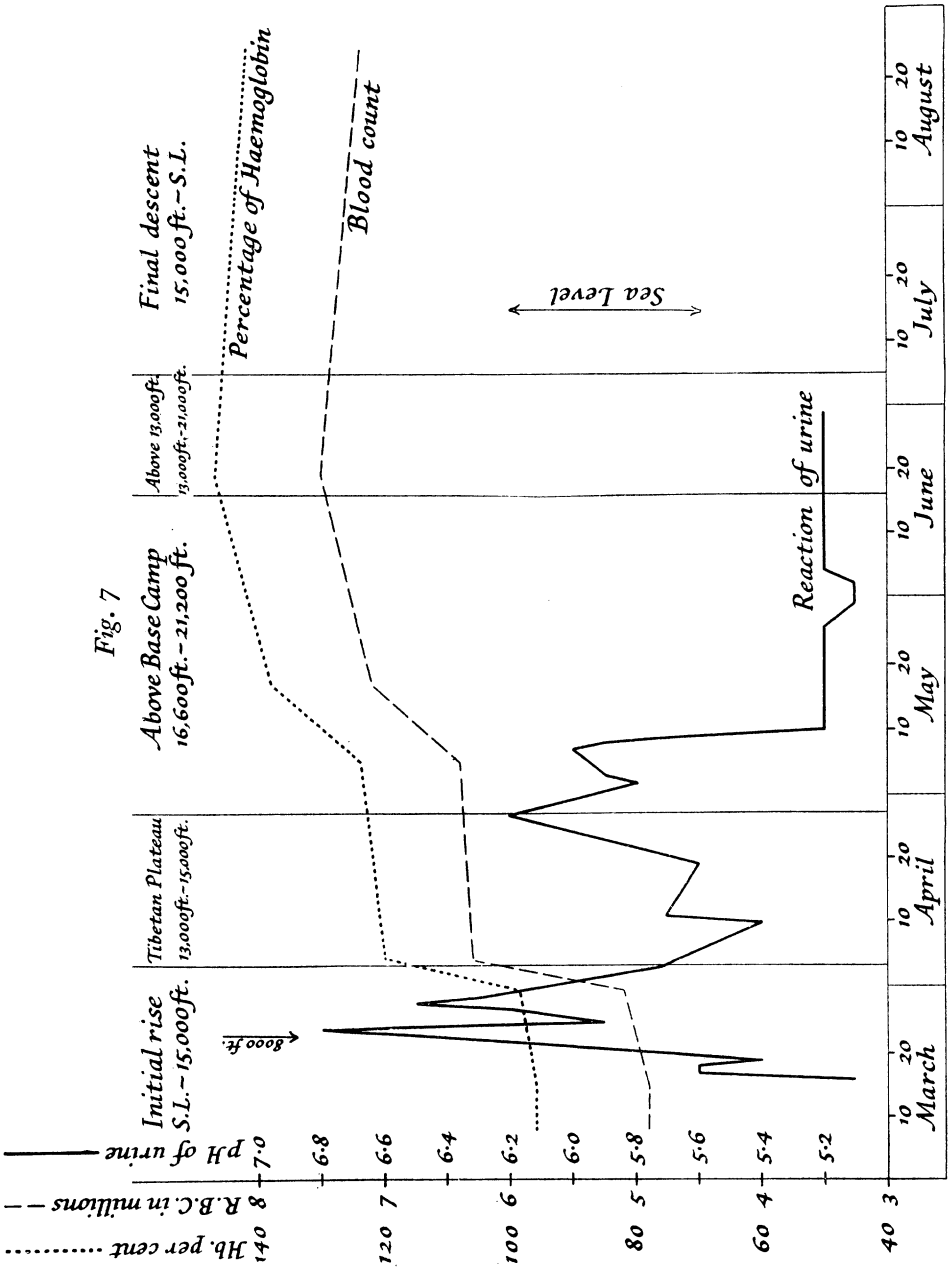


Fig. 7
Initial rise
S.L.–15,000ft.
Tibetan Plateau
13,000ft.–15,000ft.
Above Base Camp
16,600ft.–21,200ft.
Above 13,000ft.
13,000ft.–21,000ft.
Final descent
15,000ft.–S.L.
8000 ft.
Percentage of Haemoglobin
Blood count
Sea Level
Reaction of urine
Hb. per cent
R.B.C. in millions
pH of urine
140 120 100 80 60 40
8 7 6 5 4 3
7·0 6·8 6·6 6·4 6·2 6·0 5·8 5·6 5·4 5·2
10 20 March
10 20 April
10 20 May
10 20 June
10 20 July
10 20 August

beginning of the expedition, but curiously enough did not seem to be so pronounced later on. This is remarkable because people with blood counts which are higher than normal usually become cyanosed or livid more readily. Perhaps we became accustomed to our companions' complexions as one becomes accustomed to new faces.

*Muscular power*

Lassitude and a sense of muscular weakness are prominent features of life at great altitudes. They were first noticed at about 12,000 feet on the outward journey but, like the difficulty with the breathing, soon passed off as we became acclimatized, only to reappear again when we got to Camp I. Above 20,000 feet there always appeared to be some lassitude. For the first few days at Camp III I found that I was always longing to sit down and do nothing. I can only compare the feeling to that sense of weakness which is experienced on first getting up after a long illness. The lassitude together with a feeling of giddiness was often particularly noticeable on getting up in the mornings. Although the condition improved after a short time spent at this camp, in my own case I found that it never disappeared completely. When climbing on the North Col we noticed that the muscles tired more rapidly than at lower altitudes. Towards the end of our stay on the mountain however this lassitude and rapid fatigue on exertion were the only signs of mountain-sickness.

*The mind and special senses*

At altitudes such as were attained by the 1936 expedition there appeared to be no diminution in acuity of hearing and vision, though this has been reported on previous expeditions.

There was a very distinct disinclination for serious mental work above about 20,000 feet, which must to some extent be my excuse for not bringing back more information than I have done for this paper. But apart from this no serious mental changes were noticed. Tempers are said to be irritable at high altitude, but although conditions on the North Col last year were provoking to say the least of it, we never really quarrelled seriously.

*The digestion*

Loss of appetite is a troublesome consequence of life above 20,000 feet. In 1936 appetites were better than usual at Camp III, but even then they were much below normal. During the reconnaissance in 1935 we made a point of writing down the estimated quantities of the various things that were eaten at each meal. On looking at these notes afterwards it was clear that everyone was eating far too little up at the higher camps, although at the time they would stoutly have maintained that they were eating enormously. This failure to take enough nourishment on the part of the climbers was reflected in their weight records. Everyone lost several pounds in weight whenever they went above 20,000 feet for any length of time, and much of this weight was regained on going down to the Base Camp for a few days. It is interesting that the porters did not lose weight like the climbers; but this is probably accounted for by the fact that when they are with an expedition they

are fed better than normally. This loss of appetite interested me, and I wondered whether it might not be connected with the process of acclimatization. Is it not possible that the hydrochloric acid which normally should appear in the stomach following a meal is conserved for purposes of neutralization in the body at high altitudes? For as we have already mentioned, there is a tendency for the blood to become more alkaline high up and any loss of acid from the body, as in the gastric secretion, would still further accentuate this alkalosis—a state of affairs which is the opposite of that required for acclimatization. If it is true that the hydrochloric acid is retained by the body and not put out during digestion, then the administration of small doses of diluted hydrochloric acid (or even of acid salts such as ammonium chloride) might help to stimulate the appetite.

