Some places on the islands are shunned by the natives, who prefer walking a long distance out of their direct way to being obliged to pass the haunted spot, where his imaginary Satan, and bad followers, are supposed to hold their meetings by night or day.

I have already stated that the whole surface of these islands is covered with vegetation. There is, in fact, not the smallest patch of land bare of trees. Gigantic creepers climb up the trunks, and after having attained a certain height, spring from tree to tree, and intertwine the whole in a close network. Here and there are to be seen on the tree trunks grand orchids of different species, some of them bearing magnificent blossoms, and splendidly coloured butterflies chase each other amongst the thick foliage. Birds, too, are numerous, and many of them of lovely plumage.

In the thick mangrove bushes of the bays a species of crocodile is found. He is often seen lying, apparently asleep, with open mouth, or on watch, perched on a fallen tree, unperceived by the passer-by, yet at all times ready for action. Above him in the trees lurks the flying squirrel, enjoying a cool draught from a stolen coco-nut, while a small-sized tree-kangaroo and bear are seen enjoying sport, each in its own peculiar way.

With regard to domestic animals, the natives only rear fowls and goats, though some of the Hindu inhabitants raise pigs, which keep to their respective villages and remain quite tame, enjoying sport with the cats and dogs, so plentiful in the Key Islands.

A Note on the Conservative Action of Glaciers.

By Douglas W. Freshfield, sec. r.g.s.

To estimate the past performances of the forces that have modelled the surface of our planet by the amount of action of which we find them capable in its present condition would be, no doubt, an elementary blunder scarcely possible to any one in the least acquainted with the progress of geology. Yet we can hardly be wrong in believing that the present action of natural agents will be similar in kind, if not in extent, to that which they have exerted in previous ages of the world's history. If running water failed to excavate rock, if no contemporary river materially deepened a ravine or enlarged a delta, we should, probably, feel compelled to look elsewhere for the origin of ravines and deltas.

A heroic part in the architecture of the earth's surface has been attributed to glaciers by high scientific authorities. Dr. Tyndall has recorded, and repeated in a popular form,* his own conviction that the "paramount influence" in the sculpture of the Alps has been that of ice, though he frankly adds, "whether the conclusion fairly follows from the facts is, I confess, an open question." This confession must be my excuse for venturing to argue in opposition to one so eminent both as a man of science and as a mountaineer. Again, Sir Andrew Ramsay, while refusing altogether

* 'Philosophical Magazine,' 1862 and 1864. 'Hours of Exercise in the Alps,' 1871.

to accept Dr. Tyndall's hypothesis, has repeatedly put forward another hardly less remarkable one of his own with regard to the powers of ice. He summarises, as follows, his own belief*:—"The chief part of the lakes of our country, I do not say all, have been formed under the influence of ice, and not of our country alone, but of a large part of the northern, and I have no doubt also of the southern hemisphere. It is a remarkable thing to consider, if true—and I firmly believe it to be true—that so many of those hollows in which lakes lie have been scooped out by the slow and long continued passage of great sheets of glacier ice."

How far do the facts brought constantly under the eyes of mountaineers bear out the conclusions of these two eminent physicists? The question has been asked and answered over and over again,† by no one better, perhaps, than by Sir Roderick Murchison in the President's address to our Society in 1864. Among geologists the answers already given may be thought more than adequate, and an attempt to add to them may, perhaps, seem superfluous. But the general public, and in particular those engaged in teaching, are, I know by personal experience, still impressed by the authority of great names, and by the persistent enforcement in text-books, both English and American, of views that have never obtained general acceptance among the most competent judges. It seems, therefore, desirable once more to discuss the character of glacier action with the advantage of the recent observations made by surveyors in the New World.

I shall assume that the behaviour of living glaciers is very much to the point in the consideration of the kind of work done by their extinct predecessors. It must be so—unless indeed it is argued that contemporary glaciers are too feeble, have not, that is, the weight and velocity needful to burrow and bore, dig holes or trenches, basins or valleys. Now, for the last twenty-five years I have had constant opportunities of observing glaciers at work in the Alps and elsewhere. The period has been one of rapid retreat of the ice following on one of advance,‡ and it has therefore been peculiarly favourable for determining the action of the lower portion, or snout, of a great glacier.

Let us look at the former beds of some of the swiftest and thickest glaciers of the Alps—the Brenva, the Bossons, the Lower Grindelwald. What have they left behind them in the valleys they occupied thirty years ago? Not hollows, but hummocks. Examine the glaciers of Shkara and Adish in Suanetia. The former has in recent times retreated quite a mile. The extreme terminal moraine has been washed away, but four or five huge blocks, lying in a curve, mark its former position, and behind them the old bed of the ice is an uneven wilderness of rubbish heaps and shallow pools formed by the damming-up of springs. There is, in fact, an exact reproduction on a small scale of the features found over vast areas within the lines of the great moraines of the Eastern States of North America.§ But I need hardly

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* 'Physical Geology and Geography of Great Britain,' 1878, p. 616. See p. 454 for further references to the literature on one side of the subject.

† See 'Geo. Proc.,' vol. viii. old series; 'Phil. Mag.,' 1863, article by J. Ball, F.R.S.; 'Geological Journal,' 1871, 1873, 1874, and 'Geol. Magazine,' 1876 and 1887, articles by Prof. Bonney, F.R.S., Mr. Marr, and Prof. Spencer; 'Scrambles in the Alps,' 1871, by E. Whymper; 'Arrows of the Chase,' vol. i., by J. Ruskin; two instructive papers by Rev. A. Irving in the 'Geological Journal' for 1883; Address by W. Mathews, 'Proceedings of the Birmingham Philosophical Society,' vol. iv. part 1. Mr. E. Whymper gives references which will enable readers to follow up the controversy.

