majority of the Europeans escaped. This may possibly have been due in part to the institution of a daily throat and nose toilet, a disgusting performance which was known to keep a whole village spellbound and to rid us of the attentions of beggars for an hour at a time.

To what extent the sore throats of Everest are a legacy of infection introduced with the dust is a question not yet settled. I hoped to prevent this serious handicap to health by the institution of the daily nose and throat toilet, and I think the incidence of the disease was perhaps reduced. The published accounts of sore throats in 1924 strongly suggest that the trouble was not due, as Hingston suggests, simply to "the rapid breathing of cold dry air," but to actual infection. "Some of the porters," he wrote, "developed severe bronchitis; one had a profusely ulcerated throat, another persistently coughed up blood." The description of Somervell's throat bears out my theory that altitude throat is probably an ordinary infective sore throat, intensified by "the rapid breathing of cold dry air." The results, however, of my attempts to cut down the incidence of infection were disappointing, and several members of the expedition who had suffered no ill-effects from the dust of the plains complained of their throats on the mountain. All cases were immensely improved by the use of the Matthews Respirator, though occasionally this means of relief was refused by the patients on what appeared to me to be psychological grounds. The respirator gave them a feeling of suffocation which had no basis in fact.

The Matthews Respirator was designed by Mr. Bryan Matthews, of Cambridge, for a very different purpose than the treatment of sore throat. He pointed out that at sea-level in dry cold air, 15 to 25 per cent. of the total heat production of the human body is dissipated through the lungs and respiratory passages, in vaporising water, setting carbon dioxide free from solution, and warming air; and that at great altitudes at least the same amount of heat will be lost, while the potential heat gain, by reason of the shortage of oxygen, is less and less. The rapid breathing necessary to obtain oxygen may result in

17

the loss of more heat than is gained by obtaining the oxygen. Matthews even suggested that at about 30,000 feet, not far above the summit of Mount Everest, there would not be enough oxygen obtainable, even by fast deep breathing, to maintain body temperature. His respirator, designed to combat this danger, consists of a squat cylinder containing layers of copper gauze, through which one breathes in and out. The warmth of the outward breath is used in warming the copper gauze, in the interstices of which the warm moisture of the breath is deposited. The dry cold air in inspiration is warmed and made damp by passing through the gauze. Much of the heat loss is thus recovered, and in addition it is damp warm air which passes over the mucous membrane of the throat. The great disadvantage of the respirator is that icicles tend to form at its junction with the beard. Largely for this reason it was not taken to the highest points reached. Those who climbed above Camp VI were, however, very conscious of what we called the "Matthews effect," a feeling of what one man described as a "central coldness," which came on only while exercise was increasing the breathing and with it the heat loss.

Sore throats, sore eyes, an occasional cold, two or three minor fractures, were our only troubles on the march. But when the discomforts of the road had been exchanged for the comparative comfort of the Base Camp, other troubles began to appear. Wyn Harris developed influenza, and Wager a less dignified complaint. Crawford, whose respiratory apparatus had been functioning ill for some days, retired to bed with bronchitis and was finally sent down to convalesce in the Kharta valley in the company of the apparently dying Ondi. Finding his progress in the Kharta valley slow, he returned to the mountain and climbed to Camp I, where he immediately recovered.

Happily these ailments were no hindrance to us, for a plan of careful acclimatisation had been formed which necessitated delays. We had learned from the distressing experiences of our predecessors, and were determined that no impatience, enthusiasm or brilliant weather would deflect us from our plan of spending at least four days at every camp, in order that our bodies should accustom themselves to the progressive decrease of oxygen in the air we breathed. In 1921 Colonel Howard-Bury recorded headaches among the porters at only 18,000 feet. He himself experienced great lassitude even late in the season on his way to the 20,000-foot camp. At this camp he confessed to laziness and a lack of mental concentration. He also noticed blueness of the faces and hands of his companions, whereas on Kamet in 1931, where acclimatisation, though not as strictly enforced as on Mount Everest in 1933, was carefully considered, I failed to detect any blueness at all at any altitude.[1] Sleeplessness was a common experience in 1921. The deep breathing realised to be essential was a conscious effort. Mallory felt mountain-sick on one occasion at least, and many coolies were seriously mountain-sick at only 22,000 feet. Some of Morshead's coolies succumbed on the Tang La, at only 17,980 feet; Norton below the Jelap La, at only 13,500 feet. Mental symptoms were noted too; Mallory confused the identities of Longstaff and Morshead after the first attempt on the summit in 1922. I have sometimes wondered whether one chapter in *The Assault on Mount Everest*, in which the author describes a process of breathing through the skin quite unknown to science, was not written at a great height. Irritability in previous parties, quickly regretted and forgiven, sometimes occurred, as described in Norton's account of the ascent to the North Col in 1924. Great difficulty was often experienced in persuading porters to start in the morning. The appalling panting of unacclimatised men, the air starvation, the rapid pulse, the lassitude which made of every step a struggle, the sleeplessness, irritability, mental deterioration, grinding headaches, mountain-sickness and loss of appetite which are described so well in the accounts of former expeditions, are all the symptoms of lack of oxygen. In so far as acclimatisation is capable of removing these symptoms, we were determined to give it every chance. Our efforts were rewarded to a remarkable degree.

[1] Greene, *Journal of Physiology*, vol. lxxv.

According to modern theory, acclimatisation to great altitude takes place in three ways : an increase in the number of red blood corpuscles, whose function is oxygen carriage ; an increase in the ventilation of the lungs ; and possibly active secretion of oxygen by the lung epithelium. Of these the increased ventilation is by far the most important. There is no use in increasing the number of oxygen carriers if there is no oxygen to be carried, especially when sufficient carriers are already present, provided that loads can be given them. The increased ventilation takes place in the following way. The first deep breathing of the ascending climber is probably caused by the direct effects of oxygen-lack, which renders the respiratory centre in the brain more susceptible to changes in the acidity of the blood. The deep breathing washes carbon dioxide out of his blood and so lowers its acidity. It is the duty of the kidneys to correct this lowered acidity by secreting more alkali and thus making the blood more acid again. When the blood is more acid, the breathing is deeper and more oxygen is taken in. Acclimatisation has occurred. But the kidneys have to be taught this function slowly.

Perhaps the most obvious reward of our tactics was the absence of serious respiratory distress. Breathing was occasionally disordered in several members during their first night at a new altitude. Except in the case of one slow acclimatiser, this trouble passed off rapidly. Very little distress was felt during exercise and, of the fourteen climbers, thirteen reached the North Col without having experienced serious discomfort. So also did the Signals Officer of Camp III, Smijth-Windham, who is not a climber. The one exception was Wood-Johnson, who had not noticed up to Camp III any increase in his breathing, so quiet and unconscious had it been. He unfortunately contracted a gastric ulcer, a disease which cannot be ascribed to the effects of altitude, and, after six years devoted to preparation for Mount Everest, was forced to abandon all active participation in the work. Above the North Col, proper acclimatisation was made impossible by the weather and by the nature of the ground. Yet our respiratory distress was not great. In the

Plate 45.—North peak, from above 27,000 feet.

ascent to Camp V (25,700 feet), though my heart was functioning poorly, I was far more comfortable than on the final slopes of Kamet (25,447 feet). Those who climbed above Camp VI needed only two or three breaths to a step, and found frequent halts unnecessary. On the porters, the effects of acclimatisation were equally remarkable. There were no cases of mountain-sickness, and there was never a shortage of volunteers for Camps V and VI. Never was there any difficulty in making them start in the morning, even under the worst conditions ; yet the weather was, according to the evidence of those who were present on both occasions, far worse than in 1924. I am sure that men like those who attempted Mount Everest in 1924 would never have been forced to retreat from Camp III to the base, had they been properly acclimatised and therefore fit.

In other particulars also acclimatisation proved its value. I have already spoken of our excellent appetites. Headaches were uncommon. Most men slept well throughout, except sometimes on their first night at a new camp or where the discomforts of their position were too great. Smythe, alone at Camp VI, slept for thirteen hours. The lassitude was less than we had expected. The party was remarkably fit, cheerful and energetic, even at camps above the North Col. Mental deterioration, apart from occasional irritability, was only noticed by those who went above Camp VI, or who were at the time sick men.

But at last came deterioration. The concept of deterioration has had a chequered career in the history of Himalayan climbing. There was a time when it bulked so large in the imagination that the possibility of acclimatisation shrank into insignificance. During this period it became a bogy, and peaks of moderate altitude were "rushed" to avoid the appalling consequences of prolonged residence at a great height. Longstaff delayed the coming of the light by his astounding effort in climbing 7,000 feet in a day to the summit of Trisul (23,406 feet), at that time the highest mountain which had been climbed. But the recent series of great expeditions on Mount Everest, Kangchenjunga and Kamet all produced evidence in favour of the opinion long held by physiologists that the greater peaks could not be climbed unaided by artificial oxygen, unless time were given for acclimatisation to occur. A reaction then set in and deterioration was forgotten. Some even denied its existence, though one school continued, assuming the majesty of Jove, shaking the spheres and threatening thunderbolts, to believe in its importance. But, however interesting and important to the scientists may be laboratory experiments on animals, like those of Dr. Argyll Campbell, the ordinary man prefers to turn to the evidence of field experiment. Accounts of all the expeditions named show evidence of deterioration to the careful reader, but especially those of the former attempts on Mount Everest. During the move to Kharta in 1921 Howard-Bury described the coolies as " stale from remaining at heights for a considerable time." " Living at great heights," he later wrote, " lowers the vitality enormously." Mallory, in the same year, wrote: " The long periods spent in high camps and the tax of many exhausting expeditions had undoubtedly reduced the physical efficiency of sahibs and coolies alike." Somervell wrote in 1922: " Some of our number (especially the older ones among us) actually seemed to deteriorate in condition while staying at a great height." In 1924 all those who went high were found by Hingston to have damaged hearts.

These observations were confirmed and extended in 1933. Probably as a result of the delays caused by bad weather at Camps IIIa and IV, signs of deterioration began to show themselves on the North Col. Several climbers reported that they moved progressively more slowly on each ascent to Camp V. But it was later, in the course of the abortive last assault, that the signs became most obvious. The party of survivors at Camp III degenerated rapidly. Crawford and Brocklebank, slow acclimatisers whose activities had been confined to the mountain below the North Col, were unaffected. But the rest of us appeared less energetic and lost appetite and weight. The effect of exercise on our pulse rates showed that our hearts were less efficient than before. The party had shot its bolt.

These observations agree with those made by Dr. Argyll Campbell on laboratory animals, and one must agree that in all probability prolonged shortage of oxygen is directly or indirectly the most important cause of deterioration. The shortage may be the direct cause. But it seems at any rate possible that acclimatisation, itself originally due to oxygen-lack, may carry deterioration with it as a noxious by-product. Crawford and Brocklebank, slow acclimatisers, were also slow deteriorators. It is unlikely, however, that deterioration is due to any one cause. Staleness in a boat's crew is due to boredom. Life on Mount Everest is an alternation of monotony with periods of great nervous strain. The food is monotonous and badly cooked. Cold and wind and snow injure the morale. All these undoubtedly play a part. An unacclimatised man is a fit man under difficulties : a deteriorated man is an unfit man with those difficulties greatly reduced. Major Hingston has brilliantly compared the interaction of acclimatisation and deterioration on a high mountain with the interaction of increasing toleration for alcohol with a concomitant undermining of the general health. The practised drunkard may pass as a sober man : he has become acclimatised by practice to his swaying environment. Yet he may at the same time be a very ill man.

The physiological problem of Mount Everest appears to lie in the difficulty of taking the middle way between rush tactics with mountain-sickness and siege tactics with deterioration. In 1933 siege tactics, owing to the weather and not to any fault of organisation, were overdone. But this admission should not be used as an argument for rush tactics, for the condition of the climbers at 28,000 feet was so good that there can be little doubt of their capacity in good conditions to climb Mount Everest without oxygen and without permanent harm. All those who suffered heart and other troubles due to altitude were soon in robust health again. They suffered no permanent danger to livers or hearts.

This difficulty in choosing the middle way has led to various attempts artificially to speed up the ascent. Of these methods the best known is the use of oxygen, by means of which acclimatisation is made unnecessary. To suggest, as some have, that oxygen is incapable of helping the climber is, of course, absurd. The special difficulty on Mount Everest, apart from the difficulties of weather and terrain, is due to the shortage of oxygen. Any practical failure of oxygen apparatus to help the climber is due to the apparatus and not to the oxygen. It is therefore unnecessary here to recapitulate the evidence on the value of oxygen collected by previous parties.[1] The apparatus taken by past expeditions should never have been allowed to leave England. I need quote only one remark on each. In 1922 Finch wrote: "The apparatus leaked very badly, and to get them into satisfactory working order four days of hard toil with soldering-iron, hacksaw, pliers and all the other paraphernalia of a fitter's shop were necessary. . . . The masks from which the oxygen was to be breathed proved useless, but . . . a satisfactory substitute was eventually evolved. . . . Without this new work no real use could have been made of our oxygen supplies." In 1924 Mallory wrote: "Irvine has done the principal engineering work on the apparatus—what was provided was full of leaks and faults, and he has practically invented a new instrument, using up only a few of the old parts and cutting out much that was useless and likely to cause trouble." Can we marvel that oxygen was hardly popular with Himalayan mountaineers?

Other suggestions for circumventing the physiological difficulties of the ascent have from time to time been made. In 1930 Richter, the medical officer of the International Kangchenjunga Expedition, attempted to stimulate the activity of the blood-forming organs and so to raise the number of red-blood corpuscles in the circulating blood. Realising the value of exercising these organs, he repeatedly bled those members of the expedition who would submit to his experiment, but failed to produce any beneficial result. Arguing also from the benefits to be obtained by its administration in certain forms of anæmia, he added liver to the diet of his companions.

[1] Greene, *Nature*, November 28th, 1931.

I had already shown that extract of hog's stomach, which has the same effect as liver, failed to raise the red-blood count of healthy men. Richter could report no success with liver.

A more hopeful experiment was the use of ammonium chloride, first suggested by Haldane.[1] I have pointed out already that one increases the ventilation of the lungs by increasing the acidity of the blood passing through the respiratory centre in the brain. Ammonium chloride is split up in the body into ammonia, which is excreted, and hydrochloric acid. The suggestion was put into practice by myself on Kamet in 1931 and by Ruttledge on Nanda Devi in 1932. The results we obtained, though by no means conclusive, were sufficiently encouraging to warrant further experiment. I instituted a series of experiments[2] in the low-pressure chamber at Oxford in 1932, which showed that the administration of ammonium chloride definitely increased the capacity for work at low barometric pressures, and followed up this laboratory work by field observation on Mount Everest. Though Crawford believed himself to be better while taking the salt, the experiment on other climbers had to be abandoned owing to its irritant effect on the stomach. At Haldane's suggestion I had already planned a similar experiment, using acid ammonium phosphate instead of ammonium chloride, but had insufficient time to begin before leaving for Mount Everest. Unknown to me, other workers had already used the phosphate with results which would make it advisable to try it on the next Mount Everest expedition.

Only one matter remains still unmentioned. An expedition to Mount Everest affords a rare opportunity of observing the clinical reactions of the body to an unusual environment and of obtaining direct experimental evidence of the nature of these reactions. I have mentioned already the theory that an acclimatised climber takes in more air, and thus, of course, more oxygen, than one who is unacclimatised. This theory was tested during the Mount Everest Expedition, 1933, by

[1] Haldane, *Respiration.*

[2] Douglas, Greene, and Kergin, *Journal of Physiology*, 1933, vol. 78, No. 4, p. 404.

taking samples of "alveolar air," air from the farthest spaces of the lungs, at Camps III, IV and V. The full results will shortly appear in the *Journal of Physiology.* Here it is sufficient to say that the results obtained supported the theory held. Much experimental work remains to be done. A laboratory could easily be erected, were funds available, at a height of 21,000 feet. It is to be hoped that the next expedition will set out well armed to attack the problems of great altitudes in comfort.

APPENDIX

LIST OF MEDICAL SUPPLIES ORDERED BY DR. RAYMOND GREENE FOR THE MOUNT EVEREST EXPEDITION, 1933

A. From Messrs. Burroughs Welcome & Co.

On Loan:

2 No. 251 Aluminium "Tabloid" Brand medicine chests.
30 No. 2510 feather-weight containers.
20 No. 2523 feather-weight containers.

Supplied.

In No. 2510 containers:

2 containers "Tabloid" Aromatic Chalk Powder and Opium.
4 ,, ,, Aspirin gr. 5.
4 ,, ,, Tr. Camphor Co. min. 15.
2 ,, ,, Ipecacuanha and Squill.
4 ,, ,, Phenacetin Compound.
2 ,, ,, Quinine Bihydrochloride gr. 5.
4 ,, ,, Soda Mint.
4 ,, ,, Sodium Bicarbonate gr. 5.
2 ,, ,, Ammonium Chloride gr. 5.
2 ,, ,, Ammonium Bromide gr. 5.

In No. 2523 containers:

4 containers "Tabloid" Chloral Hydrate gr. 5.
4 ,, ,, Potassium Permanganate gr. 1.
2 ,, ,, Calomel gr. $\frac{1}{4}$.
4 ,, ,, Dover Powder gr. 5.
2 containers "Tabloid" Potassium Chlorate gr. 5. (N.B.—This quantity should be quadrupled.)
4 containers "Soloid" Boric Acid and Zinc Sulphate.
2 3-oz. Chlorodyne.

2 No. 318 bottles "Tabloid" Santonin gr. 2.
4 100 "Tabloid" Quinine Bihydrochloride gr. 5.
4 2-oz. Mandl's Paint, each in metal case.
4 2-oz. Tincture Iodine in metal cases.
24 regular tubes "Tabloid" Mag. Sulphate Effervescent gr. 60.
12 uncompressed Triangular Bandages.
2 yds. Jaconet, full width.
2 doz. assorted Safety Pins (2 boxes of 12).
2 25 12-inch lengths of Silkworm Gut, in spirit.
2 tubes Catgut as in No. 363 case.
1 yd. Gooch's Splinting 18 inches along the wood strips.
1 sq. yd. Poroplast.
15 large tubes "Hazeline" Cream.
8 ½-pint tins Castor Oil, with screw tops.
2 25-c.c. "Epinalin."
2 1-oz. Ephedrine Spray Co.
30 Nasal Irrigators (Duck Pattern), each in strong card box.
30 No. 2574 feather-weight containers, each containing 12 "Soloid" Naso Pharyngeal Co.
1 tin of "Soloid" Naso Pharyngeal Co. (1750).
15 1-oz. tubes Vaseline.
4 1-oz. bottles Collodion, each in metal case.
2 1-oz. screw-capped pots Ung. Hyd. Nit. Dil.
2 1-oz. screw-capped pots Ung. Sulphuris.
2 1-oz. screw-capped pots Ung. Resorcin Co. with 1 % Cocaine.
2 tubes of 20 "Tabloid" Hypodermic Morph. Sulph. gr. ¼.
12 1-oz. "Paroleine" Spray Co.
3 2-oz. bottles Chloroform.
8 10,000 units in 25-c.c Anti-dysentery Serum.
2 ½-lb. tins Sodium Sulphate Crystals.
2 ½-lb. tins Potassium Permanganate Crystals.
2 1-oz. 8 % Solution Zinc Chloride.
12 small-size Kaylene powder.
3 4-oz. Kaylene-Ol.
400 tablets Acriflavine gr. 1·75.
10 ampoules Percaine with Adrenalin (Clayton Analine Co.).
50 capsules Nembutal in bottles of 25 (1½ gr.).
15 First-Aid Boxes, each containing 4 glass tubes empty (free).
1 box of spare gummed labels (free).
96 1-oz. "Tabloid" Compressed Boric Lint.
120 1-oz. "Tabloid" Compressed Absorbent Cotton.

48 2½ ins. by 6 yds. "Tabloid" Compressed Bandages.
48 3 ins. by 6 yds. "Tabloid" Compressed Bandages.
6 3 ins. by 10 yds. Zinc Oxide Plaster.
4 2 ins. by 10 yds. Zinc Oxide Plaster.
6 small tubes Lanoline.
2 yds. Oiled Silk.
2 1-lb. pkts. Gamgee Tissue.
12 3 yds. "Tabloid" Compressed Absorbent Gauze.
12 3 ins. by 3 yds. Crêpe Bandages.
12 4 ins. Plaster-of-Paris Bandages, each in tin.
12 15-c.c. Coramine. (N.B.—An unnecessarily large supply).
20 ampoules Coramine.
2 yds. Rubber Tubing No. 3604.
4 Hot-water Bottles 12 ins. by 8 ins.
2 Higginson's Syringes in card boxes.
24 Throat Brushes, straight.
12 ½-min. Clinical Thermometers, lens front.
36 Iodine Pencils.
12 Glass Eye Baths on foot.
12 small Camel-hair Brushes No. 4003.
6 2-c.c. Hæmoplastin.
2 Medicine Tumblers with lips and 1-dram Measures in red cases.
2 Rustless Steel Spatulas.
2 Wooden Spatulas.
2 pair Scissors.
30 boxes Eucalyptus Pastilles. (N.B.—This quantity should be quadrupled.)
4 tubes of 12 "Tabloid" Ophthalmic Cocaine Hydrochlor gr. $\frac{1}{20}$.

B. Surgical Instruments from Messrs. Allen & Hanburys Ltd.

1 Finochietto's Tourniquet, complete with rubber cord, 3890.
1 pkt. half-circle Needles Nos. 7–12.
1 pkt. half-circle Needles Nos. 13–18.
1 pkt. straight Needles Nos. 13–18. (Greased.)
2 boxes "Azoule" Minor Sutures, all Silkworm Gut.
2 Bowle's Stethoscopes, small-size chestpieces, thick med. tubing, 6804.
1 A. & H. Knife Handle.
1 Double-folding Scalpel, S/S. 740.
1 pair 5-in. Dissecting Forceps, S/S. 830.
1 pair Michel's Dissecting Forceps, S/S. 1501.
1 pair Splinter Forceps, S/S. 1197.

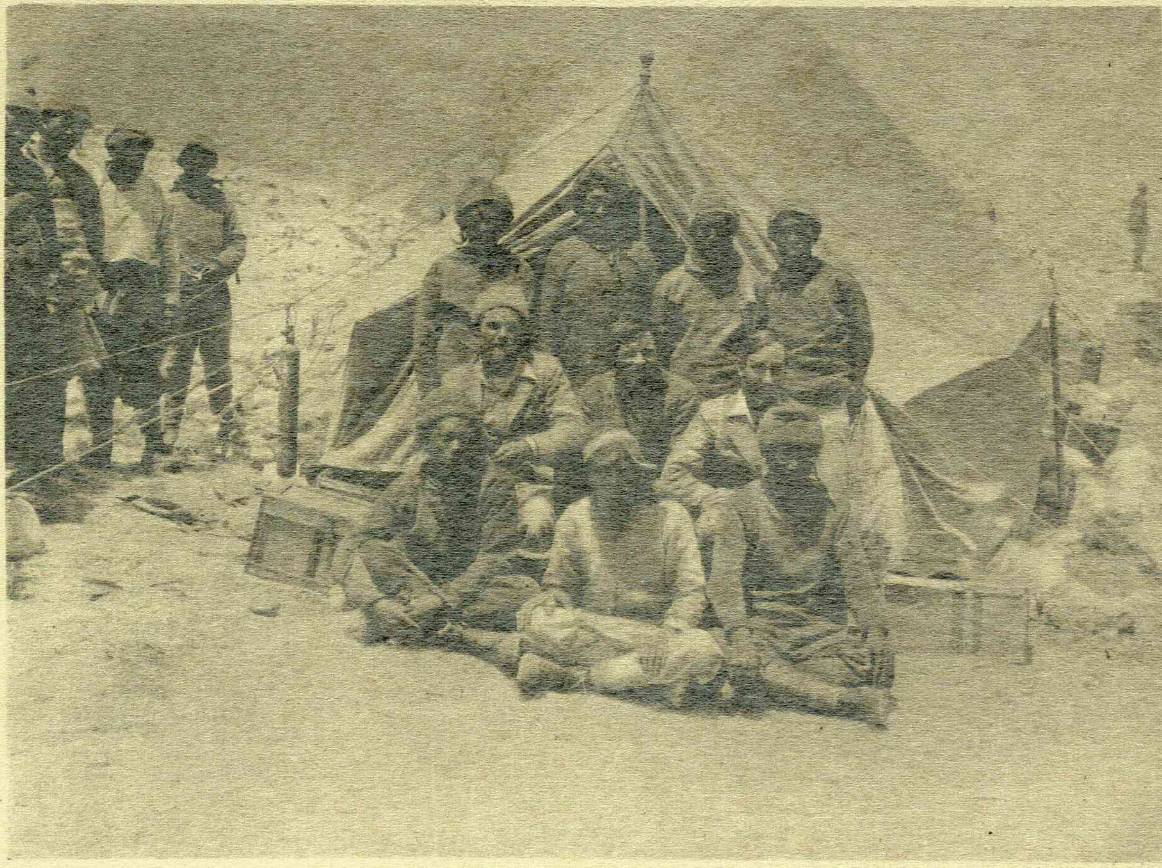


PLATE 46.—The party which established Camp VI (one porter absent; Kipa Lama wearing a pugaree in the back row).

1 pair Universal Dental Forceps, S/S. 6591.
6 pairs Moynihan's Artery Forceps, box-joint, S/S. 784.
2 6-in. Silver Probes.
1 pkt. A. & H. Knife Blades, No. 1.
2 pairs 5-in. Sharp-pointed Scissors, S/S. 877.
1 pair 5-in. Blunt-pointed Scissors, S/S. 871.
1 pair 5-in. one blunt and one sharp point, Scissors, 882.
2 1-c.c. 20-min. Record Syringes in spirit-proof cases, 3801.
6 each Nos. 20 and 16 Record Needles, S/S.
1 No. 14 De Vilbriss Spray, 8746.
1 No. 15 De Vilbriss Spray.
1 "Kompak" Baumanometer.
1 Schimmelbusch's Mask, 68.
4 Cope's Radius Splints, aluminium.
1 set of 8 Aluminium Universal Splints, 7785.
1 each Black Gum Elastic Aboule Catheters, Nos. 6, 7, 9, and 10.

C. Presented by Messrs. Smith and Nephew

Elastoplast Finger Dressings, 2 boxes of 3 dozen.
Elastoplast Gauze and Plaster Dressing Strip, 1½ ins. by 1 yd., 2 boxes of 1 dozen.
Elastoplast Gauze and Plaster Dressing Strip, 2½ ins. by 1 yd., 2 boxes of 1 dozen.
Elastoplast Bandages, 2½ ins. by 3 yds., 2 boxes of 1 dozen.

N.B.—1. Future expeditions will, of course, take adequate supplies of Evipan, an invaluable anæsthetic which had not been introduced when the 1933 expedition left England.

2. Supplies of Bacteriophage, an essential part of the medical equipment, can be obtained in India.

3. Supplies of medinal and veramon were kindly presented by Messrs. Schering, and of allonal by Messrs. Hofmann Laroche. Allonal and medinal have proved their value in the insomnia of altitude. Veramon is undoubtedly the best drug for altitude headache.

III. TRANSPORT

By E. O. Shebbeare

The transport officer of an Everest expedition should be a "jack-of-all-trades," so that, in writing of "transport," I may stray in places from the strict path of what a soldier would call "S. & T." and wander among other branches of "Q." In this wide sense I have included the whole business of putting a party on the mountain fully equipped and provisioned for the attempt, feeding the climbers on their journeys out and back through Sikkim and Tibet, as well as feeding the porters whenever they are out of reach of local supplies.

The task therefore begins, as far as provisions are concerned, with the important work of choosing in Europe the best supplies, calculating the correct quantities of each to take, sorting and listing them in the right order, and getting them packed in the right kind of boxes and shipped to Calcutta. The choice of equipment is even more important and difficult than the choice of provisions, and means selecting or designing the most suitable clothing, bedding, tents and climbing gear, not to mention such vital details as the right kind of cooking-pots and means of heating them.

All this preliminary spade-work had been done before those of us who were already out in India had come on the scene at all, but it would be a very unimaginative transport officer who failed to realise the task that had been accomplished at Home, the amount of thought that had been given to apparently insignificant details, or how important such details could suddenly become when put to the test.

It is, perhaps, not so easy for anyone who has not provisioned and equipped a similar venture to grasp the full significance of all this. An example will make it clearer. I have written, rather loosely, of "sorting and listing them in the right order," and if I explain all the implications I had in mind when I wrote this, I hope it will enlighten readers with no personal experience of such work without boring them too much.

Sorting the provisions at once raises the controversial question "bulk boxes versus man-day rations." I will explain. Bulk boxes are simply ration boxes containing all one commodity, say sugar or flour. Man-day ration boxes, on the other hand, contain an assortment of food calculated to feed so many men for a day or, conversely of course, a man for so many days. It is the rival merits of these two methods of packing, or rather the proportion of boxes that ought to be packed by each method (for I think everyone is agreed that there should be some of each kind) that constitutes the problem.

At first sight it might seem immaterial how the stores were packed so long as they were all there, but a moment's consideration will show that a situation might occur in which it would be inconvenient to transport a bulk box of *every* commodity required for a short halt at some spot. This is a minor drawback, for it is easy enough to fill an empty box or two with all that is required from the bulk boxes. There is, however, a far more serious drawback. Tibetan transport drivers, and even our own porters for that matter, show no inclination to " grow into plaster saints." On the contrary, unfortunately, each successive expedition has shown them to be more and more confirmed and accomplished pilferers, handy with a screw-driver and nice judges of the correct weight of stones to replace stores removed. A box once opened is never quite the same again, it always shows scars from the screw-driver: hence the importance of having as few legitimately broached packages as possible in the store dump. If it were possible to have man-day ration boxes so perfectly calculated that the mess secretary need only hand over the requisite number to the cook and leave him to feed the party, all would be well. But this is a counsel of perfection. What is required is some practical approximation to this ideal reinforced by surplus commodities in bulk.

There are many more sides to this still unsettled question. Some mistrust man-day rations as tending to monotony; their opponents maintain that the scheme propounded by Beetham, as mess secretary, in *The Fight for Everest, 1924*, would ensure plenty of variety. Others accuse man-day rations of being wasteful, because any food left over from a box must be given away; their opponents say that, unless the total quantities of each kind of food taken exactly coincide with requirements, the surplus must inevitably be wasted whether it is packed in bulk or man-day boxes, and further claim that the man-day system automatically apprises the quartermaster of shortage or excess early enough in the proceedings for him to put matters right by sending for more or dumping. I must not weary my readers with any more pros and cons. I can assure them that, though no decision was reached, it was not for want of discussion: it was almost as popular a subject for mess-tent debate on the return journey as the merits of rival routes were on the way up.

With all the preliminary work done for us, the transport problem which faced the transport officers in India was a straightforward and comparatively easy one. It consisted in the moving of some twelve hundred packages, weighing about twenty-one and a half tons in all, from Calcutta and Bombay, firstly, to the head of the Kalimpong ropeway. This also was done for us by the Army and Navy Stores in these parts, so that we can hardly claim this as a part of our work.

