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I.—*On Himalayan Glaciation.*—*By* J. F. Campbell, Esq., *F. G. S.*

(Read January 17th, 1877.)

[We so seldom have the advantage of foreign opinion upon matters of scientific observation in India, that the Society will no doubt welcome the following notes upon Himalayan glaciation addressed to one of its Secretaries by Mr. J. F. Campbell, so well known for his remarks upon ice-action in every quarter of the northern hemisphere. The notes are left in their epistolary form, which is so well suited to communications that do not pretend to be exhaustive.]

Kotleh, November 19th, 1876, *Kangra valley.*

My dear Sir,—On the 27th Sept. I landed with you at Bombay. By your advice I have come here to look at certain marks supposed to be glacial. Let me refer you to the second volume of '*Frost and Fire*' for marks which I had recognized when that book was printed. Let me refer you to '*My Circular Notes.*' (Macmillan 1875) for references to other papers of mine on glacial subjects, and for the result of my observations during thirty-five years. From these writings you may estimate my knowledge of glacial marks and my opinion.

1. I have now skirted the base of the Himalayas from Hirdwar to Lahore. In the plains of Europe and of North America, I have seen large stones, carried great distances from parent rocks, say from a thousand to fifteen hundred miles, over plains. These commonly are smoothed, polished, and grooved, exactly like stones which are found beneath existing glaciers. These erratics reach as far south as icebergs now float in the

Atlantic, namely, to Lat. 37° N. in America. I have not seen one large stone in the plains of India so far as I have travelled, except stones carted and carried by men for building purposes. Of these not one was striated.

2. I have been to Simla, and to "Monsuri" (so named by the people), and for short distances inland. In Scotland, Scandinavia, the Alps, and in North America; in Labrador, and in Vancouver's Island: in all northern countries where marks of ancient glaciations abound, and where I have travelled to study them; I have seen rocks and mountains of a particular rounded form, on which grooves mark out the course of the ancient glaciers or icebergs which moved over these rocks and rounded them. In Scandinavia horizontal grooves are visible on the large scale from end to end of fjörds more than a hundred miles long, up to a height of more than a thousand feet above the sea level. All the rocky islands which stud the Norwegian coast are striated, up to considerable heights, and great blocks of transported stone are poised upon the hill-tops everywhere. Many of these erratics are angular blocks, as big as small houses. In 1841, I slept under a stone of this kind with fifteen other persons, guides and travellers, upon an Alpine glacier, Such stones abound in Scotland, and in Ireland, some as high as three thousand feet, and rest upon the tops of isolated mountains. I have not seen one "perched block" in the lower Himalayas, nor have I seen one hog-backed ridge ⌒ or one rounded valley ⌣. I have seen every where far and near, with my telescope, and at my feet a constant repetition of the form V which I attribute to the action of running water, *not* to glacial action.

3. I went to Hirdwar, to the exit of the Ganges from the basin in which that river and its branches take their rise in glaciers. I have photographs of these glaciers. In all the glaciated countries that I have visited, the ends of great basins of this kind are abundantly strewed with glaciated stones. I sought carefully from Deira to Hirdwar, and from Hirdwar to Roorkee along the Ganges canal, and I did not find one glaciated stone there.

4. It sometimes happens that large glaciated stones are found in rocks consolidated, and classed geologically as old rocks;—"old red sandstone," &c. I have looked at the "Siwaliks," at the rocks which contain fossils of large extinct animals. I have not seen one glaciated stone in these beds. The fauna of the Siwaliks &c. as described in books, indicate a warm climate, like that which now exists here, and do not indicate anything glacial.

5. From Pathankote (here named "Puttânkote") to Nurpur, I crossed the mouth of a wide valley in which are several large rivers which take their rise amongst glaciers according to the maps. I saw nothing glacial on that stage. These streams drain the northern slopes of the Kangra range.

6. From Nurpur to this place I have crossed several rivers, which descend from the southern face of a snowy range behind which rivers flow which I crossed yesterday. The range is some 12 or 13,000 feet higher than my road, according to the maps, and the top of it is distant about 12 or 13 miles. I have seen a vast number of large stones near these rivers. I have not seen one stone or one exposed rock surface with any mark of glaciation along my route thus far. Several large stones, some of granite, are below this house. Their surfaces are well preserved, and they are all dinted by rolling, not striated by sliding.

