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(*Read March* 2. 1818.)

I HAD last winter the honour of laying before the Royal Society a few hasty remarks on what are called the *Parallel Roads of Glen Roy*, suggested to me by an accidental ramble through that valley, in the course of a pedestrian tour in the West Highlands, during the previous August. My curiosity having been much excited by what I then saw, I was induced to revisit the highly interesting district of Lochaber, in the beginning of last June, and had thus an opportunity of devoting three whole days to a more complete inspection of these remarkable shelves, which I was surprised to find, were to be traced through a much more extensive stretch of country than former observation had led me to imagine. My first visit to Glen Roy was accidental; but upon this late occasion, I went with the purpose of endeavouring to put myself in possession of all the facts I could possibly collect, regarding these curious appearances; and in doing this, I had several advantages which I did not formerly enjoy. I was accompanied by my friend Mr MACLEAN, civil engineer, who kindly assisted me in ascer-

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taining the horizontality of the lines. The weather was particularly favourable for our purpose, having been remarkably calm and clear during the whole of our stay in Lochaber. We had also the good fortune to be hospitably received, as the guests of Mr Macdonell of Inch, whose residence, situated near the junction of the rivers Roy and Spean, afforded us the most centrical point, from whence we might make excursions in every direction; whilst extreme acuteness of observation in our host, and the great interest he has taken for many years, in the very investigation in which we were engaged, and the constant opportunity he has had of making himself acquainted with the various appearances, rendered him an intelligent, as well as a willing guide. I am, therefore, now enabled to offer an account of these shelves, not only much more particular, but embracing a much greater extent of country. And although I am well aware of the numerous sources of error to which the investigator of so many intricate mazes is exposed, yet I trust I may venture to hope, that my inaccuracies are few in number, and, individually, unimportant. In this hope I am the more confident, from having the highly valuable testimony of Mr Macdonell of Inch to support me, from whose communications I have even described some particular spots, which I had not an opportunity of visiting in person. Indeed I cannot sufficiently express my sense of the obligations I owe to that gentleman.

In the first part of my essay, I propose to give a general description of the form and appearance of the shelves. I shall next suggest the theory, which may account for the formation of such appearances in general. I shall then give a particular account of the whole shelves of Lochaber, as connected with the topography of the glens where they are found. And, lastly, I shall conclude, by stating the theory, which appears to me most likely

likely to explain the circumstances of their particular formation. My remarks will, I hope, be found more intelligible, by reference to a map, which, however, must be considered as a mere eye-sketch of the country, its construction having been merely aided by the observation of a few angles and bearings, and therefore having no pretensions to geographical accuracy, beyond what is necessary for the purpose to which it is dedicated,—that of giving an idea of the courses of the different shelves, to which I have affixed distinguishing figures. Though the shelves are laid down in continuous lines, it is by no means meant to convey the idea, that they are strictly so in reality: partial deficiencies in their continuity are certainly to be observed, but these are too trifling and unimportant, to be noticed in a general view of them on so small a scale. It should be also remembered, that it is only in the most important points, that the detail of their various lesser bendings is attended to. Where such a point occurs, as at the head of Lower Glen Roy, the attention which has been paid to mark the sinuosity of the lines, as correctly as possible, has compelled me to devote more room to that part, than it would be entitled to were strict proportion observed; and thus Upper Glen Roy is more reduced in size than it ought otherwise to have been. Besides the map, I have ventured to give a few sketches of what appeared to me to be the most remarkable views of the shelves. These are taken from above, or on the same level with them, so as to produce that natural rise of the perspective, observable in the lines of level water. Without this, it is not easy to comprehend their horizontality from a drawing. This, however, lends them the character of bird's-eye views, and consequently gives a more confined appearance to the glens than they present when seen from below. There are also two plates of diagrams, which may be found useful in illustrating the theory of their formation.

General Appearance and Character of the Shelves.

The shelves run in a series of horizontal lines, along the sides or faces of the mountains of Lochaber *, bounding the valleys of Glen Gluoy, Glen Roy, Glen Spean, and several of their smaller tributary glens. One range of these is to be observed on each side of Glen Gluoy, running at a level somewhat higher than that of any of the linear appearances in the other glens, with none of which it has the least connection. In Glen Roy there are three corresponding ranges, the uppermost being at a level about 12 feet under that of the shelf in Glen Gluoy. The next is about 80 feet below the level of the one immediately over it; and the lowest line of all, is about 200 feet underneath that to which it succeeds in elevation. These two last measurements, however, are merely such as could be accomplished by an ascertainment of the distance of each range from that above it, at different parts of the glen, corrected by a calculation of the intensity of the various slopes, producing an approximation to the truth. The two uppermost shelves of Glen Roy are entirely confined to that valley, and those immediately tributary to it; but the lowest of all, is seen to sweep

* The Gaelic word *Lochaber*, signifies the influx of a lake into a river, or the sea. The district so called, comprehends Glens Gluoy, Roy, and Spean, Lochs Laggan and Treig; and the country stretching in the direction of Fort William, and as far to the westward as the Ferry of Balachulish.

sweep out to right and left, from its mouth into Glen Spean; running on the one hand, by various sinuosities, in the direction of Highbridge, and extending up the north side of Glen Spean, and round the upper extremity of Loch Laggan, whence it returns on the south side of the same valley. There are thus four distinct ranges of these shelves, which, to avoid circumlocution, and for the sake of greater perspicuity, I shall uniformly number from above downwards. I shall, therefore, call that having the highest level, and belonging exclusively to Glen Gluoy, *Shelf 1st;* those two coming next in elevation, and which are to be found in Glen Roy alone, I shall call *Shelf 2d* and *Shelf 3d;* and, lastly, That which is lowest, and which being common to both Glen Roy and Glen Spean, is by far the most extensive, I shall designate as *Shelf 4th.* All these will be found in the map, with their respective numbers attached to them. There are also some other indications, in the bottom of Glen Spean, to be afterwards described, to which, as they appear to owe their formation to causes similar to those of the shelves above mentioned, I have affixed the numbers 5, 6, and 7. All these different shelves are found to maintain the horizontality characterizing the surface of water, throughout all the various windings of their linear extent, and round the hollows and projections of the hills, whether these are small or great, sudden or otherwise; and each respective range, on one side of any of the glens, is exactly on the same level with that corresponding to it on the opposite side. Indeed these lines, which are thus of similar level on different sides of the glens, are manifestly identified. For whenever the level of the bottom of a glen, by rising above that of any one particular shelf, obstructs its farther progress upwards, that shelf immediately winds round, and crosses the bottom of the valley on the same level, in the form of a broad shelving plain, whence

whence returning downwards on the other side, it produces, when opposed to that part of it running upwards, the appearance of two twin shelves, when, in reality, they are discovered by examination to be one continuous line. There is, of course, every where, a perfect sameness in the perpendicular height of one range above that which is beneath it. But a deception is produced to the eye, with regard to the apparent relation of the whole shelves, to the valleys where they lie. For, from the inclination of the bottom of the valleys, being opposed to the perfect horizontality of the shelves, the whole of the latter have the deceitful appearance of sinking on the sides of the hills, as they run in a direction towards the sources of the streams; and of rising, as they approach the openings of the several glens. Although the perfect linear horizontality of these shelves, and the correspondence as to level, of each particular part of a shelf, on the two sides of the same glen, has been always admitted, upon simple ocular inspection, yet it is by no means easy to put this important matter beyond doubt. It is indeed impossible to perform a mathematically accurate levelling process, on such rude and indefinite subjects as these shelves are. For although they appear very distinctly, and even sharply marked, when viewed from the glen below, or from some distance, yet when the observer climbs up to inspect them more narrowly, he always finds it impracticable to discover their precise limits, and they are then indeed so very indistinct, that he may even be actually treading on a shelf, without being in the least aware that he is doing so. This shows how very imperfect they are as to form, and how very little they deviate from the ordinary contour of the hills along which they are traced; for whilst their outward edge is very much rounded off, they are united interiorly to the acclivity of the mountain above them, by a highly inclined slope, so as to

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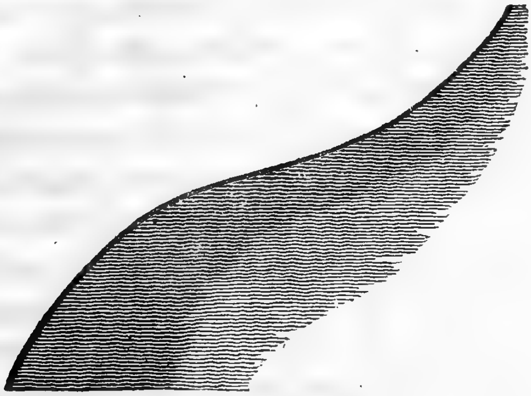
make the section of the line of their profile somewhat like this:



And every part of the breadth of the shelf also, deviates so far from the level, that the sections of it would exhibit an inclination outwards of from one foot in five, to one foot in three, and in some places a great deal more. Their actual surfaces are all so rugged and irregular, that no proper series of operations could be carried along any of them, with a hope of determining their true linear level. My friend Mr MACLEAN and I, therefore, conceived that we did nearly all that could be well accomplished for this purpose, by using the following means, in the course of three several observations, taken on shelf 2d, shelf 3d, and shelf 4th, which, together with the results, I shall now detail.

