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PHOTOGRAPHIC SURVEYS IN THE MOUNT EVEREST
REGION: *A paper read at the Afternoon Meeting of the Society on
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THE main purpose of Mr. Shipton's Expedition of 1935 (*Geogr. J.*, February 1936) was to see whether the conclusion of 1921, that the monsoon season was unsuitable for an attempt on Mount Everest, was applicable every year. When I was asked to undertake survey work as a member of the 1935 expedition I realized that conditions were likely to be adverse, since the Reconnaissance Expedition of 1921, while carrying out the important preliminary mapping of the region, experienced much bad weather and cloud. But it seemed that photographic methods of survey might be suitable, and it gave an opportunity to put the technique acquired in Greenland to a test of some severity.

From a surveyor's point of view things turned out by no means badly. Not only was Shipton an encouraging and gifted leader to the party, but he and his colleagues surprised me by throwing themselves actively into the business of assisting the survey. In particular he, Warren, and Kempson showed throughout the summer an unflagging interest in map-making which expressed itself in taking one of the instruments to stations on pinnacles and places that an untrained mountaineer would never have reached. Nothing can be more gratifying to a surveyor than such practical enthusiasm.

The dominant recollection of the summer is cloud. Nevertheless the weather was, I think, better than that of 1921. Wheeler must have had a very difficult time during his survey. He covered a large area and occupied high stations, resolutely climbing several times to the same point if necessary. One advantage he had over me: he was an experienced climber. But on the other hand I think I can reassure any prospective surveyor without this training by saying that even in the Himalaya effective stations can be reached by just walking; and that as far as 22,000 feet the normal person is not put to any severe endurance test.

The Mount Everest Committee were anxious to obtain a more detailed map of the north face of Mount Everest than that available: a more precise

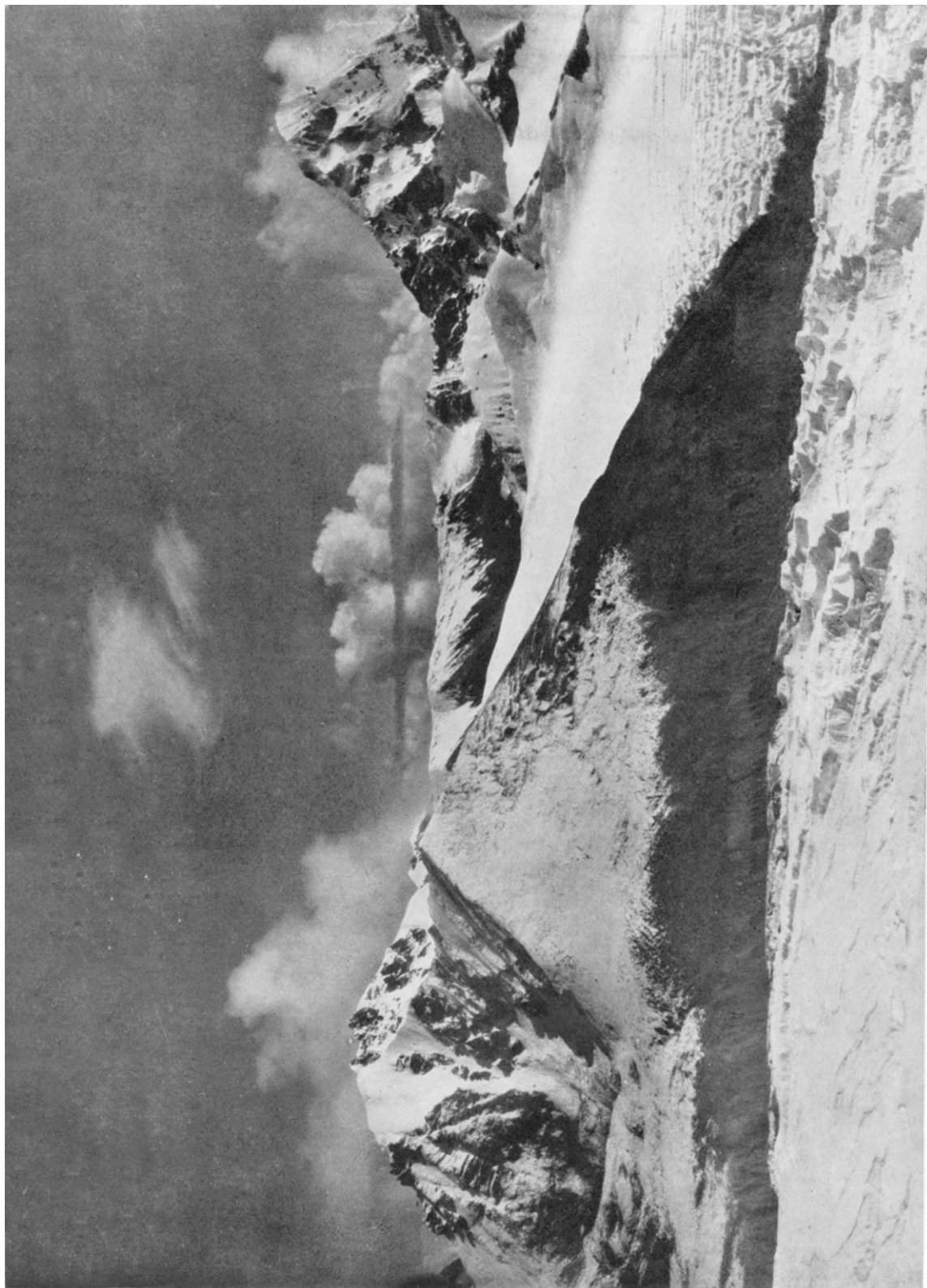
knowledge of the heights on the route followed up the mountain would also be of value to the mountaineers of the 1936 expedition. This then was the principal task. Naturally we hoped to be able to add something *en route* to our rather slight knowledge of the country through which we were to pass.

The Wild photo-theodolite belonging to the Society and used by Major Mason in the Shaksgam in 1927 seemed in every way suitable for the Mount Everest part of the survey. But I felt that for rapid work in high territory something at once lighter and to me more familiar would be desirable. So I suggested that the Committee approach Professor Nørlund, Director of Denmark's Geodetic Institute, to see whether he might be willing to lend us the Zeiss photo-theodolite adapted for roll-film that I had used in Greenland in 1933. With great and, if one may be so bold as to say so, characteristic generosity Professor Nørlund put the instrument and two tripods at our disposal, and in this way assisted the expedition very materially. All the work of assembling the equipment had to be done in three weeks, and I have reason to be grateful for the promptitude shown by certain firms such as Messrs. Agfa and Perutz, supplying film, and Messrs. Watts and Leitz (Leica), supplying instruments.

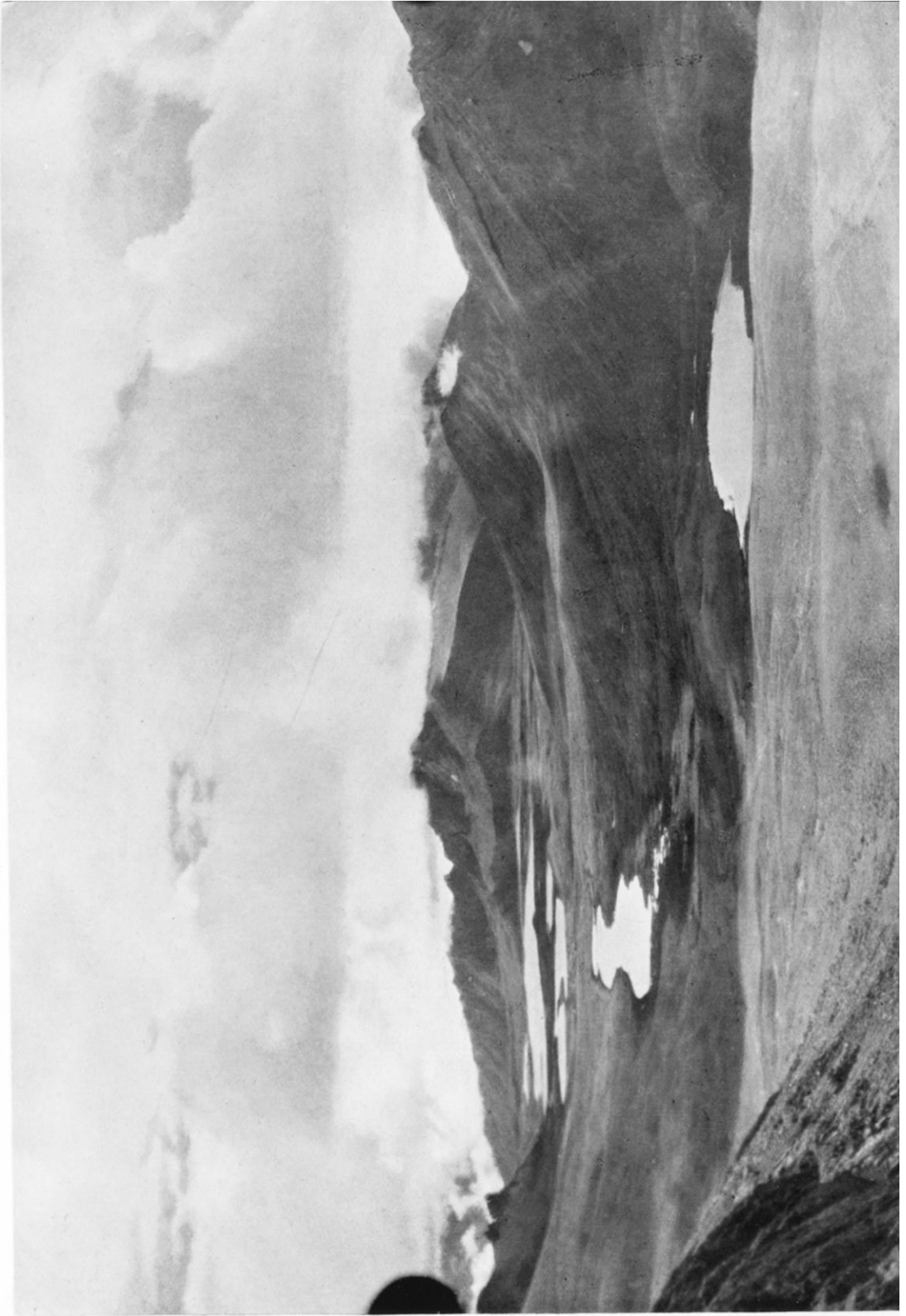
Mr. Hinks and I were agreed in considering the opportunity as one in which the broadest possible experience should be gained. So to the two sets of equipment already decided upon for photographic survey we added a third. The Watts-Leica photo-theodolite was to be the very extreme of portability and simplicity. The instrument as we took it into the field was a hastily constructed assembly of a Leica camera on a Watts Mountain Theodolite. It was intended for the Canadian or single-picture method of photogrammetry; but it was also an end in itself to find out to what extent this or any other technique of photogrammetry could suitably be recommended for people more skilled in climbing or travelling than in survey work. The value of a semi-calibrated camera to the explorer has not yet been fully worked out; here was a chance to make a start towards finding the usefulness of photographic methods to exploratory surveying. (Folding map at the end of the *Journal*.)

