determined by M. Tresca that one-half of the motive power generated by steam was really transferred to a distance of above one kilometre from the furnace. The motive power which has been utilised for farming land can be employed for excavating, or executing any description of work.

THE carrier-pigeon service is now in full operation in France, and has been placed under the direction of the head of aërial communication. The number of birds fed by the Government is 6,000. These pigeons are located in Paris and twelve other large fortified towns. A number of soldiers and officers have been taught the art of pigeon breeding, and carriers are constantly sent from place to place. The Minister of Public Instruction and the Minister of Agriculture have established prizes for pigeon races.

THE strong interest recently awakened in Owens College, Manchester, has been shown in a desire on the part of some of his admirers to do honour to the founder. This has taken the form of a memorial window, which is to be erected in St. John's Church, near the College; and the donors have commissioned Mr. W. G. Taylor, of Berners Street, to carry out the work, which will be completed towards the end of next month. At the foot of the three lights are the words "Ars, Religio, Scientia," symbolised by subjects illustrating music, charity, and astronomy. The arms of the College and of John Owens occupy the bases of the side lights.

ONE of the new Cardinals, Haynald, Archbishop of Kalocsa in Hungary, is eminent as a botanist, as we learn from the *Gardeners' Chronicle*, and is probably the first botanist who has ever held so exalted a rank.

THE Sanitary Institute of Great Britain has issued a very satisfactory second Annual Report.

WE note that Dr. W. G. Farlow, for the past five years Assistant Professor of Botany at the Bussey Institution, Harvard University, has been appointed Professor of Cryptogamic Botany in the University proper. This is the first professorship in this important and difficult department established in the United States. The laboratory for instruction and research in the lower cryptogamia is now established at Cambridge.

FOR the schools of California, "A Popular Californian Flora; or Manual of Botany for Beginners," has (in part) been lately published by Mr. Volney Rattan, teacher in the Girl's High School, San Francisco. A second part will complete it. It is restricted to plants of the San Francisco region, extending north to Mendocino County, south to Monterey, and west to the foot hills of the Sierra Nevada.

"CINCHONA CULTURE IN BRITISH INDIA" is the title of a useful pamphlet by Surgeon-Major G. Bidie, Superintendent of the Madras Central Museum, being one of the Museum Popular Lectures of the season 1878-9.—We have received a separate copy of a paper "On Pollen," by Mr. M. S. Evans, read before the Natal Microscopical Society on November 18 last.—The Fifth Report of the Boulder Committee of the Royal Society of Edinburgh contains notes on a considerable number of boulders in Scotland, with numerous illustrations.—West, Newman, and Co. publish a monograph by Mr. P. H. Gosse, F.R.S., on "The Great Atlas Moth of Asia (*Attacus atlas*, Linn.)," with a coloured plate of its transformations.—We have received a very favourable Report of the Condition and Progress of the Davenport (U.S.) Academy of Natural Sciences, which is now in its eleventh year, and doing good and varied work.—"On the Lancashire Coal Fields," is the title of a paper by Mr. C. E. De Rance, reprinted from the *Proceedings* of the Geologists' Association.—A fourth edition of Bloxam's "Laboratory Teaching" has been issued by Messrs. Churchill. The most important alteration is the introduction of the formulæ representing the various chemical compounds described in the notes in the tables.

THE additions to the Zoological Society's Gardens during the past week include a Grey-cheeked Monkey (*Cercocebus albigena*) from West Africa, presented by Mr. Robert Surry; a Patagonian Sea Lion (*Otaria jubata*) from the Falkland Islands, presented by Mr. F. E. Cobb; a Roseate Cockatoo (*Cacatua roseicapilla*) from Australia, presented by Mr. Head; a Blue-winged Green Bulbul (*Phyllornis hardwickii*) from India, presented by Mr. A. Jamrach; two Horned Lizards (*Phrynosoma cornutum*) from Texas, presented by Mr. E. Loder; a Javan Fish Owl (*Ketupa javanensis*) from Java, a Ceram Lory (*Lorius garrulus*) from Moluccas, three Abyssinian Guinea Fowls (*Numida ptilorhyncha*) from Abyssinia, a Nicobar Pigeon (*Calænas nicobarica*) from the Indian Archipelago, a Victoria Crowned Pigeon (*Goura victoriæ*) from the Island of Jobie, a Mace's Sea Eagle (*Haliaëtus leucoryphus*) from India, two Black-tailed Godwits (*Limosa melanura*) twelve Common Widgeons (*Mareca penelope*), European, purchased; a Cheetah (*Felis jubata*) from Africa, two Bactrian Camels (*Camelus bactrianus*) from Central Asia, deposited; two Black Swans (*Cygnus atratus*) from Australia, received in exchange; two Chinchillas (*Chinchilla lanigera*), a Black-necked Swan (*Cygnus nigricollis*), bred in the Gardens.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

FROM No. 6 of the *University College School Magazine* (London) we see that the editor's post is not altogether a pleasant one, though the number is very creditable. The U.C.S. Scientific Society seems in a healthy condition. In connection therewith we notice that a series of sixteen lectures are to be given during this term on the Science of Daily Life. We trust they will be well attended.