It was from a very commanding position, marked *d* on the map, that we levelled shelf 2d. From this point we enjoyed very nearly the same view as that represented in plate IV., and had the advantage of observing some considerable portions of the same shelf on the other side of the valley, immediately opposite to the eye, and at no great distance from it, whilst there were also a variety of different distances, receding in perspective behind one another. We employed a very delicate eighteen

teen inch levelling instrument, made by Jones. It was planted, as nearly as we could guess, (where the limits of the subject we had to work upon were so ill defined,) rather towards the lower edge of the shelf, and we endeavoured to adjust it in such a manner, as to make the levelling telescope itself of the same height with what we supposed to be the higher or interior angle of the shelf. Directing the object-glass of the instrument to the nearer and immediately opposite corresponding line of shelf, it applied all along, most accurately, to the horizontal hair; but when pointed to those farther off, (some of which were perhaps five or six miles distant,) they appeared to sink sensibly below the hair, and this in proportion to their distance from the point where we stood; but they were nowhere observed to do so in a greater ratio, than the allowance for the curvature of the earth at such rectilineal distances demanded. And, what was in our opinion most conclusive, when the telescope was pointed to, and made to traverse along any particular portion, which, from being directly opposite to the eye, might have been presumed to be nearly equidistant in all its parts, it was found to preserve an uniform relation to the horizontal hair.

Our observation taken on shelf 3d, was, if possible, even more satisfactory, from the point we chose, (see *f* in the map,) being still better adapted for the purpose, as we not only commanded a view of the head of what may be termed Lower Glen Roy, (see plate V., the sketch for which was taken from hence,) but we could also see the shelves, running continuous all the way down to the mouth of Glen Turret, to which we were opposite. We could follow them with the eye throughout the greater part of their progress around that tributary glen, and so down the north-west side of Glen Roy, for a considerable distance; forming altogether a line, which, if it had been

been extended, would have stretched perhaps five or six miles, whilst, from its numerous bendings, the rectilineal distance of the farthest visible part of it from the eye, was probably not so much as two miles, and most of it was greatly less than one. And what was still more advantageous in this position, in traversing the telescope of the instrument round, many points could be touched upon which were evidently nearly equidistant from the eye. Here the perfect coincidence of the line with the horizontal hair, was more generally striking than it was in our first experiment.

Our third trial was on shelf 4th, and we were fortunate in selecting a very excellent point of view for that also. The spot where we planted our instrument was a little to the eastward of the house of Inch, on the south side of the entrance of Glen Spean, (see *b* in the map). It was from thence that I sketched the view of the entrances of Glen Roy and Glen Spean, as represented in Plate II., which, when compared with the map itself, will afford some idea of the great extent of shelf 4th, which we commanded at one *coup d'œil.* We could trace it, sweeping from Ben-y-vaan on the left, up Glen Collerig,—returning from that little valley, and embracing the south side of the round hill of Bohuntine, and disappearing into Glen Roy,—re-appearing on the faces of its southern mountains, till it is again lost behind that of Crag-dhu, which divides the entrances of the two glens,—coming into view again as it circles round the bottom of that projection, and identifying itself with the upper line of a high inclined plane, whence it sweeps into the mouth of Glen Spean, where we could of course trace it much farther, than could be embraced within the angle of vision employed in the delineation of a perspective sketch. We could also trace the same line faintly encircling the isolated rock of Mealderry, which appears in the drawing much nearer the eye. We traversed the telescope

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of the instrument around all these different points, and the results were perfectly satisfactory. In short, from all our experiments, and from all our other observations, there did not remain a shadow of doubt in our minds, that the whole of these shelves were perfectly horizontal in themselves, and that every part of any shelf on one side of a glen, was decidedly of the same level with the corresponding portion of it on the other side.

The breadth, or depth of these shelves, on the steep sides of the hills, is very various, and is evidently much modified by circumstances, particularly by the nature of the ground. That part of the shelf is generally deepest, and most strongly marked, where the face of the mountain forms an acute angle, or rounded promontory ; and this is more particularly the case, where the promontory is of comparatively soft materials. In all other places, whether bay or projection, where the surface of the hill is soft, and easily worn away, the indentation is almost uniformly better defined than where a harder soil occurs. Where rock manifests itself, little more generally appears than a slight tracing on its surface, merely enabling the eye to follow out the line with difficulty; but on the fronts of many of the rocks, all appearance of it is lost for a space, until it again manifests itself on the softer surface. The indentation of shelf 4th, on the rocks at the entrance to Loch Treig, is peculiarly strongly marked; and the same shelf is also well defined in its circle round the top of Tom-na-Fersit, a small isolated hill near the same point; but these form, perhaps, the only striking exceptions to what may certainly be considered as a general fact.

These remarks, apply rather to the degree of distinctness with which the shelves are traced along the length of the glens on the steep sides of the flanking mountains, than to their actual breadth. For when any one shelf approaches the point, where, (by the rising of the level of the bottom of the valley) it it is compelled to cross to the other side, the breadth of it is always greatly expanded, so as to give it the appearance of a broad inclined plane, in some instances so much as half a mile, or perhaps even a mile wide; and this is almost invariably covered, to a certain depth, with a stratum of peat-moss. In such cases, the level of the linear appearance infallibly applies to the upper bounding line of the expanded inclined plane. These expansions of the shelves, are not only to be met with in those places, where they cross from one side of a valley to the other, but are also to be observed in many other parts of their course, particularly where the hills are low, and of a gentle slope, or rather where the shelves run along the bottom of such hills. On a first hasty observation, these expansions may be overlooked, as having nothing to do with the shelves, and it may be supposed, that some cause has here operated to interrupt them for a time. But a little attention to their appearance and level, will at once show, that these inclined planes have been formed by the same cause, as the more properly defined shelves, and that they are in fact nothing more than expanded continuations of them, which, from the very circumstance of their greater breadth, lose that extremely sharp and striking appearance, so remarkable in those parts where the hills are steeper and more lofty.

The shelves are in many places covered with large masses of stone, some of them many tons in weight, lying for the most part quite detached on the surface, and having their acuter angles rounded off in the greater number of instances; in short, in every respect resembling those fragments generally found strewed on the margin, and in the shallow edge of alpine lakes. In some places, where the stones are large, and the shelf narrow, a single block covers its whole breadth. Where rock appears any where on a shelf, its angles are also for the most part rounded. One fact is very important, and

 deserves

deserves particular notice: the nature of the soil in each valley, is materially different above and below its highest line of shelf; all above this natural division, being found to resemble the bare moorish soil covering any other mountain; whilst large depositions of alluvial clay, sand, rounded pebbles, and gravel, present themselves every where below that point, and this, more particularly towards the mouths of the different valleys. Marine exuviæ, however, are nowhere to be met with. Perhaps the most interesting circumstance regarding these shelves, is, that wherever an isolated little hill happens to rise from the bottom of the valley to a height above that of the level of any shelf, a delineation runs round the little hill, at a level corresponding to that of the shelf on the mountains of the side of the glen.

Such, then, is the general description of the character and appearance of these shelves.

Theory which may account for the formation of Shelves running horizontally along the sides of Mountains confining Glens.

In the total obscurity in which the origin of these singular shelves is involved, some have been inclined to regard them as productions of art, others as the work of Nature. Of these two opinions, I confess I cannot hesitate in rejecting the first. The immensely arduous nature of the undertaking, arising not only from its extent, but from the numbers of accurate measurements and levellings it must have required,—the impossibility of the supposition, that the engineers of those early times to which they must be referred, could have known how to make the exact allowance for the curvature of the earth, and this, too,

too, at a period when our planet was believed to be a plain, extending *ad infinitum*;—the difficulty of imagining any rational object for the construction, in such a situation, of such a series of terraces, so precisely horizontal, so equidistant in all their parts, and so exactly corresponding on the two opposite sides of the valley, and in some places sweeping in one continued circle round the tops of detached hills in the middle of the glens;—above all, the actual structure of these shelves, as they at present remain, constitute, in my mind, insurmountable objections to any hypothesis, which would ascribe their origin to human labour and ingenuity *.