The real hard work began at Kalimpong, where a great deal of opening up, issuing of kit, reshuffling and repacking had to be done. Here again the official transport officers of the expedition had their work done for them by someone else; George Wood-Johnson and I were still engaged in our normal occupations of tea-planter and forester, and our leave did not begin until the 13th and 1st of March respectively. The work of reshuffling could not wait for us, the advance baggage had to be despatched without delay; Jack Longland and Eric Shipton volunteered for what was actually the hardest and most difficult work of the whole transport business. I believe I am in a better position than anyone else to judge their work, for I had a similar, but far less difficult, task to do in Kalimpong in 1924, and I doubt if anyone else fully realises the amount of work that they got through in the course of a few days or what a splendid job they made of it. From this time onwards they were the real authorities on the whereabouts of equipment, for some drastic re-packing had been necessary, and it was a long while before George Wood-Johnson and I had mastered their intimate knowledge of the contents of packages or got our store-books fully up to date. Later on

PLATE 47.—The party which established Camp V (Boustead absent).

Jack Longland acted as quartermaster and, without his help, many hours would have been wasted in long searches for articles of equipment on the march.

The advance baggage was sent ahead of the party from Kalimpong to Kampa Dzong, a fort on the plains of Tibet, so that it was not until we reached this place that the whole baggage of the expedition was once more assembled in one spot. Nursang, a sirdar who has accompanied every expedition to Everest or Kangchenjunga since 1921, had been sent on to Kampa Dzong to take delivery of the advance baggage as it arrived, in convoys of various sizes according to the trade-route mules available. These were supplied by Pangda-Tsang, the Government transport contractor in Kalimpong.

In Tibet no convoy is complete without its watch-dog, whose duty is to bite all strangers approaching within a hundred yards of the baggage under its charge. Nursang had not failed in this respect, and had provided himself with the usual Tibetan mastiff, an attractive bitch about the size of a sheep-dog, but of more stocky build, with a thick, dark-brown coat and buff points, which he had christened "Police-ie" in allusion to the duties she was appointed to perform. The name looks clumsy in print but was quite serviceable in practice, and she certainly lived up to it, for no officer of the Criminal Investigation Department ever took his duties more seriously. C.I.D. officers, it is true, are handicapped by having to investigate, a formality that Police-ie could dispense with, for by her code all strangers were guilty until they had proved themselves innocent—a point which the victim could discuss, if he chose, while one of our medical officers was dressing the wound. She made no mistake, however, as to identity, and any man of our party of sixteen Europeans and seventy porters, once known, was never forgotten, or at any rate never bitten. How she managed to distinguish some of our men, who often wore Tibetan dress, from the local population has always been a mystery to me.

Her first meeting with the party was unfortunate. The store dump at Kampa Dzong was about two hundred yards from the main camp, and therefore in the neutral zone as far as Police-ie was concerned. As I walked across to see Nursang, I noticed the dog in the offing and, from earlier experiences with Tibetan mastiffs, insisted on a formal introduction, but forgot to warn George Wood-Johnson, who came across a few minutes later, and Raymond Greene was soon busy with iodine and cotton-wool. The rest of the party lost no time in making the acquaintance of our guardian, and I do not think any other member of the expedition was ever attacked.

She was a friendly beast, and liked to be made a fuss of, but would never enter a tent, nor did she show the slightest interest in any sahib's food. I suppose she lived on barley meal and an occasional mutton bone, but I never saw her eating. Her bed was the bleakest and most exposed part of the camp, preferably on snow or ice; she scorned the lee of a tent even in a snow-storm, and all that was visible on such occasions was a nose sticking out of a small rounded drift. After we had reached the Base Camp I expected that she would remain there in the comparative luxury it afforded, but I had under-estimated her hardihood. Completely independent, she would follow any party up the glacier, usually at a distance of a hundred yards or so; and, though friendly to all, she owned allegiance to no one, not even Nursang. She made several trips up and down the glacier camps, coming or going at her own discretion. The highest point she reached was the foot of the rope ladder below the North Col; had it not been for this obstacle I believe she would have helped to establish Camp VI.

Poor Police-ie; no one knows what became of her or when she came to grief, but she had been seen to treat crevasses with a contempt that they did not deserve, and we fear that this was her undoing. Let us hope she broke her neck and did not suffer long.

I have digressed and must return to the transport at Kampa Dzong. Here we parted with the quick and efficient mules of the trade-route, and had to rely on whatever transport animals we could get locally. It is not possible to take one lot of transport animals through the whole journey across Tibet.

The drivers are not willing to leave their homes for more than a few stages, so that several complete changes of animals are necessary. It is at the stages at which transport animals are changed that the greatest confusion occurs, as well as the greatest danger from pilfering, for the departing drivers know that they are saying good-bye and we shall see their faces no more.

The scene on the morning of one of these changes of animals is interesting and amusing enough, no doubt, for anyone not personally concerned with the safe transit of the expedition's property across Tibet. It can be a heart-breaking enough spectacle for the transport officers, who must wait behind to see the last package loaded.

Before the arrival of the three hundred or more animals which have been ordered through the local Tibetan officials, the baggage has been made up into loads weighing approximately eighty pounds a side, carried by each animal. Theoretically each owner has as many pairs of loads pointed out to him as there are animals in his string, his name is written against them both by the Tibetan officials and the transport officers of the expedition, and he proceeds to load up and move off. In practice, unfortunately, there is more in it than that. To begin with, each driver notices certain loads which appeal to him as appearing both light and handy, and he proceeds to pick these out at random from all over the baggage ground amid loud protests from other drivers to whom some of them have already been allotted. Before long the whole baggage ground is a battle-field of little groups gesticulating and quarrelling among themselves, while a few solitary prospectors wander among the baggage, feeling the weight of the smaller packages, and trying to get away with half-loads. The transport officer is well advised at this stage to keep a wary eyelid lifted for little strings of animals moving quietly away and availing themselves of any cover provided by stone walls or houses.

After this sort of thing has gone on for an almost incredible time, the gyembos, who are supposed to be helping in the operation, are at last persuaded that something must be done, a few packages are loaded up, and animals begin to move off.

This is the time to see that half-loads do not get away, or the supply of animals will, of course, run short. One is lucky if this does not happen.

So it goes on, with more hunting round for animals that should have arrived and have failed to do so, and more disputes as to whose beasts should take which loads. The usual way in which this last question is finally settled, in Tibet, is to collect a garter from each disputant, shuffle them, and throw one over each of the loads—a decision by lot which I have never seen questioned.

Time goes on, and the loads on the ground slowly diminish in numbers in spite of everything. Just as one is beginning to congratulate oneself that all will soon be clear, a hasty count of unloaded animals and unloaded baggage makes it clear that all is not well. More hunting for animals follows, with long waits which seem all the longer for the glib assurances of the gyembos that large herds of yaks and donkeys are, even at that moment, about to round the nearest corner. But my description is becoming as wearisome as the real thing, and it is enough to say that, at one of these changes of animals, he is a lucky transport officer who leaves the camping-ground behind the last load earlier than one o'clock in the afternoon.

It may be thought that I have made too much of the inconvenience of stopping behind, but it is more than a question of mere impatience. It is all in the day's work, and just a part of one of the most interesting jobs in the world, but it has its drawbacks. The west wind in Tibet does not get up much before eight o'clock in the morning, and seldom begins really to blow before nine or even ten. Given an early start, it is possible to ride in considerable comfort, and by nine o'clock reach the next halting-place where, thanks to the mess mules having left at daybreak, the mess tent should have arrived or may even have been pitched. The late starter, on the other hand, heading westwards as he must, has to face anything from a strong wind to half a gale, carrying with it sand or fine snow as the case may be. What distressed me more than this minor discomfort was the fact that the passage of the earlier starters

PLATE 48.—The expedition (except Boustead) at the Base Camp in June.

generally dispersed some of the wild life of the plains, at least the larger animals, and the late comer was less likely to see such heartening sights as a herd of wild asses or a solitary gazelle. Even so the birds, and sometimes small mammals, were to be seen, and with these and the scenery a walk across Tibet (even under the most unfavourable conditions) can never be dull.

I must not give the impression that the solitary task of bringing up the rear always fell to my lot. I was fortunate in having the most good-natured of colleagues, and must confess that George Wood-Johnson did a great deal more than his share of the dirty work. Often we stopped behind together, and generally either " Tommy " or " Smij " (Thompson and Smijth-Wyndham of The Royal Signals), who luckily did not trust me to supervise the loading of their delicate wireless apparatus on pack animals, stayed back as well. I shall always remember a part of the long march from Kampa Dzong to Lingga with the four of us cantering along together singing ribald songs at the top of our voices.

From Kampa Dzong westwards the transport animals are mainly yaks to begin with, but the proportion of donkeys steadily increases at each changing-stage, and beyond Shekar they are in the majority. We could seldom get many mules, except when the kindly Dzongpen of Tengkye, a good friend to us, lent us fourteen of his own so that our bedding and tents could get through in good time.

After mules, yaks are probably the most efficient pack animals. Slow but sure, they move across the plain like a regiment in column of squadrons, the drivers behind urging them on with stones and wild cries. The difficulty with yaks is that, on the outward march, after the scanty grazing of the long winter, they are in poor condition and loads must be kept as light as possible, whereas, after the fat feeding of the spring and summer, they are apt to be over fresh and buck their loads off in every direction. An incident of this sort occurred just outside Kampa Dzong on the return journey, and I shall not forget the desperate scene of broken boxes and runaway yaks scattered over the plain, or how each successive animal, as it grasped the humour of the situation, began to throw a series of bucks that would have shamed a broncho. A yak has one of the saddest faces in the animal kingdom, but I could not help feeling that, somewhere inside those great, tousled carcases must be rumbling the yak equivalent of a hearty laugh.

The tiny, woolly Tibetan donkey is a wonderful creature, because in spite of his size (he only stands the height of a dining-table) he can carry the same load as the much larger mule and, by comparison, the gigantic yak, and apparently with equal ease. The donkey's greatest difficulty is falling down under his load. This is attributed to laziness by the callous and to tiredness by the humane. I believe that both conclusions are equally wrong. Donkeys fall down just as often at the beginning of a march as at the end, which seems to me to dispose of the tiredness theory ; and as it is not always the same animal which makes a habit of falling down, laziness does not seem a likely explanation. My own opinion is that the greater comparative size of his load prevents him from recovering his balance as a yak or mule would do and, if he pecks, he is forced to let himself go and wait there until his driver picks him up, when he hurries on after his companions ; for he is above everything a "matey" creature. For the rest, he is much smaller, woollier, and darker than an English donkey, often almost black, with a dun snout and points.

The other pack animals used in Tibet are zos (a cross between cattle and yaks), and a few ponies. I have omitted sheep, which are only used for carrying salt and borax, commodities that can be sewn tightly into bags and bound on their backs. They are more often used in Western Tibet, I believe, but we did not see any pack-sheep this year as far as I know. In 1924 we found a sheep that had fallen off some rocks and broken its neck. It had apparently escaped the notice of its owners, for the salt panniers were untouched, thus providing us with the mutton and the seasoning at one stroke.

It has often been suggested that something more efficient than that most ancient form of transport, the pack-saddle, could be used to convey an expedition and its baggage across

Tibet. I believe bullock-carts were tried towards the end of the Younghusband expedition of 1904, but I never heard with what success. Nowadays the talk is of motor-lorries or even aeroplanes. I believe the greatest obstacle to the use of such new-fangled contrivances in the sacred land of Tibet would be the religious objections of the rulers, backed by the hard-headed, practical opposition by those of less high degree who make a more or less modest profit out of the supply of transport animals. Those who understand such matters seem, on the whole, to think that the landing speed of a load-carrying aeroplane at 15,000 feet would put flying out of court. I do not pretend to understand flying problems, but I know something of motor-lorries—my private "car" being, in fact, a one-and-a-quarter tonner. I do not believe that, if the passes and fords were made up, motor transport to the Base Camp is outside the range of practical politics, nor that it might not even be cheaper than pack transport after allowing for the cost of road-making. There is only one real objection, but I believe it is an insuperable one—the religious sentiment of the country. Wait—I have forgotten one other objection, also based on sentiment, my own and that of many more who would be sorry to see the last of the mule and the yak for reasons which we should find it hard to put on paper. I suppose we should have to abandon our prejudices if the success of an attempt on the mountain were at stake; but, for the present, we lie safely entrenched behind the prejudices of Tibet.

To those unacquainted with the route of the expedition, it may come as a surprise that motor transport to the mountain could be even seriously suggested. Seeing that the object of the expedition was to visit the highest mountain in the world, it might be supposed that the country traversed would, for the most part, be mountainous. This idea is even stronger in the minds of the inhabitants of Darjeeling, who, seeing the tumbled mass of mountains facing them, into which expeditions disappear, find it hard to realise that the greater part of their way will be across plains and rolling country, once they have passed through the barrier of the hills. This barrier is only about sixty miles wide where the expedition crossed it, the actual route being about a hundred miles. The subsequent journey across the tableland was something less than two hundred and fifty miles, at an average elevation of between fourteen and fifteen thousand feet above sea-level.

The ranges of hills which cross the tableland all have well-worn passes through them which offer no difficulties to the pack animals, so that the only obstacles are the rivers. These are all easily fordable in early spring, while the glaciers, which are their head-waters, are sealed with frost, so that at the time of our approach to the mountain it would have been possible for animal transport to move in almost any direction through this part of Tibet. On our return journey, in July, the rivers were swollen with the thaw, though still generally fordable, especially in the early morning before the sun brought down the full spate, if the right spots were chosen. In some places good bridges have been built with piers of stone, and wooden spans and single-span bridges over the smaller rivers are common.

At Gatong, on the return journey, the whole expedition crossed the Phung Chu River by a yak-hide ropeway. I had heard of this Gatong ropeway but never seen it. The descriptions given me by porters had led me to expect something more thrilling, and I must confess to some slight disappointment when I found that, instead of spanning a gorge, the rope was stretched just above the water. The river here was a raging torrent, and we were distinctly anxious about our ponies, who would have to swim. The stillest pool in the neighbourhood was chosen, only a few yards below the ropeway as it happened, and, by tying them, one by one, to a rope held by men on the far bank and pushing them into the water, we "swung" across the current without mishap. I think we were all greatly relieved when the last of them was safely across, but it was interesting to watch the way in which individual ponies faced the ordeal, some frankly scared, some with a sort of desperate resignation, and some as if they had been doing it all their lives. As they got out of the slack water under the bank and into the main force of the current, the pull of the rope round their necks heeled them over and the heads of even the strongest swimmers were under water for a few minutes; some made an almost completely submarine crossing.

Luckily we changed transport at Gatong, so that the pack-animals did not have to be crossed, and it was only necessary to sling our baggage and ourselves across the rope bridge.

It was a crude contrivance, three ropes of raw twisted yak-hide stretched across over a forked post on either bank and anchored at each end with a heavy pile of stones. On these ropes slid a wooden yoke, fashioned out of the bent branch of a birch tree, to carry the load, human or otherwise, and this was pulled backwards and forwards by strong yak-hair cords. The yoke has a horn-like handle on either side; the passenger grasps these and is bound on to them by raw-hide thongs passing under his knees. Thus trussed up, with his knees to his chin, he is hauled across in a half-sitting, half-lying position, while his friends, if he happens to be a member of an Everest expedition, heave rocks into the water below him and drench him from head to foot. This pastime, starting among the sahibs, soon spread to the porters and helped to relieve the monotony of five weary hours spent in passing the baggage and personnel across the Gatong Aerial Ropeway.

No account of the transport of the 1933 Everest Expedition would be complete without a jibe at the system of numbering packages—the transport officer's standing complaint, ever present to provide us with a grouse when a grouse was most needed to relieve our feelings. On previous expeditions each package has been given a serial number, and this, stencilled on the box or bale, has served to link it up with an entry in the store-book. It was also the custom to paint coloured bands round some boxes as a clue to their contents. This year the coloured bands were enormously elaborated, but still all went well until, in an unlucky moment, it was decided not to give a different serial number to every package on the expedition, as heretofore, but to start a new series of numbers for each colour. Now, there were twenty-one separate colour schemes this year, which meant twenty-one number ones, twenty-one number twos, and so on. Theoretically it should have been easy to distinguish "No 1 black and blue" from "No. 1 purple and green." Had all concerned had a good eye for colour results would have been better. Unfortunately George Wood-Johnson happens to be colour-blind, and, judging by appearances, the artist who assisted the packers seems to have suffered from the same disability. Colours, too, seem to have run rather short, for there was a red-and-black as well as a black-and-red series. Another difficulty was that the coloured bands were painted round boxes exactly where the pack-ropes go, so that the colours wore away. But, apart from these drawbacks, it is a miserable system from the point of view of the transport officer. His work consists largely in making lists of packages and, when he has to write down two colours as well as a number for each box, and a mule-load consists of four boxes, it is not to be wondered at if, fumbling with a blunt pencil in a biting west wind, he has hard things to say about this kaleidoscopic system.

I must not end up on this peevish note. Transport is the most interesting job on the expedition, at any rate on the out and back journeys, and the transport officer sees more of the people of the country than anybody else, except the leader. One meets, and has dealings with, all types of Tibetans, from the suave, Chinese-looking official or business man, with his face bleached by the paper-windowed twilight in which he lives, to the hard-bitten, picturesque muleteer of the plateau, whose tanned and leathery skin is seamed by the sand-blast of the Tibetan dust-storms. Though the former type regards one as a barbarous simpleton who must be solemnly humoured to obtain the best financial results, it is to be hoped that the latter sometimes sees in one the semblance of a fellow-man.

IV. QUARTERMASTER'S NOTES

By J. L. Longland

These notes have been compiled from a diary and from recollections arising out of about six weeks' quartermastering on the march across Tibet and the first advance up the glacier. They are not intended as any general summary of the work of handling stores during such an expedition, but are simply a series of suggestions which may be useful in one small part of the organisation which will be necessary before the next attempt.

This naturally means suggestions for alteration or improvement, but the reader should not run away with the idea that things were bad this year, simply because there is no space to mention the results of all the forethought that was devoted to the stores in England, the many admirable innovations that were introduced, and the extraordinary completeness of our equipment in view of the very short time that the leader and Mr. Scott had for preparation.

The first principle which impressed itself upon one this year was the necessity of making the whole business of stores—format of store-book, arrangement of categories, programme of issues—as automatic, or, more bluntly, as fool-proof as is possible before an expedition leaves England at all. The obvious point that transport difficulties in Tibet, and bad weather or sickness on the mountain, will probably cause a series of opportunist modifications in any previously contrived plan, is a bad reason for forming no plan at all until a crisis arrives. It is rather additional grounds for working out in advance a system which is as complete and uncomplicated as can be managed, that illness or a sudden change in the strategy of assault on the mountain may remove your transport officer or quartermaster from the key-point in the line of communications, and involve in his job at the shortest notice another member of the party who has had no previous work with the stores at all.

Preliminary Arrangement of Stores

1. If possible, the quartermaster's post should be given to a member of the party in England as soon as ever the first stores are being collected. He should be someone who can spare time to supervise personally the whole of the packing, and who has a power of veto if badly packed or badly marked stores are sent along to the clearing-house. It is not easy for anyone who has not himself wrestled with embodied chaos to realise what it means to be confronted for the first time in India with a mountain of assorted stores piled higgledy-piggledy in a small and heat-baked godown. And it would have taken a confirmed cynic to estimate in advance the number of mistakes that could be made in marking and numbering stores which were arriving at the packers' from all directions in a desultory stream for many weeks. But I doubt if the obviously high proportion of colour-blindness among packers' foremen has ever received the amount of medical attention that it deserves.

2. An Everest expedition has to cart about some curiously varied equipment, ranging from foot-muffs to football pumps, from candles to cascaras. But since transport of boxes occupies an enormously greater proportion of time than consumption of their contents, it is important to simplify the numbering and marking in the interests of the transport officers and more especially of their sardars, even if this involves some waste of time when individual boxes are needed for opening. I suggest that there should be no duplication of numbers at all, but that each box should have its own number, which does not reappear even in a box of a different colour category. Colour bands fade or disappear in the course of constant handling and bad weather much more quickly than stencilled numbers, and in the later stages of the expedition we were frequently faced with apparently indistinguishable boxes with identical numbers when the colour bands had disappeared. Serial numbering avoids this difficulty, and also checkmates any mistakes in colouring. It would be best to choose a large series, say from

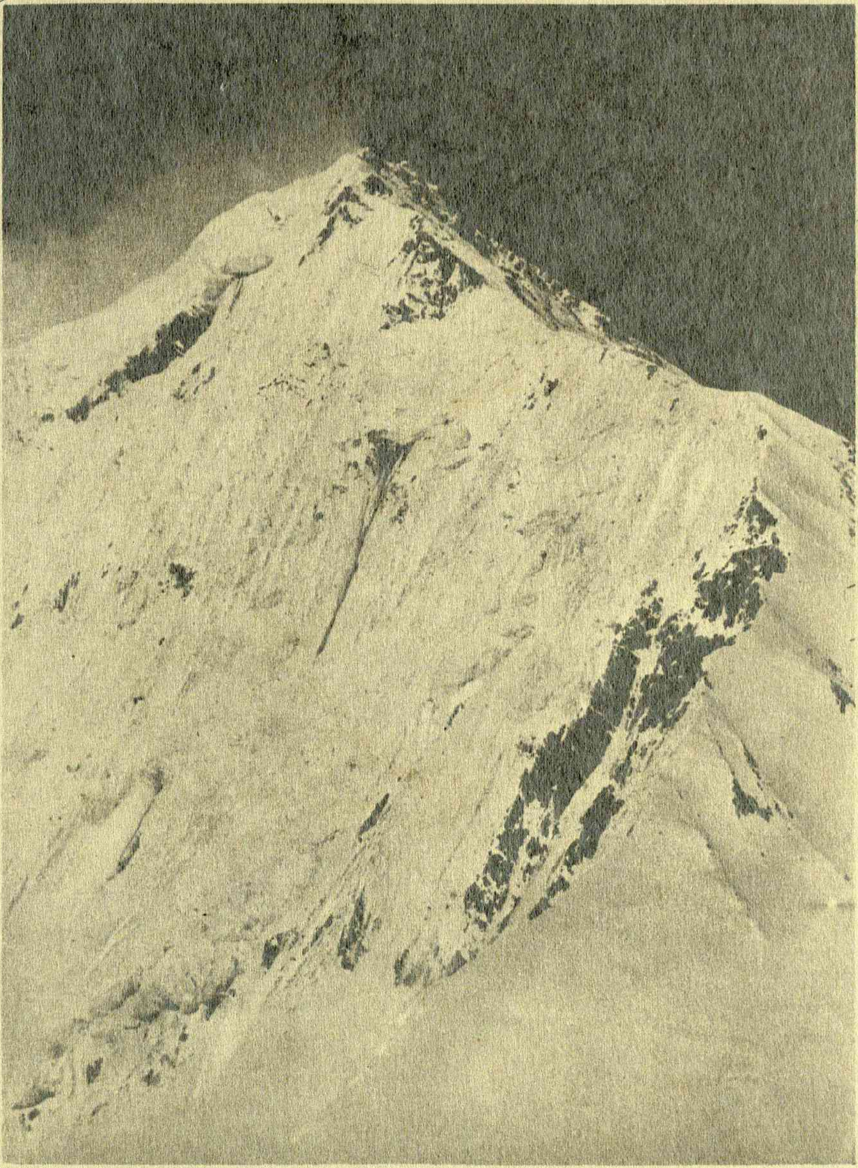


Plate 49.—S.E. face of Mount Everest, from summit of peak above Rapiu La.

1 to 1,500, and leave gaps between the different categories, so that any stores which arrive late as last-minute gifts or unavoidable afterthoughts can be fitted into the system without dislocation. As boxes cannot always consistently be piled in the same way in godowns or in camp the numbers should be stencilled clearly, in waterproof ink, on all *six* sides of each box.

Three colour categories should be enough, dividing the stores into main groups of March, Glacier, and High Camps. Perhaps broad single bands of dark blue, red, and bright yellow respectively will be best for these divisions, as these colours are less likely to fade until they become indistinguishable as did the dark blue and black, and blue and green, in our stores this year. These bands should pass right round the boxes in two directions on the long and the short axis, for the same reason that has been suggested for stencilling the numbers on all sides of the boxes. Then even if some of those who handle stores turn out to be colour-blind, they might be taught to distinguish between these three simple colours, if necessary, by using paints with different smells ! With such a clear method it will be easier to enforce the system, more difficult to accomplish with our complicated colour series this year, of making the muleteers tie up all loads in identical colours, and stack them in camp in the same way, for greater ease in checking and prevention of pilfering.

To facilitate the identification of individual boxes, the system adopted this year with part of the stores of stencilling a " short list " of the contents on the outside lid of each box should be made universal. This can be supplemented by fastening a complete list of contents on the inside of every lid.

3. To ensure that animal loads are in every case nearly identical, all boxes should conform to a 40-pound standard, so that the transport officials can see at once that a full load (two maunds = about 160 pounds = 4 boxes) is being carried. Certain heavy articles which are not bulky, such as money in rupees or Meta fuel, could be made up into 80-pound boxes. If certain boxes are only 20 or 25 pounds, though this is an admitted convenience for such things as high-altitude rations which have

to be carried on the upper parts of the glacier where the coolie load is only about one half of the normal 40 pounds, it is very hard to ensure equitable loading, both for transport animals and porters. It was a common sight this year to see a gigantic yak stalking along, with four high-altitude boxes totalling well under 100 pounds on his broad back, beside a tiny donkey staggering under the full two maunds. Also, when porters were carrying between Camps III and V, with a descending sliding scale of loads from 30 to about 18 pounds, they almost invariably broke open the ration boxes and carried their contents, to save weight, in the special light rucksacks. It does not therefore seem necessary that even the high-altitude ration boxes should be less than the 40-pound standard. There are two exceptions to this method: one, certain light but bulky articles, e.g. "Everest carriers," cannot be done up in packages of the standard weight without making the animal fully loaded with them look like an over-decorated Christmas tree, and so in practice it is easier to load him up on each side with one large and light package, and one small but heavy box; two, for convenience of shipment, stores must often be combined into bales or crates of much more than 40 pounds, but here the principle should be enforced that each component package must be separately packed sufficiently strongly to stand the journey across Tibet. The contents of some of our huge bales and crates this year had to be separately made up into packages in Kalimpong, against time and in circumstances that made efficient packing impossible, with the consequence that by Shekar Dzong many loads were disintegrating and pilfering of their contents was positively encouraged.

4. This brings us on to the very difficult question of the best methods and materials for packing the various sorts of stores. Here a compromise is necessary, since a type of packing at once proof against thieves and against the rough usage of constantly changing and variously unskilful muleteers would swallow up too large a proportion of the total weight and leave little over for the contents. The ordinary Venesta case, while

admirably light, will not stand up against either a determined thief or a series of obstreperous yaks. But unless something almost equally light and a great deal stronger can be designed, these cases will probably be retained for such store-boxes as are only opened *once*, their total contents all distributed, and the boxes discarded (e.g. day rations, or articles of equipment all issued at once to members of the party at a certain stage of the advance). Even with these boxes I suggest that the usual warehouse method should be adopted, of putting a tight steel band round each box, fixed tight with a ratchet and sealed, so that it is nearly impossible to tamper with the contents and not have the result readily detectable. When the transport officer wishes to open them on his lawful occasions, a stout pair of cutters will obviate the damage to box and contents caused if the homelier ice-axe is used.

Where a box must be constantly opened and closed, and only part of the contents extracted each time, the Venesta case is not suitable. The securing screws round the lid soon cease to hold after several openings, and the box consequently begins to break up, no longer being rigid ; and it is not hard to get at the contents, once the screws along the sides have gone, even when the box is padlocked. For these stores, then, as well as for those which are taken out each day and replaced in their boxes for the next march, such as Kranzow lamps, crockery, or books, stouter cases and more complicated locks are necessary. When these boxes are opened at irregular intervals, this year's practice of having set-screws, passing right through the lid, as well as the lock, is probably best ; but where they must be opened every day, I suggest they should be fitted with two locks, just like a suitcase, to hold the box rigid and prevent unauthorised peeps under the lid. Money or other particularly valuable stores might be packed in very thin sheet-steel or aluminium cases, and Messrs. Chubb have very kindly offered their advice on the question of the best kind of lock. Alcohol should be packed in stout boxes fitted with internal divisions, and only one or two keys should be provided, to be kept in charge of the quarter-master or leader : it should not be impossible to design the different locks so as to allow a master-key to be constructed, again for use by authorised people. Similarly, I doubt if it is good policy to have a separate key with the padlock inside every box : it would be easier to control issues if keys were only supplied to the head cook, mess-man, Gurkha N.C.O.s, and selected sardars, with a small reserve supply in the quarter-master's possession.

Only stores which cannot possibly be put into boxes (e.g. big tents, bulky bedding) should be done up in gunny bales. Bales offer a very indifferent resistance to bad weather or rough handling, and, since it is often possible to feel attractively shaped objects under the outer covering, are much more provocative of looting. Valuable goods such as climbing boots, windproof suits, or high-altitude sleeping-sacks, all of which were heavily plundered on the march, should certainly be put in boxes, in spite of the greater weight and bulk involved.

Weighing bales and boxes periodically in camp proved an insufficient precaution, since a thief who was skilful enough to open a package and close it again without leaving any obvious traces was also cunning enough to replace the articles he abstracted by stones and turf sods of approximately correct weight. I can well remember our disgust at Camp I when, on opening up some luxury boxes which had been weighed and passed at Shekar, we found that all the crystallised fruits had vanished, though their lead outer cases were left as a make-weight, suitably reinforced with stones, while the two tinned Stiltons had been pierced with an ice-axe, and left in their places, the native nose not being sufficiently civilised to tolerate the delicate smell that emerged.

But with suitable supervision, and the adoption of methods similar to those I have described—metal bands for all Venesta cases, stouter boxes and better locks for frequently needed stores, and the elimination of gunny bales—it should be possible to checkmate attempts at theft on the march. On the glacier pilfering, which seems generally confined to small quantities of food and alcohol, is much harder to check. In glacier camps

PLATE 50.—Mount Everest from a peak above the Base Camp.

few people have the time to devote to effective supervision, and in fact in camps above Camp III, where it is particularly necessary to give porters all the food and luxuries they will eat, pilfering becomes so unimportant that it might almost be encouraged! In camps up to III, the only safeguard is a very limited issue of keys; but since climbers after a hard day or in blizzards are naturally very ready to leave the cold business of issuing stores to mess-man or cook, and will consequently hand their keys to him, no system that is completely reliable can be devised.

5. Certain special stores need particular methods of packing. Money in coin and alcohol have already been mentioned. Petrol or paraffin fuel is something of a problem. You want a container which is readily opened and yet proof against leaks, since if the tins are nearly full at Darjeeling, several openings will be necessary, to prevent bursts, in the gradual climb to reduced air pressures at the Base Camp. The ordinary petrol tin seems to serve well, but it would be a great advantage if some lock could be fitted to the cap. Porters are careless about filling Primus stoves, and once they have lighted them, tend to keep them roaring in their cook tent all day for warmth, and, since our very generous supply this year began to fail in June, months before it should have done, it is obvious that rigid control of fuel issues is required. Also Venesta cases are not very suitable for transporting the tins across Tibet; constant opening and screwing up again weakens the boxes, and the unstable weight in the filled tins completes their demolition.