FROM the Report for 1878 of the Rugby School Natural History Society we learn that it is fairly flourishing. The entomological, geological, and archæological sections have been vigorous, though the workers in each are fewer than they should be. Altogether there does not seem to us to be that hearty interest in the Society among the boys that conduces to complete success; all the more reason, therefore, for the real working members keeping up their work with unflagging zeal and doing their best to enlist the sympathy and help of the indifferent. A satisfactory observatory Report from Mr. Seabroke is appended.

SOCIETIES AND ACADEMIES

LONDON

Royal Society, May 1.—"On the Origin of the Parallel Roads of Lochaber, and their bearing on other Phenomena of the Glacial Period." By Joseph Prestwich, M.A., F.R.S., F.G.S., &c., Professor of Geology in the University of Oxford.

Of the various hypotheses that have been brought forward since the time of Macculloch and Dick-Lauder in 1818, to account for the origin of the Parallel Roads of Glen Roy, the one so ably propounded by Mr. Jamieson, in 1863, has been most generally received and adopted.[1] It is a modification of the views originally expressed by Agassiz, to the effect that the barriers of the lakes—to the shore action of which both the above-named geologists attributed the "roads," but were at a loss to account both for the formation and removal of barriers—had been formed during the glacial period by glaciers issuing from Glen Treig and Glen Arkaig, supplemented by others from Ben Nevis. The subsequent determination, by the Scotch geologists, of an intermediate milder period succeeded by a second cold period, led Mr. Jamieson, with whom the pre-glacial and glacial deposits of Scotland had been a subject of especial investigation, to conclude that the extension of these two places took place during the second cold period, which he thinks was of little less intensity than the first, and that, while the glacier from

[1] Darwin's well-known paper, in which he considered the "roads" to be old sea-beaches, appeared in the Philosophical *Transactions* for 1839. This marine hypothesis was afterwards earnestly advocated by R. Chambers and Prof. Nicol, but is no longer held by its distinguished author.

Glen Arkaig blocked up Glen Gluoy, the glacier from Glen Treig formed a barrier to Glen Roy.

The "roads" were, he considers, formed by long-continued shore action at each successive level of the lake, that level being determined by the height of the cols over which the lake waters escaped.

To these views it has been objected, by Mr. Milne-Holme and others, that it is difficult to conceive the glens to the north of the Spean Valley to have been filled with water while at the same time those on the south were filled with ice, and he advocates a detrital barrier formed of clay, sand, and gravel, by marine origin, when the sea stood some 3,000 feet higher than at present.

Prof. Nicol, also, has pointed out that, had lakes existed in Glen Gluoy, Glen Roy, and Glen Spean for the length of time required to form the "roads" by erosion, and to accumulate the deltas, the cols by which their surplus waters escaped during those periods must have cut a channel in the rocks in the same way that the rivers (which now represent the same drainage, or probably less) have since excavated their channels in the present valleys; whereas, although there are indications of water-wear in the passes, nothing like a defined river channel exists. Prof. Nicol attempted to explain the facts on the theory of the "roads" being sea beaches. But the absence of corresponding beaches outside those glens—the limitation of the highest "road" to Glen Gluoy—and of the second and third to Glen Roy, and the total absence of marine remains in any of the various drift beds, renders the marine hypothesis inadmissible.

Sir John Lubbock, looking at the form of the "roads" which has been described by Macculloch as parallel layers applied in succession to the sides of the hills, contends that such a form is incompatible either with the heaping up of materials on a shore line, or with their removal by erosion, as in the one case a notch and in the other a projecting ledge in the hill side would be formed, whereas, with one exception of one superior talus pointed out by Macculloch, no such structure exists. Sir John points out that a parallelism between the slopes may, however, have been formed by wavelet action, in consequence of the detrital matter taking, as it successively fell and was removed, the same angle of repose as that which the detrital slopes originally had, that angle being the same in water as in air.

Besides these objections to Mr. Jamieson's hypothesis, which the author considers valid, he points out the difficulty of conceiving that the Arkaig glacier could have ascended the hills at the entrance of Glen Gluoy to a height of not less than 1,200 feet, while at the same time a pass existed at the head of the glen only 500 feet high, which presented a ready outlet to the west coast.