That

* "As there is nothing left upon record," says the Reverend Mr Ross, in his account of the parish of Kilmanivaig, (Statistical Account of Scotland, vol. xvii. p. 549.) "respecting the times when, the persons by whom, or the purposes for "which, these roads were constructed, we can only mention the common traditions "regarding them. One is, that they were made by the Kings of Scotland when "the royal residence was in the castle of Inverlochy, which is not above eleven "miles from the nearest of them; and, what gives an appearance of truth to this "tradition, in the opinion of those who maintain it, is, that the construction of "these roads was so vast an undertaking, as could not be effected by any vassal or "nobleman, however powerful. Another tradition, which is that of the natives, "is, that they were made by the Fingalians, and, under the name of *Fingalian* "*Roads*, they are still known in this country. They are likewise called the *Ca-* "*san*, *i. e.* the *Roads*, by way of eminence. Of this the natives are convinced "from this circumstance, that several of the hills of this glen have retained, from "time immemorial, the names of some of the heroes of Fingal, such as the Hill of "Gaul the son of Morni; that of Diarmid; and of Fillan; and likewise of Bran, "the famous dog of Fingal, &c. Now the popular belief cannot be considered as "a direct proof of any opinion, yet we cannot help remarking, that the original "tradition, (which in this case has been always invariable,) gives a strong degree "of credibility to the existence of such heroes, and renders it by no means impro- "bable, that these extraordinary roads have been the result of their labours. The "purpose which they were designed to serve, seems to have been, (agreeably to "the common opinion,) to facilitate the exercise of hunting; for in ancient times,

"and,

That theory seems to me infinitely the most probable, which attributes the formation of the shelves to the action of the waters of a lake. The perfect horizontality of the lines, and their exact agreement in height on the opposite mountains, added to the fact of their running up the smaller tributary glens, and following the retiring, as well as the projecting parts of the faces of the mountains, with so much regularity and precision,—the circumstance of their encircling isolated hills with a perfect ring, totally unconnected with any other part of the shelves,—the rounded edges of the rocks, and fragments on their lines,—the change which takes place in the soil above and below the shelves,—their expansion into mossy flats or inclined planes, whenever the level forces them to do so,—all combine to show, that nothing but the surface of water could have caused them. That alpine lakes, filling deep hollows amidst mountains, *rising from their bottoms with steep and almost precipitous acclivities*, do generally form similar shelves around their margins, must be sufficiently well known to every one who has had an opportunity of visiting such scenes. Indeed a little reflection will show, that this must necessarily happen. For if we suppose the almost perpendicular sides of such a hollow to be filled, to a considerable height, with a lake of this character, as exemplified in the diagram, (Plate VII. fig. 5.), in which the dotted line A represents its level, then the

" and, indeed, till within this century, the valley was covered with wood, which " made it very difficult to pursue the deer, &c. and rendered certain avenues necessary for effecting this purpose; in corroboration of which opinion, it may be " observed, that upon the sides of the roads, there have been found some stakes " fixed in the ground, probably the remains of some of the paling or fences, which " in those days were made use of to confine the game, till they were driven in " upon a field, called *Dal-na-sealg*, or Hunting Dale, where the presumption is " they were killed."

the agitation of the surface of this lake, by the various winds to which it may be exposed, will naturally drive its waves against some of the points round its margin, as *a a*, and will gradually eat away the bank there by the frequency of their action against it; whilst all being still underneath, it will not be affected any where below. Then, as the water thus mines away the banks, where they are on a level with its surface, the earth and other materials will naturally fall down from above, so as to form two sloping cuts or notches in the side of the hill, as represented by BB, between the dotted and black lines. All the smaller and less ponderous substances, such as gravel, earth, and sand, will of course be washed inwards, towards the deeper part of the lake, and immediately on getting beyond the shallow, will sink down, and form an accumulation at the bottom, and on the sides, as represented in the diagram by D, between the dotted and black lines. But the violence of the waves of a lake, is seldom such as to move those large masses of stone that may be supposed to be uncovered, loosened, or undermined, and brought down by the almost continual, though gentle, fluctuation of its surface towards its shores. These, therefore, would gradually accumulate on its shelving beach. It is almost unnecessary to add, that the breadth of the shelves (BB in the diagram) would vary according to the degree of hardness or softness of the materials forming the various parts of the bank on which the water would have to operate; and that where stubborn rock should present itself, unless it were placed in some peculiarly exposed situation, it might remain for ages, hardly, if it all affected. Wherever there were swells or promontories, these would in general be most acted upon by the agency of the waves, unless other circumstances should prevent it. This is, indeed, the precise character of all mountain lakes, *filling hollows between very*

steep

steep acclivities, like those I have supposed. I should have little difficulty in enumerating many such pieces of water. In the earlier part of the very tour which ultimately led to my first visit to Glen Roy, our party accomplished a rather arduous expedition to Loch Aven, a lake very much answering the above description. It is situated in the very bosom of the Cairngorum range of mountains, having that which is more properly called Cairngorum rising on its western side, directly from its waves, almost to the utmost height of the mountain; and on the south-eastern side Ben-mach-duie, the highest point of the whole chain, is seen elevating itself equally suddenly, and with a rocky, and almost overhanging front, still grander and more abrupt. This lonely lake presents an assemblage of every thing that is wild and sublime in Scottish scenery. The gentlemen of our party who were familiar with the ruder parts of the Swiss Alps, admitted that Loch Aven furnished no very insignificant specimen of the terrific scenery to be met with in that interesting country; and the resemblance was rendered more striking, when we saw it, on the 1st of August, from an immense unmelted glacier, which shone through the thin mist floating on the brow of the rocks, at the farther extremity of the lake. Mr Robson, who, in his "*Sketches of the Grampians*," has given a very faithful outline of it, is, I believe, the only person who has had the merit of noticing this desert and desolate, but magnificently gloomy spot. As we climbed the rugged, and almost inaccessible front of one of the crags, rearing itself over its upper extremity, by a pass which ascended between two torrents, precipitating themselves with dreadful roar from the glacier on the brow of the mountain above us, I could distinctly perceive, when looking downwards to the lake, that a narrow shallow shelf almost every where surrounded it, within which it seemed, by its sudden

den change of appearance and colour, from an extremely green transparency, to a pitchy blackness, to become all at once of an apparently unfathomable depth. This circumstance, which I remarked at a moment when I had not even a thought of Glen Roy, struck me very forcibly. But I had afterwards occasion to notice, during the remainder of the same tour, that such was almost invariably the case with those lakes having steep shores of the same description. In Loch Lochy, Loch Oich, and Loch Ness, wherever the mountains rose from a depth with a sudden acclivity, the same appearances presented themselves. And what appeared more extraordinary, and what I scarcely expected, in sailing down the salt-water lake or arm of the sea called Loch Linnhe, from Fort William towards Coran Ferry, we even found the same kind of shelf in similar circumstances on its southern side, though on a larger and ruder scale. Since that time, I have had occasion to make the same remark, where the hills rise abruptly from Loch Awe, Loch Lomond, Loch Tay, and almost every other Highland lake that I have visited. Most of the mountain lakes of Switzerland and Italy, having sides of the same precipitous description, are surrounded by the same shelving margin; and, amongst many others, the lakes of Nemi and Albano were particularized to me by an intelligent friend, as being both of this character *. But I wish it to be always understood, that the foregoing illustrations, as well as the diagram to which I have referred, are merely applicable to the formation of a shelf on the *steep side of a mountain*, where, though it may not be found so broad as in other places, it will always be more sharply marked than when the waves are

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* Since this paper was presented to the Society, I have had an opportunity of satisfying myself of the accuracy of this remark with regard to these lakes, as well as of adding to the examples of this general fact, from my own personal observations on the lakes of *Maggiore*, *Lugano*, and *Como*, as well as in the upper part of the *Lake of Geneva*, and several other continental lakes, having precipitous shores.

expended on a more gentle slope, where they will produce shelves less distinctly indented indeed, but much broader. The number of lakes which furnish examples of these broad shallows within the margin, where they have easily inclined shores, is so great as to render it unnecessary to instance any of them. This last remark, however, should be kept in view, because it will be found to apply to many parts of the particular description of the courses of these Lochaber shelves, which it is my intention to give, and will more especially explain those parts of them, where an inattentive observer would be apt to suppose that they disappear entirely, when, in reality, they only become less distinct, by becoming wider, and consequently more gradually shelving.

After subjecting mountain lakes to this close investigation, it will probably strike every one, that the consequence of the sudden escape of the water from one of them, would be the immediate appearance of a glen having a range of horizontal shelf, traced high up on the face of its mountains, and in every respect similar to those exhibited in Lochaber; and this would be either distinctly seen all around it, or would appear only partially, as the nature of the different parts of the sides of the hills happened to be more or less obdurate or friable, and would present all the modifications of breadth, that might have been occasioned by their various degrees of slope, as well as by their numerous promontories, swells, hollows, or bendings. Through the kindness of a friend, who was one of the party in my first visit to Glen Roy, and who is well acquainted with the spot I am now about to describe, I am fortunate in having it inmy power to produce a case exactly of this description, where there cannot be a doubt that such an escape of the waters of a lake did unquestionably happen, although the exact time when, and the actual manner how it occurred, is lost in the obscurity of the dark ages. The valley to which I allude is situated a little above the town of Subiaco in Italy, lying about forty-six miles to the eastward of Rome, and twenty-eight from

from Tivoli. The river running through the valley nearly retains its ancient name, being there called the Aniene; but as it approaches Tivoli, it takes the more modern appellation of the Teverone. Subiaco is an Italian corruption of Sublaqueum, by which name it was anciently known. Following the course of the river upwards from Subiaco, the mountains, which are part of the Appennines, and of very considerable height, begin to close around, confining the bottom into a narrow glen; and in about half-a-mile after leaving the town, the valley is observed to be blocked up all at once, by an immense wall of rock, perhaps 100 feet high, crossing it at right angles, (see Plate VII. fig. 1. and fig. 4. A). This appears rent perpendicularly from top to bottom in the centre, as if by some unaccountable convulsion, presenting a chasm, which is only 12 or 15 feet wide, and which it is quite impracticable to enter, as the bottom is filled by the river, which is, indeed, very much confined in its passage through it. This natural barrier of rock, is perhaps not less than an hundred yards in thickness, and although it is quite perpendicular towards Subiaco, it has a slope towards the other side, which faces up the river. The sketch of it, (Plate VII. fig. 1.) was drawn from an outline done by my friend from recollection, and is sufficiently accurate to give some notion of this singular rock, at least as far as regards the present purpose; and the perpendicular section of it, (Plate VII. fig. 2.), supposed to be made on the same line with the ravine, gives an idea of both its steep and its sloping side. The plan of the valley, (Fig. 4.), although it is drawn from a mere sketch from memory, by the same gentleman, will illustrate the description. Having got beyond the rocky wall, (marked A, fig. 4.), the glen to which I wish to solicit attention, is found to be deep and narrow, and about a mile in length. The river Aniene runs along in the bottom, and the mountains on either side rise immediately from its margin, and, with a very sudden and steep acclivity, as is re-