To glance over a few sheets of the Trans-Frontier $\frac{1}{4}$ -inch survey is to realize how many opportunities there are for a surveyor in Tibet. At one time we had hoped to photograph the country to the west of and, for us, beyond the approaches to Mount Everest. The Lapche Kang range is only very approximately known and might have given some climbing experience to the party. But after talking it over we thought that it would be better, if we were to attempt any work away from Mount Everest, to use the fine weather before the monsoon broke. Since we expected to reach Rongbuk at about the time of the break of the monsoon, this meant that it would be best to photograph some district on the road between Sikkim and Everest. The Nyönno Ri range was the obvious point of interest.

After leaving Darjeeling on May 27 we crossed into Tibet on June 4, making for the junction village of Sar, which lies at the foot of the range we called the Nyönno Ri, after the Survey of India's designation of the highest peak, a 22,000-foot mountain. (This name, by the way, was unknown in the district. Nor was the name Sangkar Ri, for a conspicuous point on the same range a



*Looking across
the head of the
Khartachangri
Glacier. Point
20750 (left)
and "Dent
Blanche" (right)*



*Deglaciated
country at the
head of the Lang
Chu*

little farther towards the north, familiar to the local inhabitants.¹) Some of us who had been finding the continued climbing slightly distressing towards the end of the route out of Sikkim enjoyed walking over the level tracts of Tibet. The ritual of Asiatic travel was new and the weather fine. At nights it would freeze, but the mornings were clear, so that until about 10 o'clock the snow-range we were marching for stood challengingly before us. We were walking along the headwaters of the Arun river. A day's march from Sar a big stream from one of the glaciers in the Himalaya to the south crosses the route, turning the uncertain trickle that comes from farther eastwards into a decisive river. At Sar it swerves north to flank the range before altering its course southwards into the valley above Kharta, after which it enters the well-known gorge cut through the Himalaya into Nepal.

There had been some delay in the issue of our passport from Lhasa, and we arrived at Sar without it. So in any case a halt was obligatory. We asked at once whether the authorities had any objection to our making a reconnaissance in the region. Finding no obstacles in our way we quickly got to work, urged by the patent inaccuracy of the existing map.

Impressions from the Sar work have been somewhat overwhelmed by the more vivid experiences in the Mount Everest region. Sar is at about 14,000 feet and the stations were at about 18,000 feet. The heights being moderate and the going easy, one could start some hours before dawn, picking a way across the marshes with a lantern and hoping for the sunrise as one kicked a way up the frozen scree-slopes. Between June 10 and June 20 I was able to occupy six stations. These I naively thought of as the beginning of a far-reaching survey to include the Nyönno Ri range and the territory to the east as far as Muk and to the south as far as the watershed. The work started by Shipton taking the plane-table, Kempson the Watts-Leica photo-theodolite, and I the Danish light equipment. Shipton found a pass through the range and made a beginning with fixing detail to the westward. Kempson's stations were on the range and commanded the country to the east. My stations were to map the range itself and then the main river valley as far as Lungme. Not until June 20 did it appear that we had unwittingly gone further than was pleasing to the higher authorities. By the next day it was clear to us, all parties being reassembled in camp at Sar, that the remaining photography we had hoped to do in the unknown western parts of the range could not be done. June 21 to 25, days of idle confinement in camp, were remarkably fine. The account of our work here would be incomplete without recording the generosity and hospitality of the Dzongpen of Sar.

The march from Sar to Rongbuk showed that the existing maps are very inadequate between Lungme and Tashidzom. When we arrived at Rongbuk on July 4 the wind was westerly and the whole country under cloud. This was responsible for giving us a very imposing first sight of Mount Everest. As we walked up through what Norton called the "gates of altitude" a slight clearing in the cloud revealed the mountain—but not where we had looked for it. The peak was just about twice as high above the horizon as expected, and the bulk of the mountain appeared enormous. The ridge to the summit seemed utterly remote and inaccessible.

¹ It is Mr. Odell's opinion that this range should be called the Gyangkar Ri.

The Rongbuk valley itself produced something equally fantastic. The numerous chortens, cairns and *mani* walls made one conscious of treading on sacred territory. But when suddenly the barren valley contained a crowd of some two hundred persons, inhabitants of the monastery, one wondered where one had strayed.

That night there was a great thunder and hail storm and in the morning the wind was in the east. July 5, 6, and 7 were days of dazzlingly fine weather, when Mount Everest and all the high peaks, white with new snow, were clear and glittering the whole day through. Unavoidably a certain amount of time had to be spent in unpacking and rearranging stores, as well as in observing the customary formalities at the monastery. We had arrived just at the end of one of the occasions of pilgrimage. Among those who had come to Rongbuk was a friend of former expeditions, known as Old Father William, a wealthy Tibetan from the Kharta valley. There was a very great crowd of people at the monastery and on the last evening they played some fine concerted music.

My own plans had meanwhile developed to become an attempt to make a survey bounded to the west by the western heights of the Rongbuk valley, to the north by Base Camp, and to the south by Mount Everest: the eastward limit was left undefined.

The decision to re-survey in part a region already surveyed did not imply that the existing map was in any way inadequate. On the contrary, Wheeler's 1-inch map covers a very large area and without it as basis I doubt whether the present photogrammetric survey would have been possible.

I began by taking stations on each hand of the Rongbuk valley at the Base Camp. Forging the glacier stream before dawn to reach the western station was possible but exceedingly unpleasant. I then went up the side valley to the east of Base Camp and managed to get two stations in the basin north of the triangulated peak 23180 (Kellas Rock Peak). After summoning more provisions from Rongbuk I started up the western side of the Rongbuk glacier, with the idea of pushing up towards the Lho La, but decided that it was the wrong side from which to descend on to the glacier, which in any case was a very unfamiliar kind of glacier to me. So, after getting a station on a height opposite Camp I, I started off to join Shipton and the rest of the party at Camp III. My party met some of the Sherpas of the climbing parties at Camp II. We were told dreadful stories of the necessity of going through raging glacier torrents waist deep in which somebody had nearly been drowned the day before. But next day we got to the "trough" up the centre of the East Rongbuk Glacier without any trouble and there met Shipton, Kempson, and Wigram descending.

There followed some change of plans. For the rest of the season I was privileged to be with one or other climbing party, on the two journeys up the Khartachangri Glacier and the final tour to Kharta. The sequence of events is described in Shipton's paper (*Geogr. J.*, February 1936).

Generally speaking I worked as described in the paper by Professor Nørlund and myself ("Some Methods and Procedure developed during recent Expeditionary Surveys in South-East Greenland," *Geogr. J.*, October 1935). But bases are much more difficult to obtain in the Himalaya than in Greenland. In particular it is difficult to find a base commanding Mount Everest.

One's problems are much confounded by the bad weather and the natural reluctance to climb induced by the altitude. Even if one knows of a possible base it is difficult to decide how many days one is prepared to invest in its doubtful success. The climber, forced to make his peak in a snowstorm and fog, considers his achievement a partial success and moves on to the next task. But a surveyor requires much more of the weather: the longer he spends getting to his station, the less likely he is to get the weather he requires.

As July passed and led into August, extreme speed of working became necessary: often I had to have all the observations from a station finished by 7 a.m. I used to attempt to get into position at the station by 5 a.m. and from then would wait until the dawn brought enough light to illuminate the theodolite circles. This meant abandoning most of the desirable features of triangulation routine. A second round of angles was quite out of court. The collimation constant of the level, which has to be known for the Wild instrument, could only be determined about once every four stations. Very careful choice had to be made of the points to which observations were made, if the station was to be finished. These rushed stations were very tiring, as much or more than a whole day's travelling.

My Sherpa assistants were excellent. In particular Tewang and Ang Tsering deserve mention. The latter was new to responsibility, but showed himself in the course of the summer to be reliable and sensible and to have a natural gift of leadership. Tewang is better known as a trustworthy and intelligent person—he can in fact write; but he is beginning to be rather too old for load-carrying at high altitudes. This summer he struggled on handicapped by amoebic dysentery: he must have had a good deal of distress, but only went back to Kalimpong for treatment after I had been frightened by the appearance of similar symptoms in myself.

On September 6 we finished as much as we were able to do for the photogrammetry of the Mount Everest region, and returned via Kharta, regretfully abandoning the completion of our photography in the Nyönno Ri Mountains in obedience to the wishes of the local authorities, who had received definite instructions on the subject from Tenkye Dzong. We had some ten days to spare, and it then occurred to me to make use of the remaining survey material in a short campaign in the extreme north of Sikkim. We had noticed on the way out that those fine peaks and ranges near and on the Tibetan border were very inadequately mapped. So I thought of spending a week in the valley which runs parallel to the frontier north of Kangchenjhou (Kangchima) and Pauhunri. The base would have been at the station Gayokang. But when we arrived there a variety of circumstances such as the parlous state of our equipment and the obvious persistence of the monsoon, together with the consideration that I had work at home more urgent than a survey having nothing to do with Mount Everest, persuaded me to give up the project and push on to Bombay with all speed.

It was possible to make a few physiographical observations on the journeys in Tibet. For instance it is obvious before one comes to Sar that the wide flat-bottomed valley of the Yaru Chu is a lake bed. My untrained eye was not able to trace evidence for more than one lake terrace above the gorge at Rongkong. In the neighbourhood of Tshetok there is still extensive flooding

of the valley floor. The lakes contain much pond-life, weeds and crustacea, which one would have liked to investigate. There are trout in the rivers and channels all up this valley. But most surprising of all is the number of common terns—animals one had previously thought of as sea-birds. There were many birds here which Kempson attempted to observe and will perhaps at some time give an account of. The Tibetan goose is one of the most striking of them.