It is a question also whether active glaciers such as Mr. Jamieson requires could have formed permanent dams to the large bodies of water pent up in Glen Gluoy and Glen Roy. Glacier lakes are occasionally formed in the Alps, as in the instance of the Margelen See; but they never last many seasons. The glacier is constantly on the move, and so long as it presents an unbroken front to the lake, so long is the barrier efficient, but when in the progress of the glacier a fissured mass of ice comes forward, the water at once escapes with greater or lesser rapidity, and cannot again accumulate until the defective ice has travelled past or the leak is repaired by winter frosts.

Equally difficult is it to imagine the existence of such vast glaciers as those of Glen Arkaig and Glen Treig, while the opposite glens of the Gluoy and Roy remained free from ice. The difference in the height of the hills is too slight to allow of so great a variation in the level of the snow line, and the cause suggested by Mr. Jamieson, viz., a great difference in the rainfall such as it now obtains in this district, can scarcely be maintained, for, although the annual fall at Fort William is 86 inches, and at Laggan 46 inches, the rainfall at Roy Bridge has now been found to be as much as 62 inches. Further, for the argument to be of any value, it should be shown that in the country further eastward, where the rainfall is much less, there was the like absence of glaciers during the second period, whereas Chambers and other geologists, including Mr. Jamieson himself, have shown that during that period local glaciers descended from every mountain range approaching or exceeding 3,000 feet in height—a height attained by the hills to the north as well as by those to the south of the Spean.

With respect to the so-called "deltas" of the Turret in Glen Roy, and of the Gulban in Glen Spean, which are supposed to have accumulated during the long time that the lakes filled the valleys, the author shows that the structure of the former is not in accordance with the bedded structure of deltas, but on the contrary, that it is formed of unstratified moraine *débris* 50 to 80 feet thick, with a thin coating of gravel water-worn and reconstructed from the underlying mass, and that the angle of terminal slope is not that of original deposition, but is due to wearing back of the terrace by the Roy, and the fall of the *débris* by weathering.

These are the objections of the author to the hypothesis of Mr. Jamieson, but while objecting to this exposition of the glacial theory, he considers that that theory affords the most satisfactory solution of the problem, only that he would suggest a different interpretation in explanation of the phenomena.

Dismissing the hypothesis of local glaciers of the second period of glaciation, the author falls back upon the original idea of Agassiz with the development acquired by more recent research, and assigns the Lochaber lakes to the close of the first period of great glaciation. He considers the phenomena are due to the peculiar physiographical conditions of the district, and shows that owing to the configuration of the country, the drainage of the Ben Nevis range is diverted into the lower part of the Spean Valley and the Great Glen near Fort William. These conditions which now give this area an excess of water drainage, must in the like manner, during the glacial period, have there led to an exceptional accumulation of ice.

The observations of MacLaren, Chambers, Milne-Home, Jamieson, James Geikie, and others, sufficiently prove the great thickness of the ice covering in this part of Scotland during the first period of intense glaciation. On the flanks of the Ben Nevis range, glacial striæ extend to a height of more than 2,000 feet, while everywhere the rocks in the lower parts of Glen Spean are intensely glaciated, as are also those at the head of Glen Roy on approaching the Col to Glen Spey, and around the Cols of Glen Glaster and Makoul. At the same time, the erratic blocks, with the beds of sand and gravel of foreign origin, which have been found widely distributed over the hills around Glen Roy to heights of from 800 to 2,100 feet, afford confirmatory testimony of the depth of the land ice which then covered the country.

With the incoming of this glacial period, local glaciers must have descended from every mountain range, and so long as the glacier of one steep glen became confluent with another of the same chain flowing in the same general direction, so long would their course be uninterrupted, and the propelling and abrading force maintained, as in the Alps at the present day; but when, emerging from these glens into valleys of small gradients dividing the several mountain chains, they met with glaciers descending from these other ranges, their progress was not only subject to be checked, and their forces neutralised, but their course diverted, for if the lines of natural drainage were barred, the ice took those of least resistance, although such might be uphill and against the lines of drainage. This, however, could not be effected without excessive pressure and heaping up of the ice at the points of junction.

These interferences must have been especially frequent in the valley of the Spean. On the one side, the glaciers descending the steep ravines of the Ben Nevis range, would issue into Glen Spean and project across it to the Glenroy hills opposite. Below to the west, the great Nevis Glen glacier emerged into the valley of the Lochy, while above to the east the great glacier, issuing from Glen Treig, flowed down Glen Spean; but, meeting with the aforesaid group of glaciers from Ben Nevis, was partly diverted over the flanks of Craig Dhu, and upon the entrance to Glen Roy.

