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On the Snow-line in the Himálaya ; by Lieut. R. STRACHEY, Engineers. Communicated by order of the HON'BLE THE LIEUT.-GOVERNOR, North Western Provinces.

The height at which perpetual snow is found at different parts of the earth's surface, has become an object of enquiry, not only as a mere physical fact, but as a phenomenon intimately connected with the distribution of heat on the globe. In M. Humboldt's efforts to throw the light of his knowledge on this question, he has, when treating of the Himálaya, been unfortunately led much astray by the very authorities on whom he placed most reliance ; and his conclusions, though in part correct, cannot lay claim to any pretension to exactness. That he was indeed himself conscious of the deficiencies in the evidence before him, is manifest from his ending his *disquisitoin* by a declaration, that it was necessary, "de rectifier de nouveau et par des mesures bien précises dont tout le détail hypsométrique soit publié, ce qui reste de douteux sur la hauteur comparative des deux pentes de l' Himálaya, sur l' influence de réverbération du plateau tibétain, et sur celle que l'on suppose au courant ascendant de l'air chaud des plaines de l'Inde. C'est un travail à recommencer" (*Asie Centrale*, T. 3, p. 325). Men of science will still long have to regret that this illustrious traveller was prevented from visiting the east ; Englishmen alone need remember that he was prevented by them.

The result of M. Humboldt's investigations on the position of the snow line in this part of the Himálaya is thus given by himself :—"The

limit of perpetual snow on the southern declivity of the Himalaya chain is 2030 toises (13,000* feet English) above the level of the sea ; on the northern declivity, or rather on the peaks which rise above the Tartarian plateau, this limit is 2600 toises (16,600 ft.), from $30\frac{1}{2}$ to 32° of Latitude, while under the equator in the Andes of Quito it is 2470 toises (15,800 ft.). I have deduced this result from the collection and combination of many data furnished by Webb, Gerard, Herbert, and Moorcroft. The greater elevation to which the snow line recedes on the Thibetian declivity is the result conjointly of the radiation of heat from the neighbouring elevated plains, the serenity of the sky, and the infrequent formation of snow in very cold and dry air" (*Cosmos. Trans.* T. 1. p. 363. *Note* 5).

The portion of the *Himálaya* to which allusion has most generally been made, in treating of the snow line, is that which lies between the north-western frontier of Nipál and the river Sutlej, and it is solely to this part of the chain that my remarks are intended to apply. It extends from about the 77th to the 81st degree of east longitude, and its entire breadth, from the plains of India on the south, to the plains of Tibet on the north, is about 120 miles. The mountains on which perpetual snow is found, are confined within a belt of about 35 miles in width, running along the northern boundary of the chain, and they all lie between the 30th and 32nd degree of north latitude.

If we now examine the structure of the mountains more closely (vide sheets 47, 48, 65, and 66 of the Indian Atlas), we shall find that from the sources of the Touse, (Long. $78^{\circ} 30'$), to those of the Káli (Long. $81^{\circ} 0'$), a space which includes the provinces of Garhwál and Kumaon, all the great rivers, viz. the Bhágirati, Vishnú-ganga, Dauli (of Niti), Gori, Dauli (of Darma) and Káli, run in directions not far from perpendicular to the general direction of the *Himálaya*. Further, that they are separated one from another by great transverse ranges, on which all the highest of the measured peaks of this region are to be found. It will also be seen that the sources of these rivers† are in the main watershed of the chain, beyond which a declivity of a few miles leads directly

* The reduction of toises into English feet is every where given to the nearest hundred only.

† I mean the most distant sources of the tributaries, for several of the rivers that I have mentioned, *nominally* end in glaciers to the south of the water-shed.

to the plains of Tibet. A line drawn through the great peaks will be almost parallel to the water-shed, but about 30 miles to the south of it.

To the west of the Touse the arrangement of the drainage is very different. From the source of this river an unbroken ridge extends to the Sutlej, almost on the prolongation of the line of the great eastern peaks, but more nearly east and west. On this range, which separates Kunáwar from the more southern parts of Bissehir, and which, as it has hitherto received no distinctive name, I shall call the Bissehir range, are the Rúpin, Gunás, Burendo and Shátúl passes; and no perpetual snow is to be found further south among these western mountains. To the north of this range and almost parallel to it, run several others of somewhat greater altitude, between which the streams of eastern Kunáwar flow into the Sutlej, from S. E. to N. W., nearly parallel to the upper, and perpendicular to the lower part of the course of that river.

If we now follow two travellers into Tibet, one from Kumaon or Garhwál, and the other from Simla or the western hills, we shall be prepared to find that the circumstances under which they will cross the snowy mountains will be very different. The former will proceed up the course of one of the great rivers before alluded to, and ascending the gorge, by which it breaks through the line of the great peaks, will pass unobserved the true southern limit of the perpetual snow; he will leave the great peaks themselves far behind him, and will finally reach the water-shed of the chain, where he may possibly for the first time find glaciers and snow. He will here cross straight into Tibet, from what will appear to him the *southern*, to what he will call the *northern declivity* of the Himálaya.*

The western traveller, on the other hand, will find almost at his first step a snowy barrier drawn across his path, and he will naturally suppose that he crosses from the southern to the northern face of the snowy range, when he descends from the Shátúl or some neighbouring pass into the valley of Kunáwar; and in this idea he will probably be confirmed, by the total change of climate which he will perceive, and by his being able to penetrate to Shipke, the frontier village of Tibet in this quarter,

* This does not exactly apply to the passes usually crossed between Juhár and Tibet, which will be mentioned more particularly hereafter. There is a pass however, the 'Lashar,' though from its badness it is not used, which affords a direct communication.

without meeting any further obstacle on his road at all comparable to that he has passed, or perhaps even without again crossing snow.*

Without waiting to enquire whether either of our travellers has in fact come to a just conclusion, it will be sufficient for my purpose to point out that they mean totally different things by their north and south declivities; and it will be indeed surprising if they agree as to the position of the snow line. It is manifest therefore that before we can expect to arrive at any correct results, we must get rid of the confusion caused by the ambiguity of the terms *north* and *south declivity*; terms which at the best are very ill adapted to convey definite ideas of position in so vast and complicated a mass of mountains. In spite of every care, they will constantly be liable to misconception, as must always be the case where a restricted signification is arbitrarily applied, in a discussion of this sort, to expressions which of themselves have an extended general meaning.†

As a substitute for the *declivities* then, the best standard that occurs to me, to which to refer when alluding to the elevation of the snow-line at any place, is the general mass of perpetual snow found on the more elevated parts of the Himálaya, *the belt of perpetual snow*, which as I before stated, is about 35 miles in breadth, and runs along the northern boundary of the chain. Instead of the height of the snow-line *on the northern or southern declivity*, I shall therefore say, the height *at the northern or southern limit of the belt of perpetual snow*, where *the limits of the belt of perpetual snow*, are to be understood as having exactly the same relation to the snowy surface in a *horizontal plane*, that *the snow-line* has in a *vertical*.