‡ See the very careful discussions in 'Scrambles in the Alps.'

§ This period of general retreat has terminated in the Alps. During the last five years the glaciers with short steep courses, such as the Bossons and the Upper Grindelwald,

multiply Alpine examples, which so many readers can supply for themselves. Burnishing I have found glaciers often, scraping or pushing back soft protuberances in their path sometimes, but scooping or excavating, never. Nor, I fancy, have my friends Professor Bonney, Mr. John Ball, Mr. E. Whymper, Mr. W. Mathews, or Mr. Nichols, been more fortunate.

Similar testimony comes to us from distant quarters of the globe. I quoted recently at one of the Society's meetings (vol. ix. p. 283) a remarkable description of an Alaskan glacier, showing how the ice had moved over without disturbing a soft bed.* To the 'Geological Magazine' for 1887 Mr. Marr and Professor Spencer contribute articles on the glaciers of Greenland and Norway, the general result of which is adverse to the supposed powers of glaciers as destructive agents.†

If we glance for a moment—and space allows no more—at the work of Transatlantic Surveyors, we shall find in Reports, which are models of clearness, and are illustrated and mapped in a manner which enables readers to appreciate for themselves many of the facts as well as of the arguments set out by their authors,‡ a mass of evidence which places it to my mind beyond doubt that the huge ice-sheets of the second glacial epoch, equally with those of our own time, advanced over soft gravelly bottoms without disturbing the surface, and were ready when needful to

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have begun to advance in a very notable manner. The Norwegian glaciers are advancing. Count H. Russell informs me that the Pyrenean névés are rising, so that the caves he had excavated near the summit of the Vignemale risk being buried shortly. The Adish glacier in Suanetia is also advancing, and so are others in the Caucasus. It would seem certain that the movements of the ice are more or less sympathetic throughout the Old World. (See M. Forel's articles in the 'Jahrbücher' of the Swiss Alpine Club.)

* As soon as arrangements are made—and there can be little doubt that American enterprise will shortly make them—for steamers to call during the summer occasionally at Yakutat, two days' steam beyond Sitka, the Pacific flanks of the mountain ranges on the frontiers of Alaska and British North America will be the most accessible spot on the globe for the study of glacial phenomena on the largest scale. Mr. Seton Karr writes ('Alpine Journal,' No. 102, p. 167), "The world offers no similar field for the study of Brobdingnagian glacial phenomena. The whole glacial system forms a province of ice measuring hundreds of miles in length and thousands of square miles in extent . . . and this in a latitude lower than that of the Shetland Islands."

† I must guard myself, however, against being supposed to accept entirely the statements and conclusions of these writers. Prof. Spencer, in particular, seems to me to have confined his attention almost entirely to the snouts of glaciers, and to go much too far in depreciating the powers of the ice.

‡ These American illustrations are in striking contrast to the obsolete old woodcuts and inaccurate caricatures which are still passed off on the English student as representations of mountain phenomena in text-books written by the best authors, and issued by the first publishers. *Corruptio optimi pessima*: and I cite therefore, without respect of persons: Huxley's 'Physiography' (Macmillan & Co., 1885), plate 39, where a moraine is represented by stone-heaps discharged at regular intervals, as if from a road contractor's cart; Geikie's 'Text-book of Geology' (Macmillan & Co., 1885), plates 140, 142; Helmholtz's 'Popular Scientific Lectures' (Longmans & Co., 1873), plates 13, 16, 20; and Miss A. Buckley's 'Fairyland of Science' (Stanford, 1881), plate 29. Some of the cuts referred to are derived from the works of the early Swiss glacier explorers, *circa* 1849! The progress of photography and photographic processes has now made bad illustrations inexcusable, even in the cheapest publications; and for those who can afford first-class wood engraving, Mr. E. Whymper long ago showed how accurately and artistically mountain features may be reproduced.

accumulate behind and overflow solid obstacles rather than to level their road by their removal.*

I must find space for one or two typical quotations from the Pennsylvania Report :—"The occurrence of lakes is one of the most characteristic features of the glaciated area of the United States. A hundred thousand exist back of the terminal moraine and almost none in front of it. They were at first ascribed to the eroding force of the ice, under the supposition that they were scooped out in the solid rock, but facts suffice to indicate that their origin is due to filling up rather than to scooping out—to obstruction rather than to removal."—p. 29.

"That the erosive power of the glacier was slight along its northern edge is shown in the uniform character of the topography, both of mountains and valleys, in the glaciated and non-glaciated regions. The straight narrow edge of the Kittatinny Mountain extends from the Delaware to the Lehigh with no apparent difference in appearance or in elevation, while the Delaware Gap and the Lehigh Gap are closely similar in shape. Yet the glacier crossed the mountain and gap with scarcely an appreciable effect upon their topography.

"There is no proof that the glacier scraped off as much as 100 feet from the top of the mountain. Cliffs 70 feet high in front of the moraine upon the Kittatinny Mountain may serve as a measure of the amount of erosion. Evidence both of the thickness of the glacier and its great impetus, however given, is afforded by the fact that it flowed upwards and across the sharp ridge of the Kittatinny Mountain, although close to its extreme southern terminus."—pp. 90–1.