 presented

presented in a section of the valley, supposed to be taken across from B to E of the plan, and given in fig 3., in which G represents the river. High up, on the face of the hills on the south side of the valley, are the remains of the Baths of NERO, (E in the plan, fig. 4. and section, fig. 3.), and the remains of the mouth of the Aqueduct by which APPIUS CLAUDIUS conveyed water into Rome, from the lake, which originally filled the valley to that height, (F, fig. 4.) On a level with these, and consequently on a level with the ancient lake, an exact, and perfectly horizontal shelf, in every respect resembling those of Lochaber, runs around the face of the hills on the southern side of the valley, as expressed by the dotted line, fig. 4. But on the northern side, (where B, fig. 4. marks the situation of the convent of Santa Scholastica, and C that of San Benedetto), there is a great deal of rock, and consequently no such appearance of a shelf is to be observed. At the head, or western extremity of the valley, (D, fig. 4.) the river enters it through a ravine, by rapids, and over a cascade. Such is a description of the present state of this singular spot, to which I must beg particular attention, as it will be found to have a wonderful resemblance, in all its parts, to some of the appearances, to be described in the sequel of this paper. The Valley of Subiaco was anciently filled with part of the *Simbruina Stagna;* and the name of *Sublacum* was given to the ancient town, from the circumstance of its being situated under the lake. Of the Simbruina Stagna, anciently three in number, none are now remaining. This was the lowest; the other two were formed by the river higher up, and it is very probable, that some interesting appearances, of a similar nature to those I have been describing, may likewise exist on the sides of the hills which served formerly to confine them. But the banks of the Aniene are little known above the valley of Subiaco, the country being so overrun with banditti, that there is no safe travelling beyond the Convent of San Benedetto, where, indeed, the regular road stops. These lakes are more than

once

once mentioned in the classics, particularly by Tacitus, who notices the fact of Claudius's aqueduct having its origin on the hills on their margin; "*fontesque aquarum ab Simbrui-" "nis collibus deductos, urbi intulit*," (Ann. lib. xi. cap. 13.); and the circumstance of Nero, who had a villa there, having made it an occasional residence, is also established by the same historian, who mentions the fact of that Emperor having been alarmed by prodigies whilst in that retreat: "*Nam quia dis-" "cumbentis Neronis apud Simbruina Stagna cui Sublaqueum" "nomen est, ictu dape mensaque disjecta erat*," (Ann. lib. xiv. cap. 22.) The remains of the baths of Nero, E, fig. 4. Pl. VII. and the mouth of the Claudian aqueduct, F, fig. 4, which are both exactly on the line of shelf running around the face of the hills on the north side of the valley, and which, happily for our illustration, were both of a nature, that rendered water essentially necessary for their several objects, sufficiently prove that it must have owed its origin to the action of the waves of the lake, which must have had its margin there, (as at E, fig 3., where BE represents its ancient surface), otherwise it is manifest that both those buildings would have been useless. The wall of rock, (fig. 1.), as described by my friend, is just the height of the shelf, and composed of what he called "the na-" "tive rock," or that which is every where prevalent in the neighbourhood. This, we know from Brocchi's late work on the Geology of the Appennines, is a peculiar sort of limestone, of a pearl-grey, dusky-white, or smoke colour, with a smooth earthy fracture, without lustre. But what forms a very singular and striking physical corroboration of the historical fact, that the river once ran over the top of this rocky dam, is, that the upper surface of it, (A, figs. 1, and 2.) is covered by a formation of the *travertina tufa*, which calcareous incrustation must have been deposited there by its waters, when flowing from the lake at that elevation. The river, as is well known, continues to deposit the same tufa every where, particularly

cularly at the cascade of Tivoli, where this substance is constantly accumulating *.

As the ancients mention the existence of the lake, which once filled the valley of Subiaco, but take no notice of the cause by the operation of which it was drained, it must have occurred at some period between the fifth and the fourteenth centuries. It is as impossible, as it is unnecessary for me, to offer even a conjecture about the nature of this; but I hope enough has been established to prove, that the valley of Subiaco furnishes a decided and well-authenticated instance of a range of shelf, in every respect like those of Lochaber, and which has been unquestionably formed by the waters of a lake. From the particular description I am to give, it will appear that the resemblance between the Glen of Subiaco and those of Lochaber, is rendered extremely strong by a number of circumstances, common to all of them; perhaps the most remarkable of these is, that the waterfalls and ravines of Subiaco, are also found placed in similar situations in the Lochaber glens.

Particular Description of the Shelves, as connected with the Geography of the Country, and the Appearance of the Glens in which they are found.

I PROPOSE to arrange the more particular description of the shelves, which I am now about to give, in the following order, which

* When I was lately at Tivoli, I had the most earnest desire to visit Subiaco in person, not only to make my own observations on the valley, but likewise to enjoy a range of scenery, described to me as being of the most romantic character; but I regret to say, that a variety of circumstances compelled me to abandon the attempt, with very great reluctance. I had, however, some satisfaction, in availing myself of the opportunity of corroborating the description in the text, by the testimony of one or two of my Roman friends, who had been at Subiaco.

which will be easily understood from the map. I mean to begin at Lowbridge, and describe the whole of Glen Roy upwards. I shall then give a general account of the Glen-mor-na-Albin, or Great Glen of Scotland, the necessity of which will appear, when I come to the theoretical part of my paper. Proceeding from thence south-westwards, I shall describe the more open part of the country about the Spean. I shall trace Glen Roy upwards to the Loch of Spey; return to the mouth of Glen Turret, and describe that valley, and the *High Glen* of its little tributary stream upwards, to where it opens at its north-western extremity into the head of Glen Gluoy. Returning to the mouth of Glen Roy, I shall describe the whole of Glen Spean, Loch Laggan, and Loch Treig; and shall conclude with a description of those very satisfactory and convincing appearances in the bottom of Glen Spean, which are numbered in the map with the figures 5, 6, and 7. and which can be viewed in no other light than as being three inferior shelves, each successively of lower level than that numbered as above it.

The general direction of Glen Gluoy is nearly S. E. and N. W., and its length is about seven or eight miles. Its mouth opens into the Great Glen of Scotland at Lowbridge, and it pours its stream into Loch Lochy, a little way below that place. The hills bounding Glen Gluoy approach one another very closely, leaving no more than room for the river to run in the bottom. They are very lofty and steep, particularly at Lowbridge, over which they rise with a bold front, there forming the side of the Caledonian Glen. They are in general covered with a short grass, and, like all the rest of the hills in this neighbourhood, afford excellent sheep-pasture. From the extreme narrowness of this glen, its shelf is not easily viewed. I am, however, enabled to describe it, by having paid two visits to the valley, in the course of which, I looked into

into it from th e side of the mountain Ben-y-vaan, guarding its entrance on the south,--traversed its whole extent, going up the one side of the river, and down the other, so as to endeavour to secure the most perfect view of the two corresponding parts of the shelf,—and looked down its whole length, from a point on the side of the mountains, at its upper extremity, (see *a* in the map), whence an excellent view of it is enjoyed, (see Plate I.) About three miles up Glen Gluoy, it is joined by a smaller valley, called Glen Fintack, whence a considerable stream, having a short run, pours itself into the Gluoy. Above this, the glen makes several gentle winds. *Shelf* 1*st*, the only one to be met with in Glen Gluoy, first appears near the top of the mountain, on the N. W. side of the valley, a considerable way below that part of it which is opposite to Glen Fintack. The sides of Ben-y-vaan, which is a long flat-ridged mountain, are rocky; and the whole sides of Glen Fintack are particularly so, presenting every where a very magnificent enclosure, of abrupt and perpendicular precipices of great height. I could not perceive any appearance of the shelf on the S. E. side, until I observed it on the face of the mountain which bends out from the N. E. side of Glen Fintack, into Glen Gluoy. At this point there even appears to be some traces of two lines; but one of these, I believe the uppermost, is not continued, and is probably nothing more than an accidental mark on the angle of the hill. And here I may take the opportunity of offering a caution to future observers, not to decide too hastily as to such faint appearances, unless in situations where the probability of their being portions of the shelf is borne out by a sameness of level. For, aided by fancy, which is always alive in an investigation of this kind, the eye is very apt to lead the judgment into error. I may mention, as one very strong instance of this, that, at one place, on the N. W. side, and nearer to the upper end of Glen Gluoy, I was for some time

time led to suppose, that there was decidedly a second line of shelf, until a more perfect view from the side of the hill directly opposite, completely satisfied me, that the undermost, extending only a short way, was neither parallel to that above it, nor horizontal in itself. On ascending, to take a nearer and more accurate inspection, of what appeared so very distinctly marked when viewed from below, I found it to be no other than a well-trod sheep-track, not more than six inches in breadth; whilst the actual shelf itself, from the steepness of this part of the hill, affords a broader and more perfectly indented specimen, and more perfectly defined, than is to be met with in any other part of the valley. The deception was increased, by a small patch of heath having been burnt by the shepherds the season before; and the line of the sheep-track having arrested the fire, and prevented it from spreading below it, the linear appearance on the face of the mountain was thereby rendered the more remarkable.