Beyond Rongkong the river has cut itself a gorge, which is now working back through the lake deposits. The river is there called the Yaru Tsangpo and again runs over a lake bed, though here the terracing is more complex and much higher above the valley floor. The structure of the river already observed is typical. A lake basin is followed by a gorge which now cuts back into the basin preceding it. The Kharkung gorge extends really from the head of the Kharta basin to the villages round about Ne. The present stream has cut deeply into the water-laid strata, apparently revealing alternating periods of drought and raininess. Terracing is again obvious in the valley of the Phung-Chu above the Kharta district.

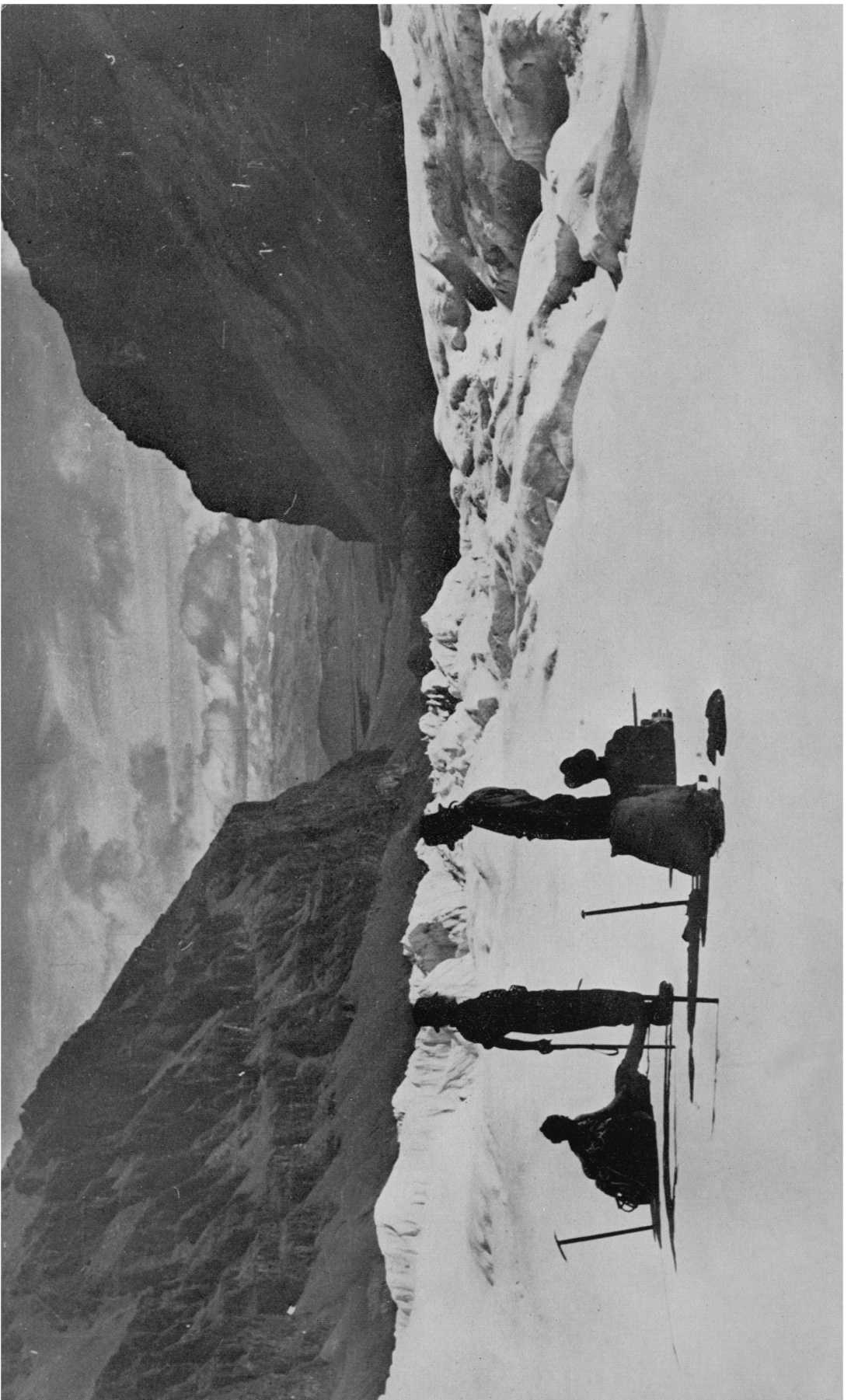
The filled-up lake floors, the rubble-filled narrow valleys seen between Lungme and Tashidzom, and the type of erosion in the Sar district all point to a period or periods of great rainfall rather than an extension of the existing glaciation. Auden, of the Geological Survey of India, has told me of similar pluvial evidence on the southern slopes of the Himalaya.

The Arun river itself is distinguished by its gorge through the Himalaya. It is generally assumed that as the folding of the Himalayan range took place the gap maintained itself. But there is a striking point in connection with the glaciation of the region. To cross from the Rongbuk region to a side valley of the Arun is equivalent to passing from East to West Greenland. The two districts are in completely different stages of glaciation. But the maximal glaciation would appear to have been the same on both sides. The present retreat of the glaciation in the Kharta valley is due to the masses of warm air coming up the Arun valley. As explained in Appendix IV, the cold north-west wind holds at even moderate heights during most of the monsoon period. Often, when the weather in Rongbuk was fine and cold, the Kharta district could be covered in a dense ceiling of cloud, under which, presumably, rain would be falling. These facts might be taken to indicate a more recent origin of the gorge.

From the photographs taken with the two photo-theodolites and earlier material the network of the Everest and adjoining survey is now plotted and heights have been calculated in the Everest region. Plotting has been by graphical methods; none other would have been possible. The rays were laid out on Kodatrace and the sheets from several stations superimposed where doubts or discrepancies arose. The state of affairs seems to be somewhat as follows. Wheeler started with a number of points supplied by the Survey of India. Morshead attempted to check the accuracy of these points by observations from a station north of the range, but he was impeded by cloud from getting any results. Wheeler found that some of the points given were non-existent, or grossly in error. Others were somewhat in error—for these Wheeler was able to determine better positions by use of the remainder. But even the remainder were probably slightly in error and any attempt to survey into the



*View from above
Sar eastwards
up the valley of
the Yaru Chu*



compromised network reveals the shakiness of the whole system. The principal effect is to make it seem that certain individual points are erroneous, partly due to an accumulation of slight error from other points. Actually the adjustment in plan can be made so that the distortion is very slight indeed. But where the observations to peaks are at such considerable angles of elevation it is difficult to make a height network of great accuracy, or even sufficient accuracy for photogrammetric purposes.

As previously stated, the long-base range-finding method was used. Its value for reconnaissance was very strongly shown during the journey to Kharta. Here, as on so many other reconnaissance surveys, it was necessary to travel as fast as possible. As travel meant crossing at least one pass every day, one tended to lose sight of one's fixed points. After crossing the last pass into the Lang Chu we were in very foreign territory. Three stations were planned and occupied in two mornings, Dr. Warren taking one of them with the Watts-Leica instrument. It was by no means easy to fit these stations together or into the network. There were in fact several possible solutions. But by using the approximate length of the rays along which distances had been measured in Station XXV a criterion for the final solution was obtained. Thus the actual lengths were not used; but the fact that they must be approximately correct was decisive.

For a surveyor interested in the development of the technique of exploratory and reconnaissance survey it was a productive summer. I found that travellers of Shipton's calibre became with greater experience more and more anxious to make maps; I feel that it is a proper occupation for experts to turn this enthusiasm to good purpose and devise methods of survey whose field operations can be carried out by climbers and people with non-technical minds. Photographic methods are not only adaptable to this end, but were taken up with understanding by the members of the 1935 party. In fact they asked to be initiated into the methods of stereo-photogrammetry, seeing its value in the survey of a region often obscured by fog, when the grasp of the topography and recognition of points necessary for plane-tabling become very difficult. The impression, strengthened by such abortive attempts to use the R.G.S. equipment as that of the Oxford University Club's expedition to Spitsbergen, that the photogrammetric method is not suited to exploratory surveys is erroneous: the criticism contained in the appendix to Mr. Glen's account ('Young Men in the Arctic,' Faber & Faber, 1935) is that of an uninstructed person.

As I see it, the crux of the problem of photographic survey is provision for the working out of results afterwards. Certainly intrinsically better and greater results can be obtained by the use of photogrammetric methods in the field; but something like a permanent establishment is required to plot the work afterwards, equally whether mechanical or simple methods are used. I suspect that in such an institution as Professor Finsterwalder's in Hanover those learning survey can help in the plotting of expedition results. No doubt the Royal Geographical Society will see to it that a Mount Everest survey is plotted. But one hesitates to advise other expeditions to use photographic survey as long as there is a risk that there may be no opportunity of getting the results worked out.

APPENDIX I: THE SOCIETY'S WILD PHOTO-THEODOLITE IN THE FIELD

In its original form the Wild outfit is portentously bulky and heavy for exploratory work. A beginning was made towards lightening the assembly by replacing the old tubular subtense-bar by the new invar bar from the same firm. Lighter tripods have also appeared since 1927; they weigh 10 lb. complete. In the field weight was cut down by leaving at the Base the long-focus camera, used only on special occasions. (That the camera was afterwards stolen from the dump was an unfortunate, but not a necessary, consequence.) Nor was this the final weight-saving. The equipment includes a heavy box containing three pairs of base-rings and sighting targets. It became my custom to take two rings and one target in my rucksack, leaving the rest below. When the station to be occupied has been especially difficult I have taken the plate slides wrapped in clothing in my rucksack and left their case (of metal) behind.

But even without this last expedient the total load was cut down from nearly 250 lb. to something nearer 130 lb., if only a dozen plates and two tripods are taken into the field. This can be distributed as three very moderate loads for mountain work or two full loads for valley transport. The remaining accessories, note-books, binoculars, etc., must be carried by the surveyor himself.

There is still a possibility of saving weight on the subtense bar, weighing at present 14 lb., by using a type that I have seen in experimental application in Denmark, where a couple of targets slip on to the ends of an aluminium rod, divisible like a tent-pole and held in a light aluminium casting. All weights in exploratory survey must be measured against the 2 lb. which is the weight of a man's daily food ration.