While the glaciers from this system of mountains were becoming confluent in and filling Glen Spean, those from the opposite range of hills were descending Glen Roy, the Rough Burn, and the other ravines of that chain, and coming into collision with those of the Ben Nevis range. In the same way other valleys were focussing their glaciers upon the end of the Great Glen north of Ben Nevis, barring in that direction the passage of the ice down Glen Spean, and diverting it northward towards Loch Lochy and Loch Oich.

Therefore, the great mass of ice descending Glen Spean, in consequence of meeting with these obstructions, was driven to accumulate in mass in the lower part of that valley opposite Glen Roy, until overcoming further resistance and confluent with the Ben Nevis mass, it wheeled round into the Great Glen at Loch Lochy.

There is no doubt, also, from the direction of the striæ and

the position of the transported boulders, that the mass of the Treig glacier struck across the valley of the Spean, and turned down its channel westward; but that a part ascended to the Col of Glen Glaster, and another passed up the Spean Valley, is doubtful. It is more probable that this glacier, after traversing Strath Spean, met with others coming down the Rough Burn, while these took an easternly direction to Loch Laggan and over the Pass of Makoul. The direction of the striæ observed by the author between the Rough Burn and Moy, points, he considers, to ice coming down from the hills on the north and joining this main east stream.

The effects of these great conflicting ice streams were not confined only to the piling up and accumulation of the ice. Although glaciers confined by the walls of narrow glens, and descending steep slopes exercise great abrading power, the observations of Charpentier and others show that when they emerge into broader and flatter valleys, they may pass over beds of loose detritus without disturbance except that of pressure. The terminal moraines of the many glaciers emerging into Glen Spean may, according to the varying conditions of the ice, have been pushed forward or rolled over by the ice, while the meeting of conflicting glaciers must have led to the deposition and heaping up of the glacial *débris* at the points of junction. The many checks and blocks that must have occurred during the growth of the great ice-sheet—the neutralisation of the ice-force in one place, and the centralisation of it in others—will serve to explain much that is peculiar in the distribution of this subglacial *débris* or Till, not only in Lochaber, but in other parts of the country, and at all levels.

The author then points out the many mounds and terraces in the Spean Valley formed of moraine detritus, though since levelled and often masked by a covering of gravel due to subsequent water action. To this cause also he attributes the large accumulation of *débris* at the entrance to Glen Roy, between Bohuntine and Glen Glaster, where he shows it to be in places 200 to 300 feet deep, and where it rises nearly to the level of the lower parallel road. Mr. Milne-Home has pointed out a similar deposit at the entrance to Glen Collarig, while the large mass at the entrance of Glen Spean, and now forming Unachan Hill, rising to a height of 613 feet, has been often described.

The next question discussed is the height of the land in relation to the sea at the period of the great glaciation, as it is not possible to suppose that with the great changes of level which took place subsequently, there is now a return to the *status quo ante* of the earlier period; and the author sees reason to conclude that the land then stood at not less than from 1,000 to 1,500 feet higher than at present, so that the Irish Channel was then above the sea level, and land extended a considerable distance westward from the present coast of Scotland.

This was followed by a submergence of not less than 1,200 to 1,500 feet in central and northern England, Wales, and Ireland, and of 600 feet in the southern part of Scotland, as proved by the occurrence of marine shells at those heights, and assuming for the north of Scotland a submergence, at all events, of 400 or 500 feet below the present level, this, added to the previous elevation of 1,000 to 1,500 feet, would establish a difference of 1,500 to 2,000 feet between the period of great glaciation and the succeeding period of submergence.

This difference of level would produce a twofold effect upon the climate—the one resulting from altitude which would be equal to a rise in the mean temperature of from 4° to 6° F., and that caused by the conversion of a continental area into an archipelago. The effects of the two causes could not be less than from 12° to 15° F., which is about equivalent to the difference of climate between Paris and St. Petersburg. There is also to be taken into account the probable increase of heat consequent on the gradual diminution of those conditions, whatever they were, to which was owing the cold of the glacial period.

The effect of those changes was to produce a thaw which gradually led to the destruction of the great ice-sheet, though subsequently other changes brought for a time a return of cold sufficient to maintain local glaciers in the higher mountain ranges. The conditions under which the ice-sheet would be placed during this period would be similar to that of glaciers where they extend below the snow line. In Europe the glacier gradients are usually so steep, and the ice is so fissured, that even in such positions water rarely lodges on the surface, but in the Himalayas, where glaciers descend into wide valleys with small gradients, and the summer heat is considerable, the glaciers often become covered with tarns and small lakes. They have been noticed by Sir J. D. Hooker, and more lately by Col. Godwin-Austen, who describes in the middle of one of these glaciers, a series of such lakes, some being 500 yards in length, and 200 to 300 in breadth, and of great depth. As intervening barriers give way, these lakes descend from lower to lower levels, and finally escape.