Again we may turn curiously to Dr. Von Haast,† a hostile witness, cited by Sir Andrew Ramsay, with legitimate satisfaction, as a convert to his views. How strangely inconsistent with such a conversion do many of Von Haast's own observations appear! We read of lakes surrounded by moraine accumulations, of huge glaciers moving forwards without disturbance to their beds. A valley on the west coast of New Zealand is described, "where the glaciers advanced over a deposit of such apparently incoherent nature as a gravel bed without destroying it to any appreciable extent." At another spot, "the peculiar conditions of an assembly of beds go far to prove that glaciers, when advancing again after their retreat, do not always clear out their former channels of moraine deposits accumulated therein; and that even under favourable circumstances the finest gravel will, when protected by moraines of comparatively inconsiderable thickness, be so thoroughly protected that no change in its stratification can take place." And again, "Lake K, like nearly every other lake on both slopes of the Southern Alps, is surrounded at its lower end by a broad circumvallation of moraines." This general statement is fully borne out by the geological map appended to Dr. von Haast's volume.‡

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* See, *inter alia*, Reports of United States Geological Surveys for 1881–2 and 1883–4 Preliminary Report on the terminal moraine of the second glacial epoch, by J. C. Chamberlin, and 'Existing Glaciers of the United States,' by C. Russell. [The lake shown (plate lii.) in this report is referred to by Mr. Eccles ('Alp. Journal,' vol. ix.), who was of the party, as formed by glacial excavation. The plate suggests rather that it may be the result of moraine rings.] Geological Survey of Pennsylvania, Report 2; Terminal Moraines, 1884. See also the Reports dealing with Alaska.

† See 'Geology of Canterbury and Westland,' pp. 385, 390–1, 396 and 223.

‡ Valuable facts may be found in two articles, Dr. Albert Penck's "Das Land Berchtesgaden," and Dr. A. Geisbach's "Die Südbairischen und Nordtirolischen Seen," 'Zeitschrift des Deutschen und Œstn. Alpenvereins,' vol. xvi., Salzburg, 1885: acts the more valuable because both writers are themselves inclined to believe in a glacial origin for at least some of the lakes described.

The behaviour of the lower extremities of glaciers is not, however, conclusive evidence against the formation of lake-basins by ice. It has been argued that glacier-snouts never could excavate; that it is where the ice is both thickest and swiftest, below the base of some upper icefall, that we should look for traces of such action. It is true this is not the line taken by the champion of the erosion of lakebeds by ice. Sir Andrew Ramsay rests mainly on weight, and believes that sluggish thick ice will exert most erosive power. But a scientific ally has differed from him on this point. Dr. Tyndall says, in effect,—"It is quite wrong to suppose that it is the snout of the glacier that ploughs; where the weight, and consequently (other things being equal) the motion is greatest the scooping power will be greatest. I say nothing about lake-basins: but it is a physical certainty that, given time enough, glaciers must scoop out valleys. A glacier with a thickness of 1000 feet will press on every square yard of its bed with a weight of 486,000 pounds. Such weight with a motion derived from a pressure from behind *must* excavate." *

I cannot speak with any personal authority on questions of physics. But while it is, I believe, certain that an increase of thickness, and consequently increased weight, will (other things being equal) increase the velocity of the upper surface of a glacier, it is not so obvious that increased weight will increase the velocity of the lower surface, which, owing to the tendency of the layers of ice to slide over one another, or shear, and to retardation consequent on friction, is generally only a small fraction of the velocity of the upper surface. But it is nevertheless true that increased thickness and weight will be accompanied by a proportionate increase of erosive power, and we may feel, I think, confidence that we are carrying on our investigation fairly if we look for the most conspicuous results in places where not only must the mass of the ice have been greatest, but also its lower surface swiftest —in short, in the sort of places in which we should expect to find running water most efficient as an excavator.

Now it is quite clear that the lake-basin generally selected as an example of glacial excavation by the advocates of this theory, Geneva, is not in such a position. The ice covering it must have been more sluggish and (owing to the well-proved tendency of glaciers to spread out fanwise when they have space to do so) less deep while it was excavating—I accept for the moment the glacial hypothesis—than in the gorge of St. Maurice, where no lake has been created. It would seem, therefore, that the bed of the Lake of Geneva can hardly have been excavated by glacier ice.

The conclusion that ice does not scoop out basins may be supported by other weighty arguments. Where on the sides of a glacier the ice has impinged against a rock surface it leaves convex, not concave, surfaces. That is, it spends its force on rubbing down projections, and does not scoop out hollows. Why should the under surface act differently? Again, some Alpine lake-basins—Lago di Lugano, for instance—do not lie in the natural tracks of glaciers. Mountain tarns are distributed not according to glacial extension but to geological formation. In the Alps they are found in far the greatest numbers among the crystalline rocks of the Maritime Alps, Canton Ticino, and the Adamello group. Again, if the presence of lake-basins involve the former existence of glaciers, the former existence of glaciers ought surely to involve the presence of lake-basins. The absence of lake-basins in ranges once extensively glaciated must be, at least, a serious objection—hardly to be met by the hypothesis that they have been, without exception, silted up—to the theory of their origin we are discussing.

My present business is not to supply a theory of the origin of lake basins, but only to assist in refuting the hypothesis which regards the majority of them as

* 'Hours of Exercise in the Alps,' pp. 238, 247.

created by glacial erosion. Such basins are, I believe, the result of many and very various causes. There were great lakes in Switzerland before the Glacial period.* Basins are common to all kinds of formations.† Many are submarine. Some lie in geological faults.‡ Others, including possibly Geneva, may result from the subsidence of the upper portion, or the elevation of the lower portion, of an ancient valley causing a part of it to be subject to perennial inundation. It would be wonderful indeed if the undulations in the earth's surface had been so ordered that there were no hollows or basins without natural vents, if lake-beds, or the greater part of them, had required to be scooped out by a special tool. Many, no doubt, though not scooped out, have been endyked by glaciers. In the simplest form this is effected by the ice moving across a valley and obstructing the stream, as at Mattmark and in the Allée Blanche. Or a retreating glacier may leave behind it a moraine compact enough to hold in a river or to dam local springs, as in some of the lakes of New Zealand (described by Von Haast) and those of North America.