It remains for me to define clearly what is meant by *the snow-line*, and I cannot do better than adopt the words of M. Humboldt, who says, "the lower limit of perpetual snow in a given latitude is the boundary line of the snow which resists the effect of summer; it is the highest elevation to which the snow-line recedes in the course of the whole year. We must distinguish between the limit thus defined, and three other phenomena; viz. the annual fluctuation of the snow-line; the phenomenon of sporadic falls of snow, and the existence of glaciers" (*Cosmos. Trans. T. 1. p. 327*).

* The ordinary route lies up the bank of the Sutlej.

† As a specimen, vide Capt. Hutton's papers noticed hereafter.

Having disposed of these preliminaries, which are essential to the proper apprehension of the subject, I shall proceed to examine the data from which the elevation of the snow-line is to be determined. In doing this it will I think be more convenient for me, both for the northern and southern limits, to explain first my own views, and afterwards to follow M. Humboldt's authorities, and point out the errors into which they have fallen.

1. *Southern limit of the belt of perpetual snow.*—In this part of the Himalaya it is not, on an average of years, till the beginning of December, that the snow-line appears decidedly to descend for the winter. After the end of September indeed, when the rains are quite over, light falls of snow are not of very uncommon occurrence on the higher mountains even down to 12,000 feet; but their effects usually disappear very quickly, often in a few hours. The latter part of October, the whole of November, and the beginning of December, are here generally characterised by the beautiful serenity of the sky; and it is at this season, on the southern edge of the belt, that the line of perpetual snow is seen to attain its greatest elevation.

The following are the results of trigonometrical measurements of the elevation of the inferior edge of snow on spurs of the Tresúl and Nanda-devi groups of peaks, made before the winter snow had begun in November, 1848.*

Point observed.	Height as observed on face exposed to the East.			Height on face exposed to West observed from Almorah.
	From Almorah, (height 5586 ft.)	From Binsar, (height 7969 ft.)	Mean.	
No. 1.	16,599 feet.	16,767 feet.	16,683 feet.	15,872 feet.
2.	16,969	17,005	16,987	
3.	17,186	17,185	17,185	14,878
4.	15,293	15,361	15,327	

* These measurements make no pretension to accuracy, but are sufficiently good approximations for the purpose for which they are intended. The heights are given as calculated from observations made both at Almora and Binsar, to show in some degree what confidence may be attached to them. The heights of Almora and Binsar are, on the authority of Capt. Webb's survey; the distance of these places, which is used as the base from which to calculate the several distances of the points observed, was got from a map of trigonometrically determined stations obtained from the Surveyor General's office.

The points 1, 2, and 3, are on ridges that run from the peaks Nos. 11 and 12, in a S. Westerly direction. The dip of the strata being to the N. East, the faces exposed to view from the south are for the most part very abrupt, and snow never accumulates on them to any great extent. This in some measure will account for the height to which the snow is seen to have receded on the eastern exposures, that is upwards of 17,000 feet. On the western exposures the ground is less steep, and the snow is seen to have been observed at a considerably less elevation; but it was in very small quantities, and had probably fallen lately, so that I am inclined to think that its height, viz. about 15,000 feet, rather indicates the elevation below which the light autumnal falls of snow were incapable of lying, than that of the inferior edge of the perpetual snow. It is further to be understood, that below this level of 15,000 feet, the mountains were *absolutely without snow*, excepting those small isolated patches that are seen in ravines, or at the head of glaciers, which of course do not affect such calculations as these. On the whole therefore I consider that the height of the snow-line on the more prominent points of the southern edge of the belt, may be fairly reckoned at 16,000 feet *at the very least*.

The point No. 4 was selected as being in a much more retired position than the others. It is situated not far from the head of the Pindur river, and lies between the peaks Nos. 14 and 15. It was quite free from snow at 15,300 feet, and I shall therefore consider 15,000 feet as the elevation of the snow-line in the re-entering angles of the chain.

I conclude then, that 15,500 feet, the mean of the heights at the most and least prominent points, should be assigned as the mean elevation of the snow-line at the southern limit of the belt of perpetual snow in Kumaon, and I conceive that whatever error there may be in this estimate, will be found to lie on the side of diminution rather than of exaggeration.

This result appears to accord well with what has been observed on the Bissehir range. The account given by Dr. Gerard of his visit to the Shátúl pass on this range, which he undertook expressly for the purpose of determining the height of the snow-line, contains the only definite information as to the limit of perpetual snow at the southern edge of the belt, that is to be found in the whole of the published writings of the Gerards; and the following is a short abstract of his obser-

vations. Dr. Gerard reached the summit of the Shátál pass, the elevation of which is 15,500 feet, on the 9th August 1822, and remained there till the 15th of the same month. He found the southern slope of the range generally free from snow, and he states that it is sometimes left without any whatever. On the top of the pass itself there was no snow; but on the northern slope of the mountain it lay as far down as about 14,000 feet. On his arrival rain was falling, and out of the four days of his stay on the pass, it either rained or snowed for the greater part of three. The fresh snow that fell during this time did not lie below 16,000 feet, and some of the more precipitous rocks remained clear even up to 17,000 feet.*

The conclusion to which Dr. Gerard comes from these facts is, that the snow-line on the southern face of the Bissehir range is at 15,000 feet above the sea. But I should myself be more inclined from his account to consider that 15,500 feet was nearer the truth; and in this view I am confirmed by verbal accounts of the state of the passes on this range, which I have obtained from persons of my acquaintance, who have crossed them somewhat later in the year. The difference however is after all trifling.