In the same way the old ice-sheet must have become covered with pools and lakes, for owing to the irregular surface of the ice, and the inevitable absence of all channels of drainage, the water must everywhere have lodged, until channels were formed, and a means of escape established. The extent of these bodies of water would depend upon the height and permanence of the obstructions. In the Lochaber district they were, owing to the causes before named, of great size and permanence, such as to form high barriers at the entrance to Glen Roy, Glen Spean, and Glen Gluoy, behind which the waters accumulated and rose until they found a channel of escape over the cols at lower levels, when a permanent water-level would be established so long as the main barriers existed.

It is well known that the Parallel Roads are terraces composed of perfectly angular fragments of the local rocks with a few rounded pebbles both local and foreign to the district. The former show an entire absence of any prolonged beach wear. The wear of the latter is due to other causes. The slope of the hills above and below the "roads" varies from 25° to 40°, and the inclination with the horizon of the "roads" themselves, which are from 50 to 70 feet wide, varies within the limits of from 5° to 30°.

Of the internal structure of the "roads" very little is known. The only published section is the one given by the Rev. Thomas Brown in his paper on the "Parallel Roads," and in this there is no appearance of any such structure as would result from successive additions to the ledge by the tipping over of *débris* removed from the shore.

Although, therefore, the "roads" indicate a line of water-level, there is nothing in their form or structure to show that they have been formed by the long-continued action of lake waters on a shore line. To what, then, are they to be ascribed?

What the conditions were immediately antecedent to the formation of the first, second, and fourth road, is not shown, but in the case of the third road the conditions preceding its formation are to be traced uninterruptedly from the conclusion of No. 2 "Road." When the lake stood at the level of "Road" No. 2, its waters escaped by the col leading to Glen Spey, while, when they stood at the level of No. 3 "Road," they escaped by the Glen Glaster Col. Now, as there is a difference of 76 feet between the height of the two cols, it is evident that a barrier must have existed on the latter col during the time the lake stood at the higher level. Whether the barrier was detrital or ice-formed is immaterial for the argument.

Now, it is well known to engineers that a breach once established in a detrital barrier becomes so rapidly enlarged that, if not at once stopped, nothing can stay the rapid destruction of the barrier, as, in the case of the Holmfirth, Crinan, and other floods. Nor is evidence wanting of similar catastrophes in connection with glacier lakes. In the notable case of the Gietroz Glacier barring the valley of the Drance, a lake nearly 2 miles, and at one end 200 feet deep, was drained in twenty minutes. The still greater flood recorded by Vigne in a branch of the Indus drained a lake formed by a detrital barrier, and estimated by Mr. Drew to have been 35 miles long by 1 mile broad and 300 feet deep at its lower end, in one day.

In the same way it is to be assumed that the Glen Glaster barrier, which was probably formed by a remnant of the glaciers descending from the mountain ranges (2,994 feet) at the head of the glen, gave way with great suddenness, and caused the rapid fall of the waters from the level of the higher "road" in Glen Roy to that of that glen's second "road," at the height of the Glen Glaster Col, when the escape of the waters was stopped.

Now, it must be borne in mind that at this time the great mantle of snow and ice which had so long covered the country was passing away, leaving the surface of the hills in Glen Roy covered with a thick coating of angular local *débris* mixed with sand and clay, the result of the intense cold and of the decomposition of the underlying schistose and granitic rocks. This and the glacial *débris* must have long remained bare and unprotected by vegetation; at all events that below the water-line was so. Now, the angle of repose of purely angular and subangular *débris* varies within the limits of from 35° to 48°, but that of clayey sands, which, when dry, is from 21° to 37°, becomes,

when saturated with water, as low as 14° to 22°. The angle of repose of the hill-side *débris* would, therefore, depend on the relative proportion of the angular materials and their matrix, and on the extent of saturation. The slopes of the hills being on the whole greater than that of the angle of repose of the saturated under-water rubble, this latter, easily set in motion on the settlement of its constituent parts as the water drained from it would, as the level of the lake water fell, tend to slip or slide down with the falling water, and this slip would continue until the disturbing cause ceased, and the momentum of the mass was checked by the inertia of the water gradually coming to rest on reaching the level of the col of escape.[1] The effect of the arrested slide would be to project the mass more horizontally forward, and form a ledge. This ledge, modified slightly by subsequent subaërial action and weathering, and by the dressing of its slope on the occasion of the next fall of the lake, constitutes the "road."