Primus stoves should each be enclosed in a tin large enough to contain all needed parts, including alternative burners, or else loss of time and spare parts seems inevitable.

Matches should be distributed among ration boxes, and not left to the hazard of a single case. A reserve supply can be kept in a *waterproof* box with a good lock.

The packing of oxygen is a matter for the particular climber in charge, but this year's experience suggests that the whole consignment should be sent to Calcutta for testing quite separately from the rest of the stores, and in charge of the responsible member.

Specially fitted boxes seem to be needed for spare tent-pegs and guys, which, if included with individual tents, are easily lost. Boxes with specially designed compartments would be useful for crockery (something on the lines of a picnic basket, but less complicated), and for the Kranzow lamps (which all got damaged in transit), and a special box for the cook to take on with his pony in advance, equipped for the midday meal, which is usually over before the main transport comes in.

Other frequently used things needing special packing and locks are gramophone records, newspapers and magazines, maps and candles.

Lastly, if there is ample time for preparation, although there is a multiplicity of small and unrelated objects that are needed on the march, it should be possible to avoid boxes which are altogether a lucky dip. A box containing Homburg hats, "Jollyboys," Grenfell smocks, and tooth-brushes is trying to the quartermagistral temper, and such infinite variety means considerable delay on those occasions when a great many people are clamouring for a great many different things. Incidental to this, individual members of the party should be made to include all the articles of kit they are certain to need before the Base Camp in their own personal luggage at Darjeeling. Certain awkward things, like crampons, which are not likely to be wanted before the glacier, can travel with the main stores, but great waste of time and efficiency is caused by issuing personal stores in small driblets to members who realise their needs at surprisingly different times. Such spare parts as tooth-paste, Bromo, or bootlaces will always require a haphazard method of issue, but if a list of individual march kit (camp-boots, blankets, etc.) not already in personal luggage were worked through at Darjeeling with the whole party present, much time would be saved on the march. It is also probably not a very good idea to encourage individuals to give their own personal luggage to the packers to be included in the general shipment. "Mr. C. G. Crawford : one pair of socks, packed in a case of champagne," would cause difficulties, as the member concerned would demand the first and not be allowed the second.

Arrangements in India and on the March

1. One difficulty is that the stores should obviously be dumped at the ropeway-head in Kalimpong, where the mule journey begins, whereas it has been customary to make Darjeeling the headquarters of the expedition in India. It is a great convenience if the party can all stay near the stores during the days before the march, both for ease in issuing kit to climbers and porters, and to familiarise all members of the party with the arrangements of stores before the journey begins. If this is not possible, it is at least essential that the quartermaster should be with the stores during this whole period, whatever the rest of the party is doing. If he is not present during all the loading of transport animals, especially if some of the stores are sent off in advance of the party, as they were this year, it becomes very difficult to check lists and numbers later in the journey. It seems very doubtful whether advance stores should be sent on ahead of the main body, unless the quartermaster or a transport officer accompanies them. I see in my diary of March 30th, when we had just picked up our advance stores at Kampa Dzong, the entry, "puzzle much over stores discrepancies (11 packages present and not on the list, and a large number unaccounted for)." This difficulty was caused by my having to be one day in Darjeeling and the next in Kalimpong during the time when the advance stores were moving off. The fact also that the stores wait for a week or more at one place before the party catches up makes supervision by a climber more necessary still, since this stationary period gives a dishonest servant ample opportunity to thieve with discretion and to cover his tracks completely.

This year half the party was sent on a week in front of the others for acclimatisation purposes, which made a further subdivision of stores and personal kit necessary. If this method, which has advantages for climbers who have never been in the Himalayas before, is adopted again, it is advisable that the proportions of stores needed by each party should be worked out in England, and the appropriate boxes at once segregated and marked in the godown. It is essential that the quarter-master should go with the second party, and not the first. This year the two people who had done the preliminary work on the stores happened to be with the advance party, and consequently muddles appeared quite naturally when the others started with their stores a week later. Through a mistake, some of the special high-altitude pots were issued to porters at Kalimpong, and recovered rather battered at the Base Camp, while Birnie had to do an all-night march from Yatung to stop the Whymper tents, which would be needed at Phari, from going right on to Kampa Dzong while their owners trailed hopelessly behind. So it seems clear that the quartermaster must keep close to the stores from the moment they arrive at Kalimpong.

2. An effective system of supervision of stores on the march, and more in the nightly camps, is essential, as we learnt from our losses this year. In camp the simplest method is probably that adopted by us after Shekar Dzong, of making all the stores into one dump as close to the climbers' tents as possible, and roping the dump in such a way as to make it difficult to remove a box. Unless this rule is enforced, each little knot of transport drivers will make sangars of the group of boxes in their charge to protect them from the cold, and if they get into camp late in the evening (as this year at Trangso Chumbab), or if there is not much room for party and animals on the same site (as at Jikyop), these little collections of boxes are often some distance from camp, and no one has the leisure to be constantly patrolling. One single dump in the middle of camp each night is, I think, the only answer, even if it means providing the muleteers with yak hair tents.

During the day's march the best precaution is to extend the system used to guard the money boxes on the way, that is to

PLATE 51.—Mount Everest and the Base Camp in June.

put a responsible sardar in charge of a definite series of boxes, which he must count both when they are being loaded and unloaded, and must also accompany throughout the march. The Gurkha N.C.O.s were very efficient in this policing, and it should be possible to parcel out the whole of the stores between them and, say, six under-officers. Where there are transport drivers with very small herds in the charge of each man, as on the marches between Kampa and Tengkye, several of these must be required to travel together, to make up the full tally of boxes.

It would be advisable to attach one special sardar to the quartermaster from Darjeeling onwards, so that he can be gradually trained as an understudy, and can be a very useful stand-by when, as will probably happen, the quartermaster is needed for climbing at the higher camps, and the transport officer has to take over his job. Also a small special squad of porters might be detailed at the beginning of the march to help with the heavy work of shifting boxes in camp.

3. In the store-book should be marked the *order* in which stores are to move up the glacier, and the various camps at which they are needed. If the store-books are marked in this way in England, and if a copy of the store-book (Glacier and High Camp section at least) is kept at each camp, it will be possible to ensure the right stores reaching the right places without muddle and without an intensive system of little notes flying up and down the glacier. The transport officer will simply have to work through as many loads as he has coolies for, in accordance with an order of "first necessities," "second necessities," etc., already printed in his store-book. The receiving officer at the camp to which the loads are carried will merely have to check the boxes in by his own copy of the store-book. This seems the best method of ensuring that, even while the climbers and some special porters may be waiting at a camp for acclimatisation, a constant stream of the right stores shall be passing up the chain of camps.

4. The food which an Everest expedition has to carry will never stay discussion as well as it may stay appetite, and,

as space is small and an individual opinion only one of a dozen opinions to which a leader has to suit his selection of food, I am not going to do more than touch certain aspects of this vexed, or rather tormented, question which belong particularly to quartermastering. For the quartermaster in his official capacity is exclusively concerned with the arrangement and issue of food, and only secondarily, as a suffering human being, with its kind and quality.

But if, as seems likely, a future expedition invites offers of foodstuffs from any firms who may be interested, some central figure will be useful who can receive their wares, sample them (aided by a staff of unimpeachable palates), and decide which will be good for the expedition, and what quantities will be wanted. And since the packing of foodstuffs is the quartermaster's care, he might take this task as well from the shoulders of the over-worked leader. It will probably be most economical either to hire a warehouse floor in London and engage a private staff of packers, or to employ some export packing firm which is *not* interested in the supplying of stores. Thus a uniform packing can be ensured for food arriving from many different sources. Of course, if firms who are actually giving foodstuffs are also prepared to pack them in accordance with the 40-pound schedule and regulation strength, it would be ungracious not to accept ; but the quartermaster must have absolute power of veto against unsuitable or inefficient packing, and must retain the right of marking and numbering the cases entirely in his own hands.

In arranging foodstuffs, the man-day ration system is probably best for the march across Tibet. I think, however, that it is a mistake to provide a *complete* ration in every box, since certain things, like butter, condensed milk, salt, tinned meat, or jam are consumed at surprisingly varying and totally incalculable rates (often in inverse ratio to the amount of palatable fresh food available at a village). The day-ration box should, then, contain basic and invariable necessities, and these other foods of variable consumption rates should be collected in separate chop boxes (e.g. one case of butter to thirty day-ration boxes). This will cause some little trouble to mess-men and cooks at first, but not nearly so much as having to make these collections, usually in unsuitable boxes, while on the march, from a number of ration boxes from which all·other stores have been emptied.

On the glacier appetites are so fickle and incalculable that it is doubtful if it is worth continuing the pretence of a day-ration any longer. But you might keep a drastically pruned series of boxes containing basic necessities (e.g. oatmeal, sugar, Ryvita) as the one stabilising force in a much larger number of "luxury boxes," packed with assortments of delicacies calculated to suit as many difficult appetites as possible. As someone said at Camp IV, "at this height *all* your food must be luxuries." These luxury boxes should be marked "Only for Camp III and above," since on the passage up from the Base Camp the resident cooks at each camp try to take toll of any delicacies for the benefit of any sahibs living in their camp, and what began as a load of vegetables may, as once this year, fetch up at IIIa as one Brussels sprout, part-worn! The ideal to aim at, though incapable of achievement, as opportunities for elaborate cooking decrease the higher you are from the Base Camp, is a scale of living which increases in luxury with each advance in height, so as to counteract discomforts of weather and mountain-sickness, and if possible delay the appalling loss of weight that attacks climbers living for any length of time at 23,000 feet or over. But the arranging of a constant service of fresh meat, fresh vegetables, and bread to reinforce the storm troops at the head is the transport officer's job and not the quartermaster's. The importance of such a supply is obvious, but has perhaps not been completely realised in the past, and is certainly worth a good deal of trouble and expense to arrange for any future party. The inevitable and cumulative distaste for patent foods and even for any tinned stuff, simply because it *is* tinned, can perhaps be postponed by keeping off tinned meat on the march across Tibet, so that when you come to eat at the high camps, in which your staple quite naturally is something from a tin, you can approach a tin with a less biased mind, and preserve that freshness in yourself which you seek in vain among your food. This should certainly help with the normal person living in England who does not eat very much tinned food in ordinary life, though for inveterate backwoodsmen and lonely outposts of Empire, whose stomachs are already heavily tin-plated, it is probable that none of these harmless subterfuges will be effective. But a complex against tins as such is largely an effect of altitude upon a mind already jaded by an insufficient variety of tinned stuffs from which to choose attractive daily meals. An entry in my diary during the first days at Camp III still makes me swallow hard, where I apparently ate a hearty meal of two kinds of food which I couldn't be induced to face now, even under an anæsthetic. A greater variety will stave off this accumulating disgust, but for the sheer irrational "anti-tin" attitude you must blame altitude. It was noticeable, when I was travelling back through Sikkim with one of the wireless officers, that he still preserved a passionate curiosity about the contents of tins, especially those that had not impinged on his quiet life at the Base Camp, while anything coming from a tin, however surprising, had in my case to be elaborately disguised before I would show the faintest interest.

V. NATURAL HISTORY AND BOTANY

By E. O. Shebbeare

Although on Everest expeditions scientific research has never been allowed to interfere with the straightforward object of trying to reach the summit, a good deal of work has been accomplished on these adventures.

In 1921 Wollaston obtained specimens representing over 200 botanical species, 10 mammals, and 61 birds, besides observing and identifying 33 more birds. In 1922 the collecting of birds was discontinued in deference to Tibetan feelings, but, working on Wollaston's notes, Longstaff and Norton were able to add to the list a great number of birds by observation, and Norton, with the help of Roomoo, the Lepcha collector, brought back botanical specimens representing over 270 species. In 1924 we took no collector into Tibet, but Hingston by his own almost unaided efforts brought back 500 specimens of plants and 10,000 specimens of animals, mainly insects. I am, unfortunately, unable to say how many species were represented in this wonderful collection. As before, no birds were collected in 1924, but we were fortunate in having with us three exceptionally keen observers of bird life—Norton with previous knowledge of Tibet, and Beetham and Hingston who, though new to the country, had had much experience elsewhere. From them, especially from Norton, I learnt to recognise most of what I saw.

This year, with the help of what I had learnt in 1924, Dresser's *Palæarctic Birds* and Ludlow's paper on the birds in the neighbourhood of Gyantse, I found that I could identify the majority of the species we met with on the expedition.

We had the misfortune to lose the whole of the zoological collection which Raymond Greene had taken much trouble to collect. It was all in one box, which was standing beside his tent when we were camped close to the village of Lingga on the return journey. In the morning it was missing, and though a thorough search of the whole village was made, we never discovered it, the thief having presumably put as many miles as he could between himself and the expedition during the night. It was poor consolation for us to picture what the rogue's disappointment must have been on examining the contents of his prize—valueless to him, so valuable to us. Among the contents was a collection of grasshoppers which would probably have been of special interest.

This year's botanical collection compares unfavourably with the work of previous expeditions, for the specimens, recently dispatched to England, number only 162 and may, allowing for duplicates, represent something like 120 to 130 species. Their condition also leaves much to be desired, for in the rush of the return journey, on which, for the sake of our invalids, we could not afford to halt, the changing of drying-papers was neglected. This caused no trouble in the dry climate to the north of the main backbone of the Himalaya, but once in Sikkim and within the influence of the monsoon, mould began to attack the specimens, and even those which had seemed perfectly dry in Tibet soon became a horrible mass of green mildew. With neither the time nor the sunshine to dry them out, for it rained most evenings, we were forced to leave matters as they were, and the herbarium did not get its much-needed sunning until after our return to Darjeeling.

This year, with no special collector, we could not hope to add much to the extensive work of earlier expeditions. We judged it best to concentrate first on the higher elevations at which any plant life was found and then on the plains of Tibet, treating the monsoon valleys as the least important. The valleys, in the north of Sikkim at any rate, are available to any botanist who can spare a fortnight's leave, and have, moreover, been extensively worked by experts from Hooker to Cave. The plains of Tibet and Mount Everest have, on the other hand, only been visited a few times, and no one can say how often we may be in a position to visit them in future. In any lists that I have seen of the collections made by previous expeditions the flora of the valleys has been combined with that of the tableland and mountain. As might be expected, the moist climate and comparatively low elevation of the former produce a luxuriant vegetation far richer in species than that of the latter, so that in any combined list the valley species outnumber and swamp those of the tableland and mountain. We therefore kept as full notes as possible on distribution, and we have tried to show in our lists the plants most commonly found in various situations.

It might be supposed, and I believe this was expected by some botanists, that the earlier and lowlier forms of plant life, such as lichens and mosses, would ascend the mountain to higher elevations than the flowering plants. This was not so. The highest plant found this year, perhaps the highest ever found, was a straggly Crucifer with a pale pink flower, which was growing on the moraine of the East Rongbuk glacier below

Camp II at an elevation of 19,000 feet as nearly as we could judge. It was rooted in a pocket of wet glacier sand and had struggled up to the light so as to hold its flower and leaves under the shade of one of the rocks of the moraine. A similar plant was found on the Kongra La at about 16,000 feet. Whether both are of the same species remains to be seen when the specimens are identified.

It may be held that an isolated plant like this, happening to germinate at this extreme elevation, should be regarded as an exception. The highest elevation at which plants normally occur on the north face of Mount Everest is a few hundred feet above 18,000, just above Camp I. Here the species that appears to go highest is a cushion-plant with moss-green, and rather moss-like foliage and small white flowers—an Arenaria I believe. Just below this, at the elevation of the camp itself, about 17,700 feet according to our reckoning, some twenty species are found, including a moss and an Ephedra, but mostly Dicotyledons with smallish but quite showy flowers. At this elevation the family best represented is perhaps Compositæ, the members of which are mostly protected by white down.

The lichens seem to stop short at about Camp I, at about 17,700 feet or perhaps a little lower. Judging by colour, there appear to be about five species—a grey, a green, a yellow, a red, and a black.

The whole life of the vegetation of the mountain, of the tableland and passes of Tibet, and even of the upper parts of the monsoon valleys, is subterranean for at least three-quarters of the year. When the expedition gets above the tree-line, at, say, 13,000 feet, on its outward journey towards the end of March, it has seen very nearly the last green thing that it will see until flowers begin to come out and the hidden vegetation comes to life again at the Base Camp in early June. A few green bushes of the gorse-like Caragana near the stream in the sheltered valley at the back of Kampa Dzong, and a couple of acres of green in the irrigated willow-garth at Tashidzom are the only relief from the absolute desert of Tibet in winter.

It is almost impossible to believe, at this time of year, that the whole country is not as barren as the Sahara. All that shows above the surface on the plains round Tatsang are a few greyish cushion-plants, looking more like stones than vegetation, while, on the sandy plains round Shilling, Caragana bushes are up to their necks in drifted sand and look dead. In spite of its barren appearance the tableland supports gazelles and herds of wild asses, which contrive to find a living throughout the long winter, and not a scanty living either, for they are as fat as butter.

The plateau is not dead, it is only asleep for three quarters of the year, every plant sheltering underground from the bitter winds that blow out of the west. Early in June the cushion-plants turn green, the half-submerged shrubs send out new shoots, flowers spring up from unseen roots, and everything prepares to rush through the business of flowering and setting seed in the short season before winter is again upon them. The whole desert is in bloom, for there is no time to be lost and everything is in flower together. *Incarvillea Younghusbandii* is a startling flower like a gaudy pink convolvulus springing direct out of the bare earth with a hardly noticeable, flat rosette of leaves pressed against the ground. On sandy plains a beautiful mauve iris (*I. kumaunensis*) grows everywhere, and occasionally one of the blue poppies, the forget-me-not one and the most handsome. Blues and mauves are favourite colours for the flowers of the plains of Tibet, and one of the commonest of all is a leguminous plant (*Oxytropis sp.*) with feathery foliage and bluish-mauve flowers.

Along the larger rivers of the plateau there are in places small groves of *Hippophæ*, a large thorny shrub, almost a small tree, rather like sea-buckthorn. At a place called Tsering-me on the Dzakar-Chu, one march down-stream from Tashidzom, I was puzzled by an old and gnarled but still vigorous tree nearly eight feet in girth. The foliage seemed familiar, but it was some time before I recognised that it was nothing more than a giant *Hippophæ rhamnoides* which, having outgrown the necessity for self-defence, had given up

PLATE 52.—Longland crossing a Tibetan River.

producing thorns, "like the high branches of a holly tree." It had evidently acquired sanctity, judged by the number of flags tied to its branches; perhaps this had contributed to its long life. It would have been interesting to know how old it actually was.

I have mentioned the willow-garth at Tashidzom as a sort of green oasis on the outward journey; on the return it was a perfect flower-garden. How it would strike anyone fresh from an English country-side is hard to say, but after months among barren moraines it was like the freshness of Colombo after arid, dusty Aden. The flowers standing in the long grass were much like those of an English meadow, though not many were actually identical. The favourite colour here was yellow—dandelions, potentillas, buttercups, mustard, a primula and a long-tubed pedicularis particularly. The trees in these rare irrigated and walled-in gardens are mainly willows, pollarded or coppiced at various heights to supply the village with withies, but there are generally a few huge poplars also planted.

Such places are full of birds and are the only nesting-places for many species. Magpies are always common in villages where there are any willows, and the trees are full of wrens, warblers, and some of the less common small birds. At Tashidzom there were grey-backed shrikes, hoopoes, and crag-martins always somewhere about the garden, and a pair of Tibetan hares spent the night among the long grass. Outside the garden were the common birds of a Tibetan village, tree-sparrows, house-martins, rock-pigeons, ravens, and kites. The Brahminy duck and bar-headed geese, which had been so tame there on our way through in April, were now busy with their broods and keeping out of the way of mankind.

The birds of the Base Camp were above all the yellow-billed chough, the rock-pigeon, and the red-breasted accentor, which this year was commoner than the little brown accentor, the friend of the 1922 and 1924 expeditions. These birds were with us most of the day, arriving at daybreak and leaving at sundown. Most evenings a few snow-finches would spend an hour or two in the camp, and for a week or so after our arrival a pair of rose-finches frequented the frozen pond in the early morning. I expected them to breed somewhere in the neighbourhood, but they seemed to have found a better spot, and I never saw them again. This year, as far as I know, the lammergeyer only visited the Base Camp twice, a mature bird shortly after we arrived, and a full-grown bird in immature plumage about the first week of June. The most surprising bird to meet at this elevation was a solitary Indian rufous turtle-dove, which attached himself to the rock-pigeons and appeared in the camp on two or three occasions about the middle of June. This bird has been recorded from the Kharta valley, which is not far off and is perhaps the roosting-place of the rock-pigeons.

Of the birds of the plateau the most noticeable, on our arrival, were the snow-finches, which share their burrows with the mouse-hares. They were still about on our return across the plains in July, when their glorious song, beginning before it was fully light and going on into the night, if there was an early moon, is one of the delights of Tibet. When I say that the larks were not conspicuous until they began to sing, I mean the Tibetan skylark, who is the best songster. The Calandra lark, strikingly marked and as big as a mistle-thrush, is always conspicuous, and so is Elwes's eared lark, perhaps the commonest bird of the plateau and coloured rather like a ring-plover.

I think we saw less of the mammals of Tibet than we did in 1924. The wild ass and Tibetan gazelle were fairly often sighted, and ovis ammon once, I believe, by some of the party. I did not hear of anyone seeing a marmot this year, though I once heard one, and saw a dead one that had been killed by a dog below the Kongra La. I only once saw the rock-pika, and that was in Sikkim and not Tibet. The herd of burhel, as usual, visited the Base Camp several times and a cinematograph picture was taken of them. Those interested in that elusive species, the abominable snow-man, will be sorry to hear that there were no reports of either him or his tracks this year.

VI. LIST OF PLANTS COLLECTED IN THE RONGBUK VALLEY

With Notes by L. R. Wager

The small collection of plants made by members of the 1933 Mount Everest Expedition comprises a fairly representative collection from the Rongbuk Valley and various haphazardly collected specimens from the other parts of Tibet visited during the return journey.

The Rongbuk Valley collection is probably typical of the flora of the high northward-running valleys of the Central Himalaya. Our specimens from here have been identified at the Royal Botanic Gardens, Kew, and for this privilege our thanks are due to the director and to those botanists who made the determinations. As Mr. Shebbeare is still in India, the task of presenting and commenting on the list has fallen to me.

Flowers first appeared at the Base Camp, 16,800 feet, in the second week of June. For some time there were only six, namely, *Sedum quadrifidum*, *Androsace Selago*, *Draba glomerata*, *Oxytropis glandulosa*, *Astragalus orotrephes*, and *Lloydia serotina*, the last apparently a species identical with that found in the mountains of North Wales. On July 2nd and 3rd Shebbeare and I, who had been for some time at Camp III in order to evacuate the camp, passed down the Rongbuk Valley to the monastery collecting on our way all the different species of plants we could find. Although only three weeks had passed since we had found the first flower, it seemed to us that most of the plants occurring in the region were either out or were sufficiently advanced to make generic determination possible. The summer being short, all the plants apparently flower at the first opportunity, and probably our collection includes most of the plants living in the Rongbuk Valley at, or above, the Base Camp.

In the lower part of the valley from the Base Camp down to the junction with the Gyachung Chu, considerably more plants are able to grow and the flowering season is longer.

Our collection in this part of the valley is undoubtedly far from representative, and it is the more meagre because here we were hurrying in order to catch up the main body of the expedition.

During the reconnaissance expedition in 1921 Dr. A. F. R. Wollaston and others collected 220 different species of plants[1] from the regions to the north, east and west of the Mount Everest Group. It is, therefore, remarkable that of the plants collected in the Rongbuk Valley in 1933 only four had been previously recorded by Wollaston. Brigadier E. F. Norton and others collected plants during the 1922 and 1924 expeditions. The list of names of the plants collected has never been published, but presumably most, or all, of the forms here recorded were collected, as the route taken was almost the same as that followed in 1933.

Along the junction of the Himalaya and Tibet the abrupt change in climate, occurring within a few miles, causes abrupt changes in the flora. For this reason, as Shebbeare has written in the chapter on natural history and botany, it is desirable to give accurately the localities of the plants collected. Rapid changes in the climate must partly account for the great difference between Wollaston's list and the present one.

The Rongbuk Valley, which extends northwards from the glaciers of Mount Everest to the junction of the Rong Chu and Gyachung Chu, is only twelve miles long. It lies entirely north of the main range of the Himalaya and its lower end is still 15,300 feet in height. The valley is therefore a circumscribed region within which climatic conditions are fairly uniform. During the winter—roughly from October to May—drifts of snow occupy the hollows, but a continuous covering probably never lasts for long, owing to the small amount of the snowfall and the extreme dryness of the air ; at this time low temperatures and violent winds are usual. During the summer months precipitation is also small and frost probably occurs on most nights. The conditions for the whole valley must differ only slightly from those for the Base Camp, described in the chapter on the weather.

[1] *Mount Everest—The Reconnaissance 1921*, pp. 346–350.

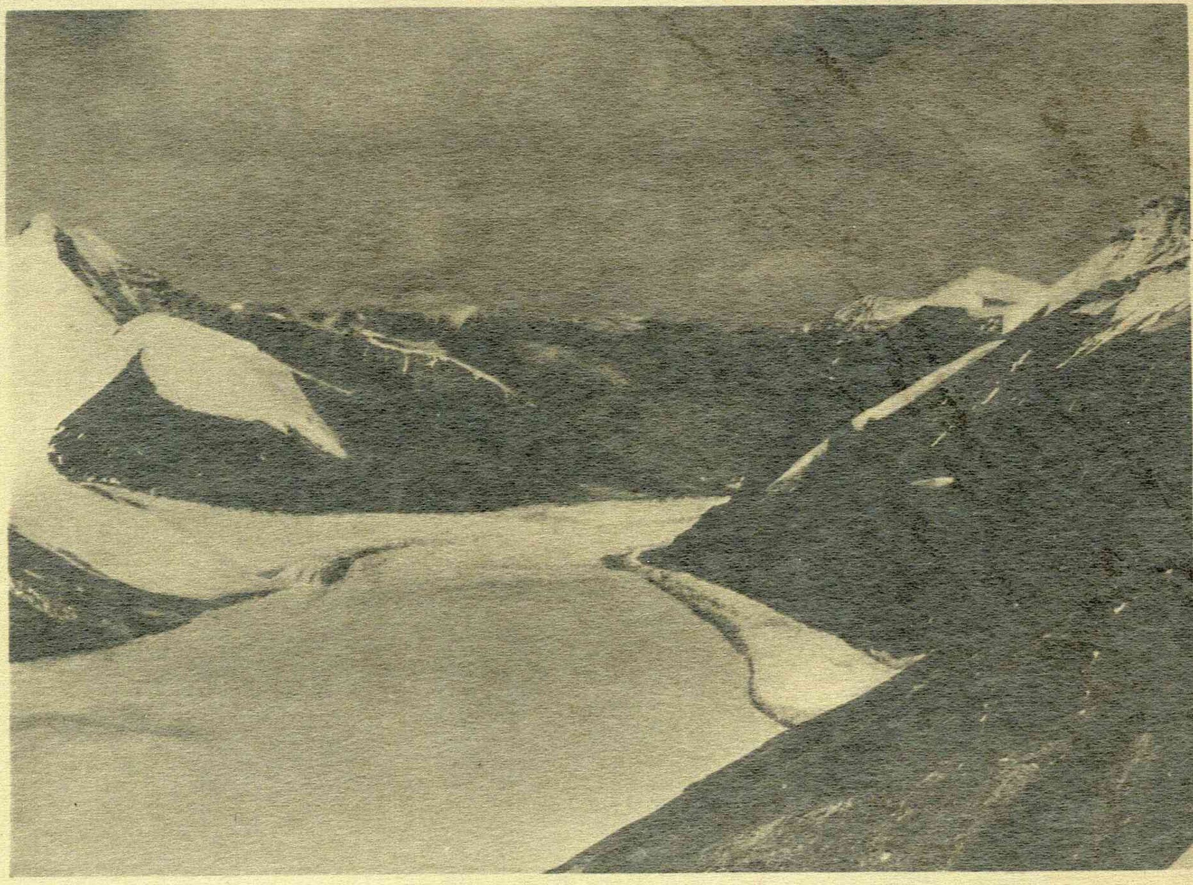


Plate 53.—The middle part of the East Rongbuk Glacier showing the troughs. Photograph from the route to the Lhakpa La.

Nevertheless, within the valley there is some variation in the distribution of the plants, which presumably is mainly the result of small climatic differences, and for the purpose of assigning localities and describing the conditions, the valley will be divided into four regions : (*a*) Camp I, (*b*) the Base Camp, (*c*) Rongbuk Monastery, and (*d*) the lower valley.

The Camp I region, extending from a point half-way between Camp I and the Base Camp up to the snout of the East Rongbuk glacier, varies in height from 17,500 feet to 18,500 feet. Compared with the more northerly and lower parts of the valley, the summer snowfalls in this region are more frequent and slightly heavier. In a general way, the climate of Camp I has been regarded as pleasanter than that of the Base Camp, and in fact it would have been made the base in 1933 if animal transport could have been used so far. Various plants also apparently find conditions at Camp I more congenial than lower down, for the flora at Camp I is richer than that at the Base Camp. Above the Camp I region only a single plant was found, a crucifer, *Ermania himalayensis.* With increasing height there appears to be no gradual falling off in the number of species, but an abrupt cessation of all plant life, and this point is so remarkable that it will be returned to later.

The plants collected in the Camp I region were found among scree and old moraine on the south- and south-west-facing hillside along the usual route between the camps. In the drier localities the following plants, which also occurred at the Base Camp, were noticed or collected [1] : *Thalictrum glareosum*, *Draba glomerata*, *D. lasiophylla*, *Viola biflora*, *Arenaria ischnophylla*, *Astragalus orotrephes*, *Oxytropis glandulosa*, *Potentilla fruticosa* (apparently the same as the English species), *Sedum quadrifidum* and *Sedum* sp. prox. *S. bhutanense*, *Artemisia* sp., *Androsace Selago*, *Rheum globulosum*, *Ephedra saxatilis* var. *sikkimensis*, *Lloydia serotina*, and various grasses.

Certain plants found rarely or not at all at the Base Camp

[1] In the complete list of the plants of the Rongbuk Valley on page 309, the locality given is that of the actual specimen identified.

and in the valley below occurred at Camp I among scree, under which water from glaciers or snowdrifts on the hillside above was running continuously during the summer. Plants found in this habitat were : *Anemone* sp., *Corydalis* sp., *Lychnis apetala*, *Petasite* sp., *Nepeta* sp., *Rheum* sp.

There were also other plants not occurring lower down the valley which, although not necessarily found near running water, were probably only able to inhabit the Camp I region because of the greater general dampness. Plants in this category were : *Paraquilegia grandiflora*, *Meconopsis horridula*, *Saussurea gnaphalodes* and *Primula Caveana*. The *Paraquilegia*, *Meconopsis* and *Saussurea* were found later on the Doya La and at other places where moisture-bearing winds penetrate from the south.

Besides the conspicuous flowering plants, a new species of moss, allied to *Barbula nigescens*, was found at Camp I, and various lichens, three of which have been identified : *Lecidea* sp., *Placodium elegans* and *Acarospora chlorophana*.