Such is the direct evidence that can be offered on the height of the snow line at the southern limit of the belt of perpetual snow, some additional light may however be thrown on the subject generally, by my shortly explaining the state in which I have found the higher parts of the mountains, at the different seasons during which I have visited them.

In the beginning of May, on the mountains to the east of the Rám-ganga river, near Námik, I found the ground on the summit of the

* *Tours in the Himalaya*, T. 1. pp. 289-347. M. Humboldt apparently interprets Dr. Gerard a little too literally, when, with reference to Dr. G.'s statement, that "Hans Bussun," a peak said to be 17,500 feet high, "had lost all its snow" and looked "quite black and dreary," he asks, "Quelle peut être la cause d'un phénomène local si extraordinaire?" (*Asie Centrale*, T. 3. p. 318, note.) The extreme summit of the peak of Nandádevi, which appears to be a perfect precipice for several thousand feet, is often in much the same predicament of 'black and dreary,' and many people are disappointed with its appearance for this reason, contrasting it with the beautiful pyramidal peak of No. 19 of Páñch-chúli, which is always entirely covered with the purest snow.

ridge called Champwá, not only perfectly free from snow at an elevation of 12,000 feet, but covered with flowers, in some places golden with *Caltha* and *Ranunculus polypetalus*, in others purple with *Primulus*. The snow had in fact already receded to upwards of 12,500 feet, beyond which even a few little *Gentians* proclaimed the advent of spring.

Towards the end of the same month, at the head of the Pindur, near the glacier from which that river rises, an open spot on which I could pitch my tent could not be found above 12,000 feet. But here the accumulation of snow, which was considerable in all ravines even below 11,000 feet, is manifestly the result of avalanches and drift. The surface of the glacier, clear ice as well as moraines, was quite free from snow up to nearly 13,000 feet; but the effect of the more retired position of the place in retarding the melting of the snow, was manifest from the less advanced state of the vegetation. During my stay at Pinduri the weather was very bad, and several inches of snow fell; but excepting where it had fallen on the old snow, it all melted off again in a few hours, even without the assistance of the sun's direct rays. On the glacier at 13,000 feet it had all disappeared 12 hours after it fell.

On revisiting Pinduri about the middle of October, the change that had taken place was very striking. Now not a sign of snow was to be seen on any part of the road up to the very head of the glacier. A luxuriant vegetation had sprung up, but had already almost entirely perished, and its remains covered the ground as far as I went. From this elevation, about 13,000 feet, evident signs of vegetation could be seen to extend far up the less precipitous mountains. The place is not one at which the height of the perpetual snow can be easily estimated, for on all sides are glaciers, and the vast accumulations of snow from which they are supplied, and these cannot always be readily distinguished from snow in situ; but as far as I could judge, those places which might be considered as offering a fair criterion were free from snow up to 15,000 or even 16,000 feet.

Towards the end of August I crossed the Barjikáng pass, between Rálam and Juhár, the elevation of which is about 15,300 feet.* There was here no vestige of snow on the ascent to the pass from the south-

* This pass is so far within the belt of perpetual snow that it cannot be held to afford any just arguments as to the position of the snow line on the extreme southern edge of the belt.

east, and only a very small patch remained on the north-western face. The view of the continuation of the ridge in a southerly direction was cut off by a prominent point, but no snow lay on that side within 500 feet of the pass; while to the north I estimated that there was no snow in considerable quantity within 1500 feet or more, that is nearly up to 17,000 feet. The vegetation on the very summit of the pass was far from scanty, though it had already begun to break up into tufts, and had lost that character of continuity which it had maintained to within a height of 500 or 600 feet. Species of *Potentilla*, *Sedum*, *Saxifraga*, *Corydalis*, *Aconitum*, *Delphinium*, *Thalictrum*, *Ranunculus*, *Saussurea*, *Gentiana*, *Pedicularis*, *Primula*, *Rheum* and *Polygonum*, all evidently flourishing in a congenial climate, showed that the limits of vegetation and region of perpetual snow were still far distant.

In addition to these facts it may not be out of place to mention, that there are two mountains visible from Almora, Rigoli-gúdri in Garhwál, between the Kailganga and Nandákni, and Chipulá in Kumaon, between the Gori and Dauli (of Dárma), both upwards of 13,000 feet in elevation, from the summits of which the snow disappears long before the end of the summer months, and which do not usually again become covered for the winter till late in December.

The authorities cited by M. Humboldt in his *Asie Centrale*, give the following heights to the snow-line on the southern slope of the Himálaya.*

	Toises.	English feet.
Webb,	1954,	or 12,500
Colebrooke,	2032	— 13,000
Hodgson,	2110	— 13,500
A. Gerard,	2080	— 13,300
Jacquemont,	1800	— 11,500

Webb, Colebrooke, Hodgson. Immediately before the list of heights just given, M. Humboldt quotes the following part of a letter from Mr. Colebrooke: "There is a paper of mine in the Journal of the Royal Institution for 1819 (Vol. 17, No. 13) on the limit of snow. I deduced from the materials which I had that the limit of constant

* *Asie Centrale*, T. 3. p. 295. I take no account of the height assigned by M. M. Hügel and Vigue, as they do not refer to the region to which I confine myself.