There is another way, to which attention was called years ago by Dr. Falconer,§ in which ice may assist in creating lake-basins. The tendency of a glacier when its course is nearly level is to raise rather than excavate its bed; but where a great trunk glacier occupies a valley or depression, it will raise the ground under it less quickly than it would, if not under ice protection, be raised by the alluvial deposits and earth-slips derived from the impending slopes. The hollow the glacier finds it will keep comparatively empty. The moraines will serve as dykes to divert the alluvial deposits of lateral torrents. The ice itself will act as a gigantic sledge, and carry down the rock-falls to build a terminal moraine. The basin or bed of the glacier, when uncovered, will differ from an unprotected valley, in being more uniform and U-shaped, without fan-like alluvial slopes or banks of talus.

Let us recapitulate. It is clear that neither the glaciers of the present day nor those of the last glacial epoch can or could on the level delve *with their snouts* even into an "incoherent shingle bed." If they scooped anywhere, it must have been where the body of the ice attained its greatest weight and velocity. Most of the great lake-basins, however, are found under the snouts of the ancient glaciers, where the ice had neither its greatest weight nor its greatest velocity. There are, on the other hand, few important lake-beds under steep slopes, where we might expect to find them. Some lakes are in positions which appear to exclude a glacial origin for their beds. Many glaciated chains have few or no lakes. Lakes and tarns are in many parts of the world distributed quite irrespectively of ancient glacial extension. There are no subalpine lakes in the South-western Alps, the Caucasus, or the Pyrenees.

With regard to any general connection between glaciers and the excavation of lake-basins I have become profoundly incredulous. But it is always well not to allow oneself to be drawn too far in the opposite direction by the enthusiasm of investigators eager to simplify the complex processes of nature in favour of some one they may have for the moment taken under their special patronage. It appears physically possible, and even probable, that glaciers—(particularly glaciers the velocity of which at all approaches the measurements said to have been obtained of the motion of the Jakobshavn Glacier in Greenland, 49 to 73 feet, or of another glacier on the western coast 99 feet ‖ per diem on the surface)—might, where the angle of their bed changed

* Ramsay's 'Physical Geology and Geography of Great Britain,' p. 268.

† Ibid., p. 298.

‡ See Reports of the Geological Survey of the U.S. for 1882–3.

§ 'Proc. R.G.S.,' o.s., vol. viii.

‖ Heim, 'Handbuch der Gletscherkunde,' p. 145, 'Nature,' vol. xxvii. p. 200. Dr. Rink, "Das Binneneis Grönlands," 'Zt. der Gesellschaft f. Erdkunde zu Berlin,' No. 137,

from a steep slope to a level, exert a very perceptible scooping or burrowing force at the angle. I do not remember having noticed any instance of such action among contemporary glaciers, but I should not be at all surprised to come upon one clearing out, or even scooping, something like a basin in such a situation.

Having ventured so far, I can hardly avoid expressing an opinion on the separate, but not quite so simple, question of the action of glacier ice in valley excavation. In science, as Sir Andrew Ramsay complains, as much as in politics, and with less excuse, misrepresentation of an opponent's standpoint frequently takes the place of argument. Let me say at once, therefore, that I am not so blind as to deny the power of the ice-stream, armed with its "gravers," the rocks and grit it holds in its grasp, to grind, smooth, scrape, scratch, and polish within certain limits any protuberances it may encounter. Given eternity, I would admit even that it might excavate valleys; that is if it could find any ranges the exposed portions of which would not sink from sub-aerial denudation faster than the "gravers" bored. But geologists work in time—though they sometimes make free with it!

I believe that a careful inspection of mountain valleys shows conclusively the very limited extent of ice action as a quarrier or excavator. And I would urge all who consider water, as compared with ice, "the weaker agent," to measure their respective performances at Grindelwald and Rosenlaui, where between the superficially ice-abraded rocks the torrent has carved for itself a bed hundreds of feet deep.

It would be tedious to recapitulate in detail arguments often urged elsewhere to show that Alpine valleys do not owe their origin or their general outlines to glaciers. And it is the less needful, as here we have our late adversary with us. What can be more explicit than Sir Andrew Ramsay's statement on this point?* "The great original valleys of the Welsh mountains were by no means scooped out, but merely modified by the glaciers." And again, "One great fact which the striations teach is this, that the broad and thick ice-sheet urged onward from the north, buried the whole of the region described; and further that the glacier, *moulding itself to the slope of the country* † (after the manner of all glaciers), was pressed right onward with so much force that the long northern slopes of the east and west valleys offered, comparatively, no more impediment to its onward march than an occasional transverse bar of rock hinders the onward flow of a river." ‡

To these far-reaching admissions I should like to add on my own account one argument or suggestion. Surely, if the Alpine valleys had been eroded by ice, those which must from a very early stage in valley formation have carried off the drainage of the largest snowy basins, those, that is, which have for ages contained the most powerful glaciers, should be the deepest. Take a familiar region: the Bernese Oberland. We find that the contrary is the case. The Aletsch Glacier lies in a trough

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gives 50 feet in 24 hours as the average motion of the central surface of the great Greenland glaciers. The highest velocity recorded in the Alps is 32 feet a day. This was reached by the Vernagt Glacier in the Œtzthaler Ferner for a few days only in 1845.