7. Where rivers are cutting through old moraines, they constantly undermine and wash out glaciated stones. A small rivulet near Dunrobin in Sutherland is full of large striated stones, washed out of an old moraine of large size. The plain rivers below Chicago in America also wash out large glaciated boulders which come from beyond Lake Superior. I have seen no such stone here, and nothing that has the remotest resemblance to any moraine that I ever saw anywhere. A fall of about a thousand feet in a mile, and the vast rainfall of these regions suffice to explain the transport of far larger stones than any which I have seen thus far in India. A very large stone was moved more than a hundred yards this year at Kalka, by the small river which there enters the plains. The stone was known because it had long been used as a washing stone. The fact was remembered because two washermen were carried away and drowned by a sudden flood. The slope at Kalka is far less than the slope here. Thus far I have seen nothing to suggest the action of ice at low levels between Hirdwar, and Lahore, Pathankote and Kotleh.

8. So far as I can see now, my distant observations from Simla with a telescope, are confirmed by detailed examination of this ground.

9. I say nothing of that kind of geology which belongs to professional men. I see enough to convince me that there is professional work on this ground for many expert geologists for many years. But generally it seems to me, that a part of the plain, formed of old as the plain is now forming, has been crumpled up against the older rocks, probably by a thrust. I saw a folded section in the right bank of the river at Nurpur yesterday with an expiring camel on the shingle to shew how "siwalik" fossils got buried of old by streams like those which now flow into the plains. They form "Deltas" △ or, if the new name is preferred fans, which now extend ten or twelve miles into the plains. These commonly spread till they meet so that a whole series make something like a continuous formation whose section must vary with the intermittent flow of rivers. Such a section of alternate beds of pebbles, shingle, sand, and brown mud I have seen in crossing the crumpled rocks which are named "Siwaliks" and "Nahuns" (?) hereabouts, and near Deiradun, I have no geological map,

and a passing traveller cannot hope unaided to unravel the complications of beds which I see here. I saw another folded E.—W. section to-day in a river bank. I do not therefore concern myself with that kind of geology which belongs to your department. I confine myself to marks of glaciation with which I have made myself familiar. About Lat. 30° 31′ I have found none in India thus far.

10. I have looked carefully for sea-margins along the foot of hills. All round Scandinavia, in Scotland, in "the Labrador", and in many other countries, "*terraces*" nearly parallel to the existing sea level mark old sea levels before the land was last raised. The form is very conspicuous, and the cause of it is often manifested by the discovery of recent shells in the sand and mud in which they died. I looked from Pathankote westwards, and saw the outline of the hills fade gradually into the plains at an angle of about five degrees. There was no semblance of a raised sea margin towards Kashmir. I have seen nothing like a "terrace" on the lower hills towards Hirdwar or beyond it. I never read of the discovery of recent sea shells anywhere in these regions. There is nothing hereabouts to suggest the agency of "floating ice" in lake or sea, or of lake or sea to float anything in.

11. But as avalanches do fall into these Indian rivers, and make snow bridges, fragments of hard snow, or of glaciers, may possibly float down streams, and carry stones on ice rafts. Thus far I have seen no stones to suggest that possible method of transport by floating ice. The glaciers of which I have photographs are full of fallen stones, angular as they were when they broke from the cliffs. I have not seen one such stone in any river course that I have crossed. All the river stones are rolled.

12. From my recent observations I see no reason to assume any great difference in this climate since the Sivaliks were deposited; since many kinds of extinct elephants lived hereabouts, with large saurians, like those which live in plain rivers now. I have found nothing to indicate a glacial period in India. What I noticed in travelling round the world you will find in the "circular notes" quoted above of which copies were at Bombay and Simla when I passed.