congelation was 13,000 feet in the parallel of 31° . according to Capt. Hodgson's information, and 13,500 feet at Lat. 30° . according to Capt. Webb's."* I am unable to refer to the paper here alluded to, but a number of the Quarterly Journal of Science (T. 6, No. 11, pp. 51—57), has come into my hands, in which is a paper entitled "height of the Himálaya mountains," signed H. T. C., and evidently written by Mr. Colebroke. From this I extract the following sentences: "The limit of congelation is specified by him (Capt. Webb), where he states the elevation of the spot at which the Gori river emerges from the snow, viz. 11,543 feet. This observation it may be right to remark is consonant enough to theory which would assign 11,400 for the boundary of congelation in Lat. $30^{\circ} 25'$." Now as Mr. Colebroke was not an original observer, the way in which he talks of the limit of snow and then of the limit of congelation, using them as synonymous terms, would, independently of any other error into which he may have fallen, afford strong grounds for our supposing that he had no very precise ideas as to the meaning of the expression, limit of snow. But all doubt on the subject ceases, when we learn that 'the spot at which the Gori river emerges from the snow,' is neither more nor less than the extremity of an immense glacier; and when we see, as I have done, that at an elevation not 150 feet less great, and within a mile of this spot said to be at the limit of constant congelation, is situated Milam, one of the largest villages in Kumaon, where crops of wheat, barley, buckwheat, and mustard are regularly ripened every year; and that no snow is to be found in the neighbourhood in August or September at an elevation of at least 16,000† feet or 4,500 feet above the spot alluded to; it is evident that Mr. Colebrooke either used the term limit of snow in a sense very different from that now applied to it, or has been left altogether in the dark, as to those facts on which alone an opinion of any value could be formed.

I am without any means of discovering whether Capts. Webb or Hodgson ever published any distinct opinions as to the height of the snow-line, but it appears probable that the information to which Mr. Cole-

* The numbers in M. Humboldt's list do not agree with this; they have possibly been transposed by accident.

† I say 16,000 feet, as up to that height I am certain, but 18,000 is more probably the truth.

brooke alludes is simply their record of the heights of places. At all events however their evidence must be considered of little value, as they neither of them knew what a glacier was. Capt. Webb, as we have seen, talks of the Gori emerging from the snow, when we know that in reality it rises from a glacier. Capt. Hodgson falls into a similar error in his description of the source of the Ganges, (*vide Asiatic Researches*, T. 14, pp. 114—117). He says "the Bhagirati or Ganges issues from under a very low arch at the foot of the grand snow bed," and from the almost exact coincidence of the heights it is plain that this is his limit of snow. There is not however the slightest doubt that the low arch was merely the terminal cave of a glacier, and that it was far below the lower limit of perpetual snow, though when Capt. Hodgson was there in the spring the place was probably snowy enough.

A. Gerard. I have not the means of reference to the passage quoted by M. Humboldt in support of the height given by Capt. Gerard, but in the "account of Koonawur," which may be presumed to shew Capt. Gerard's latest views on these matters, he says:—"The limit of perpetual snow is lowest on the outer Himalaya," (by which he means the Bissehir range), "and here the continuous snow beds exposed to the south are about 15,000 feet."* It is not impossible that the height which M. Humboldt gives refer to some *line of perpetual congelation*, on a number of different varieties of which Capt. Gerard remarks, such as where it always freezes, freezes more than it thaws, freezes every night, or finally where the mean temperature is 32° Fahrenheit. These, however interesting in their own way, are not the *snow-line*.

Jacquemont. The height given by this traveller is fully explained by the note that M. Humboldt adds, "au nord de Coursali et de Jumnautri ou la limite des neiges est horizontalement très tranchée."—*Jacqu: Voy. dans l'Inde*, p. 99. Now M. Jacquemont visited Jumnautri in the middle of May, when no doubt he found the snow line

* Account of Koonawar, p. 159. It appears to me possible that the Gerards, who knew as little of glaciers as Webb or Hodgson, did not fall into similar mistakes in their estimate of the height of the snow-line on the Bissehir range, because there are no glaciers or none of any size on that face, owing to the small height, less than 2000 feet, that the average line of summit rises above the snow-line. This however is only conjecture, for though I am satisfied that glaciers do exist on the north face of that range, I have in vain endeavoured to come to any conclusion as to the southern face. It may be proper to add that I have never been there myself.

'très tranchée' at 11,500 feet. I have already shewn that I found the same thing myself at Pinduri, where the snow in the autumn had all disappeared up to 15,000 feet or more. If his visit had been made in January he would probably have found the snow below 8000 feet, but this is not *perpetual snow*.

These heights therefore must all be rejected; nor can it be considered at all surprising that any amount of mistake as to the height of the snow line should be made, as long as travellers cannot distinguish snow from glacier ice, or look for the boundary of perpetual snow at the beginning of the spring.

2. *Northern limit of the belt of perpetual snow*.—My own observations on the snow-line in the northern part of the chain were made in September, 1848, on my way from Milam into Hundes, viâ Unta-dhúra, Kyungar-ghát and Balch-dhúra, at the beginning of the month; and on the road back again viâ Lákhur-ghát at the end of the month.

Of the three passes that we crossed on our way from Milam, all of them being about 17,700 feet in elevation, the first is Unta-dhúra, and we saw no snow on any part of the way up to its very top, which we reached at about 4 P. M. in a very disagreeable drizzle of rain and snow. The final ascent to the pass from the south is about a thousand feet; it is very steep at the bottom and covered with fragments of black slaty limestone. The path leads up the side of a ravine, down which a small stream trickles, the ground having a generally even and rounded surface. Neither on any part of this, nor on the summit of the pass itself, which is tolerably level, were there any remains of snow whatever; the ground being worked up into deep black mud by the feet of the cattle that had been lately returning to Milam. On the ridge to the right and left there were patches of snow a few hundred feet above; and on the northern face of the pass an accumulation remained that extended about 200 feet down, apparently the effect of the drift through the gap in which the pass lies. Below this again the ground was everywhere quite free from snow. On the ascent to Unta-dhúra, at perhaps 17,000 feet, a few blades of grass were seen, but on the whole it may be said to have been utterly devoid of vegetation. On the north side of the pass, 3 or 400 feet below the summit, a Cruciferous plant was the first that was met with.

The Kyungar pass, which is 5 or 6 miles north of Unta-dhúra,

was found equally free from snow on its southern face and summit, which latter is particularly open and level. The mountains on either side were also free from snow to some height, but on the North, as on Unta-dhúra, a large bed lay a little way down the slope, and extended to about 500 feet from the top. On this pass a Boragineous plant in flower was found above 17,000 feet; a species of *Urtica* was also got about the same altitude, and we afterwards saw it again nearly as high up on the Lákbur pass.