An attempt was made to detect changes in the acidity of the gastric secretion at two different altitudes by means of a test-meal. The most unpleasant part

*Gastric Acidity*

| | C.B.M.W. | | E.W. | |
|---|---|---|---|---|
| | 17,700 ft. | 21,200 ft. | 17,700 ft. | 21,200 ft. |
| Fasting | o | o | o | o |
| → 15 min. | + + | o | o | o |
| 30 " | + | o | + | o |
| 45 " | + | o | o | o |
| 60 " | + | o | | |
| Histamine | + + | + + | + + | + + |

+ .. *Free Hydrochloric acid present*
o .. *No free acid present*

*Fig. 8*

of the performance of this test is persuading your victim to swallow the stomach tube. It was only fair therefore that I should set the example by doing the first test-meal on myself. Wigram, being a student of medicine, volunteered to be the second victim of the experiment. But as he remarked afterwards, the fact that he was given a little icy cold alcohol down a tube was hardly sufficient compensation for such good nature on his part. In performing a test-meal the subject is made to swallow the stomach tube first thing in the morning before any food has been taken. The fasting contents of the stomach are then withdrawn and tested for free hydrochloric acid. Immediately afterwards a definite quantity of alcohol (the meal) is run down the tube into the stomach. Then at fifteen-minute intervals samples of the gastric contents are withdrawn and tested for the acid. If no acid appears in the later samples then an injection of histamine is given into the arm, and a few minutes later another sample is withdrawn and tested. This last sample should contain free hydrochloric acid; if it does not, the subject is one of those people who cannot secrete the acid at any time. The results

of this test performed upon two of the climbers, first of all at Camp I and then at Camp III, are shown in Fig. 8. It will be noticed that in both cases there was free hydrochloric acid in at least one of the samples following the meal at Camp I, whereas at Camp III there was no acid at any time until histamine had been given.

*Acclimatization*

We now come to consider what is the sequence of events in the process of acclimatization. Breathing becomes deeper and more rapid in order to increase the amount of oxygen reaching the alveoli or farthest spaces of the lungs. At first this increased ventilation of the lungs is partly voluntary and for this reason is felt as a difficulty with the breathing. But as we have already mentioned, the deep breathing causes the acid gas carbon dioxide to be washed out of the lungs and so tends to make the blood more alkaline. With the loss of carbon dioxide from the circulation however the normal stimulus to the breathing mechanism has gone, and the depth of the breathing dies down again. In order that the deep breathing, which is such an advantage to the body at high altitudes, may continue the kidneys after a time learn how to get rid of the excess of alkali from the blood, and thus its reaction is restored to normal. In this way the loss of carbon dioxide is compensated for and the breathing allowed to go on at the new level. In addition to this mechanism there is the one whereby the number of red corpuscles is increased in the blood. At first this increase is probably brought about by contraction of the spleen. When this organ contracts red cells are squeezed out from its meshes into the general circulation as water is squeezed from a sponge. Obviously the number of red cells in the circulation can quickly be increased by such means. At a later stage it seems likely that there is actually increased formation of red cells by the red bone marrow, which appears to be stimulated into activity by lack of oxygen. These are the principal means by which the body can adapt itself to the changed state of the atmosphere met with at high altitudes. The extent to which these changes are taking place during the climbing of Mount Everest may be judged from this paper.

*Deterioration*

Before leaving the subject of acclimatization in connection with the climbing of Mount Everest something must be said about the deterioration in the physical condition of the climbers which is alleged to set in above a certain altitude. As a result of experiments with animals which were kept at low atmospheric pressures for a long time, Argyll-Campbell and Sir Leonard Hill came to the conclusion that it was useless to attempt to acclimatize to altitudes greater than 21,000 feet by staying for prolonged periods at the higher camps on the mountain. Above this altitude their animals eventually died, and when examined were found to have dilated hearts and fatty degeneration of all their organs. It is possible to argue of course that their results with animals need not necessarily have any bearing upon what happens in the human organism under similar circumstances. But it is interesting to note that after the 1933 expedition it was decided that in future the climbers ought not to stay in the camps above Camp III (21,200 feet) for longer than

is absolutely necessary. In 1936, after the first attempt to get above the North Col the whole party retreated to Camp I, having lived at Camp III for a period of eleven days on that occasion. Morris and Smijth-Windham were both at Camp I when we came down, and they told me afterwards that we all looked thin and ill when we came into camp. It was also remarkable how we at once began to eat with our accustomed appetites at this camp (17,700 feet). At Camp III most of us had been worried by sore throats, but on going down to lower levels they improved remarkably. The increase in the basal pulse rate which was observed in most of the climbers whenever they went above 17,700 feet has already been mentioned.

To summarize, the evidence which points to deterioration taking place at about 21,000 feet is: loss of appetite, with attendant wasting and loss of weight which is rapidly regained on going to lower levels; an increase in the basal pulse frequency which is only present above 17,700 feet; and in experiments with animals, the inability to prevent them from ultimately dying with fatty degeneration of their organs.

Have we any evidence that acclimatization is still going on at 21,000 feet in spite of the fact that deterioration in the physical condition may have started? To begin with it should be mentioned that we all felt much less distress on our second and third visits to Camp III. The only other evidence is to be derived from the blood counts. Between the time of our first visit to Camp III and our final return to the Base Camp at the end of the expedition there was in most cases a further increase in the red cells and the haemoglobin-content of the blood. Therefore it can at least be said, that our later stays at 21,200 feet did not prevent the blood count from continuing to rise. This finding appears to be in agreement with some observations which were made recently by Matthews in the Andes.

*The oxygen problem*

When a man goes to a high altitude he has to breathe an atmosphere which contains less oxygen than there is at sea-level, though the proportion of oxygen to nitrogen remains the same: that is, oxygen still forms 20 per cent. of the atmosphere. What has altered is the barometric pressure, so that the pressure exerted by each of the gases composing the atmosphere has altered also. Oxygen passes from the air in the lungs into the blood, which is circulating through those organs, as a result of the pressure exerted by the gas, and the amount which is taken up by the blood depends upon this pressure. If the partial pressure of oxygen in the breathed air is reduced, as it is at high altitudes (and in low pressure chambers at sea-level), then less of it is taken up, the blood leaves the lungs less fully saturated with the gas, and so has less to deliver to the tissues. Enough oxygen must be supplied to the tissues if their life and function are to be maintained. It is lack of oxygen for the tissues which gives rise to the symptoms of mountain-sickness and which calls forth the adjustments known as acclimatization.