APPENDIX II: LUBRICATION

A minor point arising out of the use of both the Wild instruments, the Society's photo-theodolite as well as the Survey of India's Universal theodolite, was the defective lubrication. Both instruments became unreasonably difficult to handle at very moderately low temperatures, *e.g.* at no more than 10 degrees of frost. If however the instruments had been all night in the field—frequently during a high traverse I would visit the station on the previous evening and leave the gear up there—exposed to such temperatures as 20 degrees of frost, then foot-screws, slow-motions, focussing-ring, etc., were all locked fast and only to be shifted by the use of considerable force. It was the grease or vaseline with which the various bearings are packed which was at fault. In one or two instances the oil supplied accessory to the instruments was used to replace the grease; it seemed to be perfectly satisfactory at low temperatures. The grease has not only the disadvantage of arresting the motion of the bearings at low temperatures, but it also begins to run at moderate degrees of warmth, so that the handling of the instrument becomes a function of temperature.

APPENDIX III: TRANSPORT

The approach to Mount Everest is over a path passable to mules, donkeys, and yaks. Which of these animals one gets is generally settled by local conditions. The mules are fastest and in good condition can do the average 25 miles of a double stage in a day. Donkeys are not so fast; when they are in good condition a double stage is not beyond their powers, but successive double stages cannot be covered without distressing the animals.

Yaks are strong and reliable, but so slow that there can be no question of double marching.

Each of these methods of transport is very rough on the loads. The best loads would be packed in boxes and would weigh about 60 lb. When Major Mason was in the Karakoram in 1927 he packed the loads in a layer of spongy rubber; the wisdom of this arrangement was well shown during this year's expedition. My own ignorance of conditions led to some avoidable wear and tear. The "Venesta" boxes are to be recommended, especially for stationery and minutiae. Rucksacks were not good; not only the contents, but usually also the rucksack itself became broken. This style of packing also offers too much temptation to mule-drivers to search and to rob.

It might have been thought that boxes were an awkward form of packing in very mountainous country. But this is not the case. A Mount Everest porter makes up such a load with his own property into a cumbersome parcel which he carries by means of a head band. It is convenient if loads can be broken down into smaller units than the above-mentioned 60 lb., though 60 lb. is a load which could be carried by a porter on a main transport line between camps.

APPENDIX IV: WEATHER

The main periods of the weather were defined first by the approach of the monsoon and then by its weakening. The front of the monsoon is not a definite thing; it is rather a zone in which disturbances from the main monsoon advance and retire and traverse. In Mount Everest literature the "break" of the monsoon is a term usually employed to mean the instant of arrival of the first of these skirmishing disturbances. From that time onwards, of course, similar disturbances are likely to come up from the plains, bringing snow and cloud. But it may be some time later that the great body of warm air reaches the highest Himalaya. And there may be a longish period of fine weather between the first storm and the arrival of the deep mass of monsoonal air.

We crossed the frontier into Tibet on June 4 and did not reach the Mount Everest region until the first days of July. Our observations are therefore taken at different times in different places. When we entered Tibet however we found a definite routine obtaining which we took to be typical of pre-monsoonal conditions for that territory. We had the Sar district under observation from June 4 until June 26, since the Nyönno Ri can be seen from the Kongra La. The mornings were fine and clear until about 9 a.m., when cumulus clouds would form round the mountains; at about 10 a.m. a south-west wind would begin to come in, soon hardening to a fresh breeze and itself strong enough to forbid instrumental work, even if the clouds had allowed it. Such conditions were however very nearly ideal for survey. The nights were cool—at 15,000 feet in the valleys there were a few degrees of frost on most nights. But even at 18,000 feet the cold was not severe. Work was possible from 5.30 a.m. onwards and to finish a station before 9.30 presents few difficulties. The form of the hills made the choice of bases easy; probably the whole district could have been surveyed without recourse to bases laid out on snow.

It is not suggested that every day was of precisely the type described. There were of course alterations superposed on this régime. But it was not until June 26 that this rhythm seemed definitely to be broken. What actually happened was that it began to rain at night and on into the morning. The days were continuously clouded. In that part of the world, some hundred miles eastward of Mount Everest, the upper, rain-bearing wind seemed to be easterly

or north-easterly, although often the day wind from south-west or west would blow underneath it. Both the valleys flanking the Nyönno Ri, the valleys at Sar and at Kharta are noted for the strength of their local winds. Curiously enough we found even during the pre-monsoonal period that as low as 2000 or 3000 feet above the valley floor these winds were very much weaker.

The weather about Mount Everest between the fine period at our arrival and the beginning of August was irregular but seemed to overlie a rhythm, occasionally concealed, of the same type as the weather of Sar. Interspaced between days which started fine and clouded up fairly early there were single days of bad weather. The worst day was July 16, when snow fell until well below 16,000 feet. This day found Shipton and his party on the North Col, where the great mass of snow made movement dangerous and rather falsified the impression of conditions there. But in general the bad days came singly, not as in the Alps in groups.

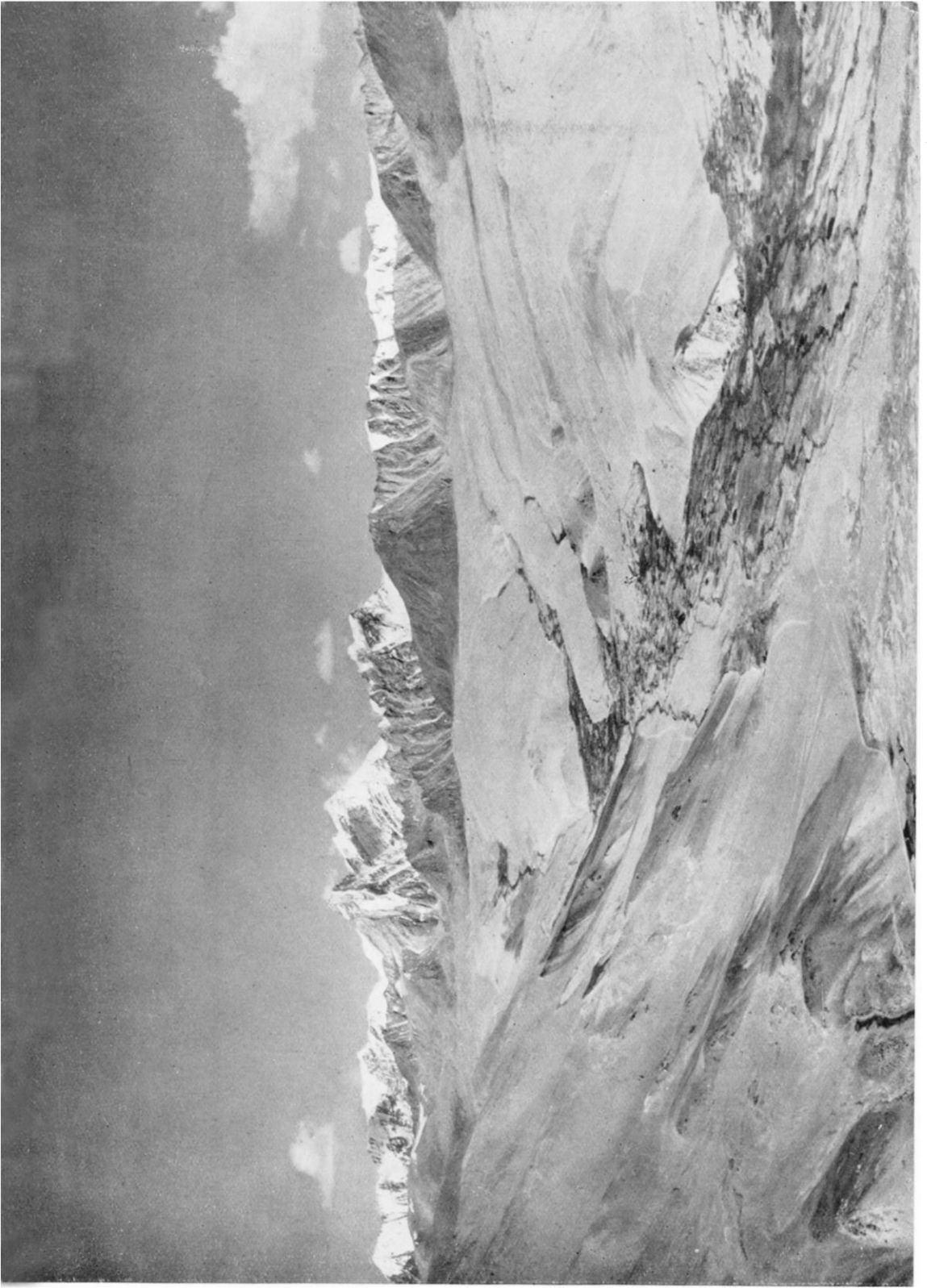
During the first part of August these bad days increased in frequency until the peak of the monsoon period. The worst week began on August 9 and was, as we found later, caused by a depression passing along the foothills of the Himalaya. The wind began in the north-easterly quadrant and snowfall was fairly continuous, though there was a tendency to clear in the forenoon. The temperatures were high even at considerable heights and the daily range very small. At that time, I was told later in Calcutta, the warm monsoon air extended to a height of 20,000 feet above the plains of India. The party attempting the North Peak encountered temperatures little below freezing point at night at a height of 23,000 feet. It was hardly surprising that snow conditions were so bad.

Towards the end of this period the wind veered round to the west. As early as August 18 I find entered in my diary the query: "Is the north-west wind beginning to blow over the top of the monsoon?" During the bad weather period survey work had been much impeded, and it had been only possible to snatch a few subsidiary stations.