The complete list of plants collected or observed in the Camp I region between 17,500 and 18,500 feet is given below. Those marked with an asterisk were not noted elsewhere in the valley.

* Anemone sp.
Thalictrum glareosum
* Paraquilegia grandiflora
Corydalis sp.
* Meconopsis horridula
* Ermania himalayensis
Draba glomerata
Draba lasiophylla
Viola biflora
* Lychnis apetala
Arenaria ischnophylla
Astragalus Heydei
Astragalus orotrephes
Oxytropis glandulosa
Oxytropis microphylla

Astragalus tatarica
Potentilla fruticosa
Potentilla nivea var. uniflora
Saxifraga sp.
Sedum quadrifidum
Sedum sp. prox. S. bhutanense
Anaphalis xylorhiza
Leontopodium pusillum
Tanacetum gossipium
Saussurea gnaphalodes
* Petasites sp.
Artemisia sp.
* Primula Caveana
Androsace Selago
* Nepeta sp.
Rheum globulosum
* Rheum sp.
Urtica hyperborea
Ephedra saxatilis var. sikkimensis
Lloydia serotina
Agrophyron sp.
Carex Montis Everestis
Carex melanthus
Barbula sp. nov. peraffinis B. nigescens
Lecidea sp.
Placodium elegans
Acarospora chlorophana

The Base Camp region includes the terminal moraines among which the camp lay and the " shelf" as far as a point half-way between the Base Camp and Camp I. Most of the plants which were found at the Base Camp also occurred at Camp I, and except for *Saussurea Kuntheana* and a *Cremanthodium*, probably all the Base Camp plants would be found at Camp I by a more careful search.

The Rongbuk Monastery division of the valley, which is taken as lying between the terminal moraine at the Base

Camp and the older terminal moraine at the Monastery, is probably as dry as the Base Camp, but the wind and cold are presumably slightly less severe. Two shrubs appear here : *Myricaria davurica* and a *Hippophæ.* As we passed through this part of the valley on July 3rd the remarkable *Incarvillea Younghusbandii,* which is widespread in Southern Tibet, and *Oreosolen Wattii* were conspicuous flowers.

Between the Rongbuk Monastery and the lower end of the Rongbuk Valley our collections, as has been explained, were scanty. The Tibetan gorse, *Caragana versicolor,* occurred, and also another shrub, *Lonicera spinosa.* Among the smaller plants we collected *Primula tibetica, Nardostachys Jatamansi,* and *Stellera chamæjasme.*

It will appear from the foregoing that in the Rongbuk Valley there is an abrupt limit above which plants do not go. Within the Camp I region forty-two species of plants were collected or noted. Above this, as Mr. Shebbeare has stated, only one plant was found, namely, the crucifer *Ermania himalayensis,* which was growing in a pocket of soil hidden among the moraine of the East Rongbuk glacier at a height of approximately 19,000 feet.

In the field we were surprised at the abruptness of the upward limit of the plants because there seemed to be no abrupt change, so far as we could see, in the environmental conditions. Near Camp III and on the ridge leading to the Lhakpa La, at heights of 21,500 feet, there were sheltered corners where we expected to see plants. The difference in the weather between Camp I and Camp III was not apparently great, and it was difficult to understand why some of the forty-two species occurring at Camp I should not have been able to overcome the slightly more adverse conditions 2,000 feet higher up.

As there were no conspicuous flowering plants, we looked carefully for mosses and lichens, but found none. I was particularly impressed by the absence of lichens, because at 10,000 feet on Mount Forel in East Greenland, in a district lying just north of the Arctic Circle and on the edge of the ice cap, there were a moss and at least two species of lichens. Here, even during the height of summer, frost occurs during the coldest part of the twenty-four hours, and the weathering of the rocks suggested drier general conditions than in the Mount Everest district.

Wollaston states[1] that, during the reconnaissance expedition, he found *Arenaria musciforinis* up to 20,000 feet at the head of the Kharta Valley, and that a few other plants approached this height. Perhaps the level above which plants cease to exist is not so abrupt elsewhere as it would seem to be in the Rongbuk Valley. More observations of the maximum height to which plants ascend in the Himalaya are required, but such as exist lead one to wonder if low atmospheric pressures do not interfere with some fundamental process in the life of plants in a way analogous to its effects on human beings.

COMPLETE LIST OF PLANTS COLLECTED IN THE RONGBUK VALLEY IN 1933

(The locality given is that of the actual specimen determined.)

RANUNCULACEÆ

Anemone sp. (Camp I).
Thalictrum glareosum Hand.-Mazz. (Base Camp).
Paraquilegia grandiflora Drumm. et Hutch. (Camp I).

FUMARIACEÆ

Corydalis sp. (Camp I).

PAPAVERACEÆ

Meconopsis horridula Hook. f. & T. (Camp I).

CRUCIFERÆ

Ermania himalayensis O. E. Schulz (glacier above Camp I).
Draba glomerata Royle (Base Camp).
Draba lasiophylla Royle (Camp I).
Draba Winterbottomii Pohle (Rongbuk Monastery).

[1] *Mount Everest—The Reconnaissance 1921*, p. 302.

VIOLACEÆ

Viola biflora DC. (Camp I).

CARYOPHYLLACEÆ

Lychnis apetala Linn. (Camp I).
Arenaria ischnophylla F. N. Williams (Camp I).

TAMARICACEÆ

Myricaria davurica Ehreb. (Rongbuk Monastery).

LEGUMINOSÆ

Astragalus Heydei Baker (Camp I).
Astragalus orotrephes W. W. Smith (Base Camp).
Oxytropis glandulosa Turcz. (Base Camp).
Oxytropis humifusa Kar. et. Kir. (Base Camp).
Oxytropis microphylla Pall. (Camp I).
Oxytropis tatarica Camb. (Camp I).
Caragana versicolor Benth. (Lower Valley).

ROSACEÆ

Potentilla fruticosa Linn. var. ochreata Lehm. (Camp I).
Potentilla nivea Linn. var. pinnatifida Lehm. (Rongbuk Monastery).
Potentilla nivea Linn. var. uniflora Th. Wolf. (Camp I).

SAXIFRAGACEÆ

Saxifraga sp. (Camp I).
Saxifraga sp. prox. S. imbricata Royle (Base Camp).

CRASSULACEÆ

Sedum quadrifidum Pall. (Base Camp).
Sedum sp. prox. S. bhutanense Praeger (Base Camp).

CAPRIFOLIACEÆ

Lonicera spinosa Jacq. ex Hook. f. (Lower Valley).

VALERIANACEÆ

Nardostachys Jatamansi DC. (Lower Valley).

COMPOSITÆ

Anaphalis xylorhiza Sch.-Bip. (Lower Valley).
Leontopodium pusillum Hand.-Mazz.
Leontopodium nanum Hand.-Mazz. (Camp I).
Tanacetum gossypium Hook. f. et. T.
Saussurea gnaphalodes Ostenf.

Saussurea Kuntheana C. B. Clarke (Base Camp).
Cremanthodium sp. (Base Camp).
Petasites sp. (Camp I).
Artemisia sp. (Camp I).

PRIMULACEÆ

Primula Caveana W. W. Smith (Camp I).
Primula tibetica W. W. Smith (Lower Valley).
Androsace Selago Hook. f. et T. (Base Camp).
Androsace coronata Hand.-Mazz.

SCROPHULARACEÆ

Oreosolen Wattii Hook. f. (Rongbuk Monastery).

BIGNONIACEÆ

Incarvillea Younghusbandi Sprague (Rongbuk Monastery).

LABIATÆ

Nepeta sp. (Camp I).

POLYGONACEÆ

Rheum globulosum Gage (Base Camp).
Rheum sp. (Camp I).

THYMELEACEÆ

Stellera Chamæjasme Linn. (Lower Valley).

URTICACEÆ

Urtica hyperborea Jacq. (Camp I).

GNETACEÆ

Ephedra saxatilis Royle var. sikkimensis Stapf (Base Camp.

LILIACEÆ

Lloydia serotina Reichb. (Base Camp).

CYPERACEÆ

Carex psychrophila Nees (Base Camp).
Carex melananthus C. A. Mey (Camp I).
Carex Montis Everestis Kuekenth. sp. nov. (Camp I).
Kobresia schœnoides Boeck. (Base Camp).
Kobresia vidua Kuekenth. (Base Camp).

GRAMINEÆ

Elymus sibericus Linn. var. (Base Camp).
Agrophron sp. (Camp I).

Musci

Barbula sp. nov. peraffinis B. nigescens. Mitt. (Camp I).

Lichenes

Lecidea sp. (Camp I).

Placodium elegans DC. (Camp I).

Acarospora chlorophana Mass. (Camp I).

VII. A REVIEW OF THE GEOLOGY AND SOME NEW OBSERVATIONS

By L. R. Wager

Few geologists have travelled in Tibet owing to the objection of the Tibetan Government; perhaps the geologist is feared because he is often the forerunner of commercial exploitation. Any introduction of Western ideas is likely to be inimical to a theocracy, and the Tibetan authorities, in attempting to exclude expeditions, and especially geological expeditions, are therefore taking up an intelligible attitude.

The first geologist to succeed in visiting Southern Tibet was the late Sir Henry Hayden of the Geological Survey of India, who was attached to Sir Francis Younghusband's expedition to Lhasa in 1904.[1] He was followed by Dr. A. M. Heron, the official geologist to the Mount Everest Reconnaissance Expedition in 1921. Heron continued Hayden's pioneer work, but as he was a member of the Geological Survey of India the Tibetan Government objected to his being attached to subsequent Mount Everest Expeditions. However, Mr. N. E. Odell, a geologist by profession who took part purely as a climber in the 1924 expedition, was able, in such spare time as he had, to make a useful contribution to the geology of the Mount Everest and Rongshar regions. In 1933 I was in the same position as Odell had been, and thanks to Ruttledge's sympathetic attitude I also was able to make various geological observations during the course of the expedition.

[1] References to published accounts of the geology are given in the section headed Data.

Building on a foundation of the work of Hayden, Heron and Odell for Tibet, and of Hooker, Mallet and Garwood for Sikkim, I propose to give a general review of the geology and geomorphology of the whole region between Darjeeling and Mount Everest. In writing this review I have endeavoured to be intelligible to those who, though not geologists, may wish to know about the rocks which compose the highest part of the Earth's crust, or may perhaps be fortunate enough to travel through the region and may wish to understand some of the features of the scenery.

Following the general account is a summary of the data on which it is based, and with this are included brief accounts of some of the new observations made this year.

The Scenery and its Development

The variety in the country through which the Mount Everest expeditions pass is due mainly to two causes—the geological structure and the climate. The Himalayan range is here at its narrowest, being only eighty miles from the plains of India to the plateau of Tibet, and nowhere in so short a space can greater differences of scenery be found. The dead flat Gangetic plain stretches for 400 miles from the Bay of Bengal to the foot-hills south of Darjeeling, and in this distance only reaches a height of 500 feet. Then the lower wooded ranges, sub-tropical in character, rise up abruptly so that at Darjeeling, only fifteen miles from the plains, the mountains are 7,000 feet high. Another thirty miles to the north the snow and glacier-covered mountains are reached, and beyond lies the dry, cold and windswept plateau of Tibet.

The mountains of the Himalaya can, in this region, be divided roughly into three types lying in zones parallel with the length of the range. This classification, which is based on the form of the mountains and their state of glaciation, is dependent more on climatic factors than on the composition of the rocks. The first zone comprises the wooded foot-hills which rise to 10,000 feet and have shapes characteristic of stream erosion. This is succeeded by a discontinuous zone consisting of the mountains and valleys between 10,000 and 16,000 feet, which are at present without glaciers but which have forms to be ascribed to recent glaciation. For this reason the mountains and valleys of the second zone resemble the recently glaciated Scottish Highlands. To the north lie the groups of higher mountains forming the third zone, that of the main range of the Himalaya. The more southerly high peaks, rising commonly to 23,000 feet, and conveniently regarded as forming a sub-zone, are piled with snow due to the immense precipitation and their glaciers, which descend to 12,000 feet, resemble in a general way the glaciers of the Alps. The more northerly high peaks, a second sub-zone, have much less snow and abnormal glaciers descending only to 16,000 feet.

The general level of the southern part of the plateau of Tibet is about 14,000–15,000 feet, and its highest peaks are 21,000 feet. Although so high, the region is free from permanent snow except for small glaciers on the few peaks reaching over 20,000 feet. The moisture-bearing winds which come from the south give a belt of high precipitation on the southern side of the Himalayan range, but little moisture reaches the northern side. Hooker, in his Himalayan Journals, was the first to describe the striking rise in the snow-line which takes place in passing from the wet southern side of the Sikkim Himalaya to the arid plateau of Tibet.

The detailed pattern of the mountain ranges of the Sikkim Himalaya is a result of the rivers which, having flowed originally along the easiest course on an uplifted area of the Earth's crust, have now cut out deep valleys between which remains the higher ground.

In the zone of the foot-hills, river erosion, acting in a wooded country with a high rainfall, seems to have been solely responsible for shaping the hills. The valleys are characterised by having practically no level flood plain and the valley sides tend to curve over more steeply as the valley bottom is approached. These characteristics indicate a youthful stage in the evolution of the rivers, and are a consequence of recent uplift.

The zone of former glaciation between 10,000 and 16,000 feet is well seen in the neighbourhood of the Natu La and Jelep La. From Freshfield's and Garwood's descriptions there seems to be a similar region on the western frontier of Sikkim. Districts belonging to this type of scenery show up on the map because of numerous small lakes, and when the mapping is more thorough this feature will be still more conspicuous. The region of the Natu La and Jelep La forms a broad upland with rocky peaks having rather an irregular distribution and rising to 16,000 feet. Bare rock is exposed extensively in glaciated surfaces, but, as Hooker first noted, glacial striæ are no longer visible. The valleys have a U shape and lakes are common—two characteristics of a formerly glaciated region. The lakes are either moraine dammed, or they are basins (such as Tsomgo) scraped out of the solid rock. It is clear that the valleys have not been occupied by ice for some time, because in many of them the glacially produced U shape has been obliterated by the slow accumulation of screes coming down from the mountains on both sides, and this has produced a V-shaped valley again.

At the former lower limit of the glaciers the broad upland valleys of the Natu and Jelep La region give place to deep V-shaped, river-cut valleys, and at the same point the gradient of the valley bottom is for a short distance abruptly increased. Between the upper part of the Chumbi valley and the Kangbu Chu there is a similar recently-glaciated upland, and the side valleys, such as that at Gautsa, " hang " in the same way to the deeper Chumbi valley. This characteristic supports the view that the country of the second zone remains as a broad elevated tract, because the glaciers, which must once have practically submerged the mountains, protected the region from the inroads of rivers, which would otherwise have cut narrow, deep, V-shaped valleys farther up towards the watershed.

The most conspicuous feature of the southern flank of the high Himalayan zone is the large snowfall, which piles up with snow and ice even the steepest faces of the mountains. The beautiful fluted form of the snow and ice slopes, which is characteristic of the mountains of this region, is probably a result of the frequent small avalanches of the accumulated snow. The glaciers resemble Alpine glaciers, but are usually more moraine-covered. In this sub-zone the moraines do not sink into the glacier and form troughs, nor do pinnacles occur.

In the more arid northern half of the high Himalayan zone and in Tibet, the relative resistance of the rocks to erosion begins to play a part in determining the shape of the mountains. An example of this will be mentioned later when the rocks of Mount Everest are described, but here it may be noted that in the foot-hills and the southern part of the main range, where there is rapid water- and ice-erosion, differences in hardness and resistance to weathering are factors of small importance in controlling the shapes of the mountains and valleys, while these differences at once became important in the arid climate of Tibet.

On the northern side of the main range the glaciers show characteristics which are probably due to the extreme aridity of the region into which they extend. Thus about half-way between the upper *névé* fields and the snouts of these glaciers narrow, sunken, moraine-covered areas are developed parallel with the length of the glacier. The 1922 Mount Everest Expedition found that one of these sunken areas made an easy route through an otherwise difficult part of the East Rongbuk glacier, and they called the feature the "trough" (Plates 24, 25 and 26). An equally well-developed trough was found this year to occur on the glacier running west from the Lhonak La, and features but little less definite can be seen on the Lhonak glacier on the Sikkim side of this col. The development of a trough seems to be controlled by the distribution of moraine, combined with peculiar climatic conditions. In every case seen this year moraine was found to be lying in the bottom of the troughs. Also the position of the troughs on the glaciers is exactly that of medial moraines (Plate 53). Although I am aware that Odell has offered another explanation of the origin of troughs, they seem to me to be the result of the dark rocks of the moraine absorbing more of the sun's heat than the good reflecting white surface of the moraine-free glacier ; melting of the ice under the moraine thus takes place, and the moraine-strewn areas sink below the level of the moraine-free surface. Troughs are not characteristic of the glaciers of more northern countries, probably because the sun is not sufficiently powerful and they are not characteristic of the glaciers on the south side of the Sikkim Himalaya, probably because the frequent snowfall covers moraine and glacier alike and makes both an equally good reflecting surface for the sun's heat.

Lower down the glacier the moraine-covered, sunken area extends more widely at the expense of the clean part of the glacier. The moraine always remains only a thin sprinkling above ice, because wherever it accumulates beyond a certain critical thickness, the lower layers, sheltered from the direct heat of the sun by those above, remain cold, and no melting of the ice beneath takes place. Any thick layer of moraine thus eventually becomes raised relative to the surrounding more thinly moraine-covered ice. This state of things is impermanent since the raised moraine slips off into the hollows. The moraine areas thus become more and more extended until near the snout they occupy the whole surface of the glacier (Plate 54).

On the East Rongbuk glacier, at about the point where the troughs first begin, the moraine-free part is fairly smooth, but it rapidly becomes cut up into hummocks, which, a little lower down, develop into handsome pinnacles of ice standing seventy feet or so above the moraine-covered glacier (Plate 55). These pinnacles seem to occur only on glaciers having troughs, and probably they have a somewhat similar origin. Even away from the moraine areas there is a good deal of dust and small pebbles on the surface of the glacier. This melts into slight hollows, perhaps at first controlled by cracks and flow structures in the ice. The hummocks of ice once established waste away less rapidly than the hollows containing the dark mud and pebbles, and gradually the hummocks grow into the pinnacles which have been admired by the members of every expedition to Mount Everest. The steep face of the pinnacles seems to be towards the south, and this is presumably due to more rapid melting by the sun on that side, but any deductions from the East Rongbuk glacier, as Shebbeare and I found, are complicated by the turning of the glacier from a north-south direction to an east-west direction near its snout.

The scenery of southern Tibet shows no evidence that the land has ever been covered by an ice-sheet. Abrupt small hills such as occur in the valley of the Phung Chu north of the Mount Everest region would still show evidence of considerable modification of form if this valley had been occupied by an ice-stream during Pleistocene times. Hayden has stated that moraine occurs on the south side of the Kampa Dzong ridge, but if this isolated occurrence is confirmed it might still be explained by an exceptional tongue of ice extending north from the mountains of Pauhunri and Kangchenjau, which are only fifteen miles to the south. Odell, following Blandford, has suggested that during the Ice Age the more extensive valley glaciers flowing north from the Himalaya perhaps united to form an ice-sheet. The lowest definite evidence of moraine in the Mount Everest neighbourhood which I was able to find is that at the Rongbuk Monastery at 16,000 feet, and only five miles beyond the present snout of the Rongbuk glacier. Farther down the valley are river terraces which often simulate moraine. It might be expected that when the southern Himalayan glaciers extended 4,000 feet or more below their present general level, an extension of a similar order of magnitude would have taken place in the glaciers flowing north into Tibet. Had this happened it would have been enough to produce a Tibetan ice-sheet. If, however, the Tibetan plateau was very little more glaciated during the Pleistocene Ice Age than at present, then probably the factor which prevented the formation of an ice-sheet was extreme aridity. Peary Land is a present-day example of a country cold enough to support an ice-sheet but which is unglaciated because of the small precipitation.

The characteristics of the river valleys of Tibet and the gorges of the Himalaya will be given below when the problem of the formation of the Himalayan range is touched upon.

THE ROCK GROUPS

The Gangetic Plain is composed of sands and gravels, the products of the disintegration of the Himalaya which have been carried down and deposited in their present position by the powerful Himalayan rivers such as the Tista and Arun. The material is spread out over an area which was sea, geologically speaking, not long ago.

The outermost foot-hills of the Eastern Himalaya consist of coarse sandstones and pebble beds of Tertiary age, which in composition are the same as the present-day Gangetic alluvium, but are more compacted and cemented. This material was brought down by rivers in Tertiary times from the young and probably lower Himalayan range, and has since been incorporated in the foot-hills of the present range as a result of later mountain-building earth movements.

The Tertiary rocks are overlain by a group consisting of shales and sandstones with occasional impersistent and crushed coal-beds. Fossil plants have been found in the shales, and prove that the group belongs to the Damuda Series, which is of widespread occurrence in peninsular India and is roughly of Permian age. Earth movement has reversed the normal order of super-position, as the older Permian rocks are found resting on the Tertiary sandstones. This observation, made by Mallet as long ago as 1874, now affords a clue to the structure of the Eastern Himalaya, which will be followed up in the section dealing with the origin of the range.

Overlying the coal-bearing beds is a group of rocks called the Daling Series, consisting of green schists with here and there black graphitic schists and light-green quartzites. This series extends along the outer margin of the Himalaya, and also up the Tista and Rangit rivers as far as Dikchu and Trashiding. Although the Daling Series overlies the beds of Permian age, it can be safely assumed that the present order of super-position is due to mountain-building movements, and that the Daling Series is actually older than Permian.

The Tertiary sandstones and conglomerates, the Damuda Series and the Daling Series are crossed during the first half of the journey from the plains to Darjeeling (see the geological map at end of volume; beyond this point the so-called Darjeeling Gneiss begins. This is a banded group consisting partly of igneous and partly of sedimentary material with such minerals as garnet and sillimanite in the sedimentary part, proving that the rocks have been subjected to higher temperature and pressure than the green schists of the Daling Series. At present the age and relations of the Darjeeling Gneiss are obscure.

During the journey from the Tista valley over the Natu La into the Chumbi valley of Tibet, rocks of the Daling Series are crossed as far as Gangtok. Here for the first time a foliated granite with tourmaline and white mica is found, which is injected into rocks regarded as belonging to the Daling Series. These rocks are more metamorphosed than the typical Daling Series and have developed pink garnets; they begin to resemble the Darjeeling Gneiss, and this may one day afford a clue to the origin of the latter. It is clear that the foliated granite or granite gneiss occurring at Gangtok was injected during the mountain-building movements which produced the Himalaya and is therefore of Tertiary age.

Beyond Gangtok there is abundant foliated granite, but it is here found injecting rocks which resemble the ancient rocks of peninsular India. It is not easy to give definite criteria for distinguishing between the older granite gneisses and the younger injecting granite gneisses which are probably Tertiary in age. The older granite gneisses differ, however, in being characteristically garnet-bearing, and in being associated with amphibolite bands, and intensely metamorphosed limestones, quartzites, and shales. The sedimentary beds are up-ended and follow a north-west to south-east direction. The fact that this direction is not the general direction of the Eastern Himalaya is evidence that they once formed part of an earlier mountain

PLATE 54.—The lower part of the East Rongbuk Glacier from above Camp I.

range trending in a different direction from that of the present-day range.

Beyond the Natu La foliated and massive granites are the dominant rock types, and I believe both are Tertiary in age. As Gautsa in the Chumbi valley is approached only the highly characteristic, massive muscovite-tourmaline-granite of the upper Chumbi valley is found. Along its northern edge the Chumbi granite injects and metamorphoses sediments of the Tibetan plateau and must be later in age than these. It is also quite uncrushed, and must therefore have been intruded after the compressive Tertiary mountain-building movements.

The Chumbi river has cut a narrow gorge through the granite, and the road has to wind between and over huge granite blocks that have fallen from the steep valley sides. Then at Dotag the valley widens abruptly because the softer rocks of the Tibetan sedimentary zone have been reached.

The rocks of the Tibetan sedimentary zone between Kampa Dzong and Lhasa were described by Hayden in 1904, and similar rocks were subsequently described by Heron in the region to the north of Mount Everest. The relatively low ground with dark rounded hills lying immediately to the north of the Himalaya is made of a thick series of slightly hardened Jurassic shales. The one-time flat bedded shales can often be seen to be intricately folded, due to compression in a north to south direction. Narrow zones which are over-folded synclines of younger rocks (Cretaceous to Eocene) stretch in roughly east to west lines across the plateau. These younger rocks consist mainly of hard limestones, and so form the slightly higher ranges, such as the hills near Kampa Dzong and the Tsipri range which stretches west from Shekar. Kampa Dzong and Shekar Dzong (plates 11 and 14), two of the important fortresses of this part of Tibet, are built on the steep rocky mountains formed of the Cretaceous limestones.

The rocks of the Mount Everest district itself were first mapped and described by Odell. The valleys occupied by the main Rongbuk and East Rongbuk glaciers were shown by him to be cut out of a succession of rocks conveniently divided into three series. The lowest is a limestone, now highly metamorphosed, which is only visible between the Base Camp and Camp I. The middle series, some 3,000 feet thick and conveniently called the Mount Everest Pelitic Series, consists dominantly of metamorphosed shales. This gives rise to the dark cliffs worn into fantastic-shaped pinnacles which occur on both sides of the East Rongbuk glacier. The upper series is also limestone, and will here be named the Mount Everest Limestone Series, since it forms the top 1,000 feet of the mountain. All these rocks, but especially the lower ones, have been extensively injected by sheets and lenses of granite and granite gneiss (fig. 1).

The form of Mount Everest and its detailed features are to some extent controlled by the character of the rocks of which it is composed. When seen from the Base Camp the mountain consists apparently of horizontal bands of rock. Actually the dip of the beds is about 30° towards the north, that is towards the Base Camp, a feature which is not realised till the mountain either is being ascended or is seen from the east. On the north-east ridge the Mount Everest Pelitic Series is found up to a height of 27,500 feet, at which point it gives place fairly abruptly to a zone known as the Yellow Slabs. The rocks here consist mainly of yellow schistose limestones approaching marble in degree of metamorphism ; they are to be regarded as the lower part of the Mount Everest Limestone Series. The Yellow Slabs form a moderately steep band from about 27,500 feet to 28,000 feet. Since the bedding dips north at 30°, and since the general angle of the slope is greater, say 50°, the arrangement of the zone of Yellow Slabs is like that of the tiles of a roof (fig. 2).

Above the Yellow Slabs is the steeper band of rock which stretches from the first and second steps completely across the north face of the mountain. A fragment of this band, brought back this year, showed it to be a dark-grey, somewhat shattered and altered limestone. Being more resistant than the schistose limestone of the Yellow Slabs, it forms a bold feature, in some places actually overhanging the zone of Yellow Slabs. There is

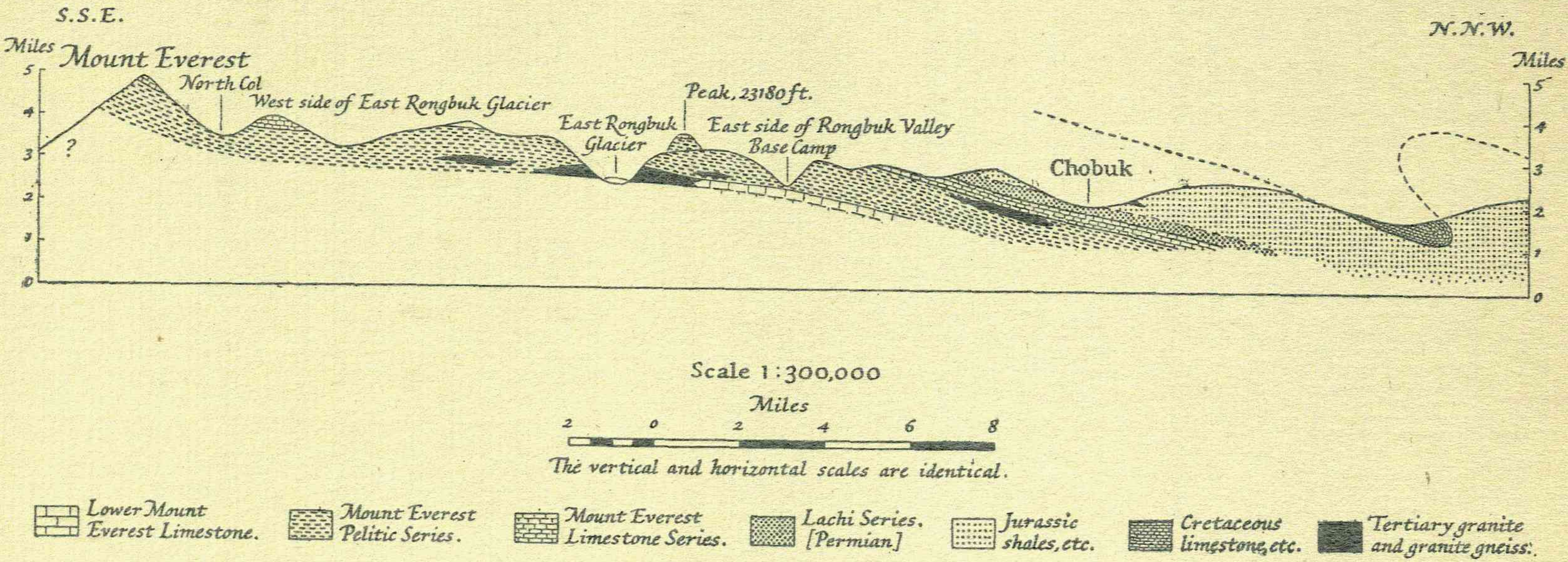


Fig. 1.—Section through Mount Everest and the Region to the North.

For the sake of clearness the section is generalised near Chobuk.

little doubt that the top 1,000 feet of the final pyramid is also composed of this same grey limestone.

The map which Odell has published represents as Mount Everest limestone the tops of the following surrounding peaks: North Peak, Khartaphu, Peak 23,180 ft., and Gyachung Kang. None of these peaks has actually been ascended, but their appearance from a distance leaves little doubt of the correctness of this mapping. Nine miles north of the Base Camp the Mount Everest Limestone Series, owing to a northward dip of

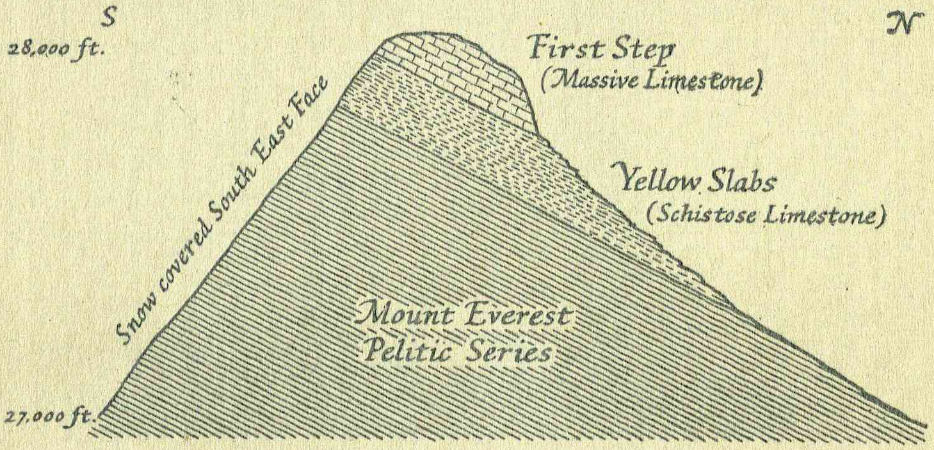


Fig. 2.—Cross-section of the Upper Part of the North-east Ridge of Mount Everest.

about 10°, descends from its position on the summit of the higher peaks and forms a continuous band along the lower ground.