If a sample of blood is exposed to air containing oxygen at a known partial pressure it becomes partly saturated with the oxygen, *i.e.* a definite percentage of the haemoglobin present in this blood becomes converted into oxyhaemoglobin. If the partial pressure is increased the blood will become more fully

saturated; but if it is reduced the saturation will become less complete. A curve can be constructed which will show the relationship between partial pressures of oxygen and the percentage saturation of the blood. This is known as the Dissociation Curve of Oxyhaemoglobin in Blood. Dr. Kellas has plotted the calculated alveolar oxygen tensions for altitudes corresponding to a number of well-known mountains (Fig. 9). The curve shows that up to about 10,000 feet the blood is almost fully saturated with oxygen, but at about 15,000 feet the percentage saturation is beginning to fall. By the time 20,000 feet is reached the curve is steepening rapidly and with every 1000 feet rise above this altitude there is a correspondingly rapid fall in the percentage saturation. At a height corresponding to the summit of Mount Everest the degree of saturation is only about 40 per cent. From a consideration of the curve it seems clear that the difficulties in ascending above 20,000

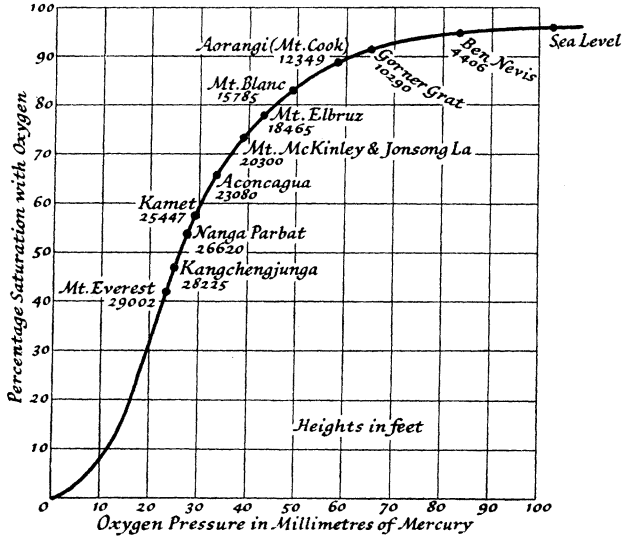



*Fig. 9*

feet will increase considerably; an observation which is borne out by the accounts of all those who have come back from the higher camps on Mount Everest. Thus, although the climbers have already struggled to 28,000 feet on the mountain, there is no reason to suppose that because they have done so they are bound to be able to climb the last 1000 feet without using oxygen.

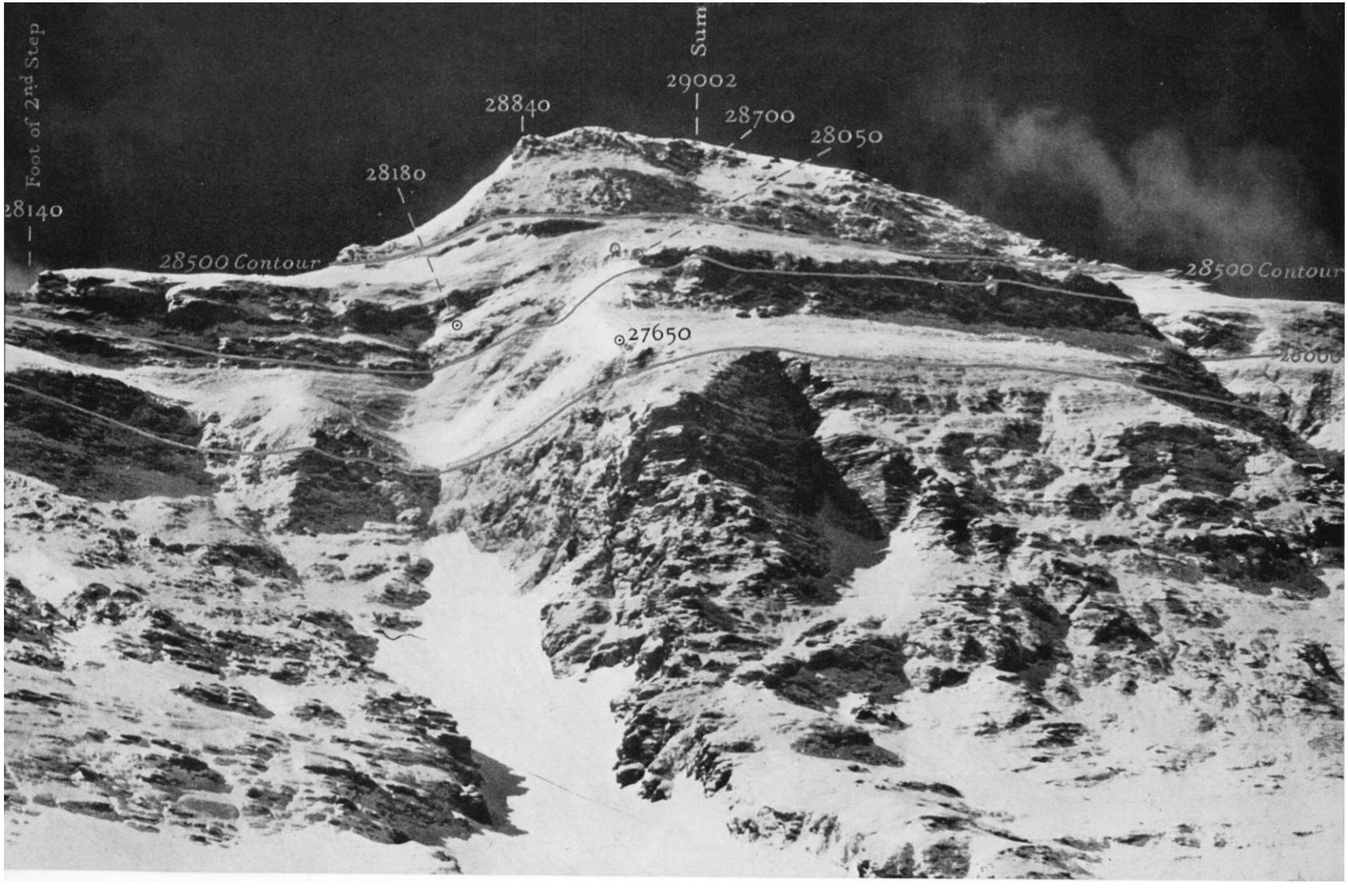
This brings us to a consideration of what happens when the partial pressure of oxygen in the breathed air falls beyond certain limits. Symptoms which are directly attributable to the diminished pressure are met with. For instance, if an airman goes rapidly to a great altitude he loses consciousness without warning. The same thing happens if he is put into a closed chamber at sea-level from which the air is rapidly exhausted. In 1875 Tissandier and his companions made their famous ascent in a balloon from Paris. At 26,500 feet Tissandier lost consciousness. He recovered to find the balloon descending, but his two companions were dead. It has been suggested that such an accident

might happen on Everest, but I do not think it is likely when we consider what happens if the oxygen pressure is reduced more slowly. With a more gradual onset of oxygen-lack the train of symptoms is as follows. The intellect and the senses become dulled without the subject being aware of what is happening. Visual acuity is diminished and sensation impaired. The subject may be in danger and not realize it; or he may realize his danger and yet be incapable of deciding upon a line of action that would put him in safety. Eventually there is paralysis of the legs and arms, and ultimately loss of consciousness. On the extreme heights of Everest the climber is likely to be brought to a standstill by the fatigue in his muscles (or by actual paralysis) before losing consciousness. He would however be exposed to the risks due to mental impairment, such as the failure to realize the danger of his position and carelessness in his movements on difficult ground. Apart from the fact that it may not be possible to reach such an altitude as 29,002 feet without using oxygen, I think that the dangers consequent upon mental impairment form the strongest argument in favour of its use on the last lap to the summit.