From the Kyungar-ghát, a considerable portion of the southern face of the Balch range, distant about 10 miles, was distinctly seen apparently quite free from snow. In our ascent to the Balch pass no snow was observed on any of the southern spurs of the range, and only one or two very small patches could be seen from the summit on the north side. The average height of the top of this range can hardly be more than 500 feet greater than that of the pass, and as a whole it certainly does not enter the region of perpetual snow. As viewed from the plains of Hundes it cannot be said to appear snowy, a few only of the peaks being tipped.

We returned to Milam viâ Chirchun. The whole of the ascent to the Lákbur pass was perfectly free from snow to the very top, i. e. 18,300 feet, and many of the neighbouring mountains were bare still higher. The next ridge on this route is Jainti-dhúra, which is passed at an elevation of 18,500 feet, but still without crossing the least portion of snow. The line of perpetual snow is however evidently near; for though the Jainti ridge was quite free, and some of the peaks near us were clear probably to upwards of 19,000 feet, yet in more sheltered situations unbroken snow could be seen considerably below us, and on the whole I think that 18,500 feet must be nearly the average height of the snow-line at this place.

M. Humboldt's list of heights for the Northern slope is as follows :

	<i>Toises.</i>	<i>English feet.</i>
Webb,	2600,	or 16,600
Moorcroft,	2900	— 18,500
A. Gerard,	3200	— 20,500
Jacquemont,	3078	— 19,700

Webb. The height given on the authority of Capt. Webb is simply that of the Niti pass, which Capt. Webb crossed without snow in

August 1819, and Moorcroft in June* and August 1811. The Niti pass is notoriously the easiest of all the Garhwal and Kumaon passes, and remains open long after those from Juhár, which I have described above, have become impracticable; and it is held to be a certain way of escape from Tibet, by the Juháris, should a fall of snow more early than usual stop their own passes, while they are to the north of the Himálaya. It may therefore be fairly concluded that the snow-line recedes considerably above the Niti pass, as it should do if my estimate of its height be correct.

Moorcroft. The passage quoted in support of this height is as follows:—"Now Mr. Moorcroft had his tent covered two inches deep (with snow) when close to Manasarowar and on the surface of the ground it lay in greater quantities; and if his elevation was 17,000 feet† we have clear evidence that the climate of the table-land, notwithstanding the increased heat from the reverberation of a bright sun, is equally as cold as in the regions of eternal snow in the Himalayan chain, although the country of the former exhibits no perpetual snow except at heights of 18,000 and 19,000 feet." (*Tours in the Himalaya*, T. 1. p. 319). The words are those of Dr. Gerard, who on his own authority thus gives 18,000 or 19,000 feet as the elevation of the snow-line in the part of Tibet near the Sutlej; and this, as far as it goes, corroborates the conclusion to which I have come.

A. Gerard. In the absence of the books to which M. Humboldt refers, I conclude that the height here given is that to which Capt. Gerard supposed the snow receded on the ridge above Nako. But this is to the North of the Sutlej, and therefore is not in the region to which I have confined myself. In the "Account of Kunawar" however the following remark that is applicable, is to be found:—"In ascending the Keobrung pass, 18,313 feet high in July, no snow was found on the road," (p. 159). This pass is situated on the water-shed of the Himálaya about 20 miles east of the great bend in the Sutlej, and about 8 miles to the south of that river; it is on the northern limit of the belt

* Not *January*, as is erroneously printed in the 'Asie Centrale' Vide, Asiatic Researches, Vol. 12, pp. 417—494.

† The elevation of Mánasarowar, as M. Humboldt correctly conjectured, is about 15,200 feet only.

of perpetual snow, the ground between it and the Sutlej not being of sufficient height to be permanently covered with snow.

Jacquemont. The Keoobrung pass of Capt. Gerard, under a name slightly changed, is the same as that from which M. Jacquemont made his observations, "Sur le col de Kioubrong (entre les rivières de Buspa et de Shipke ou de Lang zing khampa) à 5581 mètres (18,313 feet) de hauteur selon le capitaine Gerard, je me trouvai encore de beaucoup au-dessous de la limite der neiges perpétuelles dans cette partie de l'Himalaya (lat. 31° 35', long. 76° 38')." "Je crois pouvoir porter la hauteur des neiges permanentes dans cette region de l'Himalaya à 6000 mètres (19,700 feet,") (*Asie Centrale*, T. 3. p. 304). I will admit that M. Jacquemont's estimate of the height of the snow-line on the southern face of the range, is not such as to induce me to place implicit confidence in this either; but, allowing for some little exaggeration, there can be no room for doubting that the snow-line must here recede nearly to 19,000 feet.

Whether the result at which I have arrived from what I saw on the Juhár passes be too little, or this too great, or whether there may not be in fact a difference of elevation, are matters of comparatively small importance. As I purpose to point out hereafter, the chances of error in the determination of great altitudes by single Barometrical observations are very considerable, more particularly when as is most generally the case, there is no corresponding observation within 60 or 70 miles. All of these heights are deduced from such observations, and errors of 150 or even 200 feet on either side of the truth, or differences of 300 or 400 feet, may, I am satisfied, quite easily arise in the calculations. I shall therefore continue to call the height of the snow-line at the Northern limit of the belt of perpetual snow, 18,500 feet; not that I consider my own calculation as worthy of more confidence than Capt. Gerard's, or M. Jacquemont's, but that it is, in the present state of our knowledge, sufficiently exact, and certainly not exaggerated.