13. *Kangra, 20th.*—I passed yesterday over ridges which have been called "moraines." My way led down stream to a fork, and then up stream to a level country. The gorge is manifestly cut by the river, and gives a section of beds of sandstone with a northerly dip. I noticed some large, rounded stones in the sandstone and some were "horse tooth" granite. Consequently the transport of such stones went on during the formation of these tilted beds. Near the top of the gorge I came to a thick bed of large rolled stones of many kinds. The bed seems to rest unconformably on the sandstones, on both sides of the river and to cover a considerable

area though generally hidden beneath the soil. At a place called "Cowlee" I found a great number of very large stones in and about a river, which is crossed by a bridge. They are far larger than any that I have found elsewhere. I measured one roughly 12 × 8 × 8 feet, and another 15 feet long. Many thousands of stones near this size have been washed out of the matrix which is hard reddish sandy stuff like the soil of the fields. As stones of this great size give reason to suspect glacial action, I sought carefully for marks. I went to the banks from which stones projected and found the surfaces where newly exposed, perfectly preserved. These were all smooth, or dinted, water-worn surfaces. There was no sign of striation on any stone that I examined. After a long search I came to the conclusion that these great stones were rolled to their present resting-place, and that this is not a "moraine," but a "Delta."

Near Kangra a view is got which shews that the region crossed, in which these unusually large stones occur so abundantly, is the estuary of a number of streams which come out of a rocky amphitheatre furrowed by steep V water-courses, which begin at the top of the ridge, at the snow. From each of the larger furrows, extends a ridge of stuff which has been taken for a moraine. I am quite certain that I crossed no moraines. An old "moraine" consists of angular stones carried upon the surface of a glacier; of stuff carried in the ice; and of stones pushed along beneath the ice. There are medial and lateral moraines; the terminal moraine forms at the end of a glacier and makes a crescent-shaped rampart crossing a valley. It often forms a lake, like a "bund." In these long ridges which I can see from this dâk bungalow, there is nothing like the shape of any kind of moraine. In crossing them I saw no large angular blocks; no small angular stuff; no striated stones, great or small. I can see minute details of the great hill face opposite to me, and there is no smoothed gorge there which could possibly have been the bed of a large glacier. From ridge to base the gorges are angular furrows, between ridges of extraordinary sharpness and steepness, in which the minutest details are picked out in snow, and in shadow. I can only see two small smooth patches on which small glaciers of the second or third order may have rested high up. I am quite certain that the "Kangra erratics" are large "pebbles" washed out of the "Cads," by heavy floods. Stones larger than any that I have yet seen, are nearer to the mountains but they are all rounded. I can hear of no angular blocks, and I have seen none. What water may do in moving stones, is matter of observation and calculation. When a reservoir burst some years ago in England, the water swept away mills and machinery houses, and everything that stood in the way of the flood. I know many cases of extraordinary effects produced by unusual causes of this kind. The force of water depends upon the volume and velocity. Here the velocity must be extreme

for the fall is very rapid. The nearer to the hills the greater is the velocity The weight of a stone in water is less by the weight of water displaced. The rainfall at Dhurmsala is 102 inches yearly. From the position of this high ridge at the edge of the plains the rainfall must be exceptionally great. A warm rain falling on deep snow causes an exceptional flood. I know a case in which such a combination worked havoc in Scotland. I cannot measure the area of the basin which I see, but it is large. From its exceeding steepness the water which falls into it, must gather, and flow out of it suddenly and with extraordinary volume, velocity, and force. Water power here seems ample, to account for the moving of the unusually large blocks of stone, which have been called "erratics."

In Java is a volcanic cone 12000 feet high, named Pangerango. A cone is the worst form for collecting water power. Nevertheless at the foot of this cone a stream has dug a gorge, out of which it has shot stones as large as any which I have seen here. There is no question of glacial action in Java. A portion of an inverted hollow cone is good for collecting water power and here is a funnel nearly big enough to hold Pangerango inverted. My opinion is that the Kangra "moraines" are "Deltas" and the "erratics" pebbles of large size, proportioned to great water power. The largest are nearest to the parent rock.

14. I found some beds of rolled stones yesterday in a hard matrix, so old that the pebbles had decomposed. Granite crumbled to sand at a touch; quartzite and slates broke to angular fragments at a tap from a hammer. This bed forms part of one of these so called "moraines." I suspect that it will be found to form part of the "Sivaliks" undisturbed. The place is not far from Kangra, near a river, at a place where a cutting has been made for a road. If I am right in this the same conditions have endured here since the deposition of these coarse pebble beds, and there has been no "glacial period" here since then.