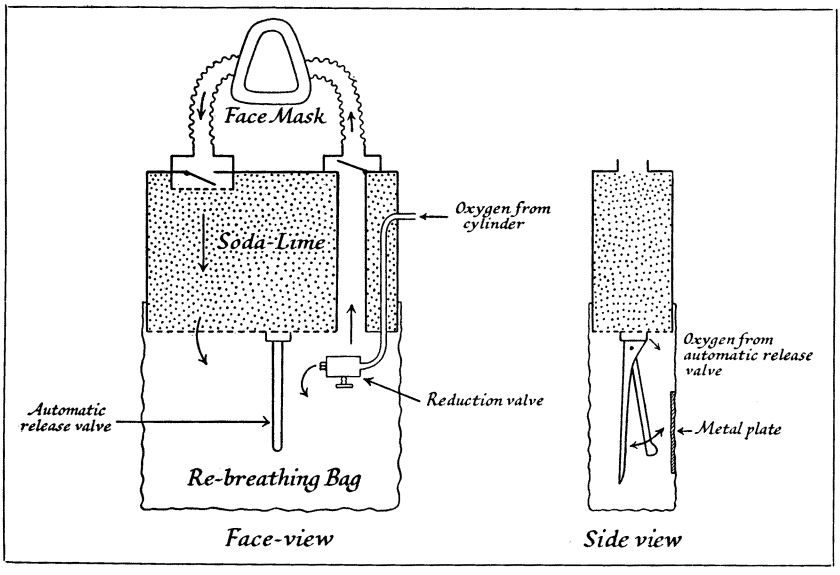
*Oxygen apparatus and its use*

Whatever type of apparatus is used, its object is to increase the pressure of oxygen in the alveolar spaces of the lungs. This object can be achieved in one of two ways. In the original types of apparatus the outside air was breathed from a bag to which oxygen was added from a cylinder at a fixed rate. The disadvantages of this method are that much of the oxygen is wasted by being expired from the dead spaces of the lungs into the outside air; that there is an uncomfortable drying of the throat; and that moisture and heat are lost from the body in the breath. Furthermore, when the ventilation of the lungs increases as it does during exercise the partial pressure of oxygen in the bag will fall. That this apparatus is wasteful of oxygen can be seen from the fact that in order to raise the partial pressure of oxygen in the air at 30,000 feet from 53 mm. of mercury to 110 mm. it is calculated that oxygen must be supplied at the rate of about 9 litres a minute. A partial pressure of 110 mm. of mercury corresponds to an altitude of about 12,000 feet, so that to bring a climber down to this level it would be necessary to supply him with oxygen at that rate. But the body only uses oxygen at the rate of approximately half a litre per minute when at rest and up to 2 litres per minute during exercise, as can be seen from the table which was worked out by Zuntz on Monte Rosa (see Fig. 10). An apparatus of this type was taken by the expedition in 1936. It contained two cylinders of "Vibrax" steel each holding 750 litres of oxygen and the reduction valve was set to deliver 6 litres a minute, though it was capable of adjustment to deliver any other quantity. With such an apparatus the supply was 1500 litres, and this flowing at the rate of 6 litres a minute would last just over four hours. Its weight was approximately 30 lb.

In another type of apparatus, instead of air being breathed to which oxygen is added, oxygen only is breathed and the carbon dioxide in the expired breath is absorbed by passing it through a canister containing soda-lime. The breathing circuit is completely enclosed, so that nothing is exhaled into the outside atmosphere. Such an apparatus is similar to that used in rescue work down coal mines and in submarine-escaping apparatus. Its advantages would




*The summit of Mount Everest from the North Col*




*Re-breathing type of oxygen apparatus*

*The apparatus in use*

seem to be that no oxygen is wasted, that heat and moisture are not lost by breathing out into the external atmosphere, and that the pressure of oxygen breathed is the same as that of the external atmosphere (*i.e.* approximately 250 mm. of mercury at 30,000 feet), a pressure which is well above the partial pressure of oxygen in the atmosphere at sea-level. The apparatus therefore should theoretically bring the climber at 30,000 feet down to sea-level conditions. The oxygen-breathing gear was designed and made for us to use on the mountain by Siebe Gorman, the well-known firm of submarine engineers. Two sizes were taken. The smaller of the two weighed 25 lb. and carried a cylinder, made of "Vibrax" steel, of 500 litres capacity. Supposing the rate of consumption of oxygen when climbing on Everest was 2 litres a minute, then the supply would last just over four hours. The larger apparatus weighed 35 lb. and carried a cylinder of 750 litres capacity, and on the same basis would provide oxygen for a period of six hours. The reduction valve in the respirator was actually set to deliver half a litre a minute, or the amount of oxygen required by the body when at rest; but by means of an automatic release valve a greater supply could be obtained from the cylinder as required during exercise.

The re-breathing type of apparatus has been criticized on the following

| | *Oxygen required per minute* |
|---|---|
| *Sea level at rest, fasting* ..... | *233 cub. c.* |
| *Monte Rosa do.* ..... | *260 "* |
| *Ascending glacier on Monte Rosa* ... | *1329 "* |

*Fig. 10*

grounds: that there is no advantage in bringing the climber down to sea-level conditions, and that such a change may even do harm; that soda-lime absorbs moisture, so that there is a loss of fluids from the body through the breath; and that nobody could tolerate having a mask over their face at 28,000 feet. In answer to these criticisms I would first of all point out that if the increase in the blood count is really one of the more important indications of acclimatization then it seems unlikely that by breathing oxygen for a few hours on end acclimatization would be seriously affected, for as we know it is a matter of weeks and not days before the blood count begins to fall after reaching sea-level. Then with regard to the moisture which might be absorbed by the soda-lime, I understand that many of the patent absorbing materials such as "Protosorb," which was used in the apparatus under consideration, are practically non-hygroscopic. And lastly, as far as the intolerance of a mask over the face is concerned, the reply is that with the proper oxygen supply given by this apparatus the climber would not be at 28,000 feet but at sea-level. A mask indeed would even be an advantage since it would protect the face from the wind and allow it to be muffled up to the eyes with clothing.

The re-breathing respirator was tested both at home in the low-pressure chamber and in Tibet on the mountain. The trials at home were not as thorough as was desirable on account of the limited time at our disposal,

and those on the mountain were not made at a sufficiently great altitude to give us any information of great value. But in order to find out what could be done in the apparatus, Shipton took it down to Box Hill and made several ascents of a steep slope in it. At the Box Hill trial he had the apparatus on for an hour and forty minutes in all. During that time he ascended 1750 feet in the course of $67\frac{1}{2}$ minutes' climbing, so that he was climbing at the very fast rate of 1550 feet an hour. The average angle of the slope on which the trial was made was measured, and worked out at 32 degrees. The surface was wet chalk. The amount of oxygen used during the hour and forty minutes of the trial was just under 250 litres, or half the supply available. A few days later I went to the same slope to test another apparatus and so had an opportunity of seeing it. I came to the conclusion that a surface of wet chalk set at a steep angle is about the most diabolical place imaginable. I have never wasted so much energy in stepping up only to slide down again as I did in the course of an hour's climbing that afternoon. On the top of it all the apparatus was a trial one and was not working as smoothly as it might have done; in consequence the unfortunate subject of the experiment became half asphyxiated and developed a splitting headache.

The oxygen apparatus was used once or twice in the course of the expedition in order to try it out and to train people how to use it. This training is most important, and until the climbers can be persuaded to devote a certain amount of time to getting used to the gear and moving about in it, we shall get no farther with the oxygen problem. On the slopes of the North Col I climbed in it for a short time and found that I could advance much faster and without the fatigue which normally is experienced at that altitude. It was worn by several members of the party to make ascents of over an hour's duration above the Base Camp at 16,600 feet, and no one suffered any ill effects when it was taken off. But the most convincing trial was done at Tangu. Here, before any of us were properly acclimatized, I used the apparatus to climb for at least 1000 feet up the hillside behind the bungalow. And yet with 35 lb. on my back I was able to climb just about twice as fast as two of my companions who were going without it.