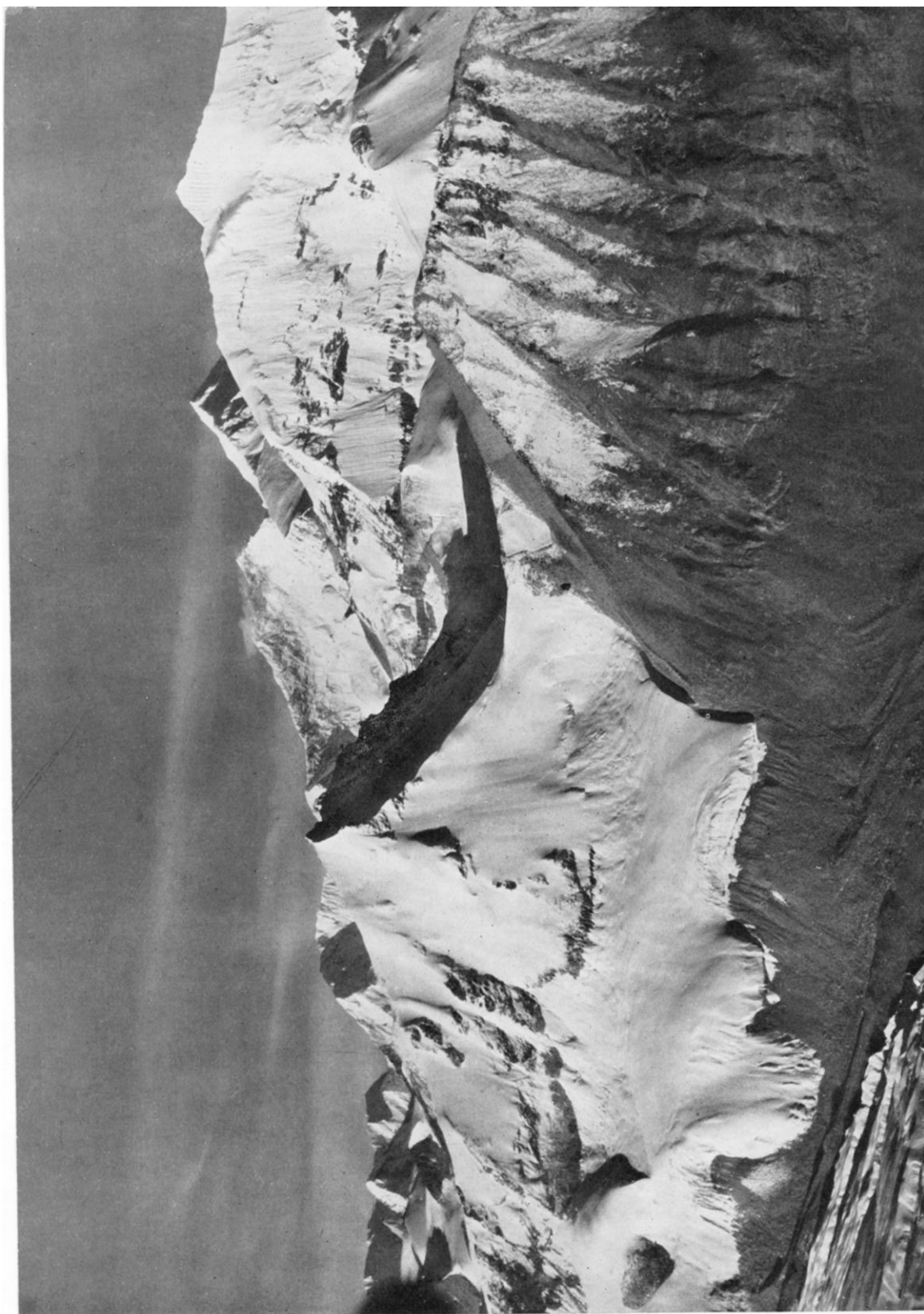
Thenceforward the weather improved continuously and it was plain that the cold, dry north-west wind was becoming dominant. The nights became colder; temperatures down to 10° F. prevailed at night at 20,000 feet and the daily range increased again. The old routine of clear mornings became re-established in the Rongbuk region and steadily spread its influence eastwards. It became possible to work major stations again, though they were actually beginning to be difficult to carry out on account of the low morning temperatures, the later sunrise, the early and sudden formation of cloud and the fact that we were often working on snow.

When we returned to Sikkim in mid-September we were somewhat surprised to find the Bay of Bengal monsoon still vigorous. Mr. Sen, of the Calcutta Meteorological Office, was kind enough to give us an interpretation of this and the other features of the 1935 summer in India.

It had, he stated, been an exceptional summer. The monsoons both in the Arabian Sea and in the Bay of Bengal had been late in starting. Nevertheless the total rainfall in Burma, Assam, and Sikkim were above the normal. On our way back to Gangtok we ourselves witnessed spoilt crops, soil washed away, landslides, damage to roads and destruction of bridges—all the features of excessive rainfall. On the other hand, Calcutta and Lower Bengal were markedly short of rain. These varied phenomena can be linked up by showing them to be caused by the exceptional strength of the westerly Himalayan wind-current, which, persisting throughout the summer, diverted the whole body of the Bay monsoon away towards the east. For the Mount Everest district this meant a weakening of the Bay monsoon to almost negligible proportions. The greater



*Ama Drime in
the "Nyömo Ri"
range; Sar in the
right middle dis-
tance*



*From a pass
on the route to
the Langtshu:
showing points
20750, Lhotse,
Everest, and
Khartaichangri*

part of the precipitation in that district is normally caused by the Bay monsoon. Actually the two branches of the monsoon, that from the Arabian Sea and that from the Bay of Bengal, meet in the neighbourhood of Mount Everest. The persistence of the north-west wind this year prevented, at all events in July, anything but occasional carry-overs from the Arabian Sea reaching our district. The August period was more normal; the presence of the depression south of the Himalaya induced monsoon air into the region. But as soon as that depression moved eastwards and filled in the north-west wind re-established itself and brought fine weather.

APPENDIX V: PHOTOGRAPHY

In the Wild camera the so-called Topographic emulsion made by the Ilford firm was used on plate-glass plates. The material was developed in England after the plates had passed twice through the tropics. On development the plates were found to be in no way fogged; the images were bright and excellent. There were however disfiguring marks all over the plates in the form of patches of deposited silver. These deposits occurred where the surface of the emulsion had been rubbed against the surface of the plate packed opposite, during the long, jogging ride on yak or mule-back. The marks were visible before the development of the plates. Had the plates been repacked with separating strips of cardboard (as they are packed by the makers) no doubt this annoying trouble would not have occurred. I have never heard of a similar case of this source of damage. However it is not expected that the plates will be any less valuable for survey purposes from this cause.

The film material was the same as that taken to Greenland in 1933. It was the well-known Perutz "Topo" emulsion on thick air survey film. On development (again after return) we were spared the disappointment of finding disfiguring marks. In fact most of the illustrations for this paper are from this survey camera. But there was a certain loss of brightness of the images, as though there had been consistent slight under-exposure. Something of the same sort happened to the film kept for a long time after the Greenland season, especially where the film had been kept in considerable warmth. After talking to Messrs. Kodak about these phenomena I realize that exposure should be deliberately made very liberal if there is a likelihood of delay before development.

The electric exposure meter by Weston was invaluable for all classes of photography and showed itself capable of standing up well to the severe conditions of a Mount Everest expedition.

APPENDIX VI: NOTE ON THE MAP

The map published with this paper has been drawn by Mr. Milne with the help of all available photographs. No really satisfactory base was obtained commanding Mount Everest; the lie of the country and the outstanding height of the mountain make it a curiously difficult subject for terrestrial photogrammetry. From the floor of the valley at Rongbuk the mountain is seen at a better angle than from the 24,000 ft. summit of the North Peak. Yet no convenient position for a long base was found at a great distance; in contrast the survey of Makalu, for instance, would be straightforward. Closer to Mount Everest all the accidents of the terrain work against finding a base. In consequence neither of the stereogrammetric stations VIII or XI gave really good contours. However, the contours obtained have been the basis of the present map; they have been checked and improved by a multitude of spot-

heights obtained by intersections from the photographs at these two stations, occasionally amplified by rays from Col. Wheeler's photographs of 1921. Prof. Nørlund kindly allowed me to plot one pair of plates at the Geodetic Institute in Copenhagen; the second pair, taken with the Wild instrument, were kindly plotted for us by Messrs. Wild at Heerbrugg. The rock drawing is taken from the diversity of pictures accumulated during the course of the various Mount Everest expeditions, and the position of the detail was fixed in relation to the spot-heights. The map is, then, a fully responsible photogrammetric survey.

DISCUSSION

Before the paper the PRESIDENT (Major-General Sir PERCY COX) said: Mr. Michael Spender has been well known to us as a surveyor since he took part in the Great Barrier Reef expedition. On his return in 1929 he devoted himself to the study of photogrammetric survey, spending more than a year under Professor Baeschlin at Zurich and in the field with the Swiss Federal Surveys. He then went to study in Germany. Following that he has spent two or three years with the Danes, first with one of Knud Rasmussen's expeditions, and later in the service of the Danish Geodetic Institute on the East Coast of Greenland. With this wide experience of the several methods in use on the continent of Europe he probably knows as much as any living man of this intricate subject of stereogrammetric survey. His latest task was, as a member of the Mount Everest Reconnaissance Expedition of 1935, under Mr. Eric Shipton, to make the first accurate survey of the northern face of the mountain, and to introduce the climbers in training to the charms of photographic survey, with the excellent results which he will now describe.

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

The PRESIDENT: I will ask Professor Mason to speak, if he will be so good. He knows the Himalaya exceedingly well and has done much good surveying there.

Professor MASON: There are one or two points I should like to stress in the extremely interesting paper submitted by Mr. Spender. Towards the end of the paper he says that the impression "that the photogrammetric method is not suited to exploratory surveys is erroneous: the criticism contained in the appendix" to a recent book "is that of an uninstructed person." I think it must be obvious to everybody that if it is possible to get an accurate map by this method at a station in twenty minutes of fine weather, an accurate map, for instance, of the north face of Everest, there are some points, anyhow, about the method. We have been waiting for the map of the north face of Everest ever since 1921. Now we have it, thanks to Mr. Spender and twenty minutes of fine weather.

As to the question of "uninstructed persons," we have no means in this country of properly instructing persons—Mr. Spender himself was instructed abroad—and I think that is a great pity. It is now nearly thirty years since this country took the lead in this method. In 1907 Vivian Thompson designed an instrument and plotted a map of the Lake District from stereoscopic pairs of photographs. He was told that the map was too much like the Ordnance Survey Map and that he must have taken a little help from that Survey.

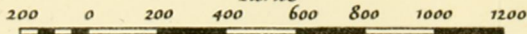
In 1913, when we in India produced a map of the Taghdumbash Pamir, we were told that it was very nice, but that there was no map to check it by. Since then we have lost the lead. Both instruments and methods have improved vastly, and yet we are still in that extraordinarily conservative habit in this

THE NORTHERN FACE OF MOUNT EVEREST

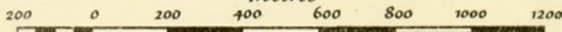
based on Photogrammetric Surveys by Michael Spender

Scale 1/20 000

Yards



Metres



Heights in feet and approximate contours
by stereo-photogrammetry.