15. I am one of those who believe that rock basins, which hold or have held water, commonly are glacial marks. The absence of lakes from these regions is evidence against glacial action. It has been said that depression at the upper end of a river valley, or elevation at the lower end may account for lakes like those of the Italian Alps. Here, in the dip of the Sivaliks, is evidence of such a movement; but there are no lakes, and I have seen nothing like old lake bottoms any where in these mountains.

I am therefore confirmed in my opinion, that the Alpine lakes and Scandinavian fjords, and Scotch "lochs" are marks made by ancient glaciers of vast size, like those of Greenland. I have seen nothing that bears the smallest resemblance to any of these, the largest glacial marks that I know, here in the lower ranges of the Himalayas. What evidence there may be of the former extension of existing Himalayan glaciers, nearer to them, I

do not know from personal observation. But so far as I can learn from photographs, and from people who have travelled in these glacier regions, there is nothing near these glaciers to indicate any extension, that implies any great change in the local climate, any great elevation or a "glacial period," that affected the whole world.

Let me say in conclusion that this opinion founded on observation is contrary to my old opinion founded upon theory. I came prepared to find evidence of extensive glacial action here in Northern India about Lat. 30° 31′. I have found none.

No. 2.

THE KANGRA BIG STONES.

Bhagsu, November 24th, 1876.

16. MY DEAR SIR,—After sending you a paper from Kangra, in order to make sure of my ground I went to "Dhada" on the 22nd. It is otherwise named on the map, but that is the name now used here for a dâk bungalow eleven miles eastwards. I find that traditions regarding the big stones resemble traditions about like stones elsewhere. They are projectiles, about which mythical beings are concerned. One stone in particular is a "deota" fenced in with a square wall, painted, and adorned with flags and flowers. The large group in which it stands is said to be the site of a battle, between hill people and plain people, and these are their missiles. The holy stone was thrown down by Shiv, to a Rani who prayed to him. On that stone I found incised the "spectacle ornament" of Scotch antiquaries in a cartouche. It is on the west side. Some one has painted a pair of feet, to make this also a human figure and a deota. Something like the sun is painted red on the east side, and numerous devices on the south. Hanuman is on the north side of the next stone to the south. The people walk in procession sun-wise about this stone, and do puja to the pictures. I have seen nothing like this stone "deota" elsewhere. At Dhada is the mouth of a V gorge where the fall is about 12,000 feet in four horizontal miles, according to the map. It is a holy spot much used as a place for burning the dead, whose ashes are cast into the stream. It comes from a snow patch high up which is full of large stones. Close to the bridge I found a section of the "Big stone formation" and got to the solid rock surface under it, newly exposed, in a gravel pit. The stuff is sorted in layers of varying coarseness, from fine angular sand to the big stones. The bed rock is *not* glaciated. The thickness of the deposit may be 80 to 90 feet. Manifestly this is the apex of a Delta △, in the jaws of a V ravine, which has direct communication

with a snow patch full of big stones about 10,000 feet higher, and four or five miles distant. I am quite certain that no glacier, big enough to carry these stones, passed over the bed rock, whose surface is well preserved; below the dâk bunglow at Dhada and under the stuff.

17. *Yesterday, 23rd.*—I crossed the big stone deposit close to the foot of the mountains, about four miles from the ridge, and 12,000 feet below the crest. I walked eleven miles carefully examining surfaces on stones of all sorts and sizes. I could not find one striated stone on the whole march. I found that granite pebbles as large as corn stacks abound, opposite to the longer and larger gorges which come from the snowy crest, and have the greatest fall. I found none of the kind or shape between these longer gorges, in the jaws of ravines which begin in nearer hill tops. These being slaty, send down slates of sorts, and the ground is covered with flat stones. I conclude that the ground which slopes from these hills to Kangra, is covered by a compound delta, arranged by water flowing from the whole series of streams which I crossed in walking eleven miles yesterday. I was unable to find any trace of glacial action at ten to fifteen miles from the base, or at the very base of the hills in this district.