As the principal object of the present enquiry is the elevation of the snow-line in the Himálaya I have in the foregoing observations confined myself strictly to that region of these mountains that I at first specified; but it is not the less important to notice the heights at which we find perpetual snow still further to the north. Capt. Gerard, after mentioning the Keoobrung pass, goes on to say, "In August when I

crossed Manerung pass, 18,612 feet," a pass on the range that divides Piti from Kunáwar, "there was only about a foot of snow, which was new and had fallen a few days before." "In October on the ridge above Nako," about 5 miles north of the great bend in the Sutlej, "we ascended to 19,411 feet, and the snow which was all new and no more than a few inches deep, was only met with in the last 400 or 500 feet; this was on the face of the range exposed to the west, but on the opposite side no snow was seen at almost 20,000 feet."—(p. 160). During the whole of our expedition into Hundes in September 1848, we only saw very small patches of snow in two places, on both occasions in sheltered ravines; but in the part of the country through which we passed perpetual snow is not to be looked for, the highest mountains probably not exceeding 18,000 feet in height. In the true plains of Tibet, snow would be just as difficult to find in the summer months, as in the plains of India. From my own observations made in this journey, I infer that the height of the limit of snow on the southern face of Kailás is not less than 19,500 feet; and there is nothing now on record that I know of, that indicates the latitude beyond which the snow-line again begins to descend.

From a review of the whole of the facts that have been brought forward, it may I think be considered as fully established, that M. Humboldt, though underestimating the actual elevation of the snow-line, was certainly right in what he advanced as to the relative height on the two opposite faces of the chain. The doubts that were raised by Capt. Hutton on this point in his paper entitled "Correction of the erroneous doctrine that the snow lies longer and deeper on the southern than on the northern aspect of the Himalaya," were perhaps almost sufficiently answered by Mr. Batten at the time they were first brought forward; but as I have reopened the whole question I will add a few words on this subject also.*

* Vide M'Clelland's Journal, Nos. 14, 16, 19, 21. Captain Hutton's first letter begins thus; "Previous to my trip through Kunawar in 1838, I had frequently heard it contended that the snow lay longer, deeper, and farther down on the *southern* exposure of the Himalaya than it was found to do on the northern aspect, you may therefore easily imagine my astonishment, when crossing the higher passes through Kunawar, Hungrung and Pitti, I found the actual phenomena to be diametrically opposite to such a doctrine, and that the northern slopes invariably

The doctrine that Capt. Hutton attacks as erroneous, undoubtedly is so. But it is a doctrine that was never inculcated by any one.—Capt. Hutton having misunderstood the true enunciation of a proposition, reproduces it according to his own mistaken views, and then destroys the phantom that he has raised. The fact that Captain Hutton saw to be true was this, that as a general rule, snow, sporadic, as well as perpetual, will be found to lie at a lower level on the northern, than on the southern aspect on any individual range in these or any other mountains. In drawing his conclusions from this fact, the first error into which he fell was to confound the north and south aspects of *the individual ridges*, with the north and south aspects of *the chain*; and he somewhat complicates matters by neglecting to distinguish between *snow* and *perpetual snow*. These mistakes having been pointed out to him, he tried to correct them, but still could not get over the terms *north and south declivity*; for he ends by assuming that they apply to the north and south aspects of the Bissehir range, which he conceives to be ‘the true Himálaya, the central or main line of snowy peaks.’ Here he falls into an error of logic no less flagrant than the former; he restricts the term ‘Himálaya’ to this range, which may or may not be central, for that has nothing to do with the matter, and then assumes that this Himálaya of his own, is the Himálaya of whose north and south declivities we speak, when we repeat that the snow-line *is* at a greater elevation on the northern than on the southern face of the chain.*

carried more snow than the southern exposure.” (No. 14. p. 275.) In his last letter he says, “I have already acknowledged the faultiness of my first letter, in so far as regards my having omitted to state in sufficiently distinct terms, that my remarks referred to the actual northern and southern aspects of the true Himálaya or central or main range of snowy peaks, and not to the aspects of secondary groups and minor ranges.” This ‘true Himálaya’ is the Bissehir range of which I have often spoken. I say nothing of Capt. Hutton’s views regarding perpetual snow, the existence of which, as far as I can understand him, he appears to doubt.

* The word ‘Himálaya,’ which to the natives of these mountains means only the snowy peaks, is in the language of science applied to the whole chain, and in my opinion properly. Any division of the chain into ‘Himálaya,’ or snowy ranges, and ‘sub-Himálaya’ ranges not snowy, such as has I believe been made, appears to me objectionable, not only as unusual in the terminology of physical geography, and therefore likely to lead to confusion such as that of which we have just had a specimen; but as artificial and unnecessary. I repeat artificial, for in spite of the specious

The height to which the snow-line has been shown to recede on the southern face of the Himalaya, though considerably greater than had been supposed by M. Humboldt, still does not exceed what the analogy of mountains in similar latitudes in the other hemisphere might have led us to expect. In the central part of Chili, in Lat. 33° S. we find that the lower limit of perpetual snow is at 14,500 or 15,000 feet, while in Bolivia, in Lat. 18° S. it reaches 16,000, and even on some of the peaks 19,000 feet.* There is therefore no appearance of any thing unusual in the general height of the snow-line, which need induce us to suppose the existence of any extraordinary ascending current of heated air, regarding which M. Humboldt enquires. The exceedingly high temperature, surpassing that known at any other part of the earth's surface, which the air over the plains of North-Western India acquires during the summer, must of course produce a sensible effect in heating the upper strata of the atmosphere. But as far as I am enabled to form an opinion from the few facts that have come to my knowledge regarding the temperature of the higher regions in these mountains, I think there is little doubt that the same cause which produces this great temperature in the plain, that is, the direct radiation of the sun, acts immediately so powerfully in heating the surface of the mountains, and thereby raising the temperature of the air over them, and in melting the snow, that the secondary effects of the heated air that rises from the plains of India must be almost imperceptible.

From the way in which the term *north declivity* was introduced into the enunciation of the phenomenon of the greater elevation of the snow-line at the northern edge of the belt of perpetual snow, an idea naturally arose that it was observed only on the declivity immediately facing the plains of Tibet, and M. Humboldt, in the quotation I before gave from 'Cosmos,' is careful to restrict it to the peaks which rise

appearance of the distinction it will not bear examination. The association of mountains into *chains* should be based upon the physical character and affinities of the mountains themselves, quite irrespective of any adventitious circumstances of snow or of vegetable and animal life. Botanical or zoological regions will almost always be found to follow closely the configurations of the earth's surface, on the accidents of which they chiefly depend; but to make the classification of the latter depend upon the former would be a manifest absurdity.