* 'Physical Geology and Geography of Great Britain,' 5th edition, 1878.

† The italics are in the original.

‡ It is true we read elsewhere (p. 384), "the whole of the regions mentioned have literally been moulded by ice" where the rôles of the ice and the land seem inverted. It is presumptuous, perhaps, in me to offer an explanation of the apparent contradiction, but I believe the difficulty lies in the use of an identical word, *moulded*, with different significations. In the first passage Sir Andrew Ramsay may refer to large outlines, in the second to small details. He may mean that the contour of the land is impressed on the ice, but the surface details of the land are modified by the ice. The contradiction apparently involved in the supposition that this mouldable substance 'originated by scooping most of the lake scenery of our country,' p. 353, I cannot pretend to explain.

higher than that of the Viesch Glacier; the Grindelwald Valley is shallow compared to that of Lauterbrunnen. Or take mountain groups. Why, if ice made the valleys, did the Tödi ice and the Bernina ice act so disproportionately? Why was the Ober Engadin left as so insignificant a depression? And one can hardly refrain from repeating to the supporters of either form of glacial erosion the often asked question: How can you expect it to be believed that a tool which made the enormous excavations of the Lake of Geneva, or of the valley of the Rhone, broke down before such an impediment as the crags of Sion? Are you honestly satisfied with the answer that they owe their survival to exceptional toughness? Have you any adequate proof of such toughness, at Sion, or at Arco, or at Bellinzona?

I have read with attention the summary * of the arguments recently (1883) used by speakers who ought to have been able to do justice to the case for glacial excavation. I can find nothing to shake for a moment my conclusion—little even calling for answer. Colonel Godwin-Austen states that Himalayan glaciers push before them soil. No wise person would dispute it: so did the Gorner Glacier; if the glacier had not the power of moving loose obstructions it could not even push forward its own moraine. Unless the Himalayan glaciers excavate solid rock or scoop out basins in flat soil, the facts stated are outside my argument. Mr. Blanford calls attention to what he conceives the *à priori* argument from the supposed fact "that lakes abound where ice has been, and are wanting or rare where ice has not been." I retort, with Sir Charles Lyell, "The Caucasus has no lakes." I traverse the general statement, and I allege that in so far as it has any foundation, other causes than glacial excavation exist to account for the basins. Professor Seeley urges a common and specious objection—founded to a certain extent, perhaps, on the indiscretions of my allies—that it is obvious that glaciers exercise erosive action, and that time, therefore, is all that is needed to have enabled them to do all the work that they have been credited with. I reply that the actions of rubbing down solid rock or pushing forward loose material, and of excavating or scooping have little in common, that it is traces of the former that we observe in the past and the present, and that to allege such traces as evidence of the latter, to confound abrasion and erosion, is illogical and illegitimate.

The conclusions I am drawn towards are of a very different nature from those lately popular in this country. I will endeavour to state them shortly and simply. The glacier I should say—adopting a terse expression from Professor Heim—is more of a sledge than a spade, the rocks that it carries with it are mainly the result of weathering on the heights that surround it.† "Scientists" have found rubbish under the ice, and they have assumed hastily that it was all excavated. But every observant mountaineer who has spent days among the glaciers knows well that a constant transference of rocks and soil is being effected from the surface to the bottom. The glacier is never silent in summer; the rattle of the stones falling down crevasses, the murmur of the streams plunging into *moulins* is continual, and the matter thus transferred must go to form ground moraines. Such moraines will only be found, however, on level ground; where the glacier falls steeply it will sweep its bed clear of loose material.‡

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* 'Geological Journal,' vol. xxxix. p. 71.

† Glaciers whose channels are little overhung by rocky slopes have comparatively small moraines. Having fewer tools in their grip in the form of fallen blocks, they will naturally grind less also. The Gul Glacier under Ushba is a capital example of a small glacier with enormous moraines, derived from the height and rottenness of the crags that encircle its basin.

‡ I may refer here in passing to a point of detail on which Sir A. Ramsay calls for

Nature does not seem to me to bear out the theory that U-shaped or broad bottomed valleys have been enlarged by glaciers. On the contrary, so far as I can see, U-shaped valleys are not V-shaped—or trenchlike—valleys broadened by ice, but V-shaped valleys are U-shaped valleys deepened by water action. I recognise that snow and ice, by protecting much of the soil from weathering, by carrying on their surface a portion of the drainage, and frequently distributing the remainder so as to diminish its erosive force, by dropping, as they withdraw, the rubbish they have brought with them, tend to protect from erosion, and even to fill up the sides and troughs of mountain valleys. Such valleys I find are apt at once to assume a V-shape and to become suddenly deeper below the principal remains of terminal moraines, that is, where the ground has been less continuously under ice protection. From this I conclude that glaciation is relatively a check to valley formation, that glaciers are among nature's conservative forces.