18. From here I have made a careful drawing of one of three or four high patches on which small glaciers may have rested. New snow makes them conspicuous from a distance. The rocks below them are smoother than elsewhere, and large stones rest on the rocks. These piles of stone have the look of terminal moraines in the snow. They end at about 14,000 feet above the sea-level, or 10,000 above this lower slope. I suppose that small glaciers once lay on these shelves, and that the climate has altered so as to destroy them. Far lower down I have seen hereabouts old snow resting in rock "gulches." In the Alps such places are "couloirs" and "chimneys." As a case to illustrate the effect of such conditions; I was hunting chamois many years ago in Switzerland, opposite to the Shreckhorn, and came to one of these steep narrow snow slopes. My guide told me to hurry over it. I was scarce landed on the rocks when a mass of big stones rolled and bounded past, with great and increasing velocity. Thin slaty stones had got on edge, and whirled past like flying wheels. They came from a small glacier like those of which I seem to see the beds on these Kangra hills; and they never stopped till they got to a large glacier, nine miles wide and twelve to fourteen miles long, which was some thousands of feet below us, in a valley.

That glacier was slowly carrying masses of fallen stones towards the Grimsel. Thence down to Interlaken all marks of enormous glaciation abound. A hot sun started the stone avalanche, by melting ice which supported the stones, on a small terminus moraine. This Kangra ridge is somewhat like the Shreckhorn at the top, and stone avalanches must

often roll down on hard snow packed in narrow gulches. I notice that many of the largest stones have something like the shape of mill stones, and rest on a flat side. I think it possible that men may have seen the arrival of some of them, and that tradition ascribes their speed to "Shiv." I ascribe it to gravitation.

19. In the Alps and in Scandinavia I have seen many snow avalanches fall from steep hills, like those which I see from this house. If many square miles of a hill face, were swept of snow by a slide, like the roof of a house in a thaw, the snow avalanche here would certainly block up a deep water-course, form a "bund," and accumulate water power. In this hot sunny region a snow dam could not last. I am told by natives that big lumps of hard snow are washed down to my road of yesterday. Ice dams have formed and burst in the Alps within human memory, and the result in the transport of rubbish was enormous. Not long ago an earthquake and heavy rains sent down from Mount Ararat a mass of snow, ice, mud, and debris, which flowed for twelve miles along a valley of less slope than the Kangra slopes below me, and carried enormous blocks of stone as far as they have been carried here. The great ridge above me has much snow on it, and may have had small glaciers high up, though no large glaciers have left marks on the hills. . Causes like those which I have here indicated fully account for this big stone formation. Some probably rolled down upon snow slopes, in gulches, and rolled on over the slopes of deltas. Others may have been rolled down on the bursting of snow "bunds," and may have been washed down normal slopes of gravel and sand by abnormal floods. A thunderstorm, or an earthquake may have helped in a region where the rainfall is said to be 102 inches, and where it may have been as great as it is elsewhere. A combination of such causes at long intervals, accounts for groups of large stones which I find here and there. Being exceptionally large and numerous, these seem to require exceptional conditions.

In any case I am quite certain that there is nothing on the ground which I have crossed to indicate the former presence of large glaciers on the Kangra slopes; either at 12 to 15 miles from the base of the high ridge, or at the base of it, or in the jaws of ravines which come from the crest of it, at Dhada, and elsewhere on my road thence to Bhagsu.

20. One of my objects in coming to India was to see for myself whether I could discover any trace of the "*Ice cap.*" Theoretically, during a glacial period, a crust of ice ten thousand feet thick came from the north pole, and went to the equator. If it did it came down the Himalayan slopes. I have now seen in India enough of jagged sierras, and of ravines of enormous depth and sharpness, of which many run from east to west, to convince me that no ice cap has crossed this region from north to south

about Lat 31° 2′. It is impossible that an ice cap can have passed from Thibet, since these gorges began to be eroded. Some are three miles deep, so they must be very old. Forms which exist in the Himalayas prove the ice cap to be impossible. There is absolutely nothing here on which to found a "Glacial period," which produced an "Ice cap." There is no evidence, even of any great extension of local glaciers here. All the change that I can trace is the possible existence here, of small glaciers perched high up, near the crest, where snow now rests. That change of climate may have been the result of something like the atmospheric conditions which make the Sind rainfall about a fiftieth part of the rainfall here; and make the rainfall elsewhere about six times as great.

I am greatly obliged to you for advising me to come here. My object is attained and very pleasantly.