The question which arises is: How should the apparatus be used on the mountain? Personally I think that to try to make the ascent using oxygen from below Camp V would be impractical and dangerous. I think that it should be used on the last lap only, and then only by a specially trained oxygen party. It would be quite useless and dangerous to let those who feel "anti-oxygen" have a closed type of apparatus up at Camp VI to use in the event of their failure to climb the mountain without it. It has been suggested that oxygen might be used in camp and at night time only, in order to do away with deterioration. But if one really believes, as do some of us who consider the matter from the physiological as well as the mountaineering point of view, that it may be impossible for a man to reach 29,002 feet without using oxygen, then such a method of administration contributes nothing towards the attainment of the summit.

A last point which requires consideration is whether a six-hour supply will be sufficient to carry the climber from the last camp to the summit and down again. Shipton has estimated that without oxygen the last 1000 feet

will take about sixteen hours up and down. Even with 30 lb. on one's back it should be possible to climb at the rate of 500 feet an hour over quite difficult ground when at moderate altitudes and without oxygen. We know that this can be done in the Alps, and in the Himalayas people have climbed up difficult rocks with loads of 20 lb. on their backs. If, then, we can produce an oxygen apparatus which will bring the climber down to sea-level when on Everest, even though it does weigh 35 lb. and has only a six-hour supply, he should be able to get to the top and down again within this time.

## DISCUSSION

Before the paper the PRESIDENT (Professor HENRY BALFOUR) said: Dr. Warren, our lecturer this afternoon, has already spoken in this Hall when, after Mr. Ruttledge's paper on the last expedition to Mount Everest, he offered a few remarks on the medical aspects of the expedition. This afternoon he is going into the matter more deeply.

As you know, the Mount Everest Expedition was not successful in its objective, and that non-success was due almost entirely to the very abnormal weather conditions that obtained in 1936. Weather conditions are not in any way under the control of the medical members of the expedition, but there are other matters of almost equally great importance that are subject to control by medical officers: questions of health, and not only questions of the health of the expedition itself, but the problem of trying out fresh apparatus. The medical officers, Dr. Noel Humphreys and Dr. Warren, did yeoman service in not only keeping the expedition healthy, but also in conducting experiments which should be of use to future expeditions. I have great pleasure in calling upon Dr. Warren to read his paper.

*Dr. Warren then read the paper printed above, and a discussion followed.*

The PRESIDENT: I would ask Mr. Matthews who has just demonstrated the oxygen apparatus to us to tell us something of his sensations in that connection.

Mr. B. H. C. MATTHEWS: There seems to be very little obstruction to respiration in the apparatus. I have had it in Cambridge during the last two days for the purpose of doing tests with regard to resistance and performance. It seems to me an enormous advance on all previous apparatus I have seen for the purpose. The difference in oxygen economy between an apparatus with a closed circuit and the open-circuit type of apparatus seems to be an overwhelming argument in favour of the use of the former type. The greatest advantage of the apparatus Dr. Warren has shown seems to me to lie in the enormously increased speed of climbing that would be possible at a high altitude, so that the time during which a man is above the danger level (28,000 feet) in extremely low pressure can be reduced, according to Dr. Warren's figures, by about five times. Thus, instead of spending twenty hours in reaching the summit of Mount Everest from the last camp, one might spend only a matter of four hours when using this apparatus.

I should like to express my great admiration for the work Dr. Warren managed to do under what I know were very difficult conditions. I have tried to take observations at 20,000 feet and I know it is by no means easy.

One point interested me very much in Dr. Warren's figures for the blood capacity in that I noticed there was a continuous increase after the climber came down from the greater height to 20,000 feet. Acclimatization went on for a long time at that height. That agrees with some observations made in Chile

about two years ago on what I think were possibly the most acclimatized group of people in the world: some Chilean sulphur miners, who live at 17,000 feet and work every day at 19,000 feet. Most of them have been doing this for ten years and they have been doing hard physical work at 19,000 feet. The effect of their acclimatization is instanced by the fact that they start at 17,000 feet in the morning, rise early and walk up the 2000 feet to the mine, sandwich in a hard day's work, come down in the evening when you would expect them to be exhausted, and proceed to play what they call football on the flat ground outside the mining camp. We persuaded some of these men to let us have samples of their blood and they confirmed the suspicion, shown again in Dr. Warren's figures, that acclimatization goes on for a very long time.

We were in Chile for about four months and living above 16,000 feet or so ourselves. The miners, as I have said, had been there for ten years, and whereas our haemoglobin rose to 125–135 per cent. of its sea-level value, theirs was about 160 per cent., so that acclimatization had gone much farther during a long-term residence.

I was particularly interested in Dr. Warren's observations on the acid base balance because we were observing a different aspect of that in Chile, in the base reserve in the blood, and we found that it fell very markedly at a high altitude. It seemed that there were two phases in acclimatization. There was the acid-base side of it and the adaptation to more rapid breathing which would normally make the blood alkaline; and a second and, as far as I could see, not necessarily related adjustment in the quantity of haemoglobin. It seemed to us that these two factors which are usually considered together really worked independently and that the increase in the haemoglobin appeared to be, to some extent, independent of the change in the reaction of the blood, and to continue long after the acid-base acclimatization was complete.

Lastly, I should like to ask Dr. Warren if he could tell us anything about his views on the question of high altitude deterioration. It is a question I know nothing about myself but I should be interested if he could say anything in regard to it.

The PRESIDENT: Mr. Wager has explored high altitudes in several areas, and we would like to hear something from him.

Mr. L. R. WAGER: I should like to congratulate Dr. Warren very much indeed on the results of his work. It is not an easy matter, as he said, to make oneself carry out experiments at such high altitudes; and it is not an easy matter to persuade the other climbers to undergo the tests; but he succeeded in doing it, and it is a great achievement.

I do not think the oxygen apparatus which Dr. Warren has shown will appeal to very many of the climbers unless they are, as he said they must be, real enthusiasts for the oxygen method. I am quite sure he is right when he says that in order to use the apparatus effectively the men will have to practise a great deal and be really keen on using it. In fact there will have to be two parts to the Everest Expedition: one that believes that it is impossible to get to the summit without an oxygen apparatus, and another part, which I hope will always exist, that believes that it is perfectly possible.

One difficulty about the apparatus that strikes me is the large number of valves. As Dr. Warren has said, one's mental powers are reduced at high altitudes. It would no doubt be possible to carry out routine adjustments to keep the apparatus going, but supposing any slight thing went wrong due to cold or a bump against the rocks, then I am afraid the mental powers of the climbers would probably not be sufficient to put the trouble right. Unless they could do it quickly they might collapse if they were no longer receiving extra oxygen.

I would also like to ask Dr. Warren whether the effect derived from the oxygen carried is not rather less than in the other form of apparatus. In the older apparatus you do breathe some of the air blowing around the mountain as well as that coming out of the cylinder, whereas in this apparatus, so far as I can see, you only breathe the oxygen you are actually carrying.

However, these are all minor points of the oxygen problem. The part of Dr. Warren's work which particularly appeals to me concerns the changes that go on under normal acclimatization and I think that, if many more of the excellent experiments which Dr. Warren has been doing and which were done to some extent on the earlier expeditions could be carried out on the next expedition, we should probably learn something of how the remarkable process of acclimatization is taking place. Personally I think it would be more satisfactory to climb the mountain by means of acclimatization, and these experiments may indicate how acclimatization may be improved or fostered in the climbers.