* *Asie Centrale*, T. 3, pp. 275, 277, 329.

above the Tartarian plateau. But this, as may have been inferred from what I have already said on the state of the three ranges that are crossed in succession between Milam and Tibet, is quite a mistake; the fact being that the greater elevation is observed on the Tibetan face in common with the whole of the more northern part of the chain. From the remarks before made on the state in which I found the Barj-káng pass, it will be seen that even so near as it is to the southern limit of the belt of perpetual snow, a perceptible increase of elevation had already taken place. M. Jacquemont, as quoted by M. Humboldt, says, "Les neiges perpetuelles descendent plus bas sur la pente méridionale de l'Himalaya, que sur les pentes septentrionales, et leur limite s'élève constamment à mesure que l'on s'éloigne vers le nord de la chaîne qui borde l'Inde." (*Asie Centrale*, T. 3. p. 303.) With the proviso that the rise here spoken of is not regular, but more rapid as we cross the first great masses of perpetual snow, I entirely concur in M. Jacquemont's way of putting the case.

That the radiation from *the Plains of Tibet* can have nothing to do with the greater height to which the snow-line recedes *generally* in the northern part of the Himálaya, is evident, for it must be all intercepted by the outer face of the chain; and that its effects even on this outer face are of a secondary order, seems to me sufficiently proved by the consideration, that on the Balch range, which rises immediately from those plains, what little snow is to be seen is on the Northern slope exposed to the radiation, while none whatever remains on the Southern slope, which is quite protected from it, exactly as is the case with every mountain anywhere.

It may therefore be concluded that some other influence must be in operation, the effects of which are generally felt over the whole of the more northern parts of the Himálaya, and such an influence is I conceive readily to be found, in the diminished quantity of snow that falls on the northern, as compared to the southern part of the chain.

The comparative dryness of the climate to the north of the first great mass of snowy mountains, is not now noticed for the first time; it is indeed notorious to the inhabitants of Simla, and travellers often go into Kunáwar with the express object of avoiding the rains. Capt. Gerard thus describes the climate of the western part of the Himálaya: "In the interior (i. e. of Kunáwar) at 9000 and 10,000 feet snow is

scarcely ever above a foot in depth, and at 12,000 it is very rarely two feet, although nearer the outer range four or five feet are usual at heights of 7000 or 8000 feet. In these last places there is rain in July, August and September, but it is not near so heavy in the lower hills. When Hindustan is deluged for three months, the upper parts of Kunáwar are refreshed by partial showers; and with the exception of the valley of the Buspa, the periodical rains do not extend further to the eastward than Long. 77°.* (*Account of Kunáwar*, p. 61). He again says relative to the most northern parts of Kunáwar and the neighbouring portion of Tibet, "With the exception of March and April, in which months there are a few showers, the uniform reports of the inhabitants represent the rest of the year to be almost perpetual sunshine, the few clouds hang about the highest mountains and a heavy fall of snow or rain is almost unknown." (*Ibid*, p. 95.).

The testimony of Capt. J. Cunningham, who passed a winter in the most northern part of Kunáwar, as to the small quantity of snow that falls, is particularly valuable. He says, "In this country a southerly wind and the sun together keep slopes with a southern exposure and 12 and 13,000 feet high, quite clear of snow, (except when it is actually snowing,) and this too towards the end of January and beginning of February, or I may say at all times." Also "here I am (*April 6th*, 1842) about 9000 or 9500 feet high, wind generally southerly, no snow whatever on southern slopes within 15 or 16,000 feet, apricot trees budding, but on northern slopes and in hollows abundance of snow."† (*M' Clelland's Calcutta Journal of Nat. History*, No. 14, pp. 281, 282).

* That the fall of snow at 7000 feet is ever 5 feet in any part of these hills may I think be doubted. The Buspa is the river that runs immediately at the foot of the north declivity of the Bissehir range; and I suppose that Capt. Gerard means, that the rains do not extend up the Sutlej beyond the point where the Buspa falls into it.

† These paragraphs are taken from extracts of letters of Capt. Cunningham, given by Capt. Hutton in support of his arguments as to snow lying lower on North than on South exposures, which accounts for the last sentence. But whatever the quantity of snow may have been on the north slopes, compare the heights here given as being clear of snow early in *April*, viz. 15,000 feet, with what I have above shown to be the limit to the South of the great peaks as late as the middle of *May* viz. 12,500 feet.

From my own experience I can also speak of the remarkable change of climate that is met with in the month of August, in passing from the south to the north of the line of great peaks, by the vallies of the Gori and Rálam rivers. A straight line joining the peaks No. 14, (Nandádevi), and No. 18, (the northern of the Páñch-chúli cluster,) cuts the Gori a little below Tola and the Rálam river about five miles further to the east near the village of Rálam. The road up the Gori being at that season impracticable, I went up the Rálam river to Rálam and thence crossed over to the Gori by the Barji-káng pass, which is on the ridge that separates the two rivers and that terminates in the peak No. 16 (Hansá-ung). From the limit of forest to the village of Rálam, the elevation of which is about 12,000 feet, the vegetation, chiefly herbaceous, was of the most luxuriant growth and boundless variety, and the soil was saturated with moisture. On crossing the Barji-káng pass and descending to the Gori, we were immediately struck with the remarkable change in the character of the vegetation, which had already lost all its rankness. But a mile or two above the village of Tola the alteration was complete; the flora had shrunk within the most scanty limits, the bushes hardly ever deserving the name of shrub, the few herbs that were there were stunted and parched, the soil dry, and the roads quite dusty. At Melam the still closer approximation of the climate to that of Tibet, is clearly shewn by the occurrence of several plants undoubtedly Tibetan, that are not found farther to the South. Such are *Caragana versicolor*, the 'Dama' of the Bhotias, which covers the plains of Tibet; a *Clematis*, dwarf *Hippophaë*, *Lonicera*, and two or three *Potentillas*; and no doubt several others might be named.

Now although it is to the winter and not to the summer rains,* that the precipitation of snow on these mountains is to be ascribed, yet the circumstances under which the vapour is condensed appeared to be the same at both seasons. Southerly winds blow throughout the year over the Himálaya, in the winter with peculiar violence;† and whatever be

* Although it does not appear to be so well known, the winter rains of North Western India are as strictly periodical as those of the summer.