Although in the case of the other "roads" there is not the same evidence of a minor col-barrier, as the results are alike in all, the causes which led to them must have been the same; and it is shown that there is nothing incompatible in the features of the ground with the existence of such barriers, or rather that there is some evidence in each glen, however slight, of water-lines at levels higher than the "roads."

Comparing the theoretical inferences of structure with the facts, so far as they are known, Mr. Brown's substratum of "clay with boulders indistinctly stratified with thin (lenticular) layers of sand," represents the sliding detrital mass; the finely stratified sand and clay—the sediment which subsided from the muddy lake waters after their fall; and the two to three feet of stones with clay—the subaërial fall of *débris* from the slopes above. In the substratum and overlying sediment, Mr. Brown found four species of fresh-water diatoms, while he found none in the upper bed. This fact serves to confirm the subaqueous origin of the body of the ledge, while it tends further to disprove the marine hypothesis.

Although there is in all the cols an entire absence of a defined water channel, such as would be worn by the long-continued flow of a river, there are in all of them traces of strong water action, such as might result from the temporary passage of a large and rapid body of water.

With respect to the main barriers acting as dams to Glen Gluoy, Glen Roy, and Glen Spean, they were due, as already pointed out, to the circumstance of an accumulation of ice at these spots so excessive and so high as to last long after the ice generally in the lower tracks had given way. Not, however, that any ice barrier could have been permanent for a great period of time, but this the author's hypothesis does not require. In any case, an ice-barrier in a state of rest will form a more effective barrier than when in motion.

Passing over the barrier at the entrance to Glen Gluoy, it is shown that the point where the Glen Roy barrier existed is that where a glacier coming down Glen Roy would meet in opposition the ice from Ben Nevis and the Spean Valley; and that this glen was occupied by a glacier is proved by the occurrence of glacial striæ on the rocks forming the bed of the valley near Dalriach, and of Till, or boulder clay, lower down the valley, nearer Achavady. But the great mass of the latter lies precisely on the spot where the Ordnance Survey have placed the line of barrier; it was there heaped up by the same conflicting causes that produced the barrier of ice. That it was originally larger and higher is proved by its occurring on the two sides of the valley, the river having worn a channel through it, and by the presence upon it of thick beds of water-worn and water-strewn gravel, the materials of which have been derived from the underlying deposit, and which was formed, in all probability, by the rush of the waters on the bursting of the barrier, for, in many places the gravel is thrown back and over, as though by downward and outward pressure of water in motion. This detrital mass extends for a length of two miles or more.

The great barrier needed at the entrance of Glen Spean is precisely on the ground that the great glaciers of Ben Nevis met the ice stream coming down Strathspean. Unachan Hill, which rises immediately behind the line of barrier marked by the Ordnance Survey, together with the rising ground on the flanks of the valley, consist of a thick substratum of till or boulder clay, with a covering of gravel, the latter formed in greater part, if not entirely, from the destruction of the former, so that there is little doubt that the detrital barrier here also was at one time much more important. Still, although the detrital matter formed a considerable element, the author believes that the great mass of ice constituted the essential element in the barriers.

The Till, although accumulated in larger masses in the above-named sites, is found in places all up the valley, generally in the form of terraces covered by gravel, as at Inverroy, Murlaggan, Inverlaire, and elsewhere. There is one feature common throughout, namely, the levelling and terracing of this glacial *débris* by subsequent water-action, which could not have been effected in the still waters of a lake bed, but probably took place on the bursting of the main barriers and during the rapid outflow of the waters. The levelling of the original glacial mounds having been effected at the time of the drainage of the lakes, and having been then covered and masked by gravel, the terminal slopes were either formed at the same time by the outpouring waters as they fell to a lower level, or subsequently by wearing back by the present streams.

An objection may occur to the foregoing hypothesis, in that, with elements so variable as the problem has to deal with, the parallelism of the "roads" with the horizon, which has been remarked on by all observers from Macculloch downwards, could not have been maintained. For the detritus of the hill sides vary, however slightly, in the relative proportions of rock fragments and soil, while the slopes above and below the "roads" vary also in their angle, so that, as these conditions varied, so would the momentum of the sliding mass vary, whilst the resisting force of inertia would remain the same. The consequence would necessarily be, that the slide would continue at some places to a lower level than at others, and the line of the "roads" could not be throughout parallel with the horizon.

There is no doubt that, to all appearances, the "roads" are perfectly level, and such was the author's first impression; but afterwards, on referring to the elaborate 6-inch Ordnance maps, he found the levels there given clearly show that the "roads" are neither at the exact height of the cols nor are they perfectly parallel with the horizon, after allowing for the variable inclination of the "roads," and for the observations being made in their centre.