The PRESIDENT: I do not know whether there are any physiologists or other specialists here who would like to ask Dr. Warren a question or two. If there are, we would be very glad to hear them.

A FELLOW: May I ask Dr. Warren whether, in the present stage of knowledge of the physiological effects of high altitudes, it has been definitely established that deterioration occurs at any altitude, even up to 28,000 feet.

General C. G. BRUCE: I really am absolutely the worst qualified of anybody in the room to offer any comments on the paper to which we have listened, but I thought I might usefully make one or two remarks upon the attitude of the earlier expeditions. If you read the 1921 book on the earlier expedition you will remember what trouble Mallory had to get to the North Col even during summer; how his men were all tired out; and how a number of them collapsed. You must remember that 23,000 feet in those days had a very great reputation, which is now torn to shreds. In fact, only once before in those early days had a climber, Mr. C. F. Meade on Kamet, slept a night at 23,000 feet. The Sherpas and others started off in those early days fearful, not so much of the mountain and of high altitudes, but of the invasion of sanctuaries. Then in 1922, when our climbers showed the way and confidence was established, and for certain other reasons as well, the men went up to the North Col without turning a hair; they carried heavy loads up and developed confidence, so that the results were very fine indeed. Many men stayed on the North Col at 23,000 feet for fourteen whole days and did an immense amount of work into the bargain.

Then came the expedition of 1924. The attitude of that expedition was that anybody who was not a complete cripple could go up to 23,000 feet in perfect comfort, with the result that we have seen. It is very clear that the psychological outlook is of great importance. A mountaineering tradition has now been established. People often say that as most Sherpas live at a high altitude they are little affected by that altitude. But that is not always the case, and it is to be remembered that one of Mallory's men who did very good work came from Sedongchen, which is only 5500 feet above the sea. Lhakpa Chédé was a Darjeeling man, so that he had not been one of those who were regularly living and working in the high mountains, though fairly accustomed to them. He was also one of Norton's particular men. Actually in 1921 he was very ill from malaria, but in 1924 he was able to work hard and climb so well that he was obviously one of the strongest men in the party, carrying loads to 27,000 feet.

For the future of mountaineering in the Himalayas this is all very encouraging, because there are many other and very good people to be found of almost equal value: they are terrified of the mountain at present, but nevertheless if we can only give them confidence, as the Sherpas have got confidence now, we can

find other helpers who will be really useful for further expeditions in most parts of the Himalaya.

The PRESIDENT: I now call upon Dr. Warren to reply to the questions and remarks that have been made.

Dr. WARREN: The main point to which I have to reply is in regard to deterioration. I think that the 1933 expedition and later expeditions have all come to the conclusion that the longer a man is kept above Camp III, at about 21,000 feet, the more does his physical condition deteriorate. It was very noticeable, I think, both during the reconnaissance and last year that people looked ill when they came down from Camp III after being up there for some time; and at Camp III they would not eat, as I mentioned in the paper. You cannot get a person to eat enough food at that camp because the appetite is completely lost. A man will tell you that he is eating enough, but it is only when you get him to write down and have taken an analysis of what he is eating that you find he is not taking sufficient food. Of course there is a certain amount of individual variation. Some eat better than others. Shipton is quite convinced that you should never keep a man a minute longer than you can help above Camp III, but I think he is an extremist in that matter.

Some experiments by Argyll Campbell on mice showed that they would live and flourish at pressures of oxygen which corresponded to about 20,000 feet, but that at lower pressures they gradually died from fatty degeneration of their organs. It is rather interesting that the altitude at which this happened should correspond roughly to the altitude at which the physical condition of the climbers deteriorates. The matter requires a great deal more investigation. It is time that an Everest expedition took out with them a small party of people trained for the particular job of working out this problem and able to do some useful work. I do not think they would impede the expedition very much, because in 1935 we had with us Spender, who ran his own part of the show very well and did not interfere in the least with the climbing part of the expedition. The outcome of an expedition is a gamble in any season because so much depends on weather conditions. But if it could return with information on this subject alone, gathered by trained observers, it would have fulfilled a useful purpose.

As to Mr. Wager's question in regard to breathing oxygen only, actually the whole point of the closed apparatus is that because you are breathing oxygen only it is of infinitely greater value to you than breathing oxygen diluted by the outside atmosphere. The advantage is that it puts up the pressure of your oxygen.

Mr. WAGER: I meant that you do get some oxygen from the cylinder and some from the air with the older apparatus. In the apparatus you have shown us the oxygen all comes from the cylinder.

Dr. WARREN: You think the air itself might be beneficial?

Mr. WAGER: Yes, there is a small amount of oxygen in the air.

Dr. WARREN: Perhaps this will answer the question. I believe people have been able to breathe in an atmosphere of pure oxygen, with $CO_2$ absorbed, for periods up to twenty-four hours without any harm accruing. In the open apparatus such a lot of the oxygen is wasted in the breath which you expire. You do not use all the oxygen you take in at inspiration; you only use a comparatively small quantity, the rest is simply blown out into the external atmosphere and lost.

The PRESIDENT: We have been dealing with very practical problems this afternoon and one can only sympathize with the wish expressed by Dr. Warren that scientists capable of collecting the necessary statistical matter should

accompany expeditions. It seems to me to be wasting an opportunity not to appoint people who can devote themselves to the scientific aspect of expeditionary work and one does hope very much that, as far as it is possible, scientists will be provided and be accommodated on the next expedition to Mount Everest. But the work that has been done so far by Dr. Warren and others is all very much to the good, inasmuch as each set of observations in regard to the health and capacity of the expedition necessarily serves as a further stepping-stone to success in this great objective, the climbing of the greatest height in the world.

I must not detain you longer because you have already had a full afternoon and a very instructive one. All I would do now is to ask you to express your thanks and appreciation to Dr. Warren for the research work which he has done and for the practical paper which he has read.

# A PERSIAN GEOGRAPHER OF A.D. 982 ON THE OROGRAPHY OF CENTRAL ASIA

V. MINORSKY

IT is a matter of regret that the achievements of Muslim geographers of the ninth and tenth centuries A.D. are still very insufficiently known outside a narrow circle of orientalists. The fault lies to a considerable extent with those who keep this treasure [1] without thinking of rendering it accessible in European languages. No partial adaptations, even so excellent as le Strange's 'The lands of the Eastern Caliphate'[2] and P. Schwarz's 'Iran im Mittelalter,' [3] can give an adequate idea of the prodigious wealth of accurate information collected by the early Muslim scholars and travellers. Marco Polo's exploration is an outstanding event but it must not be forgotten that, three centuries before him, Muslims possessed most detailed descriptions of the countries, peoples, roads, and products of the area extending from Spain and Morocco to the outskirts of China and Tibet. The object of the present paper is to analyze the ideas of the Muslims on the orography of Central Asia, as they appear in the Persian geography written in A.D. 982, and bearing the title of *Ḥudūd al-'Ālam*, which may be translated as "The regions of the World." The author, whose name is unknown, dedicated his work to the local ruler of Gozgan (Northern Afghanistan) and presumably himself lived in the same region. From the point of view of Persian literature, the importance of the book is obvious, for it is earlier than Firdausi's famous 'Shah-nama' (A.D. 994). As regards its contents, the 'Hudud al-'Alam' is a compilation based chiefly on earlier books in Arabic, but the writer has preserved to us some very valuable data on such countries as China, Tibet, India, and Central Asia which are not found elsewhere. There are good reasons for believing that the original authority for these particular data is Abu 'Abdullah Muhammad ibn-Ahmad Jayhani, of whom it is known that in A.D. 913–4 he became Vazir during the minority of the Samanid king Nasr ibn-Ahmad. Jayhani's famous work, which consisted of seven volumes, is now lost and only known to us from occasional quotations. Owing to his high position in Bukhara, Jayhani was able to gather much new and valuable information. According to Muqaddasi (about A.D. 985) "he assembled foreigners, questioning them on the kingdoms, their revenues, the kind of roads leading to them, the height of the stars and the length of the shadows in their land in order in this wise to facilitate the conquest of provinces, to know their revenues," etc.