Foot of Seco

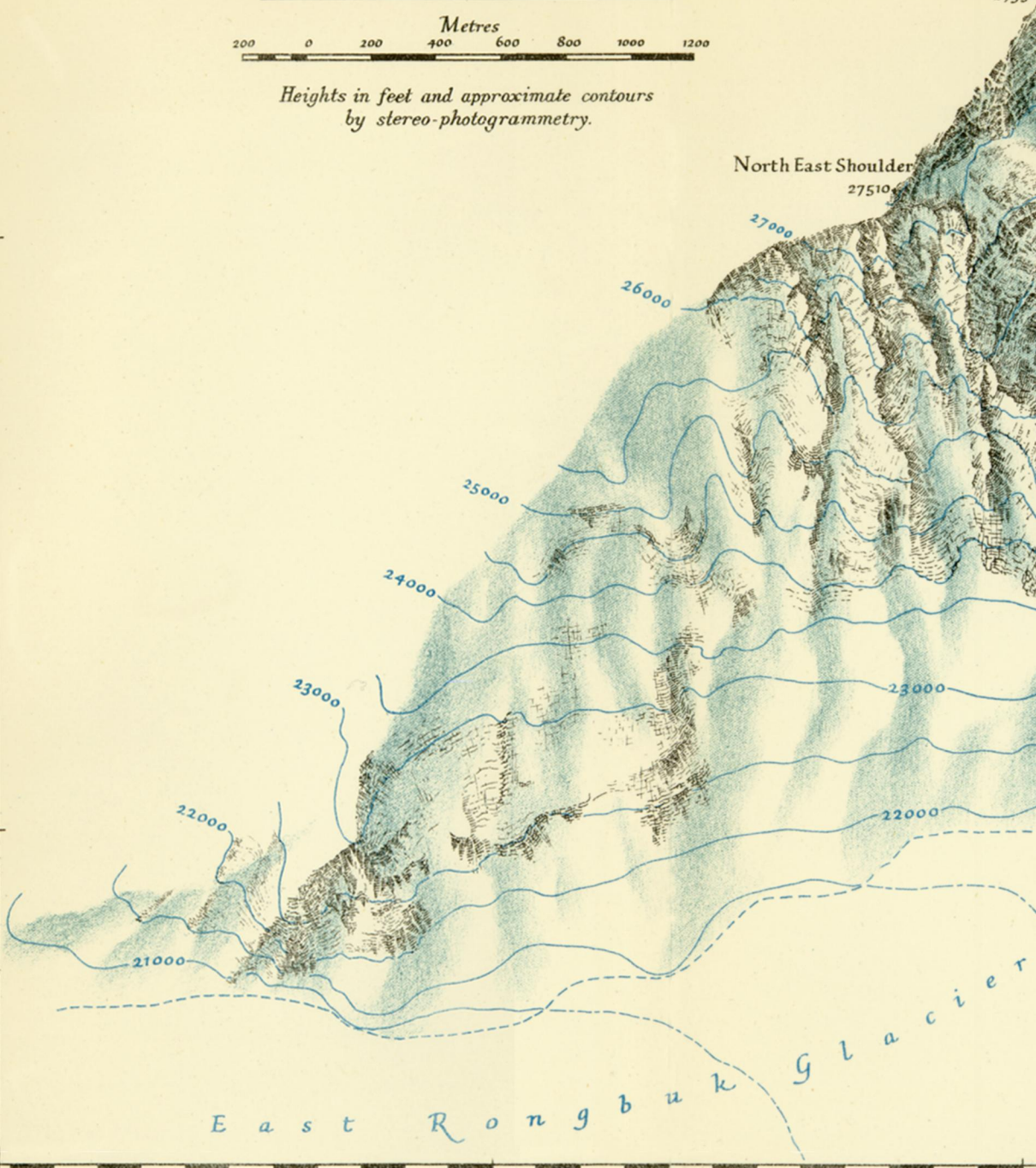
Foot of First Sta
27950

North East Shoulder

27510

28°

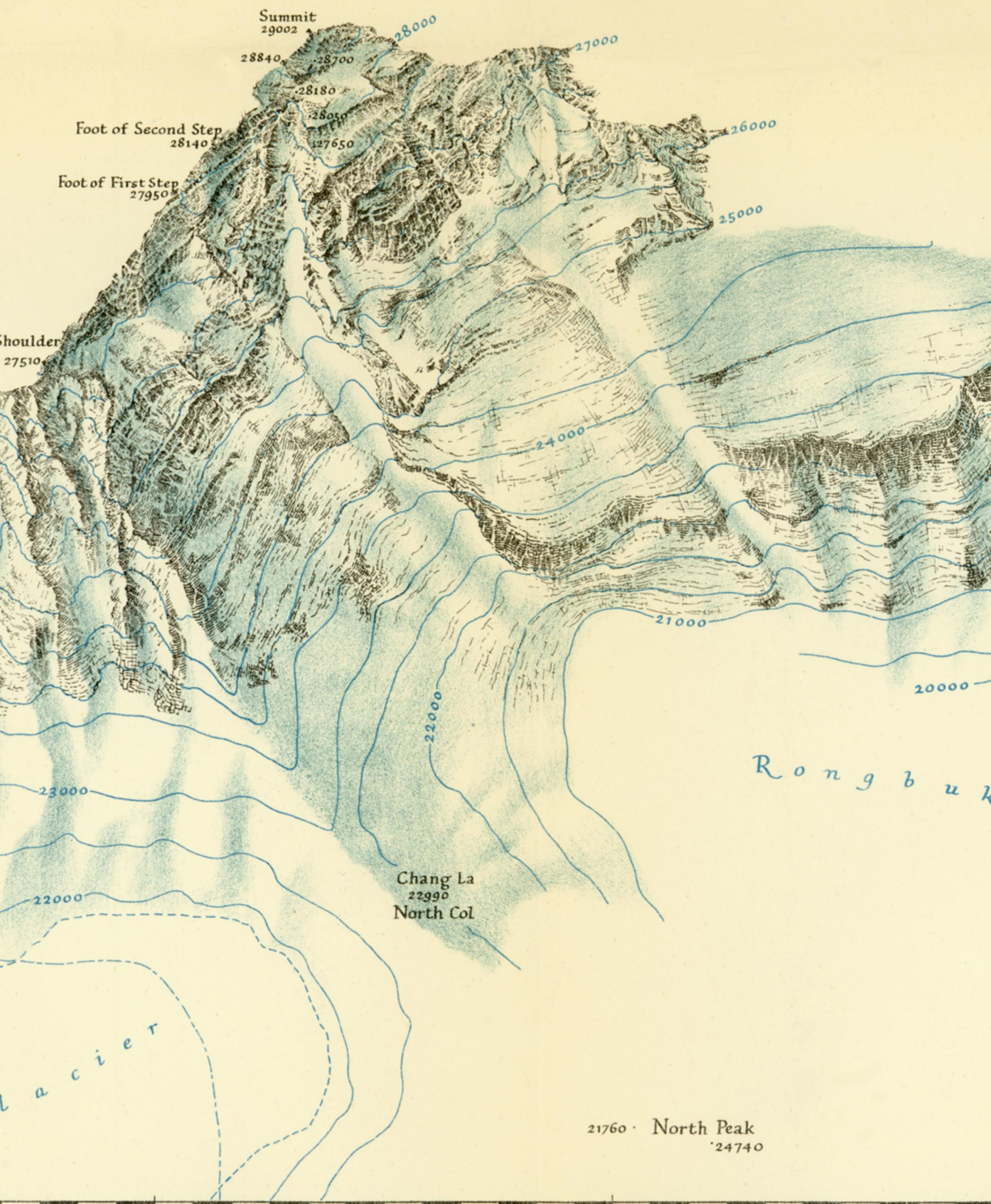
28°



East Rongbuk Glacier

56'

86° 55'

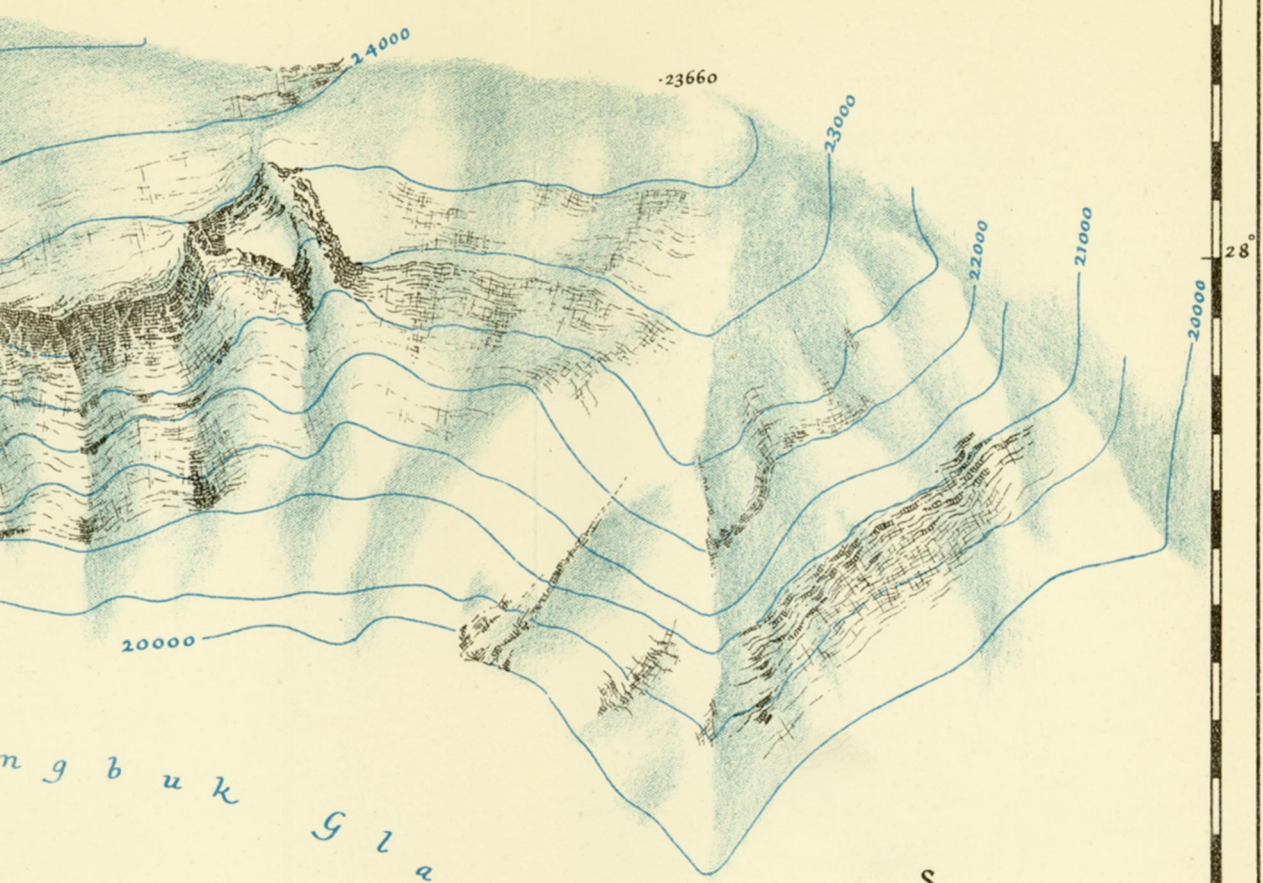


56'