The bottom of Glen Gluoy rises considerably towards its upper extremity, which, turning south-eastwards, is rather expanded into an amphitheatre; and from the end of it there is a vista through another glen, falling towards Glen Turret and Glen Roy, and which, to mark the difference between it and those lower-bottomed glens, I have distinguished in the map by the words *High Glen*. The shelf having begun on each side of Glen Gluoy, at the points already noticed, is very easily traced almost every where throughout its whole course upwards. That part of it on the north side, runs around the semicircular boundary of the head of the glen, and just touches the level of the bottom of the stratum of moss, lying in the mouth of what I have called the High Glen, which I shall afterwards have occasion to describe more particularly. From this point the shelf bends round to the south side of Glen Gluoy,

Gluoy, where it expands into a wide inclined plane, and where it is united to, and identified with, the twin portion of it coming up on the faces of the hills on that side of the valley. This broad part of the shelf is about one hundred yards wide, and presents the abrupt face of a bank to the bottom of the glen. By an examination of the map, the river Gluoy will be observed to enter the glen from its southern mountains, whence it throws itself in a cascade, and falls by a series of cataracts into a very remarkable ravine, dividing the inclined plane or broad part of the shelf, at right angles to its line of extent. Throughout the whole length of this singular chasm, which, though only a few feet wide, is perhaps not less than fifty or sixty feet deep, the river has worn out a passage on a level, not much above that of the bottom of the valley, into which it issues, and where it is almost immediately joined by a branch coming from the hills to the north. Some little way below the junction of the two streams, the river begins to lay bare the rock in its course, which becomes more rugged, as it deepens in its progress towards the Great Glen of Scotland.

The *Glen-mor-na-Albin*, or Great Glen of Scotland, enough of which is laid down in the accompanying map, to show its reference to the district under consideration, bisects Scotland in a straight line, from N. E. to S. W. from the east sea at Inverness, to the west sea at Fort William. It is narrow throughout its whole length, seldom much exceeding a mile in breadth, except where it expands towards the lower end of Loch Ness. The mountains forming its sides are every where lofty, abrupt, and precipitous, bearing every appearance of having been severed from one another, by some tremendous convulsion of nature. The bottom is chiefly filled by Lochs Ness, Oich, and Lochy, and has so very small a rise from the two seas

seas towards the center, that the summit-level, as taken for the Caledonian Canal, is not more than ninety-four feet above high-water mark. Where the bottom of the glen is not occupied by the lakes, it is covered to a great depth by alluvial matter. Even at the summit-level, where the canal is now excavating to a depth of twenty-five feet, the workmen, after cutting through a thick stratum of moss, found nothing but sand, clay, gravel, and rounded stones, the debris of rocks of the primitive series, nor has the slightest appearance of marine exuviæ been any where discovered. From the Glen-mor-na-Albin, several others branch off at considerable angles, and there are some lesser cracks and ravines of similar bearing to these dividing the faces of its mountains.

Proceeding from Lowbridge along the road towards Fort William, the mountain of Ben-y-vaan, on the left hand, stretches from the mouth of Glen Gluoy, in a S. W. direction, opposing an abrupt and rocky face to the Glen-mor-na-Albin, and terminating suddenly at a point above a mile from Highbridge, whence it turns back towards the N. E. at an acute angle, and then begins to form the northern boundary of the wider and more open country, stretching southwards towards the Ben Nevis range. The river Spean, issuing from its glen, and immediately afterwards uniting with the Roy, runs across a large basin in this open country, in a direction nearly west, laying bare the rock as it advances, and cutting more and more deeply as it approaches Highbridge, where the ravine, having become of great depth, is crossed by the tall pillars and arches of the picturesque military bridge, which has received its name from its remarkable elevation. Through this, the Spean foams onwards in a series of rapids and cataracts, to join the river Lochy. This latter part of its course divides a range of lesser hills, running from the foot of the

 mountain

mountain Ben-y-vaan south-westwards, along the side of the Glen-mor-na-Albin, and, as indicated in the map, sweeping in a semicircular series of still smaller eminences, combining to form a rather elevated moor, stretching towards the western projection of the mountain Aonach-more, where it completes the inclosure of what may be termed the Basin of the Spean.

In the neighbourhood of the House of Inch, which is more than three miles above Highbridge, the mountains on all sides begin to approach nearer to one another, forming what may be considered as the proper entrances of Glen Roy and Glen Spean. The sketch, Plate II. (taken from the hills on the south side of Glen Spean, at the point marked *b* in the map), affords a much better general notion of the situation and nature of the mouth of Glen Roy, in relation to that of Glen Spean, than any words can convey. I may, however, remark in reference to it, that the mountain Ben-y-vaan, after returning eastward from its angle opposite to Highbridge, opens backwards towards the north, making room for a pretty considerable, but much elevated valley, called Glen Collarig, lying between it, and the round hill guarding the western side of the mouth of Glen Roy. This round hill, which is marked on the map by its name, *The Hill of Bohuntine*, is particularly interesting, owing to a number of circumstances, to be afterwards noticed. It is isolated from the neighbouring mountains, by Glen Roy making a great and sudden bend around its base upon the eastern side; on the south and west by Glen Collarig, and the little stream sent by that valley, through a deep dell, to join the Roy; and on the north, by the upper part of Glen Collarig, marked *Gap* in the map, which forms a pass into Glen Roy. The bottom of this opening however, is at a great height above that of Glen Roy, into which it falls suddenly,

suddenly, having the appearance, when viewed from that valley, of a very singular breach, high up in the sides of its north-western mountains. When viewed from Glen Collarig, the Gap appears as in Plate III. fig. 1. (which was sketched from point *c* in the map); and fig. 2. of the same plate, (which was sketched from the point *e* in the map), shows its appearance when looked at from Glen Roy. This Gap, is what, in my former paper, I had conjectured to have a communication with Glen Gluoy; but the description I have just given of Glen Collarig, shows this notion to have been erroneous. Glen Gluoy has indeed no other communication with Glen Roy, than by the *high glen* of Glen Turret, which I shall have occasion to describe afterwards.

The shelf which is marked all along its line with the figure 4 in the map, and which I said I was to designate as *shelf 4th*, makes its first appearance high up on the side of Ben-y-vaan, somewhat more than a mile to the east of Highbridge. From this point it runs faintly eastward, sweeps up the Glen of Collarig, and crosses it just above some cottages, in the form of an extended mossy flat, or rather gently inclined plane, which has steep banks towards the bottom of the valley. It then begins to return indistinctly back, on the western side of the round hill of Bohuntine, increasing in strength as it embraces its southern side; and again winds round it in a northerly direction, till it bends into Glen Roy. Plate II. will show this part of the course of shelf 4th, and Plate III. fig. 1. will furnish some notion of the mode in which it crosses Glen Collarig. In this last Plate, shelf 2d and shelf 3d, are seen coming from Glen Roy through the Gap towards the eye, and terminating abruptly on both sides, as I shall afterwards explain more particularly.

The

The lower valley of Glen Roy stretches in a N. E. direction, from the junction of its river with the Spean, to a point at the distance of about nine miles, where it is terminated by a rock, having a dry craggy hollow on its north side, and a deep ravine, containing the river, on the south, so that it may almost be said to be isolated from the higher rocks flanking the glen, between which it extends across. The country above this point, being of a different character, may be called *Upper Glen Roy.* Though not quite so narrow and confined as Glen Gluoy, yet the green mountains of Lower Glen Roy are as high, and rise with acclivities, which are in general fully as steep as those of the former valley; and throughout the greater part of its extent there is not much more space in the bottom than is sufficient for the bed of the stream. Having wound over the natural boundary dividing Lower from Upper Glen Roy, and proceeding to trace the stream of the Roy upwards, the country is found to open out into a wider and higher valley, expanding, as it stretches eastward, the hills apparently sinking in elevation, as the level of the bottom rises. Into this the waters of the Roy enter, by two several branches, from the sloping hills which bound it. At a point about three or four miles above the isolated rock, the valley becomes extremely flat. It is skirted on the north by a low rocky ridge, which, as it loses itself in the bottom of the plain, offers no interruption to the very gradually, nay, almost imperceptibly rising level, of the mossy ground stretching to the Loch of Spey, the source of the river of that name. From this point, which is the summit level, there is a gentle fall of the country, by the course of the Spey, towards Garvamore. Returning downwards to the head of Lower Glen Roy, we find that the river forces its way, with great fury and precipitation, through the ravine, (marked in the

the map), which surrounds the south side of the isolated rock, and at a little distance below, it throws itself over a beautiful, and very considerable waterfall. From this point, where the valley widens for a little way, the river runs through a gravelly alluvial, and being soon afterwards joined by the stream from Glen Turret, it begins gradually to display rocks in its bed, through which, as it advances, it continues to cut deeper and deeper, till it approaches the flat ground near the Spean. But although the immediate course of the stream be thus held amongst rocks, yet large beds of alluvial matter, chiefly a red * clay, with rounded pebbles and sand, are every where to be met with, hanging, as it were, on the sides of the inclination of the valley, between the shelves and the river. These beds are stratified more or less regularly, and fine sections of them are afforded by the streams which cut through them in various places, in their way to join the Roy, which, in its progress down the valley, receives several tributary brooks.