The author of the 'Hudud al-'Alam' [4] often mentions a map prepared by

[1] See 'Bibliotheca geographorum arabicorum,' ed. by J. de Goeje, Leiden, 1870–94, 8 volumes (of which only one is translated). 'Bibliothek arabischer Historiker und Geographen,' ed. by H. von Mžik, Leipzig, 1926–31, 4 volumes published (only a few chapters translated).

[2] London, 1905, reprinted 1930.

[3] Vol. I, 1896–1929; vol. II in progress.

[4] 'Hudud al-'Alam,' translated and explained by V. Minorsky, published by the "E. J. W. Gibb Memorial," New Series, vol. 17, 1937. The text of the translation has been divided into paragraphs, and the system of references has been retained in this paper. Signs of length have been used in rarer names when they are first mentioned.

himself, on which he evidently transferred the details found in Jayhani and the other sources accessible to him. This map has unfortunately not come down to us, but some idea of the "Face of the Earth" as represented by the author may be derived from the general chapters (§§ 3–7) in which he enumerates and describes the seas, islands, mountains, rivers, and deserts existing in the world.

The chapter on the mountains (§ 5) opens with the mention of [1] some Far-Eastern peninsula called *al-Tā 'in fil-bahr* ("Thrusting into the sea") and by a very detailed description of [2–5] a composite range [1] which must represent the longitudinal chains of Indo-China, continued by the mountains of the eastern Tibet, then by those stretching to the south of Sinkiang


*The 'Belt of the Earth' according to the author of 'Hudud al-'Alam'*

(Nan-shan, Kunlun), and finally the westernmost parts of the Tien Shan connected with the mountains which form the eastern and northern watershed of the Sir Darya (Jaxartes). Among the branches of this range are separately mentioned [6] Tafqan (Turfan?) which according to the details given corresponds to the Eastern Tien Shan, and [8] Tulas, which seems to be the Altai wrongly located to the north of the Issiq Köl.

After this comes the description of the "Belt of the Earth," which is the particular subject of the present paper. All the controversial points are fully discussed in my book and here we shall touch only on the geographical aspects of the question. Some names marked by asterisks have been restored to their better-known forms. The text runs as follows:

[1] Called *Manisa*, a name which may have been inaccurately transmitted.

" 9. Another mountain stretches from the district of Kūlī in Kanbāya belonging to Hindūstān. It follows an easterly direction, to Ṣāmūr, then takes a northerly direction, passing between Dahum's country and that of the raja of the Hindus up to the limits of Hītāl. Then this mountain splits into two branches."

*Commentary.*—As the Lesser Mihran (Narbada) is said to flow through Kuli the initial point of the chain is probably to be sought to the south of this river (the Saler peak?). The name Samur is somewhat doubtful but, if we restore it as *Saymur*, the latter is the usual name of the modern Chaul. It is also possible that, by a mistake of orientation frequent in our author, "eastern" must be understood as "southern." In any case the further extension of the range must be imagined in the direction of the Mahadeo hills and then across the Ganges valley to some point in the Himalaya. It is noteworthy that our author entirely overlooks the existence of the Ganges though the latter is well known to the Arab geographers. By the "raja of the Hindus" the master of Kanauj is meant, whereas Dahum is said to be the king of central and eastern India. Hital (or Hibtal) is one of the three sub-Himalayan principalities named by our author in the region of Nepal.

" 9A. One branch running northwards enters the confines of Tīthāl and Nītāl and passes between the farthest border of India and Tibet, while it runs north of the confines of Bolor, Samarqandaq, *Shughnan and Wakhan, and south of the desert; then on the confines of Zhāsht it takes a north-westerly direction and crosses the region of Buttamān belonging to Transoxiana, until it reaches the confines of Usrūshana. This mountain has numberless ramifications in the districts of Shughnan, Wakhan and Zhāsht."

*Commentary.*—Hital, Tithal, and Nital are three sub-Himalayan countries, and the form *Nital* in Arabic characters can be very easily read as *Nepal.* The point from which this branch continues northwards can be tentatively taken for Dhaulagiri. Bolor is the region of Ladakh, etc., and Samarqandaq is probably Sarhad near the sources of the Oxus. The chain represents the Karakoram continued by the Pamir knot and the Alai mountains. Zhasht (usually Rasht) is Garm on the middle course of the river Vakhsh. This river rises in the Alai valley and in its lower course is the most important right-bank affluent of the Oxus.[1] The further extension of the range is the northern watershed of the Oxus separating it from Samarqand. Usrushana is the old name of the province lying between Samarqand and Khojend.

"9Aa. From the interior of Wakhan and Zhāsht start numerous mountains spreading out inside the region of Khuttalān. One of the branches of Khuttalān separates and joins another stretching from the district of Buttamān. From them numerous ramifications run into the district of Chaghāniyān, where they scatter. And where the said original ridge of the mountain [9A] comes near Buttamān it splits into two, but near Usrūshana (these two branches) unite again. From the region of Buttamān a branch shoots off which passes between the Buttamān-of-Daryāzha and Chaghāniyān and skirts the confines of Samarqand and Soghd down to the confines of Bukhara . . ."

*Commentary.*—This paragraph refers to the mountainous country corresponding roughly to the area of the present-day Soviet republic of Tajikistan

[1] Even the Greek name of the latter (Ὦξος) is supposed to be a tentative rendering of the Iranian name Vakhsh.

on the northern bank of the Oxus. Khuttalan was the district between the Wakhan river and the Pamir; Chaghaniyan stretched to the north of Termez and to the west of the Vakhsh; Buttaman represents the parallel chains of Turkistan, Zarafshan and Hissar stretching south of Samarqand. Daryazha (a Soghdian form for Persian *daryacha* "small lake") corresponds to Iskandar Köl feeding the Samarqand river.

" 9B. As regards the other branch, from the frontier of Hītāl it runs inside Hindūstān, follows the border of *Kanauj and passes between the country of the 'continental' Jāba and the kingdom of al-Jurz, where it is called Qasak. And so it runs north of the confines of Kashmir, Vayhind [the capital of Gandhara], Dunpur and Lamghān and south of Bolor, Shughnan, Wakhan and Badhakhshan, to the south of the districts of Khuttalān. Then it enters the region of Tukhāristān, stretches between *Talaqān, Sakalkand, Khulm [Tashkurghan], Simingan [Haibak], and south of Balkh and penetrates into the region of Sān and Chāryak belonging to Gozgan."