86° 55'

54'

53'



Ngabuk
G l a c i e r



54'

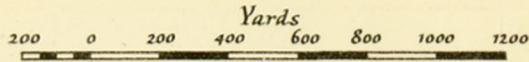
53'

THE NORTHERN FACE OF MOUNT EVEREST

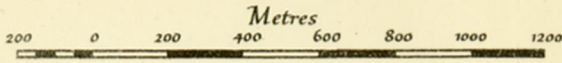
based on Photogrammetric Surveys by Michael Spender

Scale 1/20 000

Foot of Second



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27950

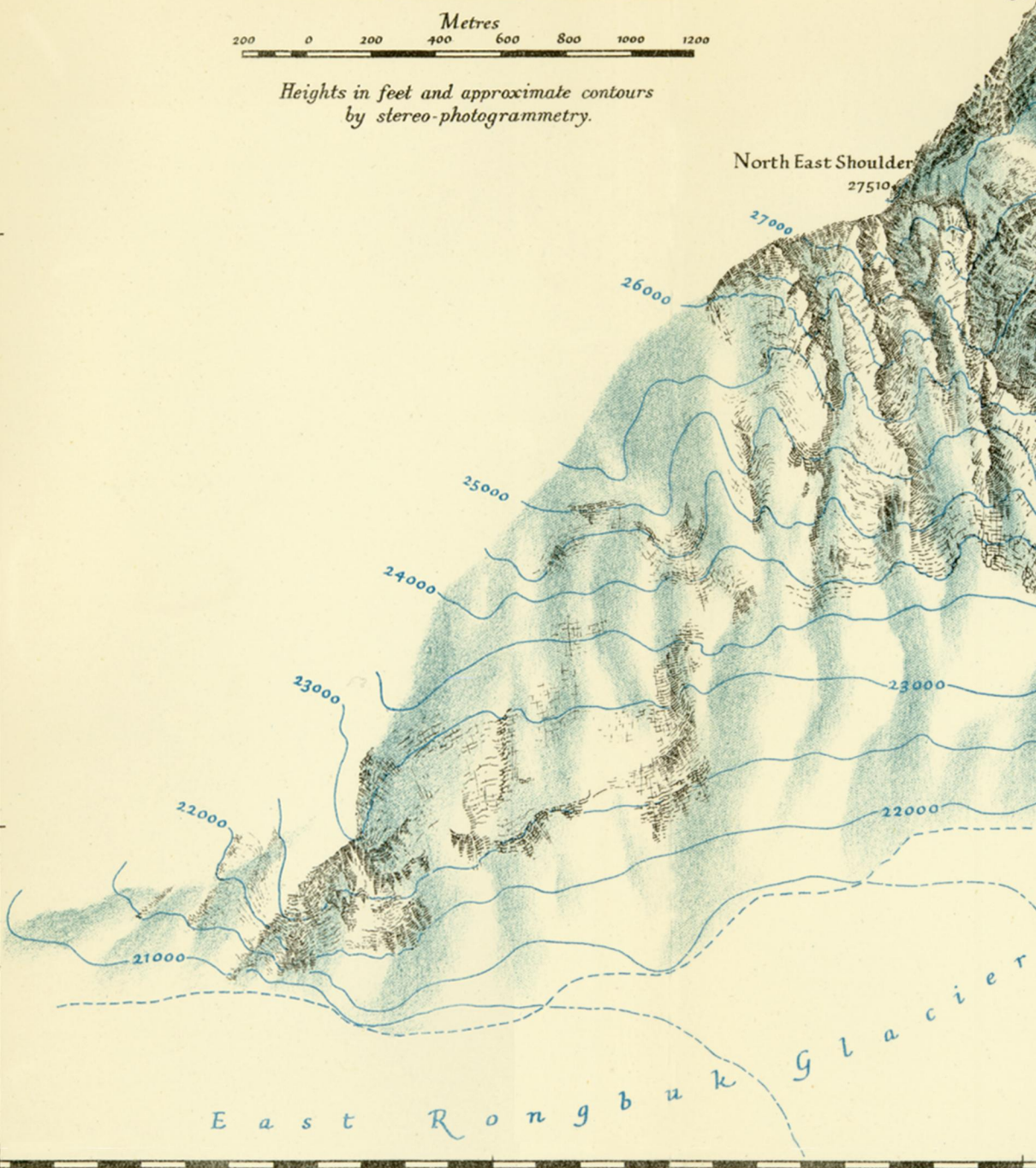


Heights in feet and approximate contours
by stereo-photogrammetry.

28°

North East Shoulder
27510

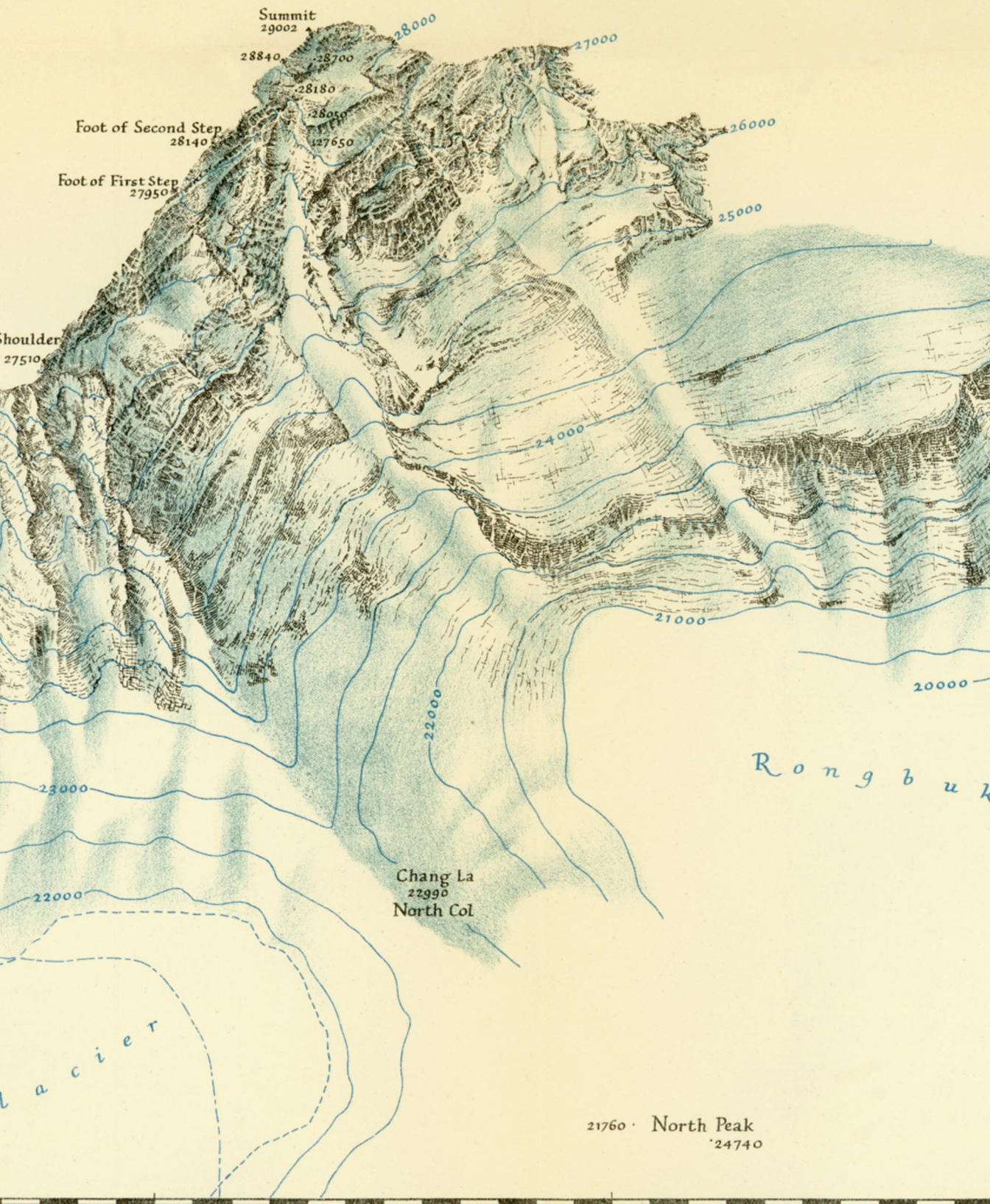
28°



East Rongbuk Glacier

56'

86° 55'