† The Southerly winds that prevail at considerable heights in the Himálaya, and in the countries to the north, are diurnal phænomena, evidently dependent on the apparent motion of the sun; and in their time of beginning of maximum and of ending, greatly resemble the hot winds of the plains of India, which have a similar origin.

the more remote cause of the periodical recurrence of the rains, there can I think be little doubt, that the proximate cause of the condensation of by far the greater portion of the snow or rain that falls on the snowy mountains, is that the current from the south is more damp or hot than the air in contact with the mountains against which it blows; a relation which holds good in the winter as well as in the summer.

Thus the air that comes up from the south, no sooner reaches the southern boundary of the belt of perpetual snow, where the mountains suddenly rise from an average of perhaps 8,000 or 10,000 feet to nearly 19,000 or 20,000, than it is deprived of a very large proportion of its moisture, which is converted into cloud, rain or snow, according to circumstances. And the current, in its progress to the north, will be incapable of carrying with it more moisture, than is allowed by the very low temperature to which the air is of necessity reduced in surmounting the snowy barrier, 19,000 or 20,000 feet in altitude, that it has to pass. Nor can any further condensation be expected at all comparable in amount to what has already taken place, as it would manifestly demand a much more than corresponding depression of temperature; and this is not at all likely to occur, for the most elevated peaks being situated near the southern limit of perpetual snow, the current on passing them will more probably meet with hotter than with colder air.

It is, I conceive, to precisely similar causes, that we should attribute the great amount of rain that is known to fall at Mahabaleshwar, on the Western ghats, at Chira-punji, in Sylhet, and generally, though the quantity is far less, along the most southern range of the Himálaya itself; and it is curious to observe that the comparative dryness of the less elevated country to leeward also holds good in these cases. In the Deccan, the country immediately to the east of the western ghats, Col. Sykes tells us, that "the rains are light, uncertain, and in all years barely sufficient for the wants of the husbandman." On the same authority we find, that while the mean fall of rain for 3 years at Poona was about 27 inches,* that at Mahabaleshwar for 1834 was no less than 302 inches.† Although I have not the exact figures to refer to, I know that the rain at Nainee Tal on the external range of the Himálaya, is about double what falls at Almora, not 30 miles to the north.

* British Association's 7th Report, p. 236.

† *Ibid*, 9th Report, p. 15, (Sections.) The exact amount is 302.21 inches.

It will therefore be seen that as I hold the direct action of the sun to be the primary cause of the great general height to which the snow line recedes, so I consider that the increase of the height in the northern part of the chain chiefly depends, not on any additional destructive action, but on the smaller resistance offered by a diminished quantity of snow, to destructive forces, which are not indeed constant throughout the whole breadth of the chain, but whose increase appears to have no dependence on increase of distance from the southern limit of the belt of perpetual snow. Among the more evident causes of the irregularities in the melting of the snow, may be mentioned, the powerful action of the heavy summer rain on the southern face, as compared with what falls as little more than a drizzle on the northern; the protection afforded from the radiation of the sun by the heavy clouds so frequent on the south, contrasted with the relative slight resistance of the less dense, but not uncommon clouds on the north; the differences in the temperature of the air that acts on the lower edge of the snow produced by the difference of height of the snow-line on the opposite faces of the chain; and lastly, the differences of the temperature of the air and of the amount of radiation and reflexion dependent on the differences in the state of the surface of the earth, which on the south is densely clothed with vegetation, while on the north it is almost bare.

Before concluding I will observe, that the height at which it is certain that snow will fall every year, in this region of the Himalaya, is about 6500 feet; and at an elevation of 5000 feet it will not fail more than one year out of ten. The least height to which sporadic falls of snow are known to extend, is about 2500 feet; and of such falls there are only two authentic instances on record since the British took possession of Kumaon, viz. in 1817 and 1847. Thus we see that the regular annual fluctuation of the snow line, is from 9000 to 10,500 feet, and it occasionally reaches even 13,000 feet. M. Humboldt informs us that under the equator at Quito the fluctuation is 600 Ts. (3,800 feet); that at Mexico it reaches 1350 Ts. (8,600 feet); and the greatest fluctuation that he mentions is that in the south of Spain, which amounts to 1700 Ts. (10,900 feet).*

A brief recapitulation of the principal results of this enquiry will show us, that the snow-line, or the southern edge of the belt of perpetual

* *Asie Centrale*, T. 3. p. 279.

snow in this portion of the Himálaya, is at an elevation of 15,500 feet, while on the northern edge it reaches 18,500 ft. ; and that on the mountains to the north of the Sutlej, or still further, recedes even beyond 19,000 feet. The greater elevation which the snow-line attains on the northern edge of the belt of perpetual snow, is a phænomenon not confined to the Tibetan declivity alone, but extending far into the interior of the chain ; and it appears to be chiefly caused by the quantity of snow that falls on the northern portion of the mountains, being much less than that which falls further to the south, along the line where the peaks covered with perpetual snow first rise above the less elevated ranges of the Himálaya.

Notes on the Languages spoken by the various tribes inhabiting the valley of Asam and its mountain confines. By WILLIAM ROBINSON, Inspector of Government Schools in Asam.

(Concluded from page 237.)

PART II.

Our subsequent remarks, according to previous division, will have reference to the second great class or group of languages. These are spoken on the southern confines of the valley, and appear, more intimately than any of those already examined, to be connected with the great Chinese Stock.

A striking peculiarity in them all is, the absence of inflections, which to the classic reader appear almost essential to the existence of human speech. That this deficiency is opposed to the formation of long and sonorous words, is certain, for it is chiefly to the numerous and varied inflections employed by the Greeks, for instance, we are to attribute their ability to produce that full and majestic volume of sound which so peculiarly distinguishes their language. But among rude and semi-barbarous tribes remarkable for their comparative taciturnity and preference of plain sense over the flowers of oratory, such deficiencies it may be supposed are unimportant ; especially when we consider that among the languages of the Western nations our own comes nearest to the Chinese stock in this respect ; the utmost number of variations which an English verb undergoes never exceeding seven.