Instead of a perfect level water line, the "roads" are really slightly *waved*, the difference between the highest and lowest point being in the four "roads" taken in descending order, 15, 11, 15, and 12 feet; and while the level of the higher "roads" is in most instances *below* those of the several cols of escape, that of the lower "road" is in all instances *above* it. Thus in Glen Gluoy, the "road," which is never more than 1 foot above the level of the Turret Col, is in places 14 feet below it. The Glen Roy "roads," Nos. 2 and 3, rise 2 and 4 feet above the col of the Spey, and sink 7 and 13 feet below it; whereas No. 4 "road" is never less either in Glen Roy or Glen Spean than 2 feet, and rises at places to 10 and 14 feet, above the Pass of Makoul. Further, as the curves formed differ for each "road," the variations *cannot be due to a common cause, such as subsequent movements of the ground*, but must be owing to differing conditions in each case. Nor do the levels on the two sides of the valleys correspond; they often vary as much as 7 or 8 feet. It is therefore not possible to reconcile these variations with the hypothesis of the "roads" being lines of water level due to shore action; nor is the very variable inclination of the "roads" themselves compatible with that view.

In the higher "roads" the lower level of the curve is possibly due to the steeper slopes, whilst the fact that the lower "road," No. 4, remains above the level of the Pass of Makoul, may be due to the circumstance either of the slopes being less, or more probably to the fact of the lake having been so very much larger, the escape of the waters was more prolonged, and the fall slower.

Various phenomena in connection with the great ice-sheet in Lochaber, and their connection with the general question, are next considered. The author objects to the term of *moraine profonde* to describe the drift of sub-glacial origin, as apt to lead to misunderstanding, although Hogard and other geologists have used it in a wider sense. It is evident that the old ice-sheet acted under very different conditions to an ordinary glacier, and it is better to use such terms as moraine detritus or sub-glacial detritus for the sum total of sub-glacial products of the former, than employ a term which was originally and still is generally restricted to a single and comparatively small product of the modern glacier.

Besides this sub-glacial *débris*, there is the larger quantity of

[1] Even now considerable slides occasionally take place on the steeper slopes of Glen Roy.

débris that must have been scattered over the surface of the ice during its melting by streams and rivulets, or spread out in the temporary lakes which were formed at all levels, and may have given rise in many instances to sand and gravel terraces of variable extent. But though true beaches may be deposited in other glacial lakes, for ledges or shelves such as constitute the Parallel Roads to be formed, a number of conditions must have concurred—such as sufficient slopes, a detrital covering, barriers at the mouth of the glens, and cols of escape at their upper end.

As the barrier ridges on the old ice-sheet melted, or burst, the waters escaped to lower levels, carrying with them, on or beneath the ice, a large portion of the surface detritus. Formed at all levels up to 2,000 feet or more, these glacial lake waters, in descending to lower levels, met with yet larger bodies of water, and the transporting forces increased in power till the last stage was reached and open channels formed in the distant plains, leaving as marks of their passage down the valleys—here great banks of gravel—there deep beds of sand, according to the distance from the point of outburst. To these floods, combined with river inundations, and with the modifications wrought by subsequent fluviatile action, are due various forms of escars, terraces, and other less defined detrital accumulations.

Meteorological Society, May 21.—Mr. C. Greaves, F.G.S., president, in the chair. The following were elected Fellows of the Society:—A. C. Bamlett, C. Browne, H. Burkinyoung, W. Radford, F. Ramsbotham. The adjourned discussion on the Rev. W. Clement Ley's paper on the inclination of the axes of cyclones was resumed and concluded. The object of this paper is to call attention to the evidences recently afforded by the results of mountain observations to the theory that "the axis of a cyclone inclines backwards." The author first reviews the state of the question up to the present time, and details his own investigations chiefly founded upon the movement of cirrus clouds; he then refers to Prof. Loomis's recent "Contributions to Meteorology," in which is discussed the observations at the summits and bases of several high mountains, the results of which confirm the theory that the axis of a cyclone inclines backwards. The following papers were read:—On observations of the velocities of the wind, and on anemometers, by G. A. Hagemann.—On the relation between the height of the barometer and the amount of cloud, as observed at the Kew Observatory, by G. M. Whipple, F.R.A.S. The author shows that the average amount of sky clouded at Kew is a little less than seven-tenths of the whole, and that the amount covered varies inversely as the barometric pressure between the limits of 29·0 and 30·3 inches, the variation being the most rapid between 29·8 and 30·1 inches. Also that above 30·3 inches cloud increases with increasing pressure, attaining the mean about 30·5 inches, and rising above it at 30·6 inches.