Calcutta, February 14th, 1877.—Had I been present at the reading of this paper, I suppose that the author's right to the last word would have been mine. I have been to Darjiling; to a fourth hill station; and I have now gained some knowledge of points in Cashmir and Bhutan fifteen meridian degrees apart. I have seen a considerable part of Ceylon, and the low country between Bombay and Lahore and along the Oudh and Rohilcund railway, opposite to Nepal. I have had the advantage of reading Hooker's journal, and Mr. Blanford's, within sight of their ground, and I have the benefit of Mr. Medlicott's criticism. I have also read papers by Major Godwin-Austen and Mr. Belt. I see no reason to alter my opinion about the Kangra "big stones." I have seen many as big, in water-courses near Kursiong and Darjiling, left by streams which made the furrows and quarried the stones. The usual water-power is not sufficient to roll these big stones, because the gathering ground above them is too small in area and too low. But given a landslip, sufficient to gather a head of water, and the furrow would be swept by a flood when the dam burst. Numerous landslips of enormous size are visible from Darjiling; but the rivers Rungeet and Teesta have swept their beds clear of all obstructions. At some places very large rolled stones are left in these water-courses. But there are no deposits in the Indian plains comparable to the glacial deposits near Turin, in the Italian plains.

The burden of proof rests upon those who hold to improbabilities, and require conditions different from those which exist. So far as my facts go, they prove that Himalayan glaciers have never extended far from the regions in which glaciers now exist. These hang about the edges of great river basins, below very high gathering grounds of large area, which condense the warm damp atmosphere of the plains, and of the Southern Ocean. I have found nothing in India to prove that these conditions have altered materially since the Himalayas grew to be mountains.

II.—*Note on the preceding paper.*—*By* H. B. MEDLICOTT, ESQ., *Superintendent of the Geological Survey of India.*

(Received Jan. 15;—Read Jan. 17th, 1877.)

Mr. Campbell has kindly permitted me to add a few words to his communication, to bring out a small residuum of difference that remains between us upon the question of a former greater extension of ice action in the Himalayas. On the wider question of the Ice Cap, I would only say that I have not understood that speculation as dispensing with local centres of accumulation and dispersion, as requiring the polar ice to have poured over the Himalayas. On the smaller question too, Mr. Campbell has taken up the comparatively easy task of confuting the most extreme opinion. Although there is no mention of names, it is plain that the paper just read is a refutation of Mr. Theobald's Ancient Glaciers of the Kangra District, with a copy of which I had lured Mr. Campbell into visiting that region. I had thought indeed that I had myself said all that was called for in answer to Mr. Theobald, by pointing out that his so called moraines were only ridges of erosion out of a diluvial deposit that must once have filled the whole valley (Rec. Geol. Survey, Vol. IX, p. 56); Mr. Campbell has, however, saved us any further trouble on that score by rehearsing all the well-known signs and tokens that must be left by a heavy glacier, and finding them wanting. In this he has entirely confirmed my own observations.

I was the first (fourteen years ago, Mem. Geol. Survey, Vol. III, p. 155) to bring to notice the big stones of the Kangra valley as probably due to ice. I would beg leave to quote the few words I gave to the subject:

"The most interesting of these deposits is that in which large erratic blocks occur so abundantly along the base of the Dhaoladhar. It first shows itself on the east, about Haurbaug, and is nowhere more strikingly seen than along the steep inner slopes of the duns east of Dhurmsala, where the huge blocks are thickly scattered over the surface. In viewing this deposit as the result of glacial action, I base my opinion chiefly upon the size of the blocks (I measured one twenty-five feet by eighteen, by ten) and upon some peculiarities of distribution. An eye more practised than mine in glacial phenomena might detect more direct evidence, but it certainly is not well-marked, and it is easy to account for the subsequent removal of all such traces of glacial action in such a position as this. The blocks occur at a present elevation so low as 3,000 feet above the sea-level, and they are found through fully a thousand feet in height. They are almost exclusively composed of the granitoid gneiss of the central mass of the Dhaoladhar, from which their area of distribution is separated by a

lofty ridge of schists, through deep gorges in which they have evidently been conveyed, a huge block being occasionally found perched on the sides of these gorges, some hundred feet above the present level of the stream; yet in such places I failed to observe any groovings or roundings of the rocky sides. The absence of evidence of this kind may, perhaps, be attributed to the rapidly disintegrating action of the heavy rains. I was many times puzzled to account for the positions in which these erratic blocks occur. They are frequently found on the slopes of the range out of the way of any of these main gorges, and even up the little receding valleys of streams, which only drain the outer hills, and down which the blocks could not have come. Must we superadd the agency of floating ice? The total absence of erratic blocks in other positions is often equally puzzling. The position of this glacial deposit more to the west, in the confined and elevated longitudinal valleys between Sihunta and Choari, impresses one more forcibly with the antiquity of its orgin; it there lies in gaps and on ledges a full thousand feet over the deep drainage gullies close by."