Summit
29002

28840

28700

28180

28050

27650

Foot of Second Step
28140

Foot of First Step
27950

Shoulder
27510

Chang La
22990
North Col

21760 · North Peak
24740

Rongbuk

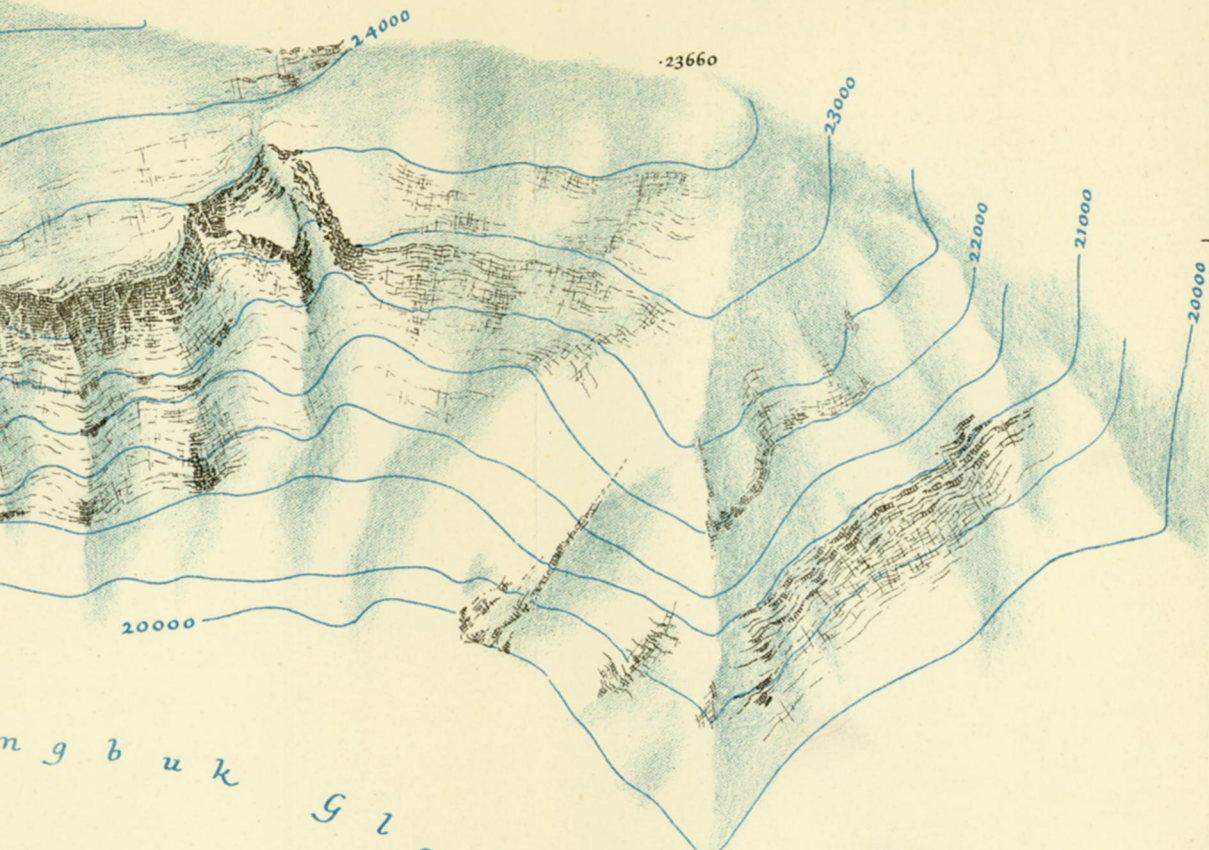
Glacier

56'

86° 55'

54'

53'



ngbuk
Glaciet



54'

53'

MOUNT EVEREST
Spender

country of saying "what was good enough for our grandfathers is good enough for us." It is not! You cannot in these days have a map that is too accurate. Geographers, geologists and geomorphologists—in fact every "geo-body"—want accurate maps. It is impossible to do scientific work properly on the old class of maps. We want to know much more about Everest, and once we get good maps we shall be able to learn more about it. The recent maps produced by Finsterwalder and others abroad are amazingly accurate and extraordinarily good. It is surprising what can be learnt from a close study of those maps. This is the first real chance we have had of doing this type of work.

The question of plotting now comes in. Mr. Spender says in his paper that he is chary about recommending this method of stereo-photographic survey to explorers from this country unless there is some probability of having the maps properly plotted afterwards. Well at present one is rather inclined to agree. We do this work now in India, yet we have to send our photographs to Switzerland to be plotted. Now this method is eminently suited to secret and confidential surveys: and in India some of our maps have to be confidential. Are we to compile these maps from material sent to Switzerland to be plotted? It seems to me that that is all wrong.

Many countries in Europe now have three or four of the instruments in constant use. We are told that this country cannot afford one. Portugal has one. There are many countries no bigger than Portugal who have them. What is the remedy? This Society cannot afford one off its own bat. Perhaps the Government of this country, which has already spent the cost of perhaps three in experimenting from first principles, might deign to buy one already made abroad! I do not know.

Then there is another difficulty. You must have trained engineers to plot these records. We are told that there is nobody in this country capable of doing it. I cannot believe that we cannot produce them. I refuse to believe it.

One last point, the question of spongy rubber as used for purposes of transport. I recommend you to read carefully the appendices in Mr. Spender's paper. They are extremely interesting. He suggests that I was a wise man when I thought of spongy rubber for protection of my instruments. It was not my idea. That, again, was one of the very many useful pieces of advice I had before I set out on my expedition from Mr. Hinks, who knows as much about this method as any man in this country, and as much as most in any other country. I can see no reason why, in addition to his many other duties, he should not find time to instruct three or four people in the use of this instrument when the country buys it!

The PRESIDENT: Mr. Thompson is a member of the Geographical Staff of the War Office. I am sure he has some useful comment to make.

Mr. THOMPSON: I am afraid I have not very much to say on the technical side, because I have had absolutely no experience of this type of mapping, all my experience being with mapping from air-photographs. I should however like to congratulate Mr. Spender on a most excellent piece of work. From what I have read of the method, the difficulty of choosing stations in ordinary country is bad enough, but in such excessively mountainous areas it must have exercised all his ingenuity. From the point of view of the usefulness of the method, I was recently over in France, and I was told by the Service Géographique de l'Armée that when they have two methods to choose from, the making of maps from air-photographs or from ground-photographs, they find that in hilly country, provided they do not get more than about 20 to 30 per cent. of dead ground in the terrestrial photographs, it is much more economical to use them. Their method in the Alps was to map the sides of the valleys with ground-photographs

and then fill in the dead ground, usually at the bottom of the valleys, with air-photographs flown up the valleys.

The other part of Mr. Spender's paper which interested me very much was that which referred to the use of the Leica camera. It would be interesting to know the kind of accuracy he was able to obtain with it. I would also like to ask what percentage of photographs were plotted in the Wild machine and what photographs have been plotted by other methods.

Mr. SPENDER: We have so far only had a couple of pairs of photographs plotted in plotting machines, one pair in Copenhagen and the other in Heerbrugg. That is all the work that has been done on the photographs. At the moment the survey is, so to speak, in abeyance.

We did not use infra-red photography in the Mount Everest region because, for the most part, the shots were comparatively short. In my experience infra-red photography is not worth considering unless you are photographing over a distance of at least 50 kilometres. Beyond that distance the infra-red method is most helpful; otherwise it renders photography more difficult. In the Mount Everest region we were of course up against much cloud, which could not be overcome by the use of infra-red photography. As for the air-photographs, they will no doubt be very useful when we come to putting together a map of the summit of Mount Everest itself. So far the map has not reached a stage in which the air-photographs have been called upon.

The PRESIDENT: If no other member of the audience wishes to make some observations I will ask Mr. Hinks to say a word or two before we conclude. You have heard the tribute paid by Professor Mason to his great knowledge of these abstruse questions, the photo-grammetric and the stereo-photogrammetric methods. Indeed, in regard to all matters of survey he is a great expert. I will ask you to excuse me now as I have an urgent appointment to keep. I will leave the winding up of the discussion to Mr. Hinks.

Mr. HINKS: I am indebted to the President for giving me the opportunity of speaking of the spasmodic interest which I have been able to take in the question of survey by photography, especially survey by the stereo-photogrammetric method. It was in 1924 that, having gone upon a mission for the Mount Everest Committee to Switzerland to arrange with M. Jacot-Guillarmod to come to London and to draw the map published in the Mount Everest book of 1924 and repeated in the book of 1933, I took the opportunity of going to see Heinrich Wild and the instruments which he had constructed at that time for stereo-photogrammetric survey. As a result of that visit, when Major Mason, as he was then, was planning the Shaksgam Expedition and inquired what the Society would do to help, it was soon arranged that the Society should buy a Wild Photo-theodolite and send it out for his use in the Shaksgam. It will be within the recollection of many present how extremely well Major Mason carried out those surveys and what very beautiful maps were produced of hitherto almost unmapped country.

Major Mason plotted the plates at Dr. Helbling's Vermessungs-Büro at Flums. We hoped that this experiment would stimulate more interest in this question in England, and that long before now we should have some means, perhaps connected with this Society, of being able to plot any pairs of photographs taken on one of the stereographic survey cameras. Indeed, in 1929, when the plans for the new part of our building were made, there was a certain room on the basement floor which was, at any rate in one's mind if not officially on the plans, intended as the place where one day there might be a stereographic plotting machine. But things do not move very rapidly in the way of converting people in England to this method.

Therefore I was exceedingly glad when Mr. Spender, on his return from the Great Barrier Reef, proposed to devote some years of his life to the study of these methods. How thoroughly he has done so the President has already described.

The question now comes: How is this knowledge going to be utilized to the best advantage? Here we are in 1936 apparently no nearer than in 1926, when Major Mason was in the Shaksgam, to having a stereoscopic plotting machine for use in this country. Mr. Spender has recorded in his paper that of the two pairs of photographs made on each of the photo-theodolites on which his map was based, one pair had to be sent to Heerbrugg to be plotted, and the other pair was taken to Copenhagen to be plotted by the kind permission of my friend Professor Nørlund.

That was all very well in 1927, but it is not at all satisfactory in 1936.

I feel that there is plenty of scope in this Society for an official whose duty it should be to establish here a more or less experimental but definite plotting department, that could make the best use of the photographs that will be continually pouring in in different ways, some badly taken, but some very much better taken if there is knowledge that they can be properly plotted. There is the mass of material mapped by the Mount Everest Expedition in 1935, and they will have mapped a great deal more in 1936. Those who took pictures in 1936 will want to be able to plot them. We want an officer on the Society's staff, aided by a draughtsman, who can deal with material like that.

A question was asked: What is going to be done with the Mount Everest Flight photographs? Mr. Spender partly answered that question. We have made here during the last year a sort of map of the southern face of the mountain from the Flight photographs, which is complete as regards horizontal detail but has no heights as yet. We are hoping that the work Mr. Spender has done will enable us to obtain approximate contours of that; and so by our method of fitting in one thing with another we shall eventually have, thanks to Mr. Spender's work, a reasonable map of both sides of the mountain.

I mention all these things only to show that if some one could find a way to provide the Society with the means for establishing a plotting machine, and to obtain some one, like Mr. Spender I hope, who could be a permanent member of the staff to carry on permanently work such as he has been doing during the last few months, it would be one of the best things the Society could ever do.

The President has left it for me to ask you now to accord a hearty vote of thanks to Mr. Spender, and at the same time congratulate him on the very admirable work which he and his colleagues did in photography on the Mount Everest Reconnaissance Expedition of 1935. We must thank also Professor Nørlund, the eminent Director of the Danish Geodetic Institute, for his kindness in releasing Mr. Spender to go on the Expedition, and in lending the Zeiss photo-theodolite which, with our own Wild, played principal parts in the enterprise.