I have already traced *Shelf 4th* around the hill of Bohuntine, and into the mouth of Glen Roy. It is continued up the N. W. side of the valley, and runs along the face of the hill, perhaps above one hundred feet below the level of the bottom of the Gap, (Plate III. fig. 2.). From this point it is almost every where very distinctly marked in its course upwards, until it comes to the opening of Glen Turret, into which it expands in a wide-extended inclined plane, above half a mile in diameter, displaying a surface of peat-moss, formed over a deep alluvial deposit of gravel and sand, and presenting a high and abrupt bank to the stream of the Roy, running in a line with the bottom of it. The level of the shelf seems here just to touch upon the houses of Glen Turret,

* Hence, probably, the name of Glen *Roy*, or the *Red* valley.

ret, situated at the upper part of this plane, near the junction of the two streams combining to form that river, whence it stretches under the mountain of Tom-Bhran, and crosses to the south side of Glen Roy, narrowing as it begins to return downwards, till it gradually again assumes the ordinary appearance of a proper shelf. I shall here content myself with mentioning, that *Shelf 4th* is to be traced all the way down the S. E. side of Glen Roy; but I shall postpone the description of its progress around Glen Spean, until I shall come to notice that valley in particular.

By looking at Plate II. Shelf 3d will be observed beginning on the north side of the mouth of Glen Roy, at a hollow on the S. E. side of the round hill of Bohuntine, whence it disappears into the glen. As Shelf 2d does not show itself until a little way farther on, its origin is not visible in this sketch; but a reference to the map will show the commencement of both these shelves, which sweep around the eastern, or Glen Roy side of the hill of Bohuntine, and then bend into the Gap which leads into Glen Collarig, where they show themselves as represented in the sketch, Plate III. fig. 2., and where they appear to terminate suddenly. The same drawing will also show, that they commence as abruptly on the north side, at points exactly opposite to those where they are broken off on the south side. From thence they run back towards Glen Roy, on the same level, sweep north-eastwards into that glen, and continue very distinctly marked throughout all their bendings, in their progress upwards. Indeed there is nowhere a more favourable view of the shelves of Glen Roy, than is enjoyed from this Gap, (see Plate IV. which was sketched from this point). Proceeding to trace shelf 3d and shelf 2d, up the north-west side of Glen Roy, they are found to turn northwards into Glen Turret, and to run around all the sinuosities of of that tributary valley; but as I mean to allot a particular and distinct description to that glen, I shall take up these shelves at present where they return from Glen Turret, sweeping boldly and distinctly around the southern side of the mountain of Tom-Bhran. The side of that hill which flanks Glen Roy, being very rocky, they are to be traced, but faintly, along its face, until they come opposite to the isolated crag that forms the boundary of division between Lower and Upper Glen Roy. Here these two shelves, which have hitherto kept company with one another, are now separated. Shelf 3d being of a level considerably below that of the crag, or rather below that of the upper parts of the bottoms of the ravines on each side of it, and being thus prevented from passing through them, and continuing onwards, at the same level it has hitherto preserved, winds very indistinctly amongst the hollows of the rocks, and along the rugged face of the isolated boundary, and is then to be traced returning along the south-western hills of Glen Roy, gaining a more marked appearance as it proceeds down that side of the valley. But Shelf 2d, running on an elevation superior to that of any part of the bottoms of the ravines, is of course not obstructed by them, but continues to run up through them into Upper Glen Roy, whilst, at the same time, vestiges of it are traced about the top of the independent central rock, some parts of which seem to rise above its level. An examination of the map, will assist in enabling the understanding to follow out the intricacies of this important part of the description. Pursuing shelf 2d above the isolated crag, it is to be traced along near the bottom of the mountains, on the north side of Upper Glen Roy, its level extending as far as within two hundred yards of Loch Spey. It, however, requires considerable attention to follow it out in this upper valley, as in most places it has less the appearance of a shelf than of a widened

 inclined

inclined plane, which ultimately loses itself in the flattish moss near Loch Spey. This moss appears to be very deep; it therefore seems to me to be probable, that although its gradual increase has raised the surface in this place somewhat above the level of Shelf 2d, yet if a body of water were raised by any means to the level of that shelf, and the stratum of moss were at the same time to be removed, a stream would naturally flow from it towards Garvamore, in the present course of the river Spey. The appearances of Shelf 2d, in its return down the south-east side of Upper, towards Lower Glen Roy, are very similar to what I have described as existing on the north-west side: it returns into the lower glen through the ravine on the south side of the isolated rock.

Let us now proceed to consider Glen Turret. When entered from Glen Roy, its mouth is discovered to have in the bottom that large semicircular inclined plane, which has been already described as an extension of Shelf 4th. The stream of the Turret, in its way to join the Roy, cuts through this vast bed of sand and polished gravel to a great depth. At the cottages of Glen Turret, (the site of which has been already stated to be nearly on a level with Shelf 4th), two little streams unite to form the Turret. One of these branches comes gently from the north, through the low bottom of the glen itself, which here rises very gradually in its level; the hills a little way above, expanding into a considerable circle, around the termination of the glen. The other branch pours precipitately into the lower glen, where the houses stand, from a much more elevated valley to the north-west, marked *High Glen* in the map. Proceeding to trace this stream upwards from the houses, it is found to exhibit a continued series of cascades, particularly at the top of this the precipitous part of its course, where it leaves the more level bottom of the *High Glen*, by falling

falling at once fifteen or twenty feet. This, as will be seen by reference to the map, is the very same *High Glen*, upon the other extremity of which I had already occasion to touch, in my description of Glen Gluoy, where I mentioned it as affording a vista from the head of that valley, into Glen Roy, through Glen Turret.

The two shelves, (Shelf 3d and Shelf 2d), in winding from Glen Roy into the south-western side of Glen Turret, are expanded on a wide, and greatly elevated inclined plane, covered with peat-moss. They are consequently indistinct for a time, and they do not become very manifest, until they cross the stream coming from the *High Glen*, and lay hold of the steeper hill. They are then particularly well defined, and are very clearly marked in their progress all around the bendings of the mountains of Glen Turret, till they return by its northwest side, and sweep around the face of Tom-Bhran into Glen Roy. But the most interesting part of their course through Glen Turret, is that where they cross the tributary stream, as it issues from the *High Glen*. In this place, Shelf 2d is found on examination to touch exactly on the uppermost waterfall, at an elevation about twelve feet below that of Shelf 1st, or the Glen Gluoy Shelf. On tracing up the course of the little stream above this waterfall, it is found to run through the bottom of the *High Glen*, with a gentle current, without creating any excavation, and displaying no section, though the surface of the rock is sometimes descried in the water. It may be about a mile from the highest cascade, upwards, in which distance it has an aggregate fall of about twelve feet. It seems to have its origin, partly from springs on the sides of the hills, and partly from the moisture of a flattish mossy meadow, which continues to have an almost imperceptible rise for about one hundred yards, till, at a point, which is not more than the thickness of the moss higher than Shelf 1st, the level of the surface sinks suddenly into Glen Gluoy. In order to have something like an approximation to the truth, as to what difference of level subsisted between Shelf 1st in Glen Gluoy, and Shelf 2d in Glen Turret, I travelled from the cascade upwards, through the *High Glen*, measuring as nearly as I could by the eye, and adding together, all the little falls of the stream, guessing at the addition, and subsequent deduction to be made at the end next Glen Gluoy: the result which I had from this rude process was fourteen or fifteen feet. In order to make certain however, of a point which I considered most material, I requested the favour of my friend Mr Maclean to revisit the ground, for the purpose of levelling it properly by means of the instrument; he was so kind as to indulge me, and the twelve feet of difference of level in the height of Shelf 1st above Shelf 2d, is given as the result of his observations. Such, therefore, is the nature of the levels here, that supposing Glen Gluoy to be filled with a body of water to a height equal to that of its shelf, and that, at the same time, the thick stratum of moss were to be removed, the consequence would be, that a stream would be discharged from it by the *High Glen*, and over the cascade into Glen Turret, and so into Glen Roy.

Let us now return to the head of Lower Glen Roy, where Shelf 3d and Shelf 2d, having wound from the ravine on the south side of the isolated rock, run faintly down the faces of the mountains on the south-west side of the glen, gaining greater distinctness of form as they proceed. They become particularly well defined, just at *f* in the map, where they subtend the mouth of Glen Turret; and in that part of the south side of the valley, there are appearances which may be worth notice. At first sight, one might be led to imagine, that there are no fewer than seven different stages of shelves here. A sketch could have given no idea of these; but the diagram,

(Plate VII.

(Plate VII. fig. 6.), may be of some use in helping the description of them. In it, the three uppermost lines represent the proper horizontal shelves 2d, 3d, and 4th, whilst all the others below have an inclination downwards in the direction of the fall of the glen, and this inclination, increases in each successive shelf, in proportion to its greater proximity to the river. These inclined lines of shelves can hardly be said to be on the side of the hill, but have rather the appearance of a series of small flats, one below another, between the hill and the river.