Thus I adopted the opinion while declaring the absence of the usual scorings, and trusting to the facts of great size and peculiar distribution. The first step was an appeal against negative evidence, based upon the possible obliteration of superficial markings, by weathering and attrition, and upon the fact that although it is quite true that *a large glacier* must score its bed and the stones that lie thereon, transport by ice occurs largely without any such marks being made. We have recently had in India, and in this very connection of ice-action, a striking illustration of the unworthiness of such negative evidence. In 1856, Mr. W. T. Blanford declared his conviction that the Talchir boulder-bed was of glacial origin. Every year subsequently one or more of the officers of the Geological Survey were engaged upon these rocks in various parts of India, and looking out for evidence for or against this judgment, yet it was not till 1872 that Mr. Fedden had the fortune to find a most complete case of striated and polished Talchir boulders resting on a scored rock-surface. There are good specimens of these scratched boulders now in the Indian Museum. I have placed a small one on the table for inspection. In the case of the Kangra boulders, any possible glaciers in the Dhaoladhar must have been short, and have had a very rapid discharge; and consequently were of inconsiderable thickness, conditions which would reduce the scoring action to a minimum.

As to direct evidence, the matter of size of the blocks is of course conditional. On an appropriate slope masses of any dimensions may be moved with very little effort. If these Kangra big stones are, as Mr. Campbell contends, solely torrential deposits from the mountain gorges, we have only to work that simple condition so as to account for them wherever found. It is here that a slight discrepancy occurs between Mr.

Campbell's observations and mine. He describes having taken a walk of eleven miles, and found no big stones in some minor gorges draining only from the outer ridges. Relying on this single observation, and perhaps also upon the privilege he claims as a non-professional geologist, Mr. Campbell eliminates and ignores what I have from the first said to be the chief argument for glacial action, that large blocks of the gneiss from the central ridge do frequently occur away from the gorges leading from that ridge, in minor valleys draining only from the outer ridge, where it is most difficult to suppose they can have been placed in the manner he supposes. It was to account for the position of these blocks that I had to imagine their transport on ice-rafts. Instead, however, of insisting on this crucial point, which Mr. Campbell ignores or denies, I am prepared to suggest how it may be compatible with the view he adopts. The fact that coarse diluvial deposits, not derivable from the Sivaliks, are found high over Kangra fort, on the hills south of the valley, makes it certain that the whole valley was once filled with like deposits, which must have reached high along the base and far up the gorges of the Dhaoladhar. It may be that under such conditions the diluvial spill from the gorges was high enough to mantle round and over spurs and to fill little valleys that are now totally cut off from those gorges.

It would be impossible to estimate the plausibility of this supposition without testing it on the ground in view of actual features. At the same time I think that Mr. Campbell can only make out a Scotch verdict of 'not proven' for the ice, as deeply implicated in the transport of these big stones. I cannot bring myself to doubt the evidence that has been given for the former extension of the great Himalaya glaciers to 4,000 feet lower than they at present attain to, as observed by Dr. Hooker, and by Mr. W. T. Blanford in Sikkim. At that time ice-agency must have been very active on the Dhaoladhar. If at present, as Mr. Campbell testifies, lumps of ice are brought by the torrents to the mouth of the gorges, the lumps of those days were probably large enough to pick up the big stones in their way. I would further suggest for Mr. Campbell's consideration, that so far as we can at present estimate it, the age of these high-level gravels along the base of the Himalayas, and to which the Kangra deposits belong, seems to be closely coincident with that of the Ice-Age of the western continents. An increase of glacial conditions in the Alps, corresponding to that proved for the Himalayas in Sikkim, would probably bring the ice down to Interlaken, if not to Neufchatel.

I would conclude these few remarks with the hope that among the many settlers in the Kangra valley, there may be some members of this Society who will study the ground they live upon with some other purpose besides the cultivation of tea.