One more general observation before I pass on. Among the most remarkable "sights" of the Alps are narrow gorges such as the Via Mala, and those found near Trient and Pfeffers. Mere cracks they appear at first sight, and cracks accordingly they were called by observers whose hastiness Professor Tyndall has rightly rebuked. Now we may notice that it is troughs of this nature, very deep and very narrow, that the sub-glacial torrents of the Grindelwald and Rosenlaui Glaciers have cut for themselves. The greatest gorge in the world of this character is the cañon of the Rio Colorado. The rainless climate of Colorado, which saves the sides of the cañon from sub-aerial denudation, is assigned as a reason for its intact precipices. In the Alps, I believe, the superincumbent ice-sheet has produced the same result—it once protected the sides of sub-glacial gorges from rapid changes of temperature and the various agencies of waste. We find that where a barrier presents itself to a glacier furnished with a strong sub-glacial torrent, the tendency of the ice is to pass over the barrier, the tendency of the water to cut through it. The one acts as sand-paper, the other as a saw.

Had the foregoing suggestions been only the *obiter dicta* of a mere climber, I might have hesitated to put them on record. It is not for any novelty in them that I claim attention. Much of what is advanced here has been advanced before and in greater detail by Mr. J. Ball, Mr. E. Whymper, Professors Bonney and Heim, Mr. W. Mathews, and others. But so long as the authority of one or two eminent and popular names lies on the other side of the questions discussed, so long as the evidence and the authorities on one side—and on one side only—are frequently put forward in this country, it seems to me the duty of an independent witness to testify to the facts bearing upon the case within his personal knowledge. My evidence has at least this value, that it is independent. I was brought up to believe implicitly in the destructive action of glaciers, and I have discarded that belief entirely from observations in the field. But perhaps I shall be told, as others have been, that I am only a climber, and recommended to confine myself to topography! I must forestall any objection of this kind by citing a case in point which exemplifies the disadvantages of allowing the discussion of physical questions to be kept solely in the hands of professed physicists.

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further information. I doubt both the accuracy of Dr. Tyndall's suggestion in 'Forms of Water' that the slender streams issuing in winter from the Alpine glaciers are derived from the gradual drainage of fissures charged during the previous summer, and the belief of other writers that the temperature under the glacier never sinks below freezing point. Springs rise below the ice from the ground, and some of these doubtless, as do many in the open air, remain unfrozen. The water from the lower Grindelwald Glacier in January last was perfectly clear, and could be leapt dryshod.

More than a hundred years ago, A.D. 1772, a citizen of Geneva, Bordier by name, went on a tramp to the glaciers of Mont Blanc, and on his return published a little 'Voyage Pittoresque,' in which he introduced two chapters on a 'Hypothesis of the Phenomena of Glaciers reduced to a single principle.' This principle of Bordier's none of the philosophers of his own day had the insight to appreciate or follow up. It was not till seventy years later that the scientific men made it out afresh for themselves, and then, with the exception of M. Rendu, they discussed with much energy which of them the idea originally belonged to, unconscious apparently (till Professor B. Studer of Bern * let out the fact) that priority of publication had been secured in the previous century.

Well might Professor Studer exclaim, "It is astonishing how, under the authority of De Saussure, the views of one of his fellow-citizens" (Bordier was a man of some position, a member of the Council of Two Hundred), "which have subsequently been accepted as the more correct, were so completely suppressed and forgotten that in the battle of recent years over the latest development of Bordier's theory, which treats glaciers as plastic (*zähflüssige*) masses, his name has not been so much as mentioned."

But so far, at least, as the most important of the preceding suggestions, the limited competency of ice as an excavator is concerned, I have no claim to the perilous originality of Bordier. My conclusion is in agreement, not only with the English

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* In 1863 Prof. B. Studer ('Physische Topographie der Schweiz') reprinted the crucial sentence in Bordier's 'Hypothesis.' At Christmas 1871, the centenary almost of Bordier's visit to Chamonix, Prof. Tyndall quoted it at the British Institution, and subsequently printed it in English in 'Forms of Water.' Two passages are there quoted from the 'Hypothesis,' in which the Genevese writer argues that glacier ice is plastic like soft wax, and that the glacier moves forward as a single piece, so that the snows on the top of Mont Blanc will one day reach the valley. Bordier went even further: he observed the opening and closing of crevasses, and "their direction towards the lower end of the glacier exactly as the waves of a stream run with the current;" he argued that in addition to obvious causes, such as, amongst others, expansion and contraction caused by changes of temperature, the crevasses and undulations owed their origin mainly to motion and pressure from above, "which makes the ice crack and the blocks at the edge fall off, just as, when a shock is given to the first of a row of elastic balls, the one at the further end will break away" (he failed, it may be noticed, to distinguish between strain and pressure). He finally suggested that the Chamonix glaciers should be regularly observed, and that stakes should be stuck in the Glacier des Bossons, which he went on to remark was too little visited, because the Chamonix guides were such creatures of habit that every tourist had to follow exactly Pococke and Wyndham to the Mer de Glace, and even in drinking on a certain rock, whatever his nationality, the health of the "Roi George." The writer of a 'Voyage Pittoresque' was naturally beneath the notice of a serious philosopher, or even of a philosopher's follower, such as old Bourrit (beloved, nevertheless, by right-minded men in that he shows himself in all his writings what Goethe called him, a "passionirte Kletterer"), who in the same breath dismissed the other "B" (Bordier) as an ignoramus, and solemnly put forward on his own account the suggestion that glacial undulations were caused by the prevailing winds, an opinion (as Herodotus remarks of a similar hypothesis regarding the floods of the Nile held by certain Greek writers) "not worth naming, except to give the reader intelligence how ridiculous it is." In the 'Alp. Journal,' vol. ix. p. 327, the more important passages in the 'Voyage Pitoresque (*sic*) aux Glacierès de Savoye par Mr. B.: Genève, Chez L. A. Caille, 1773,' are reprinted. Note the anticipation of subsequent popular authors in the description of the circular journey of the snowflake from the top of Mont Blanc to the sea and back again, through the ocean and the air, to its starting point.

authorities I have cited, but also with the verdict, "Glaciation is equivalent to relative cessation of valley formation," arrived at by Prof. Heim as the result of a careful examination of glacier research in the minute and comprehensive work he has lately published on the subject.* The volume abounds in curious experiments and observations, for a full account of which the student must turn to the original. Here I can only mention that the milky colour of glacier-streams is shown to arise from the *fine division* of the particles held in suspension, and not from their quantity. The solid matter brought down by a glacier-stream in the year has been found by experiment to be far less than that brought down by a stream draining an area of similar extent not glaciated.