Near the junction of the Rong Chu and the Gyachung Chu the combined rivers cut through the Mount Everest Limestone in a short gorge. Here the limestone is at least 1,000 feet thick, and it still overlies the Mount Everest Pelitic Series. Although there are complications due to faulting, omitted in fig. 1, the limestone continues in general its northward dip and disappears under the younger sediments of the Tibetan plateau. The Mount Everest limestone is the same as that mapped by Heron to the east and west of the Rongbuk valley, and called by him "Permo-Trias?" This year the same limestone was traced with but few breaks into Northern Sikkim, where it

PLATE 55.—Pinnacles on the East Rongbuk Glacier two miles above the snout.

was found still to overlie the Mount Everest Pelitic Series. Here, as in the Mount Everest region, the pelitic series is much injected by granite and granite gneiss.

Near the Dongkya La in the extreme north of Sikkim, where Hooker in 1848 found indeterminate fossils, a new locality was found this year for quite well-preserved fossils. These occur in a calcareous sandstone associated with quartzites and hardened shales. Together these rocks form a distinct series overlying the Mount Everest limestone and underlying the typical Jurassic shales of Tibet; and it is proposed to call them the Lachi Series from the local name of the hills in North Sikkim in which the fossiliferous horizon occurs. The fossils, which are dominantly brachiopods, are being examined by Miss H. M. Muir-Wood, who considers that the series is approximately Permo-Carboniferous in age.

The occurrence of fossils by which the age of the Lachi beds can be determined makes possible certain new correlations. Thus the Mount Everest limestone which immediately underlies the Lachi Series is probably Permo-Carboniferous or Carboniferous in age and not Permo-Trias, as was formerly suggested. Also the Mount Everest Pelitic Series is probably of the same age as the Daling Series, since they were both apparently deposited in the interval immediately preceding the Permo-Carboniferous or Carboniferous periods.

The sedimentary beds of Tibet were laid down in an ancient sea to which the Austrian geologist, Suess, gave the name Tethys. This sea at one time stretched across Southern Europe and Central Asia, and its southern border, of which the present peninsular India forms part, was an extensive land mass known as Gondwana Land. The northern edge of this land was roughly the present line of the Himalaya. In Eastern Nepal and Sikkim, during a phase when the Tethys extended more to the south, the Mount Everest Pelitic Series and the Daling Series were laid down. Then, owing to uplift of the southern area, which caused a northward movement of the coastline, the Darjeeling district became land and the Damuda Series, which is a land deposit, was formed. At the same time to the north and to the east of the Darjeeling district there was still sea, and in this the Mount Everest Limestone Series and the Baxa Series of the Duars were forming. In the north the sea persisted so that the Mount Everest Limestone Series was followed by the Lachi Series, consisting of shallow water deposits with some marine fossils. Then for a long period conditions remained the same. In the south land persisted, while to the north thick Jurassic shales and Cretaceous limestones were laid down in the Tethys sea. With the advent of the Tertiary period the Tethys rapidly shallowed, and coarse sandstones, which are almost pebble beds, were formed. This was the beginning of a mysterious series of changes which turned the eastern end of the formerly deep Tethys sea into the Himalayan ranges and the Plateau of Tibet. To the south at about this time the Tertiary sandstone and conglomerates were forming, the materials for which came from the erosion of the slowly rising Himalaya. Continued mountain-building movement later incorporated these deposits into the present-day range.

The Mechanism of the Formation of the Himalaya

In the preceding section the materials which compose the Eastern Himalaya have been described and their origin related to the geography of past times. In the present section an attempt will be made to explain how the sediments laid down in the Tethys sea became elevated into the high Plateau of Tibet and the Himalayan range.

From the evidence in Tibet of intricate folding of once horizontal sediments, and from the evidence in the Darjeeling district of complete overturning of the sediments, it is clear that horizontal compression has been the main factor in the production of the Himalaya as in the Alps and other ranges. This compression, in a north to south direction, folded the sediments laid down in the Tethys sea and presumably also the underlying deeply buried rock floor, but the region which was formerly Gondwana Land resisted folding. Along the southern

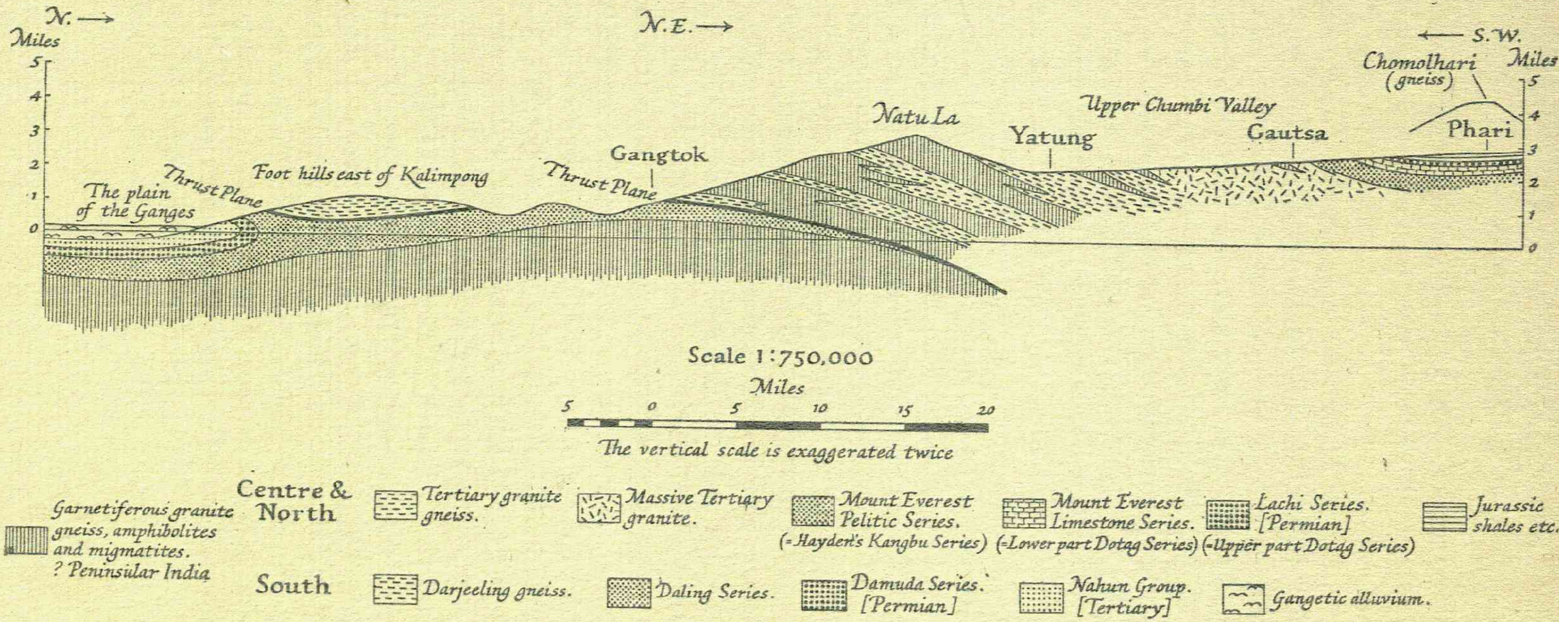


Fig. 3.—Generalised Section through the Sikkim Himalaya.

edge of the belt of folding a great slice of the Earth's crust, including old rocks which once formed the extreme northern edge of Gondwana Land, seems to have moved southwards, overriding the Daling Series and rucking up the Damuda and Tertiary beds (fig. 3). In association with this violent earth-movement granite magma was injected into the upper part of the Earth's crust and gave rise to such rocks as the massive Chumbi granite, and the later granite gneisses of Gangtok, the Mount Everest region and elsewhere.

Besides horizontal compression which has produced the folding, and which must be regarded as the primary cause of the formation of the Himalaya and the Plateau of Tibet, there is evidence of a purely vertical uplift which has considerably increased the height of the region which is now the Himalaya. As maps were gradually made, the remarkable fact emerged that many of the big rivers of the Himalaya, such as the Arun and Tista, had their source behind the main range in one of the smaller ranges that cross Tibet in an east-west direction. The Arun river, for instance, has its origin in a series of streams draining from the Ladakh range, a low watershed which lies just to the south of the Bramaputra and nowhere rises above 22,000 feet. For part of its length the Arun has an east-west course in what is now a slight depression of the Tibetan plateau between the Ladakh range and the main range of the Himalaya. Then it turns southwards and cuts through the Himalaya in a series of gorges. Here the Himalaya is at its highest; immediately to the east of the river is Kangchenjunga, immediately to the west is Mount Everest, and these mountains rise 7,000 feet above the highest peaks of the Ladakh range where the river has its source.

The remarkable behaviour of the Arun is by no means unique among Himalayan rivers, and two opposed hypotheses have been offered in explanation; one is that rivers of steep gradient and large dimension flowing down the southern slopes of the Himalaya have cut back through the range and captured east-west flowing Tibetan rivers. The other explanation, which is to my mind more probable, is that the Arun and similar rivers have always had approximately their present course, established at a time when there was a continuous slope from the Ladakh range to the Plains of India, and that the Himalayan mountains have risen across the course of the rivers, but so slowly that the rivers managed, by rapid erosion, to keep their channels open.

There is a plausible conception of the structure of the Earth's crust which was first put forward by Sir George Airy on the basis of work carried out by the Indian Geodetic Survey. Briefly stated, the Airy hypothesis suggests that the crust of the Earth consists essentially of two different materials—granite, forming the continental masses, and basalt, in which the lighter granite of the continents is floating much as an iceberg floats in water.

Analogy with a floating iceberg is only of value in illustrating the particular aspect of the Earth's crust which is relevant here. In one way it gives a completely false idea, as the basalt in which the granite is considered to be floating has considerable rigidity and strength. Only when a large area is considered is it legitimate to postulate that the granitic layer takes up a position which is controlled by the specific gravity difference between granite and basalt. Even then the degree of approximation to the relative positions which would be taken up if hydrostatic forces were the only significant ones is open to doubt. It must be realised that this conception of floating granite continents is only one explanation of the facts on which the so-called isostatic theory rests, but nevertheless it is of value to consider the implications of this conception in the case of the Himalaya.

It is possible from the existing map of Sikkim, interpreted in the light of observations made during the expedition, to show that, for the country between Lat. 27° 30′ and Lat. 28° 0′, the volume of land above 16,000 feet is almost equal to the volume of the valleys below 16,000 feet. This level of 16,000 feet is significant because it is the general height of the southern part of the Tibetan plateau. The region for which the calculation was made includes such great differences in height as Kangchenjunga, 28,146 feet, and the Tista valley as low as 4,000 feet. The volume relationships show that by planing off the mountains down to 16,000 feet and filling them into the valleys the country could be levelled up to a plateau 16,000 feet in height, and since no material would have been added or removed there would be no upsetting of the postulated hydrostatic balance of the crust. In its relation to the crust as a whole the Sikkim Himalaya are therefore equivalent to the extension southwards of the Tibetan plateau at a height of about 16,000 feet.

Let it be supposed that the compressive mountain-building movements produced no localised Himalayan range, but only the Tibetan plateau extending southwards over the region where the Himalaya now are and then falling away gently towards the plains, and let it also be supposed that on the plateau there was an indefinite watershed where the existing watershed of the Arun now lies. On the southern slopes of the plateau there would be high rainfall, and rivers of steep gradients would rapidly cut out deep valleys. The material removed by the rivers would tend to upset the postulated hydrostatic equilibrium, but it is suggested that this has been readjusted by an upward arching of the crust along the belt where the Himalaya now stand. The up-warping, raising the ridges and peaks, is regarded as the direct result of the lowering of the valleys by river erosion, and it has occurred in such a way that if at any particular time the mountains were levelled up by piling into the valleys the plateau so formed would approximate to the more extended Tibetan plateau, which it has been assumed was produced initially by the compressional earth movements. In this way it is believed that the border of the plateau has been slowly turned into a region of deep valleys and high peaks, while rivers like the Arun show the anomaly of flowing through a mountain range higher than the range in which they have their source.

There is evidence to show that the upward arching movement was probably by no means regular : Since the maximum extension of the glaciers there has been in the upper Arun drainage area a period when an average of 300 feet of river gravels have been laid down in all the valleys. This may well have been due to a period of more rapid rising of the barrier of the Himalaya. Since the time of this aggradation, there has been a period during which the Arun and its tributaries have cut down 200 or 300 feet into the gravels which they had formerly deposited. This probably corresponds to a temporary cessation of the uplift of the Himalaya.

Although this is not the place to discuss more fully the evidence for these views, or to elaborate the undoubtedly over-simple statement of the mechanism, it is interesting to note that Hayden and Burrard thirty years ago, without drawing any conclusions, pointed out that for the Himalaya as a whole, the higher parts were found where the watershed lies behind the range, and the rivers cut through it in deep gorges ; in those parts where the watershed is along the range, no gorges exist and the general height of the range is lower. The association of Mount Everest and Kangchenjunga, with the deep-cut gorges of the Rongshar, Arun and Tista, is a particular case of this, and, in the view here taken, the association is not a coincidence. Perhaps the high annual rainfall of the Eastern Himalaya, the greatest in the world, instead of causing the rapid eroding away of the mountains is actually an important factor in making them the highest land on the Earth's surface.

The production of the Himalayan range would thus appear to be divided into two distinct episodes ; first—the formation of a high plateau due to folding caused by horizontal compression, and second—upward arching of the southern border of the plateau to give the localised belt of high peaks. The slight upward warping of the crust which actually gives the Himalaya its dominance is not easily demonstrated by the usual geological methods. The conception of a late stage vertical uplift here put forward will not be subscribed to by many geologists, and it must be regarded as a hypothesis to be confirmed or abandoned as our knowledge of the Himalaya is extended.

Data

In the preceding sections attention has been paid mainly to general conclusions rather than the evidence on which they were based. In the present section will be given some of the evidence—especially that connected with the stratigraphical relationships. This will unavoidably involve slight repetition.

The key to the stratigraphical sequence in Sikkim and the adjacent parts of the Himalaya is, I think, provided by the Mount Everest limestone, which is easy to recognise lithologically and easy to map. It is a massive limestone, over 1,000 feet thick, with arenaceous impurities, if any, and, where it is now exposed, it has not suffered the same intricate folding as the younger, dominantly argillaceous beds to the north. Moreover, it seems to be resistant to granite injection, and from Mount Everest to the neighbourhood of Phari it usually marks the upward limit of complications due to this.

The limestone which caps Mount Everest and the surrounding high peaks forms a continuous band fifteen miles to the north, and it was here that Heron[1] mapped and called it "Permo-Trias?" This year, Heron's so-called Permo-Triassic limestone was traced eastwards into the limestone which Garwood[2] found in the range on the north side of the Lhonak valley. The same limestone was picked up again at the south end of the Lachi ridge, and it also occurs in the Chumbi valley at the base of Hayden's Dotag Group.[3] In 1848 Hooker[4] found and described a limestone from Tso Lhamo, immediately north of the Dongkya La in northern Sikkim. Garwood suggested tentatively that Hooker's limestone and the one which he found on the north side of the Lhonak valley were the same. It is clear that Hayden later doubted the correctness of this corre-

[1] Heron, A. M., "Geological Results of the Mount Everest Reconnaissance Expedition." *Records Geological Survey of India*, Vol. LIV, Part 2, 1922, pp. 215–34, and *Geographical Journal*, Vol. LIX, No. 6, 1922, pp. 418–31.

[2] Garwood, E. J., "*The Geological Structure and Physical Features of Sikkim*," Appendix to *Round Kangchenjunga*, by Douglas W. Freshfield, London, 1903.

[3] Hayden, H. H., "The Geology of the Provinces of Tsang and Ü in Central Tibet." *Memoirs Geological Survey of India*, Vol. XXXVI, Part 2, 1907, pp. 1–80.

[4] Hooker, J. D., *Himalayan Journals*, London, 1854, Vol. II, pp. 176–77.

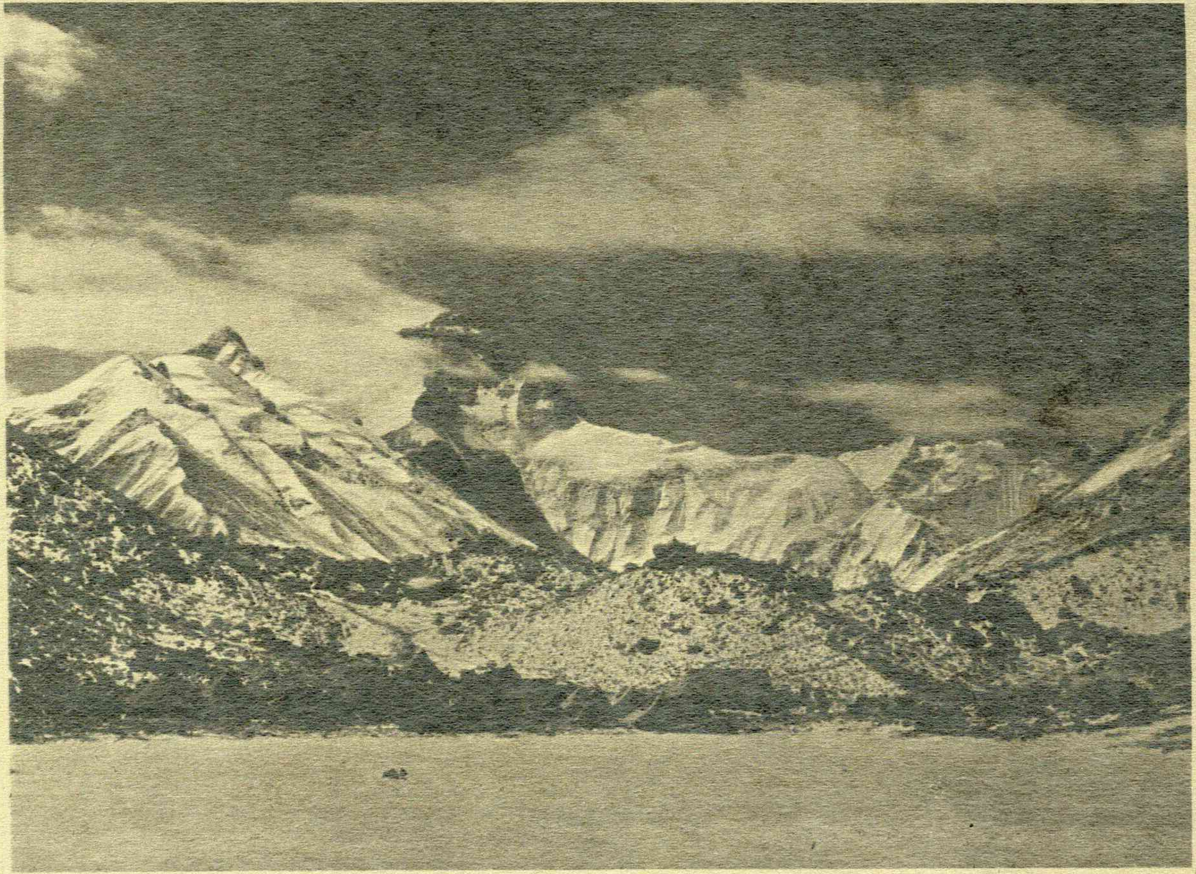


PLATE 56.—Mount Everest from the Base Camp in April.
Fracto-cumulus clouds in the west wind.

lation, but he was not able to visit both localities. The Tso Lhamo limestone of Hooker is a thin blue limestone associated with shales, and is certainly not the same as the Mount Everest limestone which was found this year in the neighbourhood. It probably belongs to the Lachi Series which overlies the Mount Everest limestone. It is proposed that the name Mount Everest Limestone Series be used for the important stratigraphical unit which up to the present has received different names in different districts. Under this new name should now be included Odell's Upper Calcareous Series of the Mount Everest region,[1] Heron's "Permo-Trias ?" of the district to the north, the limestone which Garwood found on the north side of the Lhonak valley, and the thick limestone occurring at the base of Hayden's Dotag Series in the Chumbi valley.

This year specifically identifiable fossils, mostly brachiopods, were found in a series of quartzites, limestones, hardened shales, and pebble beds[2] which form the Lachi ridge, a spur near Tso Lhamo just north of Kangchenjau. Miss Muir-Wood, who is describing these fossils, considers that the fauna is Lower Permian in age. Hayden found similar quartzites and shales in the Chumbi valley, which he included in the Dotag Group, and Odell noticed quartzites and shales which he thought might be a distinct series above Heron's "Permo-Trias ?" north-west of Mount Everest. This series, especially now that its age can be determined by fossil evidence, is of sufficient importance to receive a distinct name, and it is proposed to call it the Lachi Series, from the locality whence the Lower Permian fossils come.

In 1922 Heron[3] suggested that what is now called the Mount Everest Limestone Series was Permo-Triassic in age.

[1] Odell, N. E., "Observations on the Rocks and Glaciers of Mount Everest," *Geographical Journal*, Vol. LXVI, No. 4, 1925, pp. 289–314, and appendix to *The Fight for Everest*, London, 1924.

[2] Mr. J. B. Auden, of the Geological Survey of India, has seen specimens of the pebble beds, and considers that they are lithologically similar to the Blaini beds of the Simla and Mussoorie districts.

[3] Loc. cit., *Records Geological Survey of India*, pp. 232–33.

This was based on lithological similarity to the Kioto limestone of Spiti and on the evidence of squashed Productids and Spirifers, found immediately above the limestone near Chö-dzong. The Mount Everest limestone lies immediately below the Lachi Series on the Lachi ridge, and also in the Chumbi valley and to the north of Mount Everest. It is thus safe to assume that the Lachi Series passes down without unconformity into the Mount Everest limestone. Since the Lachi Series is Lower Permian, the Mount Everest Limestone Series must be of Permo-Carboniferous age and perhaps also older.

Above the Lachi Series the oldest fauna so far known was found by Hayden in the Chumbi valley, and was ascribed by him to the Lias or Rhætic.[1] Neither Hayden nor Heron, to whom we owe our knowledge of the younger sediments of the Tibetan plateau north of Sikkim and Eastern Nepal, found any fossils of Triassic age, but it is likely that Triassic rocks, although still unrecognised, will one day be found among the shales which are now classified as Jurassic.

Odell has shown that, underlying the Mount Everest Limestone Series in the Mount Everest neighbourhood, there exists a dominantly pelitic group of rocks which he sometimes called the "Gneissose Biotite Series" and sometimes the "Banded Biotite Gneiss." This series was also found underlying the Mount Everest limestone in the Lashar plain and the Lhonak valley, and Odell has also described it from the Rongshar valley. It is clear, therefore, that between the dominantly pelitic series and the Mount Everest limestone, there is no unconformity as was tentatively suggested by Odell nor a thrust as stated by Dyrenfurth.[2] Because it is desirable to stress the sedimentary character of this group, it is preferable to change Odell's tentative names to the Mount Everest Pelitic Series.

Evidence has been given for regarding the Mount Everest Limestone Series as approximately Permo-Carboniferous, and thus the Mount Everest Pelitic Series, lying conformably below,

[1] Loc. cit., p. 26.

[2] Dyhrenfurth, G. O., *Himalaya—Unsere Expedition, 1930.* Berlin, pp. 293–311.

must be Carboniferous in age or slightly older. Hayden considered that his Khangbu Series in the Upper Chumbi valley lay below the Dotag Group.[1] He first suggested a Palæozoic age for the series, but later thought it more likely to be Pre-Cambrian. The series being equivalent to the Mount Everest Pelitic Series is now proved to be of Palæozoic age.

A stage in the study of the Eastern Himalaya seems to have been reached when correlation is possible between the rocks of the northern border and those in the foot-hills to the south. By showing that the Damuda Series overlies Tertiary rocks in the Darjeeling district, Mallet,[2] in 1874, proved the wholesale inversion of the rocks of the foot-hill region, although in those days the facts were not explained in this way. In the Darjeeling district and the Western Duars the descending geological sequence may now be interpreted :

Nahun Group (Tertiary).
(*Unconformity*)
Damuda Series (approximately Permian).
Baxa Series (present in the Duars only).
Daling Series.

On fossil evidence the Damuda Series and the Lachi Series are now proved to be roughly equivalent in age. The Baxa Series of the Duars includes thick dolomitic limestones, and is probably the continuation of the Mount Everest Limestone Series. In the Darjeeling and Katmandu districts the Baxa Series is missing. It is probable that this is not the result of earth movement, but of a non-sequence between the Damuda Series and Daling Series in these districts, a reasonable supposition, since the Damuda Series is terrestrial in origin. The Daling Series is dominantly pelitic, and is probably the equivalent of the Mount Everest Pelitic Series. These two series are different in present appearance, because

[1] Op. cit., p. 20.

[2] Mallet, F. R., " On the Geology of the Darjiling District and the Western Duars," *Memoirs Geological Survey of India*, Vol. XI, Pt. 1, 1874, pp. 1–96.

the Mount Everest Pelitic Series has suffered, in its type locality, a metamorphism between thermal and regional in character, while the Daling Series is dominantly a chlorite schist, the result of pure regional metamorphism

Until a microscopic examination has been made, a discussion of the intrusive igneous rocks and the various rocks of the metamorphic zone will not be attempted in more detail than has already been given in the general part of this essay. The exact separation of the Tertiary gneisses from the earlier ones will always be a matter of great difficulty. Besides their occurrence in the Natu La region, rocks considered to belong to the older series were noted about Tsuntang in the Tista valley and in the Nyönno Ri range. Similar rocks were found by Garwood in western Sikkim.

Hayden and Heron both accepted the hypothesis that the present remarkable drainage system was produced by the Himalayan rivers cutting back through the range and capturing east-west flowing Tibetan rivers. Odell was inclined to favour the alternative view here adopted of uplift of the Himalayan range subsequent to the establishment of the present drainage pattern.[1] He suggested that the uplift in the Nyönno Ri range might be due to the intrusion of a late granite, but in 1933 the range was visited and found to consist very largely of rocks belonging to the older gneisses of peninsular India type. Although not dealing specifically with the Himalaya, Nansen[2] and Jeffreys[3] have both considered as theoretically probable such late-stage vertical uplift of mountain ranges as has been suggested here.

Hayden and Burrard's classic work[4] on the geography and geology of the Himalaya Mountains and Tibet has been a continual source of information in considering all geomorphological problems.

[1] Odell, N. E., "Observations on the Rocks and Glaciers of Mount Everest," *Geographical Journal*, Vol. LXVI, No. 4, 1925, p. 300.

[2] Nansen, F., "The Earth's Crust: Its Surface-Forms and Isostatic Adjustment." *Norske Videnskaps-Akademi, 1 Oslo 1 Mat. Natur. Klasse*, 1927, No. 12, 1928, pp. 1–21.

[3] Jeffreys, H., *Gerlands Beiträge zur Geophysik.* Bd. XVIII Heft 1/2, 1927, pp. 17–18.

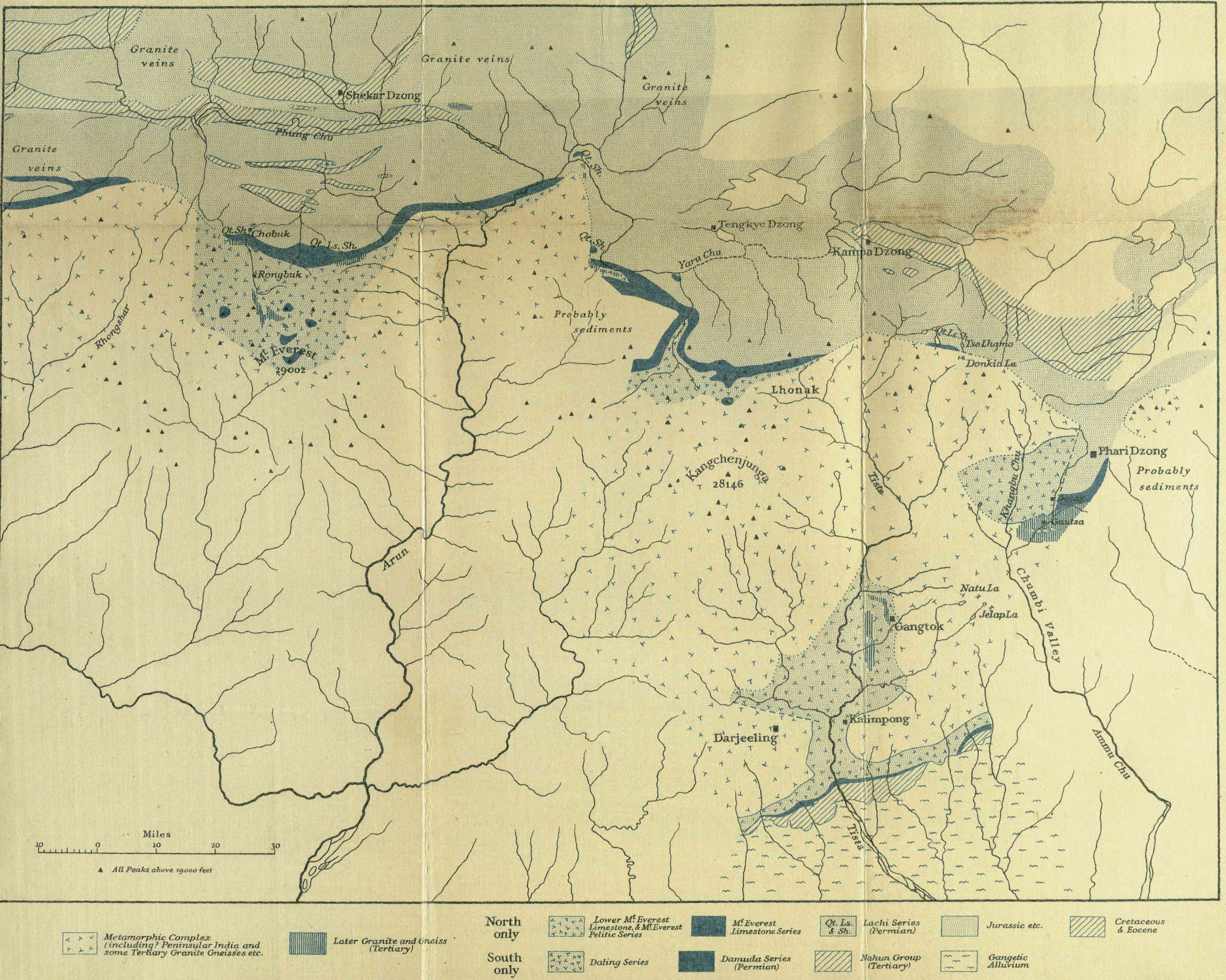
[4] Burrard, S. G., and Hayden, H. H., *A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet.* Calcutta, 1907.