Shelf 2d and Shelf 3d, are to be traced, as well as Shelf 4th, with very little interruption along the faces of the mountains running down the south-east side of Glen Roy. Opposite to the hill of Bohuntine, the glen makes a great bend to the south, and afterwards returns to its south-east direction. It is near to this point that the mountains on the south-east side of the valley, though they still keep their roots so advanced as to leave the glen perfectly narrow in the bottom, yet retreat backwards above, surrounding and embracing a high and very extensive semicircular plane, apparently covered with a peat-moss; but soon afterwards they again advance in some degree, and at last finally terminate in the rocky prominent hill of Craig-dhu, which forms the more elevated part of the division between the mouths of Glen Roy and Glen Spean. Shelf 2d and Shelf 3d, being both of elevation superior to that of the bottom of the high plane, naturally bend away from Glen Roy, in a manner somewhat similar to that in which they run into the Gap of Glen Collarig, and winding around the amphitheatre of hills, and returning with them again, all traces of Shelf 2d are suddenly lost, nearly opposite to the point where it begins on the south-east side of the hill of Bohuntine. Shelf 3d runs on a little farther, to the rocky angle of Craig-dhu, where it likewise is abruptly terminated, also opposite to the

the spot where it is first observed on the hill of Bohuntine. Neither of these shelves are ever met with afterwards, in any glen below these points of termination. Shelf 4th, which is at an elevation below that of the high semicircular plane just mentioned, does not bend into it like the other two; but the hills nearest the river beginning now to sink in height, it continues to run in a more direct sweep towards the foot of Craig-dhu. From the base of this more retired, and more elevated hill, an apparently mossy, and considerably inclined plane, stretches for half a mile in a south-west direction, towards the point of junction of the rivers Roy and Spean. But just above the spot where these streams unite, this plane again rises into the circular and isolated rock called *Mealderry*, which is particularly laid down in the map, and which may be easily recognized in Plate II. as being near the eye, and just beyond the mouth of the valley of Glen Spean. Shelf 4th, as it sweeps from Glen Roy around the base of Craig-dhu into Glen Spean, applies exactly in level to the upper line of the inclined mossy plane, lying between Craig-dhu and Mealderry; and the top of the isolated rock of Mealderry, rising somewhat above this level, is surrounded by a partial delineation, of what the levelling instrument proves to be an independent portion of the same shelf.

Although Craig-dhu, which may be properly considered as the mountain dividing Glens Roy and Spean from one another, thus appears to retreat backwards above, from the actual point where the rivers meet, yet the entrance of Glen Spean is very much confined, by the advance of the lower rock of Mealderry, on the north side of the valley, towards the base of the mountain on the south side. These come bending from Aonachmore, a mountain of the Ben Nevis groupe, and making a vast sweep around the great hollow basin, in the country be-

low

low the junction of the Roy and Spean, push their roots into the very bed of the latter river, just above the House of Inch. From hence they run westward up the glen, forming its south side, with a straight and highly inclined face. The side of the mountain Craig-dhu, constituting the north wall of Glen Spean, has a front as even and as steep, as that of those opposite to it. Just above the narrow entrance of the glen, the hills on each side of the valley are about half a mile asunder; but some miles farther up, they begin to recede greatly from one another, and they seem to sink in their elevation as the bottom of the valley rises. The whole length of Glen Spean, from Inch to the Pass of Muckul, is about twenty miles. This pass, affording an opening between Glean Spean and the Valley of the Spey, is the summit level between them. Although it is not productive of any streams, it disparts the waters that run to the eastern and western seas; and yet the highest part of its bottom, is only elevated a few feet above the present level of Loch Laggan. By a reference to the map, it will be seen, that the river Pattaig, after issuing from its loch, has a directly north-east direction, as if it were about to run towards the river Spey, which is certainly its most natural course; but just before coming upon the bottom of the Pass of Muckul, it meets with the rock laid down in the map, which compels it to make a sudden and capricious bend to the west, at a very acute angle to its former line, and after a slow run of somewhat more than two miles, a considerable part of which is navigable by a boat, it empties itself into the upper end of Loch Laggan. This lake is eight or nine miles in length. On the north side, the mountains are partly of gentle acclivity, but in some places, they rise almost perpendicularly to a very considerable height. Although those on the south side are of inconsiderable elevation, yet they are bold and rocky to the

the water's edge; and, indeed, the whole shores of the lake may be in general called rocky. There is a good deal of wood upon both shores. The river Spean, which issues from the western extremity of Loch Laggan, runs slowly and smoothly for about two miles, cutting its course through flats of deep alluvial earth and clay, and rarely exhibiting any rock. The Spean, in its progress downwards, receives the Gulbean water, which enters it from the south; and, at about four or five miles above the House of Inch, it is joined by the river Treig, which has a run of nearly two miles from its lake lying to the south, the valley of the Spean being here of very considerable breadth.

The opening into the north end of Loch Treig is very romantic, being reduced to a narrow but grand pass, by the advance of the mountains on each side, which present two lofty and rocky fronts, guarding its entrance, (see Plate VI.), from which the lake expands, as it extends in a direction a little to the west of south. The shores of Loch Treig are in general bold and rocky, having their woods of birch-trees scattered over them. Immediately opposite to, and to the north of the narrow outlet of Loch Treig, there is a very singular, round, isolated little hill, with a flattish rocky summit. This is laid down in the map, and is called *Tom-na-Fersit.* After leaving the lake, the river Treig, winding amongst hillocks, rushes violently over the rocks which it exposes in its progress, and as it approaches the point of junction with the river Spean, its bed becomes deepened into a ravine, and it is projected over several falls.

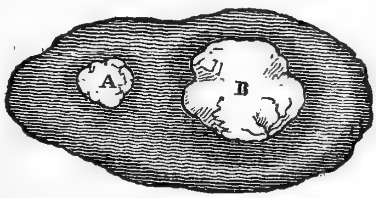
Proceeding to trace the river Spean downwards, after its union with the river Treig, its course will be found extremely interesting; for it is not only bounded, on the great scale, by the mountains forming the proper walls of the glen, at some distance,

distance, but it has also, much nearer to its bed, a second and interior bounding enclosure, consisting of a line of banks on each side, flattish, and rather plain above, but having steep and abrupt, though perfectly smooth faces, towards the level bottom in which the river runs. These banks seem to be chiefly formed of alluvial matters. They appear immediately below the junction of the river Treig, whence they sweep with various bendings, sometimes at a greater, and sometimes at a lesser distance from the Spean, enclosing a beautiful narrow plain about a mile in length, through which the stream flows gently over a gravelly bottom. This plain is suddenly shut in at the lower end, by the close approach of these banks on both sides. Here the river, suddenly altering its character, pours itself into a deep ravine, which it seems to have worn through a rocky neck of about five hundred yards in thickness, where it is heard roaring along in a series of cataracts, of which the great waterfall of Tulloch forms the grandest specimen. The stream has no sooner effected this turbulent passage, than it enters a second beautiful and level plain, about two miles long, and bounded on the sides by a similar series of banks. Through this it again flows with perfect placidity, until, by a second approach of the sides to one another, at a point a little above what I have called the *Mouth of Glen Spean*, the tranquillity of the river is a second time interrupted by another rocky neck, like that I have just described. Here it again forms into an abyss, of the same depth and appearance as the former, where, besides being hurried over a number of lesser cascades, it is precipitated over the fall of Munessie, equal in grandeur to that of Tulloch. These two necks of rock, through which the Spean has thus cut its way, are both called in Gaelic *Kenmuir*, which signifies, *the End of the Lake.* Escaping from the gloomy and overhanging rocks of this second deep and narrow ravine, the river again puts on the peaceful character, and flows in a broad channel through the Meadows of Inch. After its union with the Roy, it proceeds, (as I have already noticed), across a hollow and shelving basin in the open country, somewhat more than two miles in extent, till the banks again approaching, and closing in on the river, it a third time, and on a still more magnificent scale, exhibits the deep ravine, and the waterfalls and rapids, which so often arrest the attention of the traveller who crosses it at Highbridge. The shores of these three successive minor valleys, which may be said to be included in the larger, are what I have numbered 5, 6, and 7 in the map.

I must now, again, take up the consideration of the course of Shelf 4th, which having wound from Glen Roy around the base of the hill of Crag-dhu, stretches very distinctly up the smooth and even faces of the mountains on the north side of Glen Spean, the bottom of the valley rising towards it as it proceeds, until at last it approaches so near to it in elevation, that the Engineer of the Parliamentary Commissioners has actually availed himself of the line of shelf, to construct on it a part of the great new Loch Laggan Road. As the shelf approaches within two miles of Loch Laggan, it begins to be identified with the upper bounding line of the flats of deep alluvial earth and clay, through which the river Spean flows from the lake. It is then to be traced all up the north shore of Loch Laggan, being only a few feet above the level of its water, and in most places only a few yards from its margin; and running along the banks of the river Pattaig for about two miles, it crosses that river at Muckul, on a level equal to that of the summit-level of the bottom of that pass, and in such a manner, that it is evident, if a body of water were raised to the level of the shelf, a stream would run from it, through the Pass of Muckul,

Muckul, towards the river Spey. Returning down the south bank of the Pattaig, Shelf 4th is to be traced all around the south side of Loch Laggan; and it exhibits nearly the same appearances on the south side of the river Spean, that I have already described it to do on the north side. As it approaches the river Treig, it sweeps round in the direction of the mouth of the glen and lake of that name, where, notwithstanding the rocky nature of the mountains, it is found to be very deeply marked. It enters the jaws of the pass into Loch Treig in the manner represented in Plate VI.