Two circumstances have contributed to the temporary exaggeration of the destructive capacities of ice as an agent of denudation. In the revulsion from the old doctrine of "Catastrophes" in geology there has been a tendency to dwell too exclusively on the last stage in the earth's history, and to magnify the part of erosion at the expense of preceding agencies. Again, the ice-tool was a very fascinating novelty. Agassiz's observations explained a great many conspicuous and hitherto mysterious details of the earth's surface, the details which, to such petty observers as mankind, give landscape much of its expression and interest. The human mind is prone to assign to the last or most conspicuous agent in all work more than a due share of the credit. Yet none of the tourists who wear with their feet or chip with their hammers the corners of great rock-temples adds a "fecit" after his name: that crowning audacity has been left for the friends of glaciers. For among the mountains ice has, we find, played the part not of a Pharaoh but of a tourist. It has rubbed and scratched. Here and there, it is true, it has shown the more respectable energies of a landscape-gardener. It has carried off loose fragments to build banks and mounds and endyke artificial waters, or has spread fertilising silt over an ungrateful soil.

But comparisons are imperfect, if not odious. I owe an apology to the glaciers for the foregoing, which fail altogether to do justice to their conservative action in protecting what they cover from weathering and diminishing erosion. Before long, I believe, this character of their action will be generally recognised. The notable power of ice to model the finer curves which make scenery will be appreciated. But it will not be thought necessary, in the face of evidence which cannot be reconciled with any such hypothesis, to impute to the same agent the original blocking-out of the mountain forms. The physicists of the future will, I feel confident, point out the impossibility of glaciers acting capriciously under identical conditions, and will insist on the incongruity of arguing that an ice-stream which did not widen the gorge of St. Maurice, on emerging from the mountains excavated the bed of the Lake of Geneva, or that a natural agent which was baffled by the crags of Sion and deflected by the ridge of the Forclaz, could have cut the Valley of the Rhone—out of what appears to be conceived as a uniform mass of uplifted ground rising throughout to a level superior to that of the present ridges by the amount these have lost by weathering since the glacial period.†

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* 'Handbuch der Gletscherkunde,' Stuttgart, 1885. Analysed in detail by Mr. F. F. Tuckett in the 'Alp. Journal,' vol. xii. I may venture to express a hope that any of my readers who feel interested in this discussion and tempted to join in it, will, before doing so, read Professor Heim's volume, or at least Mr. Tuckett's careful and clear summary of its contents.

† See 'Phil. Transactions,' 1862, p. 172. I have found in Mr. Ruskin's 'Arrows of the Chase' several letters in which he has forestalled and expressed with his habitual force and eloquence some of the arguments made use of above.

GEOGRAPHICAL NOTES.

The Disaster in the Caucasus.*—Additional information has been received from the Caucasus which, though far from giving any absolute certainty, agrees in pointing to a particular place and manner in which Mr. Donkin and Mr. Fox with their guides may have probably lost their lives. The map published in the 'Proceedings' last June will explain the relations of the localities here referred to. A woodcut of the Ullu-auz Glacier —contained in the 'Alpine Journal' (No. 101)—shows the supposed scene of the accident. The first evidence is that of Mons. N. Djukoff, of the Russian Survey. Mr. Donkin informed M. Djukoff that their plans were to attempt the ascent of Dychtau (16,925 feet), to cross the glaciers to Karaoul, and then to cross to Gebi, south of the chain, by the well-known Pasi-Mta Pass. The next important witness is the Bezingi villager who accompanied the travellers with a baggage horse to their camp in the Doumala Valley. He describes with great apparent clearness how they started on the morning of the 26th August up the glacier of Ullu-auz, which fills the head of that valley. On the morning of the 28th, about 10 a.m., they returned (he noticed) in very high spirits. The circumstances—the two nights spent at a higher bivouac, the hour of return, the high spirits of the party, taken in conjunction with Donkin's communication to M. Djukoff—point irresistibly to the conclusion that the party had attacked Dychtau (N.B. the Dychtau of maps is the Koshtantau of local usage) and had succeeded. On the 29th the party rested in camp. At 3 a.m., on the 30th, before it was light, they started again up the glacier. The native went back to the interpreter with a note dated August 28th, and written in German by Mr. Fox (of which, owing to an obscurity of expression, we at first misread the opening sentence) to this effect:—"We are gone over the mountains to Karaoul. Meet us there." The only discrepancy so far is that the note fixes their fresh start for the 29th. The villager is quite clear in his recollection, and it seems probable, therefore, that after writing it the travellers determined to rest another day. The pass they intended to cross is well shown in the photographs taken by M. de Déchy while I was with him last year. It is obviously not difficult on the Doumala side, and does not *look* dangerous. Mr. Phillipps-Wolley was given to understand that it is used occasionally by native hunters, who, as the fact of an old cairn having been discovered on the Shkara Pass proves, venture far among the glaciers in pursuit of their game.