Plate 57.—Capping cloud on Mount Everest, 9.30 a.m. on the 17th June, 1933.

Geological Sketch Map of Drainage Areas of the

ARUN, TISTA, AND AMMU CHU

From observations by Hooker, Mallet, Garwood, Hayden, A. M. Heron, N. E. Odell & L. R. Wager



VIII. THE WEATHER

By L. R. Wager

Although unexpected climbing difficulties confronted the 1933 Mount Everest Expedition, the main cause of failure is to be put down to the adverse weather conditions. If a party established at Camp VI, and acclimatised to the extent attained in favourable cases this year, could have had one or two days of snow-free rocks and calm weather, there seems to be no reason why the summit should not have been reached. What, then, are the chances of getting two days of the right weather, and when is this likely to happen? This question was asked repeatedly during the course of the expedition, but it only revealed how little is known of the weather in the Mount Everest region.

As in most mountain districts, the weather in the neighbourhood of Mount Everest is extremely variable. There is the usual short-period variation which determines whether progress can be made on the mountain on any particular day or not. Good judgment of this variation would often prevent waste of valuable time, and would be a safeguard against the dangers which may result from unexpected changes. But besides this there is a seasonal change in the weather, which is just discernible through the short-period variations. The climber on Mount Everest is beginning to experience with satisfaction somewhat warmer days and less strong westerly winds when another, but in this case adverse, seasonal change sets in, namely, the oncoming of the monsoon. Monsoon conditions quickly change the north-west face of the mountain, which in winter is bare rock, into a dead-white snow-covered face impossible to climb. The whole timing of a Mount Everest expedition depends on what is known, and what is surmised, of the date at which the monsoon will begin.

What little information exists about the weather in the Mount Everest region is solely the result of the previous expeditions. Mallory gave a valuable general account of the weather and snow conditions experienced by the reconnaissance expedition from the middle of June to the middle of September 1921.[1] Unfortunately, only scattered observations have been recorded for the 1922 and 1924 expeditions. Ruttledge, therefore, wisely determined that this year systematic weather observations should be made. These were entrusted to me, but I received help from other members of the expedition and especially from Smijth-Windham. On the basis of these observations an account is here given of the weather experienced during our crossing of Tibet in March and the first half of April, and during our stay in the neighbourhood of Mount Everest from the middle of April to the beginning of July.

The Indian Meteorological Department offered to give us all the information that they could about weather conditions, and in particular when the monsoon might be expected. Thus weather reports and forecasts were received twice daily at the Base Camp from Dr. Sen, the director of the Meteorological Station at Alipore, and we on our side sent to Alipore our daily weather observations. Dr. Sen is, himself, to give an account of the basis of his forecasts. Since weather in mountain districts is usually so capricious, we were at first sceptical of the value of Dr. Sen's predictions, but a careful comparison with our weather log has shown an unexpected agreement. Weather bulletins of the sort received in 1933 would be of great value to future expeditions now that some faith in their validity has been built up.

The Weather during the march from Darjeeling to the Base Camp

During the latter half of February we watched the Kangchenjunga group from Darjeeling. Usually the high mountains were visible early in the morning, but between 7 and 9 a.m. they were blotted out by cumulus clouds which formed above the deeper valleys. Just before this happened, Kangchenjunga

[1] Mallory, G. H. L., in *Mount Everest: the Reconnaissance, 1921*, Chap. XVI.

was usually seen to develop a cloud flag indicating a powerful west wind. This west wind became extremely familiar to us later, as it blew daily, almost without exception, during the time the expedition was in Tibet.

Near the beginning of the journey, during a stay from March 9th to 15th at Tsomgo, close to the Natu La, the mornings were clear, but usually ragged clouds (the cumulus seen from Darjeeling) surrounded us in the latter part of the day. These clouds were drifting from low levels up the valley, whatever that direction might be, and on three occasions hail fell from them which was sufficient to whiten the ground. During six days in the Chumbi valley at Gautsa, 12,000 feet, there was slight snow on three afternoons, and at Phari, 14,500 feet, on the afternoon and evening of March 22nd, five inches of snow fell ; this was brought, like the snow at Gautsa, by gentle up-valley winds. The snow which fell at Phari, except that in the shadow, had disappeared by the following midday, mainly by sublimation and not by melting. Considerable falls of snow are expected by the Tibetans in March at Phari, but at Gyantse, 100 miles farther north, there is at this time practically no precipitation.[1]

For one more march, that over the Tang La to Shabra Shubra rest-house, we were under the direct influence of clouds blowing up the Chumbi valley, and as we crossed the pass there was a slight snowfall from fracto-cumulus clouds drifting past us. At Shabra Shubra we had the most severe weather of the whole journey through Tibet. Here, during the afternoon of March 25th, a south-south-west wind reached force 6 of the Beaufort Scale. The minimum temperature during the night was $-4°$ F., and it was only $+4°$ at 6.15 a.m. the following morning, when we were having breakfast in the open. On this day, as fortunately was usual, there was no wind at breakfast time, but at 9 a.m. a north-west wind arose which was sufficient to produce blizzard up

[1] This information is derived from a paper in the *Ibis* for October 1927, on the Birds of Gyantse, by Frank Ludlow. Although there is a British Military Outpost at Gyantse, apparently no weather record is kept.

to fifty feet above the ground. Towards the end of the day's march we had reached a region where, although higher, there was too little snow lying to allow of the formation of any appreciable drift. The snow to the north of Tang La was practically confined to the Tang Pun Sum Plain. This local distribution of snow is due to the Chumbi valley, which allows moist air to be brought up from the south; as might be expected, highly local conditions prevail at the junction of the Himalaya and the Tibetan plateau.

From Mating to the immediate neighbourhood of Mount Everest, more uniform weather was experienced, as our route lay some way north of the Himalaya over the southern part of the Tibetan Plateau. The following generalisations apply to the period from March 27th to April 16th during the journey from Mating via Kampa Dzong, Tengkye Dzong and Shekar Dzong to Rongbuk.

The barometer (a Carey Aneroid) was read each day at about 6 p.m. and at the same place on the following day at 6 a.m. With only four exceptions during the eighteen days for which measurements are satisfactory, the atmospheric pressure was greater in the morning. The average difference between morning and evening readings was ·05 inch, and the maximum difference was ·09 inch. The maximum diurnal variation was presumably greater than this.

Over the same period, on seventeen days the early mornings were calm, and on the other five days there was a slight wind which never attained more than force 1. But between 9 or 10 a.m. on most days a west wind began to be felt which reached its maximum, about force 5 or 6, early in the afternoon. These winds are so unpleasant that, at any rate in the colder part of the year, the Tibetans travel only in the morning, often starting before it is light. The expedition followed as far as it could the native custom, and was usually in camp by 1 or 2 p.m. On five days out of the twenty-two here considered the wind is recorded as slight. Three of these days followed unusual nights when the barometer was lower in the morning than in the previous evening. The

PLATE 58.—Cumulus clouds, with false cirrus above, obscuring Mount Everest, 2.40 p.m. on the 17th June, 1933.

daily rise and fall in the strength of the wind is perhaps directly connected with the marked daily variation in pressure, but Dr. Sen is more competent to trace such connections than I am.

The daily temperature range was always considerable, as the nights were clear and the days sunny. Minimum temperature observations were made for most nights, but daily maximum temperatures could only be taken on non-travelling days. Although the height of our camps averaged about 14,000 feet, there was considerable variation and little value therefore in quoting an exact average minimum temperature. The lowest minimum of — 4° F. was at Shabra Shubra, 14,900 feet, on the night of March 25th. Between Kampa Dzong and Shekar the minimum varied from + 6° to + 23° F. and averaged about + 15° F. The daily range of temperature was recorded for those places where we stayed for two or more nights. At Kampa Dzong on March 31st, the range was a little more than 30° F., at Tengkye on April 4th it was at least 45° F., and at Shekar on April 11th at least 30° F.

On twelve out of the twenty-two days the sky was clear in the early morning, but even on these days clouds appeared later. Over Tibet, cumulus and fracto-cumulus clouds, blown by a west wind, were commonest. Cirrus and cirro-cumulus and alto-stratus clouds appeared on several occasions, and in certain cases, namely at Kampa Dzong, Khenga and Shekar, they were succeeded by cumulo-nimbus clouds from which there was a slight snowfall. The intermittent fall of snow at Shekar from 9.30 a.m. to 3 p.m. on April 13th was the greatest that we experienced after the fall at Phari, but it only amounted to half an inch. On this occasion there was a very striking change, due to the moisture in the air, from the usual yellow-and-brown coloration of the Tibetan landscape, so well shown in Somervell's paintings, to blues and purples which reminded us pleasantly of the Hebrides or the west of Ireland. Although no hygrometric measurements were made during the march, the air was obviously dry, and it tended to affect our throats. The only exceptions were on April 12th, 13th and 14th, the days of the blue and purple distances, and it was then a pleasure to take deep breaths of the moist air. As a result of the usual dryness of the air, hoar-frost was rare, occurring only twice. One of the occasions was the night when the expedition was encamped in the lee of Pauhunri and patches of snow were lying in hollows; the other was on April 13th, when there had been half an inch of snow, some of which by nightfall had not disappeared from places in shadow. The usual dryness gave a harsh outline to the hills, and visibility was remarkably good except on April 7th, 8th, and the morning of the 9th, when a haze reduced visibility to three miles. These three days succeeded a day of unusually violent wind, and the haze was presumably the result of dust blown into the air.

Although travel in Tibet in March is unpleasant because of the strong and cold winds, and although the conditions would presumably be a little more severe in February than in March, yet the journey through Tibet would not, I believe, be unreasonable either for Europeans or porters if on a future occasion it was decided that the Base Camp ought to be occupied earlier than it was this year.

Weather at the Base Camp and above before the beginning of Monsoon Conditions

The Base Camp, at a height of 16,800 feet, lies in the Rongbuk valley which runs approximately north and south between mountains rising to a height of 21,000 feet. Twelve miles to the north the typical Tibetan plateau country begins, and twelve miles to the south is Mount Everest. On the whole the weather at the Base Camp, since it lies north of the main Himalayan range, resembles the weather of Tibet.

When we arrived at the Base Camp on April 17th there were drifts of snow in every slight hollow, and flat areas of gravel were deeply covered by ice from streams which had continued to flow during the winter. We found drinking-water, however, at various places beneath the ice, and this would no doubt be available throughout the winter. It was cold enough when we first arrived to make windproof clothing and gloves always necessary.

The systematic observations made for April and May at the Base Camp will be dealt with in the same order as has been adopted for those made during the march across Tibet. The barometer (the Carey Aneroid), as was to be expected at those heights, remained much more steady than at sea-level. There seemed to be no significant change when the monsoon conditions set in, and during the whole time we were at the Base Camp, that is, from April 17th to the beginning of July, the barometer fluctuated around 15·98 inches, the lowest value recorded being 15·85 inches and the highest 16·08 inches. The daily variation which was noted during the march across Tibet at an average height of 14,000 feet was equally conspicuous at the Base Camp. Out of fifty-six days for which satisfactory records exist, only on one day was the barometer higher in the evening than in the morning. Before monsoon conditions set in, a general fall in pressure independent of the daily variation was usually accompanied by slight snow. After the beginning of monsoon conditions, similar fluctuations of pressure occurred, but precipitation was by no means limited to the periods of falling pressure.

As the Base Camp is in a narrow valley, the actual wind experienced was either up or down the valley, that is, either north or south. The Base Camp was also sheltered by moraines especially from south winds, and a wind recorded as force 3 from the south meant a wind of force 5 or 6 on the other side of the moraine. The site of the Base Camp, having been chosen because it offered some shelter from the winds, was thus not ideally situated for a weather-recording station. On nearly all early mornings there was a calm or only a slight wind, but usually by 10 or 11 o'clock a wind from the south had developed which was recorded at Base Camp as of force 2 or 3. The motion of the clouds between 20,000 and 30,000 feet in the pre-monsoon interval nearly always indicated a wind from the west of considerable strength. Exceptions occurred on April 18th and 19th, when the movement of the clouds proved a high north-west current and a north wind was experienced at the Base Camp, and again on May 17th, when fracto-cumulus clouds were blowing up from the east and there was slight snow. In the pre-monsoon period, because of the violent west winds and small precipitation, the mountain appears from the north as a dark rock-face free from snow. This appearance is maintained until towards the end of May.

At the Base Camp the average minimum temperature from April 17th to April 30th was + 15° F., the lowest minimum being + 10° F. and the highest + 20° F. The average maximum during this time was + 39° F. The May records are far from complete, but the June records will be mentioned here for comparison. The average minimum temperature for the month of June was + 25° F., varying from + 12° F. to + 32° F., and the average maximum was + 62° F., varying from + 52° F. to + 68° F.

Almost without exception, there was less cloud in the early mornings than later in the day, yet the mornings were rarely completely clear. Even if the usual stray fracto-cumulus clouds were missing there would almost certainly be a cloud-flag on Mount Everest formed from moist air drawn up the south-east face of the mountain by the west wind. The maximum development of cloud was usually in the early afternoon. The commonest clouds were cumulus or fracto-cumulus, between 20,000 and 30,000 feet, which were blown along by the powerful westerly wind (Plate 56). There was also frequently a little cirrus cloud, while the usual cumulo-nimbus and stratus clouds were associated with the snow-storms.

Precipitation took place on twelve days between April 17th and May 31st, but it was mostly slight. On April 22nd there were three inches of snow ; on May 3rd and 9th about half an inch, and these were the occasions of greater precipitation. The air was always very dry and the snow disappeared almost at once, except in the case of the three inches that fell on April 17th. Only one case of hoar-frost was noted. Satisfactory humidity observations were made only for a short period in June.

There are scanty observations from the higher camps. The lowest minimum temperature recorded in 1933 was — 21° F., at Camp II, on May 11th. During the 1924 expedition a minimum of — 24° F. occurred on May 22nd at Camp III, 21,000 feet. This year our lowest temperature at this camp was — 20° F. on May 8th. The only temperatures recorded above Camp III were taken at Camp V, 26,700 feet on May 29th. The minimum was — 4° F., and it was + 4° F. at 8 o'clock when the party left to establish Camp VI. Average minimum temperatures for different periods at various camps compared with the Base Camp are given below. The table shows what was always suspected, namely that Camp II at 19,800 feet is as cold as Camp III at 21,000 feet.

Average Minimum Temperatures for Different Periods compared with Base Camp (degrees F.)

Time	Base Camp	Camp I	Camp II	Camp III
April 28th–May 1st	+ 17½	+ 14		
May 2nd–6th	+ 15		— 1	
May 3rd–6th	+ 15			— 1
May 7th–17th	+ 18		— 8	— 7
May 28th–June 5th	+ 18			— 10
June 28th–July 1st	+ 30½			+ 18

Winds at Camps III and IIIa were often violent, producing drift, but I should not care to give a definite estimate of their strength. It has been suggested by members of the earlier expeditions that high up on Mount Everest there was sometimes less wind than at the North Col, but this year we always found the reverse.

When we first arrived the almost level glacier at the foot of the North Col slopes was polished ice, and this is presumably its usual winter condition, but on May 9th it was covered by six inches of snow. Despite high winds, especially those on May 17th and 18th, precipitation remained in excess of ablation and removal by winds, so that dry glacier was not seen again here. The snow usually fell as single-crystal snow, and I find in my diary a special comment that on May 10th some of the snow came as flakes. Until the height of summer the snow on the North Col and above was either wind-compacted or remained as a powder. Both Mallory[1] and Odell[2] have discussed the problem of the height to which melting of the snow or its transformation to *névé* occurs. This year two relevant observations were made. On May 22nd, drinking-water was obtained from ice chipped from the rocks behind the tents at Camp V. Melting must therefore sometimes occur at 25,700 feet. The ice was probably formed from a thin sprinkling of snow covering dark rocks which had melted on some exceptional day of a previous summer, and the water, having trickled into the shadow, had refrozen. Norton's couloir at about 28,000 feet contained mainly light powder snow, but at one point we scraped steps in what seemed not merely wind-compacted snow but genuine *névé*. Above 27,000 feet, however, most of the summer snow which whitens the northern face of the mountain must remain as a light powder until it is blown away by the winter winds.

The Weather in June—Monsoon Conditions

This year the exact date of the onset of monsoon conditions was not obvious to observers either on the mountain or at the Base Camp.[3] By May 15th Camp IV was established and we were in a position to watch a great sea of cumulus clouds rolling up the Arun valley each afternoon. This was at first taken to be a sign of the arrival of the monsoon, but it is probably a phenomenon taking place in summer and winter alike, and comparable with the floods of cumulus which were often seen coming through all the main passes in the Himalaya during the march across Tibet earlier in the year. On May 24th at the North Col it was warmer than usual and some snow fell, but on the following day the old conditions of low temperature with violent west wind and drifting snow returned. On May 26th there was snow in the night, and the morning was

[1] *Mount Everest: The Reconnaissance*, 1921, pp. 266–267.

[2] *The Fight for Everest*, 1924, p. 310.

[3] I am purposely using the term "monsoon conditions" because the true monsoon of India is a relatively low-lying current of wet air which only exceptionally reached the north side of the Mount Everest group.

cloudy and warm, but by evening the cloud-level had again sunk below us. On the afternoons of May 27th, 29th, and 30th snow fell at heights of at least 28,000 feet. On these days in the early morning there were sporadic cumulus clouds at about 23,000 feet; the clouds became more abundant and higher during the course of the day, generally reaching 25,000 to 28,000 feet in the early afternoon; by sundown they had sunk again to a general level of about 22,000 feet and decreased in amount. On the night of May 30th an inch of snow fell at Camp V, and during most of the next day intermittent snow occurred at least as high as Camp VI. Perhaps May 30th is to be regarded as the beginning of monsoon conditions. Snow fell on June 1st, 2nd, and 3rd, generally in the afternoons and in small quantities only. Then there followed a few days when the mountain was mostly clear of cloud and no snow fell. Throughout this period a west wind usually blew at night and in the early morning.

By June 8th monsoon conditions were definitely established. All members of the expedition had returned to the Base Camp, and the mountain was at this time watched from there. A quarter of an inch of snow fell at the Base Camp on the night of June 7th; on the 9th snow fell from 11 a.m. to 4 p.m.; on the 10th it snowed on Mount Everest but not at the Base Camp, and on the 11th, 13th and 14th there was again slight snow at the Base Camp. During this period Mount Everest certainly received more snow than the Base Camp, and by June 10th the north face of the mountain had assumed its usual summer appearance (Plate 51).

Beginning on June 7th, and therefore simultaneous with the more snowy weather, a sudden rise of the minimum temperature was noticed. For the first seven days of June the average minimum temperature at the Base Camp was 16½° F., while for the remainder the average was 28° F. The barometric pressure, and the wind direction in the valley and at 25,000 feet as judged by clouds, showed no significant change. On most days the early mornings were clear except for a few ragged cumulus clouds over Tibet or a capping-cloud on Mount

Everest (Plate 57). Between 9 and 10 a.m. cumulus clouds began to creep over the low col, 19,500 feet, to the west of Mount Everest, and these quickly deepened until the mountain was blotted from sight. During the afternoons cirrus, and often handsome anvil clouds of false cirrus, were to be seen above the cumulus (Plate 58). By 6 p.m. the clouds over Everest were usually thinning, and before dusk a glimpse of the summit was generally obtained, whitened still more by the day's snowfall. To the north in the early morning there were usually isolated cumulus clouds which increased in size and abundance during the day (Plate 59), and in the afternoons several storms could usually be seen passing westwards only ten or twenty miles north of the Base Camp. During June the Base Camp was much freer from cloud and precipitation than either Mount Everest to the south or the plains of Tibet to the north. This local but advantageous peculiarity seems to be partly the result of the Base Camp lying just south of the tracks of the isolated convection storms which drift over the plains of Tibet and partly the result of its being sheltered by the Mount Everest group from most of the moist air coming up valleys from the south.

Extracts from Dr. Sen's weather reports from Alipore may be compared with the description just given. According to these reports, on May 31st the seasonal monsoon, trough of low pressure, was becoming pronounced over north and north-west India, and the monsoon was very active from Darjeeling to Mussoorie. The trough was less pronounced on the 6th. On the 7th western disturbances were affecting the Mount Everest region and the monsoon was again active at Darjeeling. On the 8th the height of the monsoon current was about 3 km. and likely to extend to higher levels. On the 10th the height of the monsoon current was 9 km. On the 12th there was a depression in the northern part of the Bay of Bengal. I cannot continue to quote even the gist of Dr. Sen's very full weather reports, but the above are sufficient to show that a close connection exists between the weather on Mount Everest and that over India.

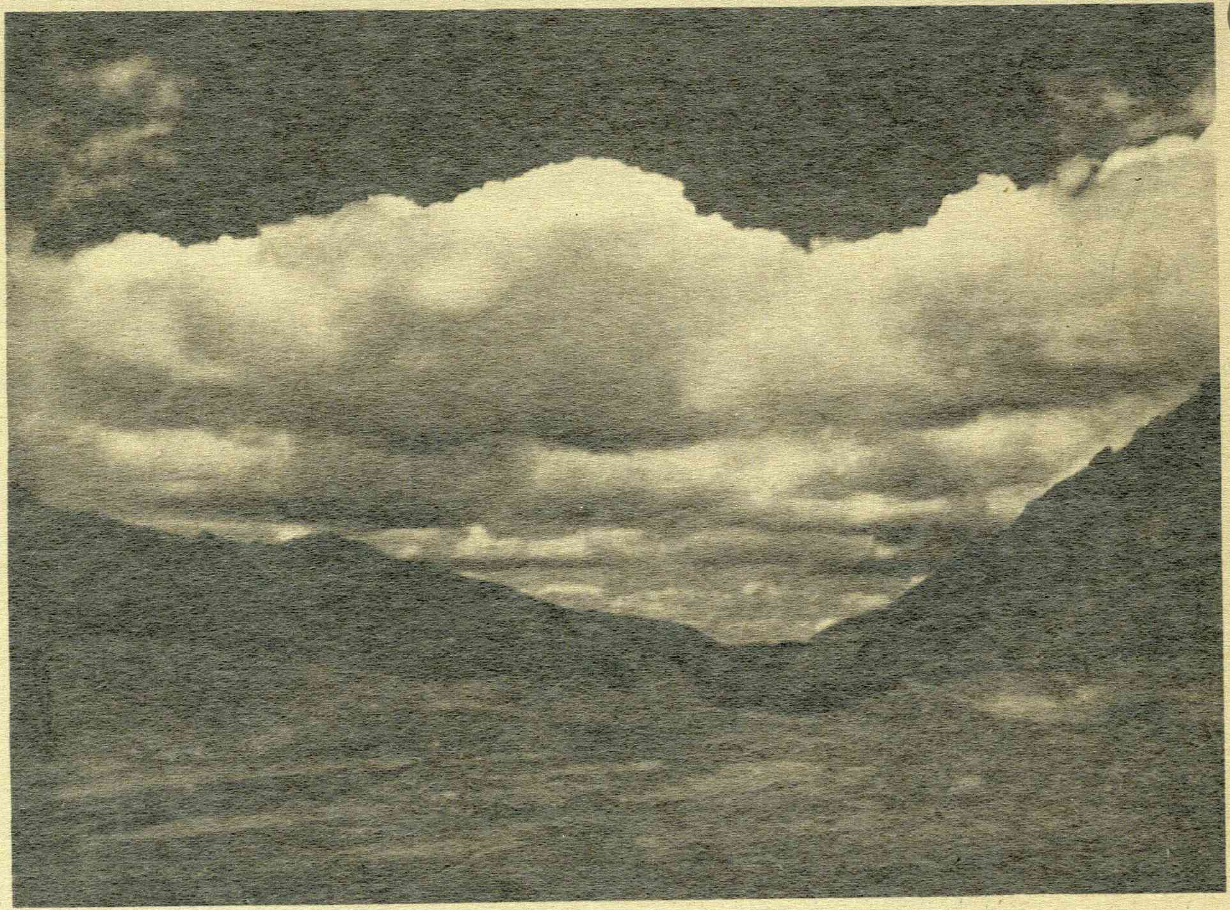


PLATE 59.—Cumulus clouds over Tibet. Photograph taken from the Base Camp at noon on 15th June.

During the second advance up the glacier between June 11th and 22nd, monsoon conditions were well established. Particularly heavy precipitation occurred on the 19th to 22nd of June from low cumulus clouds blown up from the south-east or east. This unusual wind direction was presumably the result of the dominance of the south-east monsoon current of Bengal. During this time the basin at the head of the East Rongbuk glacier was described by those at Camp III as "alive with avalanches."

The weather was very different at Camp III from June 27th to July 2nd, when Shebbeare and I were there to evacuate the glacier camps. Then we never saw or heard an avalanche despite a powerful sun. The minimum temperatures from June 28th to July 2nd were 14°, 17°, 20°, 23° F., and the maximum temperatures 64°, 64°, 67°, and 67° F. On each day there was a short snowstorm coming from the west or north-west. The amount of snow that fell, however, never exceeded half an inch, and the wind did not exceed force 1 during the whole of this time. We were probably experiencing an exceptional fine spell. There was a good deal of water on the glaciers as high as 20,500 feet. Up to at least 22,500 feet the snow was compacted for a depth of nine or twelve inches into a coarse granular mass which overlay powder snow or *névé*. It would have been easy and safe to reach the North Col if a party had started sufficiently early to arrive by 8 a.m. Probably Camp V could have been reached, but the deep snow above which could be seen completely covering the tent at Camp VI, was presumably a fine powder which would have prevented further progress.

General Conclusions

Although our experience of the weather in Southern Tibet amounts to little more than a quarter of a year, yet it covers the change from winter to summer. From the observations of the few other travellers in this region, it is clear that the winter conditions which we experienced hold roughly from November to May, and the warmer and somewhat damper summer conditions from June to October.

The difference, however, between summer and winter is apparently not great. The general barometric pressure at the Base Camp remained the same. The diurnal variation and the longer period variations also remained unchanged in amount and character. In summer and winter alike the prevailing wind was westerly, the only difference being that the winter wind was a little stronger than the summer wind both on the Tibetan plateau at 14,000 feet and on Mount Everest at 30,000 feet, as judged by clouds.

The usual weather régime is modified, but not greatly, by two main factors, the so-called westerly depressions and the Indian monsoon. The depressions moving from the west over Southern Tibet and occurring in both summer and winter seem to cause more air to be drawn from the south, with an increase in the strength of the wind and the amount of precipitation. The monsoon had no effect on the barometer at the Base Camp, and the south-east monsoon current reached the north side of the Mount Everest group only once during the period of our observations. The monsoon, however, provides more moisture than is available in the winter, and there is consequently more precipitation on Mount Everest and in southern Tibet.

In 1933 the weather on Mount Everest was undoubtedly set against a successful conclusion to the expedition, and probably it is fair to consider that the weather was exceptional. Mallory states that in 1921, on June 19th, the expedition at Ponglet was drenched by a storm which was followed by a general break in the weather, but even a few days later the north face of Mount Everest was described as still comparatively black. Apparently that year monsoon conditions did not arrive till late June. In 1922 the snowing up of the top part of Mount Everest began in early June, which is about the same time as in 1933. In 1924, there was good weather from May 28th to June 8th, and it was considered that the monsoon did not actively break until June 16th. This year, by May 30th the slabs on the north-west face of Mount Everest had a sprinkling of snow which was enough to make climbing slow and difficult.

There was still more when an attempt was made on the summit on June 1st, and after this snow continued to accumulate until we left the district. At the end of July and the beginning of August, Darjeeling enjoyed an almost unique spell of fine weather, and it would have been interesting to have known what the conditions were like on Mount Everest at this time, but unfortunately we had all left the district. In India there is a belief that heavy and late winter snowfalls in the Himalaya mean a late monsoon; in 1932–1933 there was said to be a heavy winter snowfall, but the monsoon arrived in Bengal exceptionally early.

Whether there is any reasonable chance of climbing Mount Everest during the monsoon period or in September is not definitely decided. The only evidence so far is that obtained on the reconnaissance expedition in 1921. This year we left the mountain at the beginning of July. It was then deeply covered in snow, and it is probable that this would never become sufficiently compacted to allow a climber to walk on it easily; but it is just possible that if violent west winds occur in July, August or September they might remove sufficient snow to allow the mountain to be climbed before the excessive winter cold sets in.

In conclusion, let me set down a plea for more extensive observation of the weather conditions when next the ascent of Mount Everest is attempted. The data obtained would contribute to the success of all future expeditions to the Eastern Himalaya, and it may be that Mount Everest itself will not fall to the next attempt. Perhaps it might be arranged to include a meteorologist in the party, but in any case daily weather observations should be made and continued into September, even if the main part of the expedition should return earlier. Several members of the expedition should make themselves competent observers. The instruments should be carefully considered before the expedition sails, special instruments in some cases being designed, and the Indian Meteorological Department should be asked in good time to give all possible help.

IX. HIMALAYAN METEOROLOGY

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1. Introduction

Meteorology has for a long time come to the aid of shipping and aviation. During the Great War the help of this science was invoked for the offensive and defensive operations of the belligerents. It is perhaps the first time in the history of meteorological science in India that weather reports and forecasts have been requisitioned in all seriousness for mountaineering.

In 1930 the Alipore Observatory, Calcutta, issued a number of experimental weather reports and forecasts for the International Himalayan Expedition which attempted to climb Kangchenjunga under the leadership of Professor Dyhrenfurth. The weather bulletins were broadcast every evening from April 18th to June 6th, 1930. An accidental breakage of the receiving set of the party, however, put an end to all experiments.

As regards the utility of the weather reports and forecasts, it may be interesting to note that the messages prepared for the Kangchenjunga Expedition were subsequently compared with the actual weather logs kept by the party. The results of the comparison were encouraging.

Towards the end of April 1933 the Alipore Observatory was called upon to issue weather reports and forecasts for the Mount Everest Expedition. It was with considerable misgivings that the task was undertaken. An idea of the handicaps may be formed from the following facts. In the vast area of the Eastern Himalayan region there is only one high-level surface observatory, namely Darjeeling, which reports telegraphically to Calcutta. Vast regions like Nepal, Bhutan and Tibet are yet meteorologically unexplored and unrepresented. The difficulties in the way of forecasting weather over this region are therefore formidable.

As the establishment of a sufficient number of surface observatories over the Himalayan range was not a practical proposition, it was thought that a few upper air observatories along the foot of the Himalaya might be helpful. Dr. C. W. B. Normand therefore agreed to make the following arrangements. The upper-air observatories at Patna and Dacca were temporarily transferred to Purnea and Darjeeling respectively. These, with the upper-air observatories already at Tezpur and Agra, formed a more or less useful chain along the foot of the Himalayan range. As the Alipore Observatory does not usually receive weather telegrams from stations on the Western Himalaya, it was arranged that the surface observatories at Srinagar, Dras, Sonamarg and Leh in Kashmir, at Simla and Mussoorie, and at Mukteswar in Kumaun should report morning and evening observations to Calcutta.

In spite of the preliminary success achieved in forecasting work during the Kangchenjunga and Everest Expeditions it cannot be claimed even now that weather prognostications for a vast unknown region like the Himalaya can confidently be undertaken from the strictly scientific point of view.