*Commentary.*—Taking again Dhaulagiri for the starting point in the sub-Himalayan region we must identify the range with the inner chains of the Himalayas. Jaba's kingdom seems to correspond to the present-day Chamba state. Al-Jurz is the Arabic name of the Gurjara dynasty which reigned in Kanauj. The further extension corresponds to the Hindukush. Dunpur and Lamghan stand here practically for the Kabul region. Dunpur (Adinapur) is situated on the Surkh-rud tributary of the Kabul river, and Lamghan along the left affluent of the Kabul river flowing from Kafiristan. Tukharistan is the region to the east of Balkh. San and Charyak (now Sang-Charak) is the small district south of Sar-i pul (to the south-west of Balkh).

"9Ba. Then it turns westwards and in a north [read: south]-western direction penetrates into Ghor, passing south of Aspizār [Sabzar], Herat, Bushang and Nishapur. Between Nishapur and Sabzawar it runs north of the [Khurasan] road and again turning westwards passes north of Semnan and Rey and enters the region of Daylaman, stretching on up to the end of the limits of Gilan."

*Commentary.*—This branch corresponds to the part of the Hindukush [Siyah-koh] stretching to the south of the Hari Rud which then is brought into connection with the southern Khurasanian mountains and the southern face of the Elburz mountains.

" 9Bb. And when this mountain after having deflected its course from Balkh reaches Madr belonging to Tukharistan, so many small and large branches spread out of it that only God knows their number. From each of its branches numerous spurs shoot off and spread in the region of Tukharistan, Andarab, Panjhir [Panjshir], Jāriyāna, Bamiyan, Bust, Rukhkhad [ancient Arachosia], Zamindavar and Ghazni and further stretch down to the region of Sind. And when the range of this mountain reaches the districts of Ghor, a branch shoots off from it and forms a circle like a finger-ring, then the branches unite again. . . . And from this ring of mountains a large branch shoots off which together with those other branches takes a westerly direction and spreads out in the region of Bust and Ghazni. Likewise in the neighbourhood of Aspizār this mountain possesses small offshoots which spread out in the districts of Aspizār."

*Commentary.*—This is the central part of the Hindukush with its southern ramifications near the headwaters of the Helmand. The "finger-ring" is most likely the valley of Dasht-Navur, which lies 35 miles to the north-west of Ghazni and has no outlet.

" 9Bc. On reaching Sān and Chāryak belonging to Ġozgan this ridge [9B] splits into two branches: the one is that which we have described [9Ba]; the other runs north of it, taking a westerly direction between Kundarm and Anber (Anbār). It stretches between Gurzivan and Jahudan [Yahudan] between Bashin and Diza, between Marvarod and Baghshur and south of Sarakhs. Then it takes a northerly direction and runs to the region of Tus, Bāvard, and Nisā, until it reaches Gurgan. Then comes a valley three days long but narrow, called Dīnār-zārī. The mountain stretching on the other side of the valley directs its course through Isfarāin until it reaches Gurgan. Then it turns south-westwards running south of Amol and the towns of Tabaristan down to the region of the town of Rey. Then it joins the other chain [9Ba]. The two chains united go up to the end of the province of Gilan."

*Commentary.*—This is the watershed of the Murghab and the Hari Rud [Band-i Turkistan] which, beyond Sarakhs, is prolonged by Kopet Dagh. Dinar-zari is the valley [Dahna-yi Gurgan] from which the Gurgan river rises. Further the description follows the watershed of the Gurgan and the rivers of Isfarain flowing towards the Iranian plateau. The range is then connected with the Elburz system, or more precisely, with its northern face overlooking the Caspian coast. According to our author the two branches meet in the region of Rey, which is not far from the truth in view of the existence of a knot of mountains to the west of Demavend.

"From Hindustan where this mountain begins up to Gilan where it ends it is called *Kamar-i zamīn* 'Belt of the Earth,' or in Arabic *Minṭaqat al-Arḍ*."

*Commentary.*—This conclusion leaves no doubt about the author's intention to trace a continuous system of mountains between India and the Caspian Sea.

Perhaps the most original point of the description is the clear tracing of the ranges to the north, and to the south, of the Oxus. It is curious that the point of their separation is placed not in the neighbourhood of the Pamir but at some knot in the Himalaya which we tentatively have taken for Dhaulagiri. The distinct course of the two chains presupposes some knowledge of Karakoram [9A], for the Great Himalaya range distinctly belongs to 9B. However, confusion in details, probably borrowed from different sources, was inevitable. So the position of the mountain Qasak (as described under 9B) seems to contradict the item quoted in the chapter on the rivers: "It is said that from the summit of the 'Mountain of Ice' which is Qasak, a water springs up like a fountain and . . . separates into two in such wise that one half flows northwards and it is the river Kharnab [one of the headwaters of the Oxus], and the other flows southwards and it is the river Sindrudh, which afterwards becomes the Mihran [*i.e.* the Indus]." The name "Mountain of Ice" (*Kuh-i yakh*) may be the Persian prototype of the present-day Turkish *Muz-tagh* (*-Ata*) which has precisely the same meaning. Muztagh Ata, situated to the east of the Pamir near the watershed of several rivers, is indeed more suitable for our author's story.

The idea of a "Belt of the Earth" may be of remote Zoroastrian origin. In the *Bundahishn* [1] the Elburz is represented as stretching "around the earth and connected with the sky," whereas the other mountains, 2244 in number, "have grown out of Elburz." The term itself *Kamar-i zamīn*, or *Minṭaqat al-Arḍ*, apparently does not occur elsewhere in Muslim geographers but Ibn Hauqal, who wrote *circa* A.D. 977 and utilized Jayhani's book, speaks of a mountain stretching along "the spine of the earth (*'ala ẓahr al-arḍ*)." According to him, in the east "it starts from China where it comes out from the Ocean and runs to Wakhan. It crosses Tibet, in the western part of the latter and not in its centre, and the eastern part of the Kharlukh land [2] until it enters Farghana which is within the Islamic territory. The ridge stretches over Farghana towards the Buttam mountain situated south of Ushrushana. . . . Then it takes a direction towards Samarqand, skirts the latter on the south and runs towards Kishsh and Nasaf [Qarshi] and the region of Zamm[opposite Karki]. Then it crosses the Jayhun (Oxus) and stretches westwards to Juzjan (Gozgan) . . . and over Talaqan to Marvarud and Tus . . . leaving Nishapur to the east. Then it stretches to Rey . . . while the mountains of Jurjan, Tabaristan, Gilan and Daylam branch off from it. Then it joins the mountains of Azerbaijan." After that it continues along the right side of the road from Rey to Hulwan [near Sar-pul in the Zagros], turns north towards Tekrit and Amid [Diyarbekir] sending off its branches into Armenia and towards the Caucasus. Then it runs on towards Mar'ash where it joins the range coming from Syria. Through the latter the principal range is joined to the North African mountains which extend to the Atlantic.

As one sees, the idea of Ibn Hauqal is practically similar to that of the 'Hudud al-'Alam' but the tracing of the range has many independent features. It connects China with the Atlantic and in the eastern parts its description is rather vague. Our author, on the other hand, is incomparably more precise in his statements and treats the "Belt of the Earth" separately both from the Far-Eastern chains and the range which—also with many curious details—he traces between the Sinai and the Caucasus.

In any case the 'Hudud al-'Alam' marks an important stage in the study of the orographic system of Asia, which even in our times cannot be considered as quite complete. The description given in the book is not only accurate in its general lines but contains a mass of very precise details. Down to the nineteenth century we should look in vain in European literature for an equally clear picture of Central Asian ranges.

[1] English translation by E. W. West, 1880, ch. XII.
[2] In the neighbourhood of the Issiq Köl.