It only remains to state the result of the search. Nothing whatever was seen or heard of the travellers on the Karaoul side of the mountains. On the Doumala side, prints of nailed boots were found in the moraine beside the lower ice-fall. Fresh snow had obliterated the tracks on the ice. But on the further side of the glacier (at about 12,000 feet), where

* Note by Mr. Freshfield.

the route to the pass leads near to the base of a great spur of Dychtau, the blue blocks of a large ice-avalanche were lying. Some of the search-party reached the spot, but no traces of the travellers were visible on the surface, and deep fresh snow prevented any thorough search. The place indicated is one where avalanches can fall but very rarely. None, I can bear witness, had fallen there last year up to the middle of August. Possibly none had fallen there for years—since the last period of glacial advance—for the source of the downfall was obviously a small glacier clinging to the cliffs above. There was naturally nothing to show the exact date of the avalanche, and it *may* have fallen subsequently to the 30th August. But if, as there seems much reason to believe, these ice-blocks cover the mountain explorers, they were overtaken by a misfortune as little to be anticipated as the earthfall which recently crushed a railway train in Southern Italy. Such stray avalanches occur from time to time in the Alps, but I know of no occasion, except perhaps that described by Mr. F. F. Tuckett, in which his party had "a race for life" at the base of the Eiger, in which mountaineers have been caught, or had a narrow escape, in a position so little apparently exposed to danger as that in which this avalanche fell.

I have also to acknowledge the receipt from Baron Ungern-Sternberg of an interesting account of the visit of Mr. Donkin and Mr. Fox to Urusbieh, where they spent several days in his company, together with copies of their observations on the summit of Dongusorun (14,600 feet), communicated to him by Mr. Donkin. The travellers' effects, which we hope may supply further details, have not yet reached England. It would be ungrateful to conclude this sad record without an expression of sincere gratitude for the sympathy in our countrymen's fate shown throughout the Caucasus by Russians of all ranks, from the Czar himself down to Cossack serjeants. And in particular thanks are due for the helpfulness and exertions of the officers, amongst others Colonel Viruboff, the Commandant of the Naltshik District, and M. N. Djukoff, of the Survey Department, whose position enabled them to facilitate, or co-operate in, the search to which winter has for the present put an end. To Mr. Phillipps-Wolley, who gave up his own plans in order to do all that was in his power to ascertain the fate of his countrymen, it is difficult for their friends adequately to express their obligation.

Dr. Nansen's Journey across Greenland.—The adventurous young Norwegian, Dr. Frithiof Nansen, has succeeded in the difficult feat of exploration he undertook,* of crossing the icy plateau of Greenland from east to west. Letters recently received at Copenhagen from him and his companion, Mr. Sverdrup,† announce their arrival safe and well at Godthaab on the 3rd of October. The party, as recorded in the September

* *Vide* 'Proc. R.G.S.,' *ante*, p. 240.

† Translations of these letters with some elucidatory remarks were kindly communicated to the Society by Mr. Walter R. Hearn, our Vice-Consul at Christiania.

No. of the 'Proceedings,'* were disembarked by the sealer *Jason* and left in their boat to find their way ashore through the ice, on the 17th of July last, in lat. 65° 2′, but we now learn that the boat did not reach the land the next day, as the captain of the *Jason* supposed, but was caught in the southerly drift, and, in spite of heroic efforts, carried as far as Andretok, in 61° 32′, nearly 210 nautical miles down the coast, before headway could be made to the northward and a landing at a suitable place effected. This was reached, at last, at Umiavik, in lat. 64° 30′, and the crossing of the inland ice was commenced on the 15th of August. A course was at first set towards the north-west for Christianshaab, in Disco Bay, but much time being lost through severe northerly snowstorms, Dr. Nansen was compelled to turn to the westward, for the nearer settlement of Godthaab. The western coast was reached after forty-six days' travelling, the distance from the point of departure being 280 geographical miles. For several weeks they were at an altitude of more than 9000 feet above sea-level, and suffered from snowstorms and loose snow and a temperature of between 40 and 50 degrees below freezing. The low land on the western coast was reached at the end of September. It is much to be regretted that the last Danish ship of the season was unable to wait a few days for the arrival and embarkation of the whole party, and, in consequence, Dr. Nansen, with his companions, remain for the winter in Godthaab.

Further Explorations in Iceland by M. Thoroddsen.—M. Thoroddsen, the geologist, to whose travels in Iceland we have had occasion to refer before,† took advantage of the peculiarly favourable weather last summer to prosecute further his explorations in Iceland. At the commencement of August he made an exploration of the volcano Raudukambar, from an outbreak of which in the middle of the fourteenth century many homesteads were, according to an old chronicle, ruined. These ruins still exist, and had never before been properly explored by a geologist. M. Thoroddsen is of opinion that they result from an eruption of Mount Hecla, which took place in 1341. In any case he states that Raudukambar is not a new volcano, but an old liparite ridge, and that there has been no eruption in its vicinity within historical time, although some old prehistoric craters exist in the lower parts of the valley. Raudukambar must therefore be struck out of the list of the active volcanoes of Iceland. Later on M. Thoroddsen paid a visit to the little-known district in the south of Hofsjökull, and between the latter place and Langjökull, where he explored the Kerlingarsfjöll, a remarkable chain of mountains which had not previously been visited by any traveller. This important range, which stretches from north to south, and not, as Gunnlaugsson's map has it, from east to west, is composed almost exclusively of liparite. Hot springs are known to exist in this region, but no one has yet come across any. Boiling quagmires of different colouring are found in many

* *Ante*, p. 591. † *Ante*, p. 306.