2. Himalayan Climatology

The meteorological data of most of the hill stations on the Himalayan range are set out in the tables at the end of this chapter. The names of the stations have been arranged in the ascending order of their heights above sea-level. For the purposes of study, the Himalayan region may be divided into two divisions. The Western Himalaya has been taken to be the portion of the mountain range to the west of Katmandu, and the Eastern Himalaya to be the portion to the east of that station. The positions of the hill stations are shown in the chart facing page 360. An idea of the normal annual variations of the important meteorological elements at the various levels may be obtained from a study of the tables.

(*a*) *Atmospheric Pressure.*—The mean monthly pressures at the various hill stations are set out in Table I. The annual variation graph of pressure in levels up to about 10,000 feet above sea-level shows a peak during the winter months and a trough during the summer months. The amplitude of the variations, however, decreases as the height increases. In levels above 10,000 feet, the character of the curve is completely changed. In these high levels the pressure graph shows two well-defined maxima and two minima during the year. The first maximum occurs in the pre-monsoon months and the second in the autumn, whilst the first minimum appears in the winter and the second at the height of the monsoon.

(*b*) *Vapour Tension.*—The mean monthly vapour pressures at the various hill stations are set out in Table II. The annual variations of this element show the same characteristics over both the Western and the Eastern Himalaya. As is to be expected, the annual wave shows a peak at the height of the monsoon and a trough in the winter, and the absolute value of vapour pressure decreases with elevation.

(*c*) *Maximum and Minimum Temperatures.*—The normal data are given in Tables III and IV. The annual variations show the same characteristics as the stations on the Indian plains.

An idea of the order of temperatures met with at the Base Camp of the Mount Everest Expedition during the period May 4th to June 27th, 1933, may be gathered from Table V. So far as the index of human comfort is concerned, these temperatures are in no way representative, because of the important factor of solar radiation temperature. As a matter of fact, the experience of climbers in the Himalaya has been that at great heights one can hardly bear the intense solar radiation even when experiencing fierce cold blasts of wind many degrees below freezing-point. In this respect, therefore, the conditions over the Himalayan heights closely resemble those at the polar regions. As a matter of fact, it would not be surprising if, on clear days, solar thermometers at the Everest region recorded temperatures some 60° to 70° Fahrenheit above the daily maximum in shade.

(*d*) *Cloudiness.*—It will be seen from Table VI that the

Western Himalaya is in general more cloudy in the winter than in the other seasons, but the cloud amounts tend to increase in the monsoon. In the Eastern Himalaya, on the other hand, the maximum cloudiness occurs during the monsoon months only.

(*e*) *Rainfall and the Number of Rainy Days.*—Tables VII and VIII show that, on the average, the Western Himalaya has more precipitation during the cold weather or the pre-monsoon period than in any other season, while over the Eastern Himalayan region maximum precipitation occurs in the monsoon months. This peculiarity and the facts noticed in Table VI above are due to the fact that most of the rain- or snow-fall on the Western Himalaya is caused by depressions from the direction of Persia—popularly known in India as western disturbances, while precipitation over the Eastern Himalaya is mainly dependent on the Bay of Bengal branch of the south-west monsoon. (See Table VII.)

The south-west monsoon is, on the average, more active on the Eastern than on the Western Himalaya. Although precipitation on the latter is caused chiefly by western disturbances, there are some stations such as Simla and Mussoorie, where precipitation during the monsoon months is considerable. The heavy falls over these stations no doubt usually occur when a monsoon depression travelling up from the Bay of Bengal breaks up against the Western Himalaya.

The number of rainy days shows characteristics similar to those of the rainfall amounts. (See Table VIII.)

(*f*) *Surface Winds in the Everest Region.*—The surface winds over the hills are variable in character. Their direction and strength are mainly governed by the local orographic peculiarities. The general trend of the wind circulation, at least in the summer months, over the Western Himalaya is up-valley during the daylight hours and down-valley as soon as night cooling is effective. On the average a surging flow of the anabatic and katabatic winds across the Western Himalayan range is in operation. In the case of the Eastern Himalaya (and possibly Kumaun), however, the principal river valley is the upper reaches of the Brahmaputra, which runs along the main mountain chain. The westerly winds down the upper Brahmaputra valley are followed by up-valley easterly winds. The latter, coming up from the lower levels, are likely to be more humid and warm than the westerly winds. Consequently, when the up-valley winds start, haze and precipitation are very often caused, especially in the summer afternoons, followed by clear weather in the nights. In this respect, therefore, weather over the Eastern Himalaya is very similar to the weather experienced on the plains of Bengal in the nor'wester season from February to June. The speed of the katabatic winds is generally at its maximum in the winter nights, and of the anabatic winds during the afternoons of April, May and June.

3. Upper-air Data

Although the surface winds are very variable over the Himalayan ranges the observations of cloud and snow drift and pilot-balloon data show that the main circulation aloft is less subject to rapid fluctuations. Upper winds, from 6 to 10 kilometres above sea-level, over hill stations such as Simla and Darjeeling, and over other stations more or less in the sub-montane regions, have been taken to be representative of winds over the Himalayan region. The pilot-balloon data picked up at random from the published records of 1928–30 and the special flights in the summer of 1933 are set out in Table IX.

(*a*) *Wind Direction Aloft.*—The upper wind and cloud data hitherto collected show that, in the months November to May, winds over the whole of the Himalayan region are predominantly from a westerly direction. The wind directions are steady in the winter months, from November to the first half of February, and fairly steady in the pre-monsoon months, from the second half of February to May. During the monsoon months, from June to September, the winds over the Himalayan region appear to be most unsteady. The monsoon current occasionally rises to great heights even above the

Himalayan peaks. On such occasions the air current over the Eastern Himalaya becomes southerly or south-easterly, backing to easterlies or north-easterlies over the Western Himalaya. In October, with the withdrawal of the monsoon from the hills, the usual westerly circulation sets in. This current becomes progressively steady as winter conditions are established.

(*b*) *Wind Strength Aloft.*—The upper winds over the Himalayan region in the months November to February are almost invariably strong, often rising to gale force and sometimes to hurricane force. Wind speeds of 100 miles per hour should not be infrequent on the summit of Mount Everest. Some falling off of the speed usually takes place in the months March, April and May, but even in these months wind often blows with gale force in 9 or 10 kilometre levels. With the setting in of the monsoon a conspicuous fall in wind speed is noticeable, and this condition persists until the approach of the winter.

(*c*) *Upper-air Densities.*—Almost simultaneously with the Mount Everest Expedition the Houston Mount Everest Flight party, under the leadership of Air-Commodore P. F. M. Fellowes, came out to India. A knowledge of the magnitude of air densities in the various levels of the Indian atmosphere near the Himalaya is useful in such operations as those undertaken by Lord Clydesdale. Table X, which gives the monthly averages of the air density in grammes per cubic metre in the various levels of the free atmosphere above Agra, may be useful in connection with future flights over Himalayan peaks.

4. Disturbances which affect the Himalaya

A Himalayan expedition is not undertaken in the winter months, for obvious reasons. The perpetual snow line is about 15,000 feet above sea-level, and the glaciers descend to about 12,000 feet. The prevailing low temperatures and the frequent westerly or north-westerly blizzards associated with snowfall make all human attempts on Himalayan peaks impossible. In April, May and June, owing to the effects of the rapid insolation of the great Indian plains extending upwards, there is a more or less sudden break in the frequent precipitations over the Himalayan ranges, in the absence of disturbances. The frequency of fogs and low clouds also decreases in these months. Mountaineers therefore look forward to one of these brief spells of fine weather in this period before the advent of the monsoon. It is probably for these reasons that hitherto almost all attempts on the Himalayan peaks have been made in the summer months.

The disturbances which primarily affect the Himalaya are :

(i) Western disturbances, and depressions and storms in the Arabian Sea.

(ii) Storms and depressions in the Bay of Bengal.

(i) *Western and Arabian Sea Disturbances.*—So far as the Indian area is concerned, western disturbances bring winter rains to the Punjab and the adjoining areas. The majority of these depressions originate in south-east Europe or the Mediterranean and travel eastwards. They have therefore the same characteristics as extra-tropical cyclones. At the height of winter these disturbances affect the extreme north of India, but with the approach of the spring their tracks on the average are more and more southerly, affecting countries such as Persia and Arabia. On the average about four disturbances reach the frontier every month from December to April, but in individual years this number may even be doubled in some months. From July to September the effect of a western disturbance appears to be mainly the accentuation of the existing trough of low pressure over the plains of Northern India, commonly known as the "monsoon trough." In the summer months wind circulation over large areas in the Arabian Sea is often controlled by these disturbances.

In the months of April, May and June a western disturbance on reaching Baluchistan and the North-West Frontier Province from the direction of the Mediterranean is very often seen to split into two parts, owing, no doubt, to the large-scale subsidence of the Himalayan air, chiefly over the plains of the Punjab.

The first portion of the parent depression generally travels in an easterly or north-easterly direction across the Karakoram and the Kashmir hills into Tibet. While over the Punjab, it usually causes widespread precipitation over the Western Himalaya, followed by blizzards. Bad weather due to the travel of this portion of the disturbance to Tibet, however, may not be felt in the Everest region at all, beyond the formation of clouds in the subsiding westerly or north-westerly currents in the rear of the depression.

The second portion of the disturbance, which may sometimes be confined to the upper layers of the atmosphere, is, however, important from the point of view of weather in the Eastern Himalaya. It travels eastwards across Central India to Bengal, often accentuating the " heat lows " over the Central Provinces.

From the point of view of weather over the Everest region, the important points in connection with a western disturbance at the frontier are, firstly, whether a particular disturbance is of considerable vertical thickness, and, secondly, whether a portion of it is likely to affect the Central Provinces, which appear to be a sensitive spot so far as Eastern Himalayan weather is concerned.

The frequency of disturbances in the Arabian Sea is much less than that in the Bay of Bengal. The effects of Arabian Sea depressions and storms on the Himalayan region are very similar to those of western disturbances.

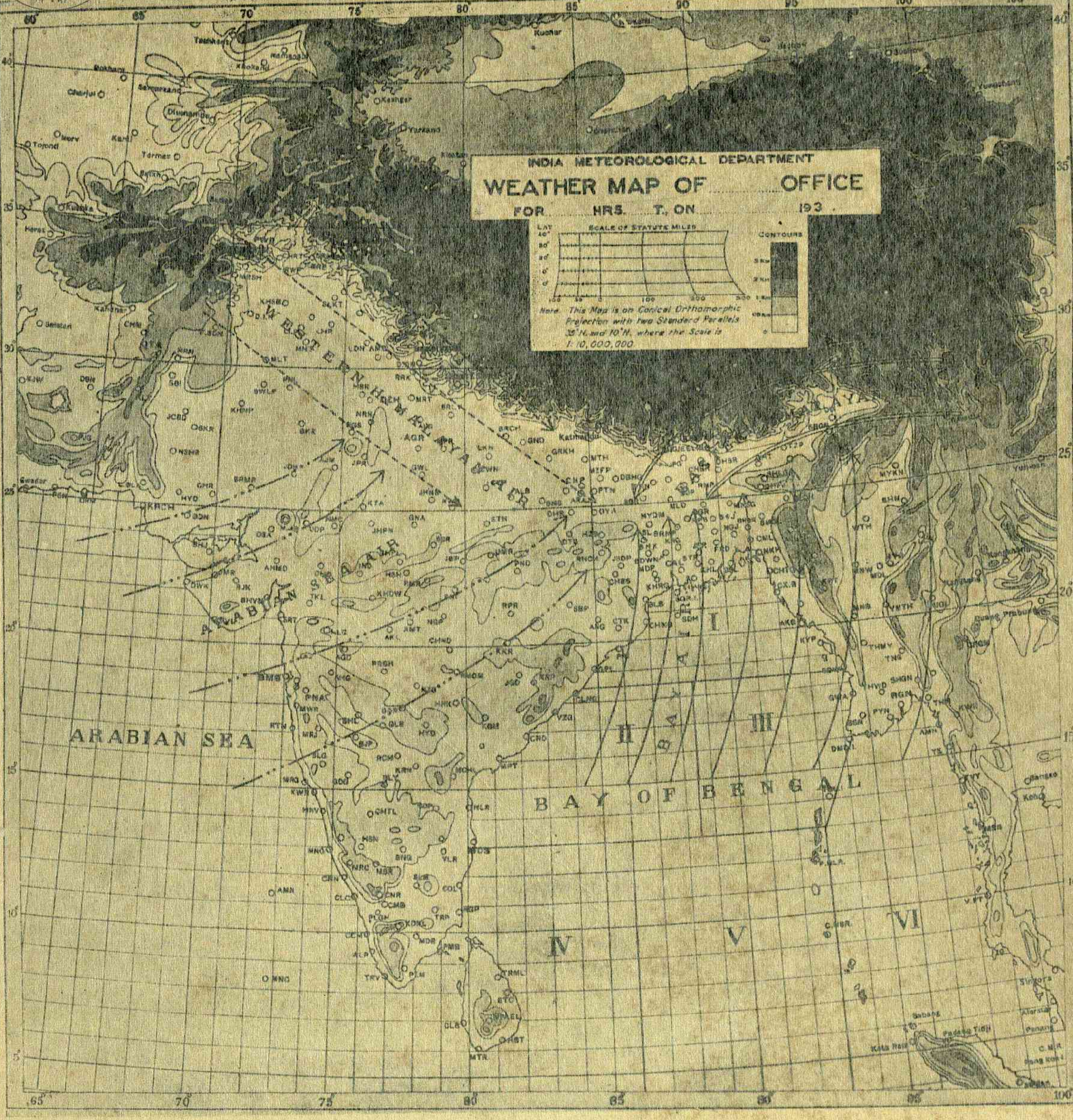
(ii) *Cyclonic Storms and Depressions in the Bay of Bengal.*— The average frequency of Bay storms and depressions, based on forty years' data, is given in Table XI. The question whether a storm in the Bay of Bengal should give rise to bad weather in the Everest region is best decided by considering the position of the centre of the storm and its probable direction of movement. In this connection a reference to *Storm Tracks in the Bay of Bengal*, compiled by Dr. Normand, is helpful. It may be safe to generalise that a storm developing to the east of longitude 90° E. is likely, in the first stages, to give rise to fair weather in the Everest region, provided there is no disturbance in Western India at the time. An example of the simultaneous presence of a western disturbance over the United Provinces and a Bay storm to the east of longitude 90° E. entering Central Burma on May 13th, 1930, at the time of the Kangchenjunga Expedition may be of interest. This meteorological situation produced very bad weather on the following day over the Eastern Himalaya. The weather diary of the party records that on that occasion a snowstorm from the west was experienced until 1 p.m. of the 14th. Then the weather suddenly improved for a couple of hours, after which the weather again deteriorated, but this time a snowstorm from the east was experienced. The weather over the Everest region will gradually deteriorate if a storm begins to move west or north-west to Orissa and the Central Provinces, as is usually the case in June. The consequence of this retrograde movement of Bay storms and depressions is to make the southerly or south-easterly humid current following the disturbance, sometimes of great vertical thickness, penetrate the Everest region.

5. Forecasting of Weather over the Everest Region

It has to be admitted that attempts at forecasting weather at levels of 20,000 feet and above must for a long time remain speculative. Modern methods of locating the various fronts can hardly be applied to regions from which no synoptic observations are available. The object of this section is simply to make a few generalisations which may be found helpful.

In the following paragraphs it is proposed to leave out considerations of local instability, subsidence, etc., which may produce bad weather at places in the Everest region. In the issue of weather reports and forecasts, only the broad features of the possible interactions of the different air masses could be considered during the Kangchenjunga and Everest expeditions. The details are explained below as briefly as possible.

In the mechanism of weather in the Everest region four


INDIA METEOROLOGICAL DEPARTMENT
WEATHER MAP OF .... OFFICE
FOR ...... HRS. ... T. ON .... 193 .
SCALE OF STATUTE MILES
CONTOURS
Note. This Map is on Conical Orthomorphic Projection with two Standard Parallels 35°N and 10°N, where the Scale is 1:10,000,000.
WESTERN HIMALAYA
ARABIAN SEA
BAY OF BENGAL
I
II
III
IV
V
VI

principal air-masses depicted in the weather chart facing page 360 appear to be involved.

(*a*) *The Western Himalayan Air.*—This air current, which is dominant in the winter months, is the coldest continental current in the Indian region. It flows down the Gangetic valley as a westerly or north-westerly current into Bengal and the Bay. With the advent of the spring, however, a hot patch of air appears over the south of the Indian Peninsula, shifts to the Central Provinces by the month of May and then proceeds north-westwards and disappears in Persia across the north-western frontier. The movement of this "thermal focus" suggests that the coldest continental air in the winter becomes the hottest continental air (apart from fresh subsidence of cold air) in the summer, so far as the Indian area is concerned. The history of the temperature changes in the various levels of this great Western Himalayan current from year to year should furnish a clue to the peculiarities of the distribution of the monsoon rainfall.

(*b*) *The Eastern Himalayan Air.*—This current usually comes down as an easterly or north-easterly current, mainly along the Brahmaputra valley. It appears to have an uncanny power of affecting the weather wherever it happens to find its way. The westerly course of the monsoon depressions from the Bay of Bengal appears to be determined to a large extent by the westward movement of this air mass. Except in the winter months, this current is the coolest of the various air masses in the Indian region. As such, it is responsible for the majority of the storms in the Bay of Bengal.

(*c*) *The Bay Air.*—In the pre-monsoon months the southerly Bay air brings moisture inland in varying quantities, obviously depending on the length of its trajectories over the sea area. By the middle of June or beginning of July, on the average, the Bay air usually merges in the Bay branch of the monsoon current.

(*d*) *The Arabian Sea Air.*—This air penetrates Western India very often under the influence of western disturbances. The heating effects of the Rajputana desert on this moist air-mass, at least in the lower levels, have to be taken into account in considering its interaction on the Western Himalayan air. In the upper levels, at any rate, the interaction of these two currents often produces clouds and precipitation, but in the forecasting of these phenomena over the Western and parts of the Eastern Himalayas, great caution has to be exercised. This air merges into the Arabian Sea branch of the monsoon current some time also in June or July. It may be interesting to note that the monsoon rainfall in Western India does not normally commence in the usual fashion until July, by which time the Eastern Himalayan air normally penetrates Western India.

Whether the disposition of the various currents at the heights of the Everest region and intermediate layers is more or less similar to that depicted in the idealised chart (facing page 360), must remain a matter for further investigation. On individual occasions, however, an approximate idea of the position of the discontinuity lines may be formed if pilot-balloon data up to 8 to 10 kilometres are available from a more or less satisfactory network of upper-air stations, especially along the foot of the Himalaya.

Let us now consider under what conditions these four air masses may simultaneously operate in producing bad weather over the Everest region.

If, for example, on a particular occasion a western disturbance, while over Rajputana, is deep in the sense that it is able to affect circulation to large heights, then the Arabian Sea air may strike even the Eastern Himalaya as a south-westerly current. With the advance of the disturbance eastwards, the Arabian Sea air-current may further be reinforced by the south-easterly Bay air-current. Thus a moist air-current of considerable breadth and height may invade the Everest region. This current coming in conflict with the cold westerly winds over the Everest region (flow induced by a depression in Tibet) is likely to cause widespread foggy and cloudy conditions and precipitation. With the eastward progress of the disturbance towards the East Central Provinces and the formation of a depression in the north of the Bay an easterly Himalayan current of considerable thickness may also flow down along the Brahmaputra and minor valleys opening out to the plains of Bengal. A conflict between the various air masses may then begin along the Darjeeling hills, giving rise to exceptionally bad weather over the Everest region.

6. Miscellaneous

(*a*) *The First "Burst" of the Monsoon.*—Himalayan climbers are generally anxious to know the probable date of the first "burst" of the monsoon. It is therefore necessary to explain what is meant by the phrase "burst of the monsoon." A reference to Table XII will give an approximate idea of the average rate of growth of the Bay air-current during the various months over the plains of Bengal.

It will be seen from the table that the Bay current steadily increases in thickness from February onwards. When the first depression forms at the head of the Bay, generally by the second week of June, the monsoon current skirts the Arakan-Chittagong coast before entering Bengal. In some cases the Bay air, whilst merging in the monsoon current, may suddenly double or even treble its pre-monsoon thickness in the course of forty-eight hours or so. It is obvious, therefore, that the monsoon current is likely to enter the Tibetan Plateau almost in the course of twenty-fours hours, establishing a wide front of fog and clouds associated with local snowstorms. These phenomena presumably are popularly described as the "burst" of the monsoon over the Eastern Himalaya.

(*b*) *Temporary Cessation or a "Break" of the Monsoon.*—The rainfall in the monsoon season need not be a daily occurrence over large areas. So far as precipitation on the plains is concerned there are spells in which very little rain falls. A typical "break" weather chart is one in which the southern half of the monsoon trough is visible over the Gangetic plain, the northern half being hidden by the Himalaya. The "break" usually appears in the Punjab and extends eastwards along the foot of the Himalayas to North Bengal. A study of the "break charts" shows that the discontinuity surface between the monsoon and the Eastern Himalayan air masses is generally along the Himalayan range. Consequently a "break chart" for the plains may often indicate heavy precipitation along the Himalaya. The same type of pressure distribution as in the "break charts" often comes into evidence when a monsoon depression strikes against the Himalaya and begins to dissipate. The paucity of observatories in the Himalaya is a great handicap to the proper study of the "break charts." It is well known, however, that on these occasions precipitation over the hills may be so large as to cause unexpected floods in rivers of Himalayan origin.

7. The Misfortunes of the Mount Everest Party

From the point of view of weather the Mount Everest Expedition of 1933 was most unfortunate. On the average the westerly Himalayan current was appreciably colder than usual. Table XIII suggests that the weather in April, May and June, 1933, was probably worse than that in the corresponding period of 1924.

Most of the western disturbances in 1933 were well marked, and under their influence the Arabian Sea monsoon frequently penetrated right into Nepal. The 1933 distribution of rainfall led to serious floods in south-west Bengal, Orissa, Central India, and parts of the Punjab.

8. Conclusion

From the preceding paragraphs it appears that a year having the following characteristics should be ideal from the point of view of an expedition to the Eastern Himalaya:

(i) The frequency of western disturbances should be below normal in the months of April, May and June. In other words, less than one disturbance per week should appear on the north-west frontier. Moreover the portion of a western disturbance which travels across the country and affects the Central Provinces should be feeble and shallow.

(ii) There should be no depressions in the Bay of Bengal in June. This may happen, on the average, once in six years.

(iii) The westerly drifts at great heights over the Himalaya should be comparatively weak.

A Suggestion.—It is not known whether there is any year of which the summer months will satisfy all these specifications. It is, however, conceivable that in years of early retreat of the monsoon there may be brief spells of good weather over the eastern Himalaya in the autumn when the mountain slopes may be free from fresh snow. In this season the vast Indian plains begin to cool down, and storms usually originate far away from the Himalayas in the south of the Bay of Bengal. The climatological and other tables quoted in this chapter do not contradict this view. It would therefore be interesting to undertake an Everest expedition in this season.

TABLE I.—MONTHLY AND ANNUAL NORMALS OF BAROMETRIC PRESSURE IN INCHES OF MERCURY AT 8 HOURS LOCAL TIME

Stations.	Ht. above m.s.l. in ft.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Kalimpong .	3,933	26·098	26·051	26·013	25·972	25·927	25·827	25·807	25·857	25·949	26·057	26·115	26·115	25·982
Drosh . .	4,500	25·227	25·155	25·144	25·096	25·008	24·873	24·801	24·835	24·980	25·137	25·210	25·231	25·058
Gilgit . .	4,890	25·272	25·214	25·173	25·134	25·102	24·957	24·873	24·899	25·057	25·229	25·314	25·323	25·129
Srinagar .	5,204	24·988	24·953	24·925	24·898	24·853	24·741	24·673	24·709	24·845	24·983	25·034	25·037	24·887
Gangtok .	5,667	24·512	24·483	24·469	24·450	24·421	24·347	24·336	24·368	24·445	24·515	24·573	24·564	24·457
Parachinar .	6,000	24·491	24·450	24·444	24·418	24·375	24·298	24·267	24·315	24·403	24·509	24·550	24·531	24·421
Simla . .	7,232	23·095	23·069	23·090	23·096	23·073	23·003	22·969	23·009	23·092	23·170	23·184	23·154	23·084
Darjeeling .	7,376	23·020	22·997	23·001	23·001	22·985	22·918	22·909	22·947	23·017	23·083	23·096	23·064	23·003
Skardu . .	7,505	22·952	22·920	22·886	22·880	22·865	22·772	22·690	22·702	22·844	22·959	23·033	23·008	22·876
Mukteswar .	7,592	22·845	22·826	22·852	22·850	22·835	22·753	22·727	22·761	22·840	22·914	22·926	22·892	22·835
Dras . .	10,059	20·771	20·758	20·775	20·804	20·822	20·756	20·706	20·727	20·811	20·878	20·898	20·838	20·795
Leh . .	11,503	19·649	19·624	19·666	19·706	19·748	19·690	19·647	19·668	19·740	19·790	19·798	19·722	19·704

TABLE II.—MONTHLY AND ANNUAL NORMALS OF VAPOUR TENSION IN INCHES OF MERCURY AT 8 HOURS LOCAL TIME

Stations.	Ht. above m.s.l. in ft.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Kalimpong .	3,933	·287	·299	·349	·439	·563	·670	·687	·688	·651	·515	·379	·301	·485
Drosh . .	4,500	·148	·157	·189	·264	·340	·400	·501	·542	·377	·236	·154	·145	·288
Gilgit . .	4,890	·140	·134	·169	·244	·314	·350	·428	·463	·381	·237	·152	·131	·262
Srinagar .	5,204	·146	·159	·230	·322	·436	·548	·630	·616	·462	·286	·189	·152	·348
Gangtok .	5,667	·235	·258	·309	·385	·474	·564	·601	·598	·559	·454	·341	·254	·419
Parachinar .	6,000	·149	·155	·194	·248	·310	·347	·503	·519	·371	·211	·168	·151	·277
Simla . .	7,232	·120	·128	·145	·188	·254	·378	·499	·503	·398	·209	·131	·106	·256
Darjeeling .	7,376	·187	·203	·243	·336	·417	·495	·524	·521	·478	·377	·268	·195	·353
Skardu . .	7,505	·106	·120	·174	·217	·260	·292	·355	·380	·316	·214	·154	·129	·226
Mukteswar .	7,592	·126	·141	·163	·183	·272	·402	·501	·508	·432	·254	·164	·115	·272
Dras . .	10,059	·051	·049	·086	·147	·220	·278	·338	·337	·244	·154	·108	·065	·173
Leh . .	11,503	·041	·044	·078	·111	·131	·171	·262	·283	·193	·113	·090	·052	·131
Gyantse .	13,110	·074	·090	·133	·143	·206	·276	·290	·275	·243	·155	·111	·079	·173

TABLE III.—MONTHLY AND ANNUAL NORMALS OF MAXIMUM TEMPERATURE IN DEGREES FAHRENHEIT

Stations.	Ht. above m.s.l. in ft.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Kalimpong .	3,933	58·9	60·7	68·3	73·1	74·3	74·9	75·1	74·7	74·3	71·6	66·5	61·0	69·5
Drosh . .	4,500	47·8	49·7	58·0	69·0	82·2	92·2	96·6	95·5	88·6	77·0	64·6	51·3	72·7
Gilgit . .	4,890	45·6	51·4	61·6	71·5	83·3	92·3	95·9	95·2	87·1	74·9	63·3	49·4	72·6
Srinagar .	5,204	40·6	43·5	55·8	66·6	75·7	82·4	85·0	84·7	79·4	70·1	61·3	48·3	66·1
Gangtok .	5,667	57·5	59·1	66·3	70·4	72·4	73·9	74·6	74·6	73·9	70·8	64·7	60·3	68·2
Parachinar .	6,000	49·7	50·2	58·1	67·6	79·0	87·6	86·5	85·6	81·6	74·6	65·6	54·5	70·1
Simla . .	7,232	45·7	46·2	55·5	65·2	73·0	74·2	69·1	66·7	66·1	62·8	56·1	49·9	60·9
Darjeeling .	7,376	46·6	48·4	56·3	62·5	64·0	65·5	66·3	65·9	64·9	61·3	55·1	49·2	58·8
Skardu . .	7,505	34·5	38·2	50·0	61·5	71·3	79·4	85·5	87·1	77·5	66·4	54·8	41·5	62·3
Mukteswar .	7,592	49·8	49·9	60·2	69·3	75·0	75·1	70·3	68·8	69·1	66·5	60·4	54·4	64·1
Dras . .	10,059	19·2	23·1	33·6	43·8	60·4	73·9	78·9	79·7	70·4	57·4	44·3	27·7	51·0
Leh . .	11,503	30·3	32·5	44·3	55·5	63·6	72·0	77·2	76·9	70·3	58·6	47·7	36·0	55·4
Gyantse .	13,110	42·2	44·8	50·7	57·8	65·8	72·6	72·5	70·2	70·1	63·0	50·3	43·6	58·6

TABLE IV.—MONTHLY AND ANNUAL NORMALS OF MINIMUM TEMPERATURE IN DEGREES FAHRENHEIT

Stations.	Ht. above m.s.l. in ft.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Kalimpong .	3,933	45·9	47·4	52·7	58·2	62·1	65·9	66·9	66·9	65·4	60·3	52·5	46·8	57·6
Drosh . .	4,500	31·7	33·3	38·7	48·9	59·2	68·4	72·9	72·2	64·7	53·1	43·7	35·0	51·9
Gilgit . .	4,890	32·0	36·5	45·0	52·8	60·3	67·1	71·8	71·7	64·3	52·8	42·8	33·9	52·6
Srinagar .	5,204	26·5	28·4	37·3	45·0	51·8	57·6	64·0	63·4	54·0	41·1	32·1	27·9	44·1
Gangtok .	5,667	32·2	34·9	41·7	47·1	50·5	54·9	56·0	55·6	53·6	48·4	40·8	34·1	45·8
Parachinar .	6,000	28·7	30·3	38·4	46·7	55·7	63·5	66·0	64·8	58·9	49·2	41·0	32·8	48·0
Simla . .	7,232	35·1	35·3	43·9	51·4	58·3	60·8	60·1	59·2	56·6	51·1	44·9	39·3	49·7
Darjeeling .	7,376	34·7	35·5	42·1	48·5	52·1	56·2	57·7	57·4	55·7	49·9	42·7	36·7	47·4
Skardu . .	7,505	16·6	18·8	32·7	42·2	49·3	55·3	60·9	61·1	53·8	41·3	30·2	22·6	40·4
Mukteswar .	7,592	35·3	35·2	42·9	50·4	55·4	58·0	58·3	57·7	55·4	49·8	43·1	38·2	48·3
Dras . .	10,059	—10·6	—10·8	4·1	19·8	33·1	41·1	47·6	48·4	39·5	26·8	15·9	0·2	21·3
Leh . .	11,503	8·5	9·8	20·8	30·3	36·7	43·9	50·1	49·7	41·6	30·3	20·7	13·1	29·6
Gyantse .	13,110	3·3	8·9	16·2	25·4	32·3	41·1	43·7	42·1	38·7	28·9	14·1	4·2	24·9

TABLE V

Date.	Air Temperature.
30·5·33 . . .	Maximum: Highest, 94° F.
4·5·33 . . .	Maximum: Lowest, 46° F.
26.6.33 . . .	Minimum: Highest, 29° F.
7·5·33 . . .	Minimum: Lowest, 11° F.