PARIS

Academy of Sciences, May 19.—M. Daubrée in the chair.—The following papers were read:—Meridian observations of small planets at the Greenwich and Paris Observatories during the first quarter of 1879, communicated by M. Mouchez.—On the resistance of elliptical boilers, by M. Resal.—On a new derivative of nicotine, by MM. Cahours and Etard. This is got by heating nicotine (100 parts) and sulphur (20 parts) together. The sulphur acts first by removing hydrogen from the nicotine. When at 160° to 170° the mass has become fluid and chrome-green in colour, the heating is stopped; and in a few days yellow prismatic crystals are formed of the new substance. Sundry reactions are described. The authors consider nicotine as probably a combination of dipyridine and hydrogen. Sulphur, acting on 2 molecules of nicotine, transforms it, with separation of sulphydric acid into *tetrapyridine*.—Formal reasons of the economical superiority of the Woolf or compound engines, by M. Ledieu. These are shown in tabular form.—Researches on the proportion of carbonic acid in the air, by M. Reiset. He operated with large aspirators, of about 600 litres capacity, movable to various parts. He finds that free atmospheric air contains, on an average, 2·942 vol. carbonic acid per 10,000 vol. (The common statement is that the quantity in atmospheric air varies between four and six ten-thousandths in volume.) In very diverse conditions the extreme variations did not exceed 3 per 100,000. Comparative observations in woods and in fields showed small differences, the numbers being 2·917 CO_2 and 2·902 CO_2 respectively, for the same hour. Other cases were: Over a field of red flowering clover in June, 2·898 CO_2; over one of barley with luzerne, in July, 2·829 CO_2. Among a flock of 300 sheep in pasture, 3·178 CO_2 (showing a considerable increase); at Paris, in May, near the Parc Monceaux, 3·027 CO_2.—M. Daubrée communicated news of M. Nordenskjöld. Whalers had seen what was probably the *Vega*, blocked in ice near Behring Strait, not far from East Cape.—Mr. A. Hall was elected Correspondent in Astronomy in room of the late M. Santini.—On the transparence of the media of the eye for ultra-violet rays, by M. Soret. He operated with the eyes of oxen, calves, and sheep, using his spectroscope with fluorescent eye-piece. It is shown that the absorption by the whole of the media must render impossible the perception of rays whose refrangibility exceeds that of the extreme radiation of the solar spectrum, or the line U. The absorbent properties of the vitreous and aqueous humours are attributed to presence of albuminoid substances. The limit of transparence of the two humours is indicated by curves.—Independence of changes of diameter of the pupil and of variations of the carotidian circulation, by M. François Franck. The iris may be dilated or contracted independently of modifications of the circulation.—A letter from Buffon to Laplace in 1774 was communicated by the Marchioness de Colbert-Chabanais.—On the characteristics of functions Θ, by M. Jordan.—On functions such as $F(\sin\frac{\pi}{2}x) = F(x)$, by M. Appell.—On a property of entire functions, by M. Picard.—On the functions introduced by Lamé in the analytical theory of heat relating to ellipsoids of revolution, by M. Escary.—Preliminary study of the action of acids on salts, without intervention of a solvent, by M. Lorin. The results indicate in general a chemical action more or less marked, and which for fatty acids decreases from formic acid to each of its successive homologues. Applications:—1. Crystallisable acetic acid may be obtained with acetate of baryta and sulphuric acid. 2. Formic acid may be had, *very concentrated*, with sulphuric acid and formiate of ammonia.—On the presence of mercury in the mineral waters of Saint-Nectaire, by M. Willm. He confirms M. Garrigou's conclusion (which had been denied), though the quantity of mercury he got was much less.—On the changes of volume of the spleen, by M. Picard. The dilatation of this organ results from dilating nervous actions exercised on the digestive organs, while its contraction results from a special well-determined nervous action.—Researches on alterations of the blood in uræmia, by MM. Morat and Ortille. Carbonate of ammonia is always found in the blood, unless death come before the end of the second day. Its presence there is posterior to its presence in the alimentary canal.—On the mode of combination of iron in hæmoglobine, by M. Jolly. His analyses confirm a former conclusion, that iron exists in the blood corpuscle only in the state of phosphate.—On hæmatoxylic eosine and its employment in histology, by M. Renant. It reveals, by an elective coloration, the two orders of cells which constitute by their union a mixed acinus of the sub-maxillary salivary glands.—On the apparatus of sound in various South American fishes, by M. Sörensen. Vibrations are communicated to the air of the swimming bladder.—On the amyloid appearance of cellulose in champignons, by M. De Leynes.

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