TABLE VI.—MONTHLY AND ANNUAL NORMALS OF CLOUD AT 8 A.M. LOCAL TIME

(Whole sky cloudy = 10·0.)

Stations.	Ht. above m.s.l. in ft.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October	November.	December.	Year.
Kalimpong	3,933	2·6	2·7	1·8	3·3	4·2	7·1	7·5	7·5	6·5	3·3	1·9	2·6	4·2
Drosh	4,500	4·4	4·7	4·8	3·8	2·2	1·4	1·8	2·4	1·8	1·9	2·2	4·1	3·0
Gilgit	4,890	7·3	6·9	6·8	6·1	4·4	3·0	3·9	3·9	3·4	3·4	4·0	6·0	4·9
Srinagar	5,204	7·7	7·6	6·1	5·1	3·5	2·9	4·5	4·8	3·2	2·1	2·4	5·5	4·6
Gangtok	5,667	3·1	3·2	2·2	2·7	4·0	6·1	6·7	5·9	5·5	3·4	2·4	2·0	3·9
Parachinar	6,000	4·0	4·1	4·5	3·5	2·4	3·3	5·3	4·3	3·4	1·1	1·9	3·4	3·4
Simla	7,232	4·8	4·5	4·2	3·3	2·5	4·1	8·0	8·2	4·2	0·8	1·5	3·6	4·1
Darjeeling	7,376	4·1	4·3	3·6	4·9	6·8	8·6	9·0	9·0	8·1	5·3	3·3	3·1	5·8
Skardu	7,505	6·7	6·4	6·6	5·6	4·5	3·3	4·1	4·1	3·5	2·8	3·5	6·0	4·8
Mukteswar	7,592	3·8	4·1	3·6	2·8	2·5	4·6	8·2	8·7	5·3	1·3	1·3	2·8	4·1
Dras	10,059	6·1	5·3	5·7	5·1	3·8	3·0	4·0	4·1	2·8	2·0	2·7	5·1	4·1
Leh	11,503	6·7	6·4	6·3	5·7	4·6	3·9	4·7	4·5	3·4	2·4	3·4	5·7	4·8
Gyantse	13,110	0·7	1·1	1·1	1·4	1·8	1·6	3·5	3·6	1·9	0·5	0·4	0·1	1·5

TABLE VII.—MONTHLY AND ANNUAL NORMALS OF RAINFALL

Stations.	Ht. above m.s.l. in ft.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Kalimpong .	3,933	0·45	1·50	1·13	2·59	4·45	15·55	22·97	19·17	10·93	2·55	0·29	0·24	81·82
Katmandu .	4,388	0·99	0·86	1·09	1·94	4·01	9·22	14·91	14·66	7·35	2·29	0·15	0·31	57·78
Drosh . .	4,500	0·91	1·13	3·42	4·15	1·95	0·64	0·57	0·70	0·63	1·22	0·36	1·07	16·75
Gilgit . .	4,890	0·21	0·21	0·49	1·05	0·94	0·40	0·59	0·45	0·37	0·25	0·04	0·11	5·11
Srinagar .	5,204	2·98	2·79	3·52	3·65	2·63	1·73	2·87	2·41	1·82	1·08	0·35	1·41	27·24
Gangtok .	5,667	1·00	2·54	5·12	11·43	19·45	20·62	24·90	22·69	19·30	5·34	1·83	0·89	135·11
Parachinar .	6,000	2·14	2·01	4·37	3·82	2·76	2·21	3·57	2·83	1·63	0·78	0·48	1·25	27·85
Mussoorie .	6,940	2·73	3·01	1·99	1·10	2·25	9·01	29·74	31·85	9·99	0·84	0·33	1·00	93·84
Simla . .	7,232	2·64	3·31	2·44	1·75	2·68	6·91	16·95	18·16	5·71	0·87	0·45	1·24	63·11
Darjeeling .	7,376	0·64	0·99	1·77	3·66	8·74	22·77	32·37	26·60	18·46	4·49	0·29	0·22	121·00
Skardu . .	7,505	0·78	0·63	0·87	1·11	1·27	0·34	0·57	0·41	1·08	0·06	0·04	0·32	7·48
Mukteswar .	7,592	2·38	2·54	1·55	1·40	2·09	5·88	13·50	12·67	6·15	1·70	0·21	0·83	50·90
Sonamarg .	8,250	11·50	9·48	16·75	10·26	5·82	3·11	4·06	3·38	4·67	1·76	1·18	5·87	77·84
Dras . .	10,059	2·73	2·39	3·82	4·01	3·09	0·71	0·81	0·48	1·31	0·42	0·30	1·71	21·78
Leh . .	11,503	0·37	0·34	0·30	0·22	0·21	0·17	0·47	0·52	0·28	0·17	0·04	0·17	3·26
Gyantse .	13,110	0·01	0·04	0·05	0·21	0·49	1·17	2·65	3·74	1·10	0·14	0·07	0	9·67

TABLE VIII.—MONTHLY AND ANNUAL NORMALS OF NUMBER OF RAINY DAYS

Stations.	Ht. above m.s.l. in ft.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Kalimpong .	3,933	1·3	3·0	3·1	6·5	8·8	15·9	23·3	21·1	12·8	3·4	0·5	0·5	100·2
Drosh . .	4,500	2·8	3·1	7·4	8·1	4·1	1·9	1·5	2·3	1·7	2·6	1·3	3·2	40·0
Gilgit . .	4,890	0·7	0·8	1·6	2·9	2·7	1·3	1·9	1·8	1·2	0·6	0·1	0·3	15·9
Srinagar .	5,204	6·3	6·3	7·9	7·4	5·7	4·1	5·7	5·4	3·8	2·5	1·1	3·5	59·7
Gangtok .	5,667	2·9	5·2	8·5	14·7	20·2	22·8	27·7	27·2	21·6	9·1	3·6	1·9	165·4
Parachinar .	6,000	4·4	4·3	9·2	8·7	7·8	4·8	7·1	6·8	4·1	2·0	1·3	3·3	63·8
Mussoorie .	6,940	4·3	4·5	4·2	2·3	4·3	10·0	22·1	22·4	10·4	1·2	0·6	1·9	88·2
Simla . .	7,232	4·9	5·8	4·6	3·7	4·8	9·5	19·4	19·8	8·3	1·3	0·9	2·1	85·1
Darjeeling .	7,376	1·5	2·4	3·6	7·1	13·9	20·6	25·0	24·4	17·0	4·3	0·8	0·7	121·3
Skardu . .	7,505	2·2	2·3	3·1	2·8	2·7	0·9	1·2	1·1	1·5	0·1	0·1	1·0	19·0
Mukteswar .	7,592	4·1	4·8	3·5	3·6	5·4	9·3	19·0	17·9	8·6	1·4	0·2	1·8	79·6
Sonamarg .	8,250	12·2	9·9	15·7	13·0	9·8	8·8	9·9	9·2	8·0	4·6	1·8	6·8	109·7
Dras . .	10,059	8·2	7·1	11·1	9·1	5·9	2·4	1·6	1·1	2·1	1·4	1·0	6·1	57·1
Leh . .	11,503	1·1	0·9	1·1	0·7	0·7	0·6	1·2	1·7	0·7	0·1	0·2	0·6	9·6
Gyantse .	13,110	0·1	0·1	0·2	0·9	1·9	3·9	7·8	9·5	3·6	0·6	0·3	0	28·9

TABLE IX.—PILOT-BALLOON DATA

Direction given in degrees from north through east. Velocity given in metres per second

Stations.	Date.	Time hrs. I.S.T.	Height above sea-level. 6 km. D.	6 km. V.	7 km. D.	7 km. V.	8 km. D.	8 km. V.	9 km. D.	9 km. V.	10 km. D.	10 km. V.
						JANUARY						
Simla . .	2.1.28	9	270	8	—	—	270	13	260	18	—	—
Agra . .	11.1.28	7	300	18	—	—	290	27	280	42	—	—
	12.1.28	7	250	19	—	—	250	30	—	—	250	47
	9.1.29	8	250	17	—	—	250	19	—	—	240	20
	22.1.30	16	240	13	—	—	250	11	270	13	—	—
Patna . .	18.1.29	12	260	21	260	30	—	—	—	—	—	—
	31.1.30	15	260	27	250	36	—	—	—	—	—	—
Tezpur .	26.1.29	8	270	25	290	28	—	—	—	—	—	—
	10.1.30	7	280	23	300	29	—	—	—	—	—	—
						FEBRUARY						
Agra . .	11.2.28	10	270	30	—	—	290	34	290	43	—	—
	26.2.29	17	270	19	—	—	280	18	240	23	—	—
	19.2.30	17	260	20	—	—	260	32	270	30	—	—
Patna . .	17.2.29	7	280	36	—	—	280	47	—	—	—	—
	12.2.30	6	300	21	—	—	290	29	290	40	—	—
Tezpur .	22.2.29	8	300	13	—	—	280	18	290	15	—	—
	13.2.30	7	330	7	—	—	300	19	—	—	—	—
						MARCH						
Agra . .	17.3.28	7	270	21	—	—	280	42	290	36	—	—
	19.3.29	8	270	4	—	—	270	11	230	13	—	—
	28.3.30	7	280	9	—	—	270	10	260	15	—	—
Patna . .	5.3.29	7	320	12	—	—	330	26	330	31	—	—
	12.3.30	6	310	20	—	—	280	31	280	32	—	—
Tezpur .	13.3.29	14	280	11	—	—	280	16	290	21	—	—
	13.3.30	7	290	19	280	22	—	—	—	—	—	—
Purnea .	16.3.33	5	250	16	250	15	240	14	240	23	—	—
	16.3.33	15	250	13	250	16	240	15	260	17	—	—
	18.3.33	6	320	7	210	1	70	1	300	1	—	—
	19.3.33	5	290	13	290	14	290	19	270	14	—	—
	29.3.33	5	280	17	280	20	260	20	280	26	—	—
	29.3.33	15	280	13	270	17	270	27	270	35	—	—
	30.3.33	5	280	19	270	23	260	28	260	36	—	—
	30.3.33	15	270	17	270	22	270	25	270	37	—	—
Darjeeling .	17.3.33	6	300	6	300	5	250	6	300	6	—	—
	27.3.33	6	280	35	290	40	290	46	—	—	—	—
	27.3.33	16	280	21	280	27	270	31	280	37	—	—
	30.3.33	6	280	21	280	25	280	30	—	—	—	—
	31.3.33	16	280	20	280	30	270	35	270	44	—	—

TABLE IX.—PILOT-BALLOON DATA—(*continued*)

Direction given in degrees from north through east. Velocity given in metres per second.

Stations.	Date.	Time hrs. I.S.T.	Height above sea-level. 6 km. D.	6 km. V.	7 km. D.	7 km. V.	8 km. D.	8 km. V.	9 km. D.	9 km. V.	10 km. D.	10 km. V.
						April						
Simla . .	22.4.28	7	260	5	—	—	270	10	—	—	270	15
Agra . .	23.4.28	6	280	14	—	—	270	34	—	—	260	73
	17.4.29	18	270	15	—	—	270	14	290	16	—	—
Purnea .	3.4.33	6	270	11	280	13	290	19	290	23	—	—
	3.4.33	15	300	18	290	17	290	17	290	10	—	—
	4.4.33	5	290	19	290	19	300	18	290	17	—	—
	12.4.33	15	280	21	290	21	300	31	310	33	—	—
	25.4.33	15	290	23	280	27	270	34	270	51	—	—
	28.4.33	15	280	18	290	27	270	30	280	29	—	—
	30.4.33	5	270	18	270	24	270	30	270	40	—	—
Darjeeling .	1.4.33	6	290	4	290	6	290	10	270	19	—	—
	1.4.33	16	290	12	310	15	310	17	300	23	—	—
	3.4.33	6	290	10	270	10	290	19	300	26	—	—
	3.4.33	16	290	13	300	17	290	20	310	16	—	—
	26.4.33	6	280	18	290	22	280	35	290	35	—	—
Tezpur .	3.4.30	7	240	16	240	21	—	—	—	—	—	—
	7.4.30	14	330	7	310	15	—	—	—	—	—	—
						May						
Simla . .	3.5.28	7	260	5	—	—	310	5	—	—	—	—
	4.5.28	7	240	6	—	—	250	9	—	—	—	—
	13.5.28	7	270	10	270	13	—	—	—	—	—	—
Agra . .	3.5.28	6	300	8	—	—	300	9	—	—	290	13
	11.5.28	6	320	11	—	—	300	20	—	—	310	28
	7.5.29	18	260	20	—	—	270	28	—	—	260	40
	28.5.29	6	250	2	—	—	40	5	—	—	70	6
	7.5.30	6	320	5	—	—	320	13	310	14	—	—
	9.5.30	6	350	7	—	—	330	14	310	15	—	—
Purnea .	1.5.33	5	260	13	270	14	270	20	260	35	—	—
	1.5.33	15	280	13	270	16	250	7	240	15	—	—
	2.5.33	5	240	14	260	15	250	22	250	23	—	—
	2.5.33	15	230	12	230	15	240	17	240	23	—	—
	13.5.33	5	230	8	310	10	300	12	310	15	—	—
	15.5.33	15	280	20	290	24	290	29	290	36	—	—
	16.5.33	15	270	17	260	19	270	23	260	30	—	—
	28.5.33	5	290	5	300	4	290	8	270	12	—	—
Darjeeling .	2.5.33	16	230	9	250	16	250	20	260	19	—	—
	3.5.33	6	220	16	230	19	230	22	240	26	—	—
	10.5.33	16	290	13	280	14	270	16	—	—	—	—
	11.5.33	5	280	8	270	12	260	14	270	13	—	—
	19.5.33	5	260	17	280	21	270	23	270	31	—	—
	21.5.33	5	270	16	280	19	290	25	290	39	—	—
Tezpur .	29.5.29	13	230	3	280	9	—	—	—	—	—	—
	13.5.30	6	290	10	—	—	310	12	—	—	280	16
	14.5.30	6	250	11	—	—	240	13	240	16	—	—

TABLE IX.—PILOT-BALLOON DATA—(*continued*)

Direction given in degrees from north through east. Velocity given in metres per second

Stations.	Date.	Time hrs. I.S.T.	Height above sea-level. 6 km. D.	V.	7 km. D.	V.	8 km. D.	V.	9 km. D.	V.	10 km. D.	V.
			JUNE									
Agra . .	5.6.29	6	360	15	—	—	280	8	—	—	320	15
	22.6.29	7	80	10	—	—	120	5	170	2	—	—
	17.6.30	17	330	9	—	—	310	15	—	—	330	20
	18.6.30	6	10	8	—	—	310	14	—	—	320	13
	30.6.30	6	150	4	—	—	100	8	—	—	80	8
Purnea. .	1.6.33	5	310	6	290	13	290	14	290	13	—	—
	10.6.33	5	130	9	120	9	130	6	160	9	—	—
Darjeeling .	14.6.33	6	230	7	210	6	—	—	—	—	—	—
	23.6.33	6	140	4	200	2	310	3	310	6	—	—
Tezpur .	15.6.29	14	210	8	—	—	200	9	—	—	—	—
	24.6.29	14	270	8	270	6	—	—	—	—	—	—
	27.6.30	14	350	5	270	5	—	—	—	—	—	—
			JULY									
Agra . .	12·7·29	18	110	15	—	—	100	17	—	—	—	—
	16·7·29	18	310	4	—	—	10	4	—	—	—	—
	4·7·30	6	150	2	—	—	180	6	—	—	—	—
	25·7·30	6	80	6	70	6	—	—	—	—	—	—
Patna . .	16·7·29	14	70	7	—	—	90	9	—	—	—	—
	23·7·29	6	100	8	—	—	90	9	—	—	—	—
	29·7·29	6	60	8	—	—	80	12	—	—	80	9
	15·7·30	6	130	6	—	—	100	7	—	—	80	10
Tezpur .	21·7·29	14	320	3	—	—	210	1	—	—	60	4
	9·7·30	15	50	7	—	—	90	9	80	7	—	—
	15·7·30	7	40	1	—	—	120	3	—	—	10	3
			AUGUST									
Agra . .	22.8.29	6	110	7	—	—	100	11	—	—	—	—
	28.8.29	18	80	5	—	—	80	5	—	—	—	—
	20.8.30	6	50	2	—	—	120	3	330	1	—	—
Patna . .	17.8.29	7	100	2	—	—	110	6	50	3	—	—
	30.8.29	6	130	2	—	—	110	4	—	—	100	7
	24.8.30	15	310	3	—	—	100	1	—	—	100	8
Tezpur .	10.8.29	14	10	3	—	—	40	1	—	—	60	12
	5.8.30	7	130	6	—	—	130	8	—	—	—	—
	9.8.30	14	350	5	—	—	250	5	—	—	230	4
			SEPTEMBER									
Agra . .	4·9·30	6	270	6	—	—	260	11	260	12	—	—
	19·9·30	6	230	5	—	—	210	8	—	—	240	12
	20·9·30	6	250	12	—	—	250	12	260	11	—	—
	27·9·30	6	360	3	—	—	260	8	240	7	—	—
Patna . .	8·9·30	7	90	8	—	—	90	7	90	6	—	—
	10·9·30	15	150	3	—	—	100	4	130	11	—	—
	25·9·30	7	220	5	—	—	200	3	—	—	170	6
Tezpur .	6·9·30	7	120	3	—	—	130	3	—	—	—	—
	20·9·30	15	240	2	—	—	200	3	250	5	—	—
	28·9·30	7	270	5	—	—	210	4	—	—	—	—

TABLE IX.—PILOT-BALLOON DATA—(*continued*)

Direction given in degrees from north through east. Velocity given in metres per second.

Stations.	Date.	Time hrs. I.S.T.	Height above sea-level. 6 km. D.	6 km. V.	7 km. D.	7 km. V.	8 km. D.	8 km. V.	9 km. D.	9 km. V.	10 km. D.	10 km. V.
						OCTOBER						
Agra . .	6.10.30	16	310	9	—	—	300	13	290	15	—	—
	12.10.30	15	290	20	—	—	270	22	—	—	—	—
	24.10.30	15	270	14	—	—	280	15	280	29	—	—
Patna . .	1.10.30	7	220	1	—	—	150	3	200	6	—	—
	3.10.30	6	270	7	—	—	240	13	—	—	240	14
	19.10.30	7	270	12	—	—	270	22	270	27	—	—
Tezpur .	9.10.30	16	10	3	—	—	290	10	—	—	—	—
	13.10.30	7	290	8	280	15	—	—	—	—	—	—
						NOVEMBER						
Agra . .	6.11.28	7	290	10	—	—	290	16	310	15	—	—
	11.11.28	7	280	15	—	—	290	25	—	—	280	35
	13.11.28	6	260	12	—	—	270	36	—	—	270	48
	17.11.28	16	250	12	—	—	250	27	—	—	230	51
Patna . .	6.11.28	6	310	8	—	—	330	15	340	20	—	—
	9.11.28	6	270	12	—	—	270	16	—	—	300	23
	18.11.28	6	270	12	—	—	260	29	270	40	—	—
	24.11.28	6	310	17	—	—	280	39	280	41	—	—
Tezpur .	22.11.28	6	290	17	—	—	290	38	—	—	290	63
	24.11.28	6	240	15	—	—	240	33	240	42	—	—
						DECEMBER						
Agra . .	4.12.29	7	290	17	—	—	290	24	290	29	—	—
	18.12.29	8	290	34	—	—	290	54	—	—	—	—
	22.12.29	16	270	17	—	—	260	31	250	29	—	—
Patna . .	10.12.29	7	280	14	—	—	280	19	260	22	—	—
	23.12.29	7	260	23	260	27	—	—	—	—	—	—
Tezpur .	11.12.29	14	240	15	—	—	240	14	250	17	—	—
	23.12.29	7	260	26	—	—	250	37	—	—	—	—
	31.12.29	7	250	38	250	48	—	—	—	—	—	—

TABLE X.—AGRA MEAN MONTHLY DENSITIES IN GRAMMES PER CUBIC METRE

Ht. in km.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual mean.	Range.
14·0	236	236	240	238	244	250	251	251	252	251	242	236	244	16
13·0	273	271	275	276	280	285	286	286	285	282	278	276	279	15
12·0	312	307	313	318	319	322	319	320	321	321	317	318	317	15
11·0	357	350	357	359	360	359	355	357	359	359	356	364	358	14
10·0	406	395	403	407	404	401	398	399	402	403	402	411	403	16
9·0	458	457	457	459	458	458	443	446	449	455	452	463	455	20
8·0	513	517	514	514	510	500	496	497	499	509	510	517	508	21
7·0	574	572	574	575	570	559	552	554	559	567	571	577	567	25
6·0	643	640	641	640	636	625	614	619	623	632	638	644	633	30
5·0	717	714	713	712	706	696	685	688	698	704	711	716	705	32
4·0	795	794	789	790	780	770	758	765	773	782	795	790	782	37
3·0	884	891	874	868	856	849	843	848	858	870	882	879	867	48
2·0	984	979	963	953	932	925	933	938	943	958	979	975	955	59
1·0	1,090	1,079	1,055	1,047	1,017	1,009	1,034	1,030	1,035	1,046	1,083	1,085	1,051	81
0·5	1,145	1,132	1,104	1,090	1,064	1,058	1,085	1,078	1,088	1,094	1,136	1,140	1,101	87
Surface (0·17)	1,190	1,173	1,138	1,130	1,100	1,090	1,120	1,115	1,130	1,140	1,175	1,175	1,140	100

TABLE XI.—AVERAGE NUMBER OF STORMS AND DEPRESSIONS IN THE BAY OF BENGAL, 1891–1930

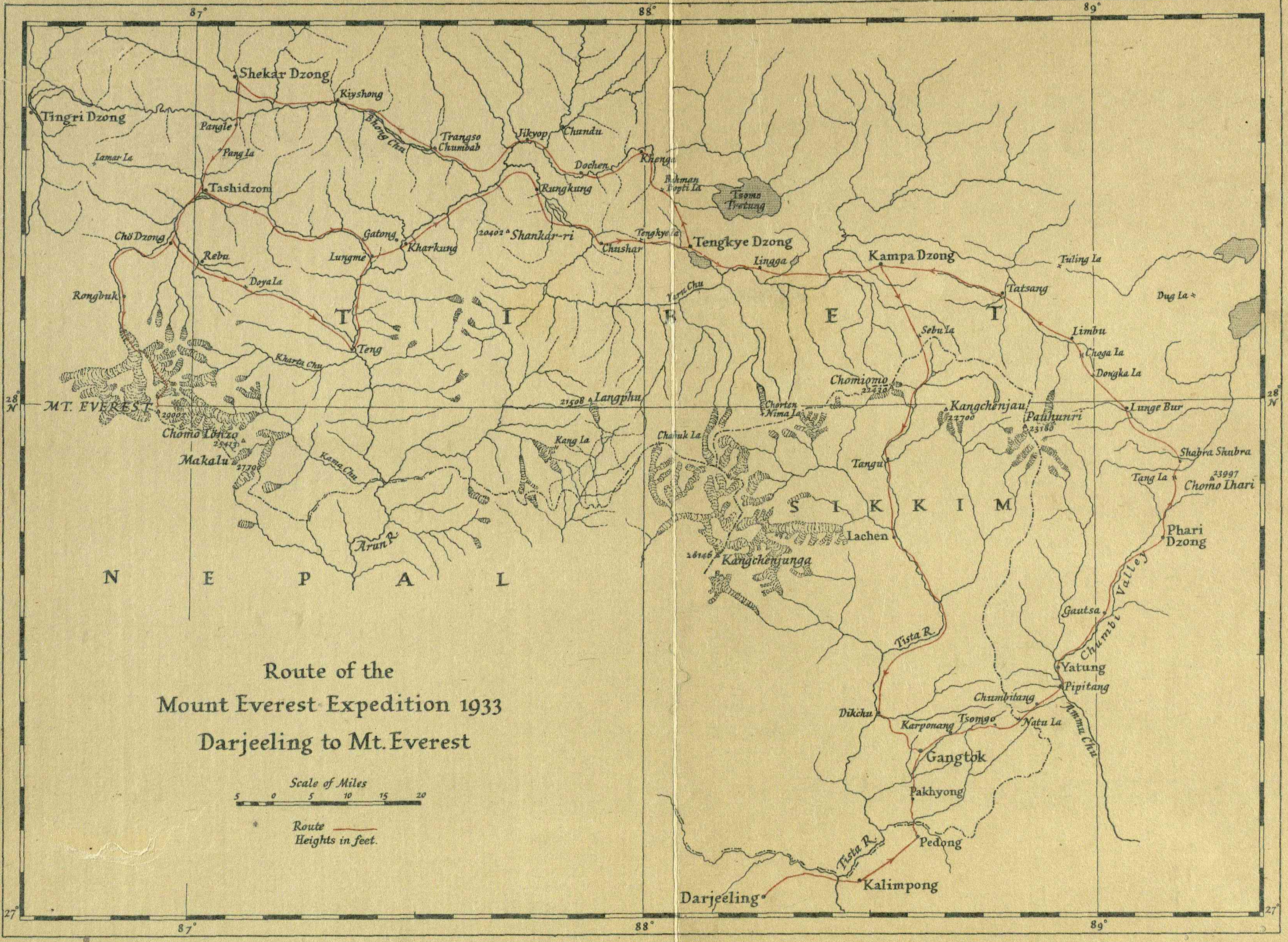
Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
0·3	0·0	0·3	0·3	0·9	1·3	1·8	1·8	2·2	1·8	1·7	0·8

TABLE XII.—AVERAGE DEPTH OF THE BAY OF BENGAL CURRENT OVER BENGAL

Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
km. 0·0	km. 0·5	km. 1·0	km. 1·4	km. 1·9	km. 2·3	km. 3·1	km. 3·9	km. 2·7	km. 2·0	km. 0·0	km. 0·0

TABLE XIII.—COMPARATIVE STATEMENT OF WESTERN DEPRESSIONS AND BAY DISTURBANCES IN 1924 AND 1933

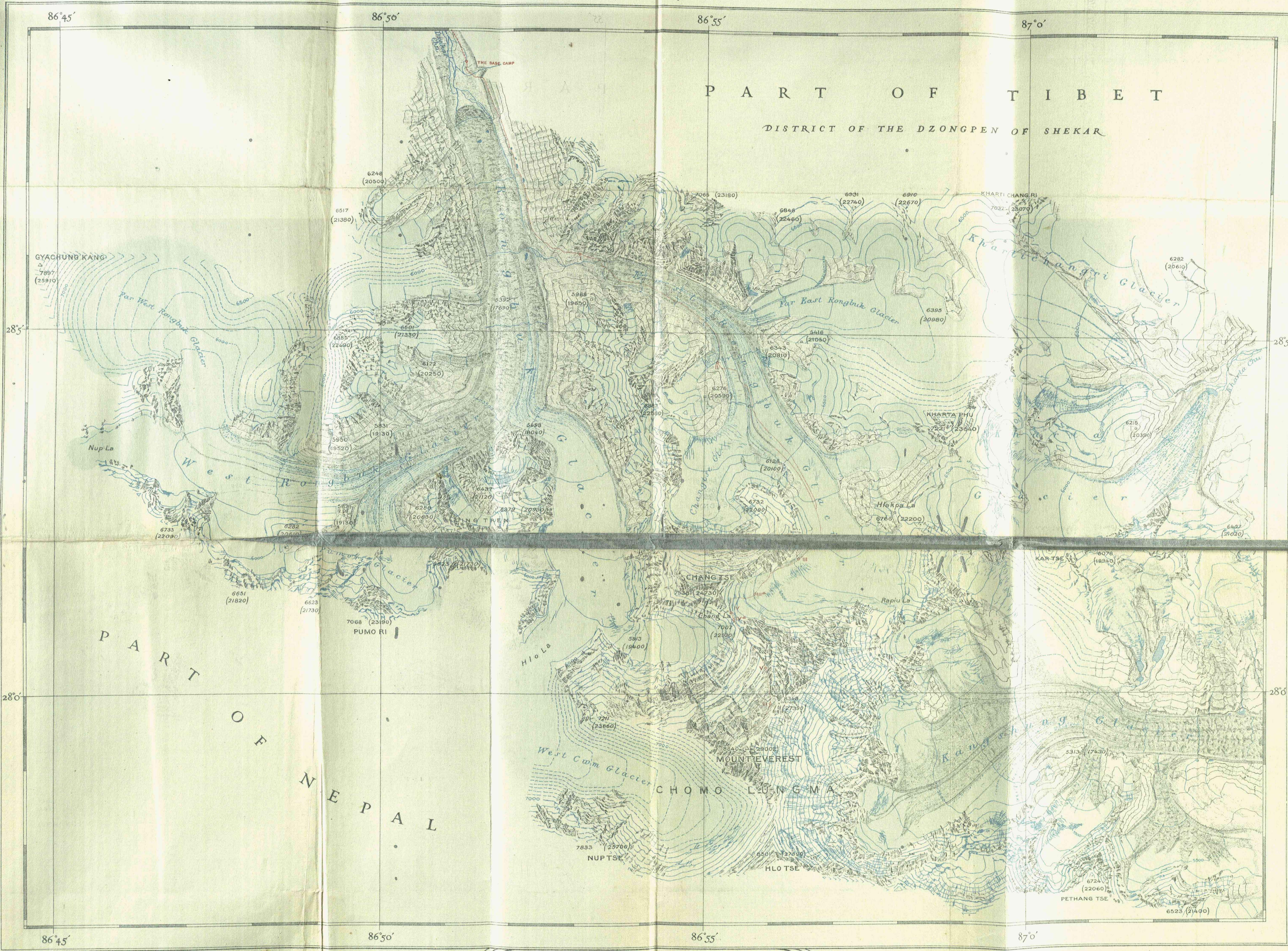
—	March.		April.		May.		June.	
	1924.	1933.	1924.	1933.	1924.	1933.	1924.	1933.
Western depression . . .	5	8	5	9	6	5	3	1
Disturbance of Bay of Bengal origin	0	0	1	0	1	1	1	3



Route of the
Mount Everest Expedition 1933
Darjeeling to Mt. Everest

INDEX

MOUNT EVEREST AND THE GROUP OF CHOMO LUNGMA



SCALE OF MILES

One Inch to One Mile, or 1:63,360

Contours are figured in Metres at 100-metre interval

Contours on Glaciers in blue

Glaciers are tinted pale blue.

Drawn by Charles Jacot-Guillarmod from the photographic surveys of Major Wheeler, R.E., Survey of India, on the Mount Everest Expedition of 1921, with additions by Surveyor Hari Singh on the Expedition of 1924, and from the photographs of the three expeditions. ¶ Reproduced for the Mount Everest Committee of the Royal Geographical Society and Alpine Club by the Ordnance Survey, 1925.

SCALE OF KILOMETRES

Heights are given in Metres and Feet 7032 (23070)

Points triangulated by Survey of India, thus

Camera Stations, thus — Intersected points, thus

Route and Camps in Red

Reprinted 1934 with Camps IIIa IVa, V and VI of 1933 added, and route towards summit