By far the most satisfactory and perfect example, of any shelf completely surrounding the top of a hill, is to be observed on the isolated one of Tom-na-Fersit, immediately opposite to the opening into Loch Treig. Shelf 4th is most distinctly and broadly traced around it, at the same level that it appears on the rocks where it enters to Loch Treig. And what is still more worthy of remark, the little hill, having a second and inferior rocky top, rising above the level of the shelf, it is perfectly surrounded also, and detached from the principal summit, so as to give this portion of shelf, which belongs independently to Tom-na-Fersit, the appearance laid down in the map, or to shew it on a larger scale, something like this:



A and B being the two tops of the hill rising out of the surrounding shelf. The rocks on the interior angle of the shelf, are here particularly rounded, and have all the characters of those bounding the edge of low and rocky islands, frequently met with in Highland lakes. Where the smaller top is divid-

 ed

ed from the larger, a peat-moss has been formed, though the comparatively trifling surface exhibited by the whole of the elevated and rather rounded top of this isolated hill, is certainly a situation where such a deposit is hardly to be looked for.

The numerous torrents that pour down the sides of the mountains of Loch Treig, have very much defaced the course of Shelf 4th around that lake. Although very distinctly seen at its northern end, it is but faintly traced along its eastern side. It is to be observed at the southern extremity, and appears very visible on the western side, where it leads back and winds again into Glen Spean.

After leaving the mouth of Loch Treig, Shelf 4th is easily traced along the hills on the southern side of Glen Spean. It appears particularly well marked on the even faces of the mountains, for a long way before it comes to what may be called the Mouth of the glen; and just above the House of Inch, it sweeps away in company with the receding mountains, where, though faint, it is easily followed, to a ravine called *Corr-a-cloichlich*, whence I thought I could even trace it, though with some little difficulty, through an opening in a thin birch wood, on the side of Aonach-more, nearly as far as the projection of that mountain, where all appearances of it are finally lost. The projection to which I allude here, is the same which, as I formerly remarked, is met by a semicircular range of little eminences, forming a kind of elevated moor, sweeping towards it from Highbridge, and enclosing what I have called the *Basin*, in the open country of the Spean. This moor rises nearly to the level of Shelf 4th, and some of its more elevated points seem even to rise above it. These last observations will be found to be extremely important in the theory which it is now my intention to propose.

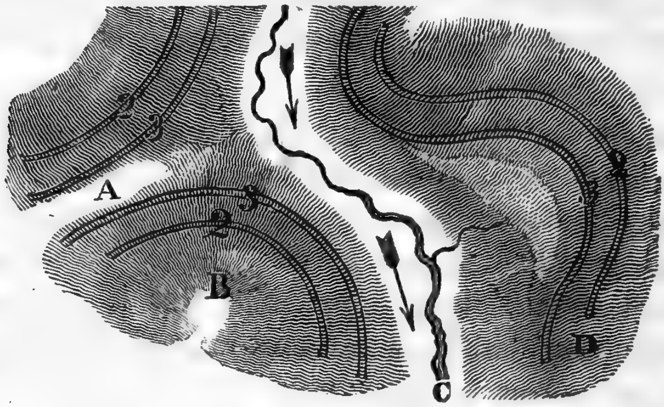
PARTICULAR

Particular Theory of the Causes which may be supposed to have operated in producing the Shelves in the Glens of Lochaber.

ALTHOUGH it appears to me, that no one can examine even a portion of these shelves with attention, without ascribing them to an aqueous origin, and without being likewise perfectly satisfied, that they were formed by the level waters of lakes, yet I have been taught by experience, that it is impossible to go farther in speculation, without a thorough knowledge of all the glens, as well as of every part of the tortuous course of the linear appearances to be found in them. Almost every step I took in this interesting investigation, seemed to lead to some new conclusion, as to what was the probable topography of the ancient lakes; and it was not until I had collected all those facts which I have stated in the foregoing pages, in what I fear will be considered as rather tedious detail, that any thing resembling a satisfactory theory of their distribution, shape, extent, and final evacuation, suggested itself to me. This I now venture to lay before the Society, trusting to its indulgence.

It appears that Glen Gluoy possesses Shelf 1st, which is the highest of all; and that it is to be found in no other glen. From this I would infer, that Glen Gluoy was at one period an independent lake, having a level higher than any of the others in its vicinity. The next two shelves in elevation, which are Shelf 2d and Shelf 3d, are confined entirely to Glen Roy, and its smaller tributary glens; and are found to run down and terminate, nearly together, in the Gap of Glen Collarig, on the north side, and in the mouth of Glen Roy on the south side of the round hill of Bohuntine, as represented in the

the map, or perhaps more satisfactorily in the following diagram, in which Shelves 2d and 3d alone are marked,



and where A is the Gap of Glen Collarig, B the hill of Bohuntine, C the mouth of Glen Roy, and D the angle of the mountain Crag-dhu. From these facts it would seem, that Glen Roy must have been for some time an independent lake also, having its south-west extremity situated somewhere near the hill of Bohuntine, where it must have terminated in two bays, one on each side of that round hill. And as we see that there are two shelves of different elevations, which are the property of Glen Roy alone, it is equally evident, that its lake must have once existed for a time at the level of Shelf 2d, and must have afterwards subsided to that of Shelf 3d. But we find that Shelf 4th is common to both Glen Roy and Glen Spean; consequently this implies a second subsidence of the Glen Roy lake, reducing it to the same level, and making it a portion of a lake which must have pre-existed in Glen Spean. In the primary state of things therefore, we find an independent lake in Glen Gluoy, which may be called *Loch Gloy;* another in Glen Roy, at a level about twelve feet below that of Loch Gluoy, which may be called *Loch Roy;* and a third, covering the

the whole of Glen Spean, Loch Laggan, and Loch Treig, at a level about two hundred and eighty feet below that of the primary state of Loch Roy, to which the name of *Loch Spean* may be given. As each of the different shelves may be traced around and across, at some point lying towards what is now the *upper extremities* of these valleys, whilst they appear in every instance to be suddenly broken off, at what is at present their *lower ends*, or mouths ; it follows, that if there ever were any barriers, to keep these several lakes up to their level, they must have existed somewhere about what are now the lower ends of the present valleys.—Having made these general remarks, it will now be proper to consider, what were the boundaries and outlets of these respective lakes ; and, in doing this, we shall begin with Loch Gloy.

The shelf which appears to indicate the former existence of this lake, is found on the north-west side, some little way above the present entrance of the glen. This entitles us to suppose, that the lake at least occupied the extent of the glen, from this point upwards, as far as the present head of it, where the shelf is seen to sweep round, in order to return. But I trust it has already appeared to be evident, from the description I have given, that when the water in Glen Gluoy was filled up to what is its present line of shelf, it must have run by a natural channel towards Glen Turret, by what I have denominated the *High Glen*, (for which see the map). To produce this effect, however, an immense bulwark or barrier would be required, at what is now the mouth of Glen Gluoy, which would in that case become the head of the lake. Let us, in the meanwhile, take it for granted, that some such bulwark did exist, at, or near to Lowbridge, and then it would follow, that what is now the upper end of the *Glen*, must have been then the lower end of the *Loch* Gluoy, from whence the river Gluoy would

would naturally issue, and whence it would run by a gentle course through the *High Glen*, into that bay of Loch Roy which is now Glen Turret, and which, in this view of the matter, we must call the *Bay of Turret.*

Let us now consider what was the state of Loch Roy when at its highest level. A glance at the map will show, that the south-eastern extremity of its present glen, must have been shut in by two barriers, or rather two portions of one great barrier, of which the round hill of Bohuntine formed the central part, and of which also Mealderry might, or might not, have constituted a fragment. This barrier then, must have run in a semicircular manner, from the projecting angle of Crag-dhu on the east, towards the south-eastern side of the roundish hill of Bohuntine; and must again have extended itself from the western side of that hill, across Glen Collarig, so as to be joined to the faces of the mountains in the northern angle of that little valley, and having the Gap on its eastern, and Glen Collarig on its western side. The supposition, with regard to this barrier, is founded on the consideration, that it could not have been higher up the glen, since it must have been lower down than the points, where the shelves indicating the existence of the independent Loch Roy are abruptly broken off; and it is not so probable, that it could have been much lower down than this, since neither Shelf 2d nor Shelf 3d, are ever again met with, after they disappear thus suddenly. Moreover, we cannot go farther to the south-westward, without interfering with what must have been Loch Spean,—and then, from the inspection of the ground itself, this appears to be by far the most natural and probable position for such a barrier, of which the very shape of the rounded hill of Bohuntine, seems to testisfy, that it formed a part. But at the tim ewhen this barrier existed, this southern end of Loch Roy must have been its

its upper extremity, from whence the surface of the lake extended all the way to the mossy ground within a few yards of Loch Spey, where we have seen that Shelf 2d is identified with the flat, in such a manner, as in my opinion to warrant the conclusion, that the primary Loch Roy discharged its own waters, and those it received from the tributary Loch Gluoy, down through the hollow of the present course of the river Spey, by Garvamore, to the German or Eastern Sea. In this state of matters, the boundary rock between upper and lower Glen Roy, some portions of the top of which seem to rise a little above the level of Shelf 2d, and around which there is a partial delineation of it, was probably a very low, rocky, and perhaps broken island; and what is now Glen Turret, must have been a large bay, having two smaller ones included in its interior. The Gap,—the mouth of Glen Roy,—and the high plane to the north of the projection of Craig-dhu, must then also have formed three considerable bays.

I shall now leave Loch Roy in its primitive state, in order to take a view of the boundaries and barriers of that of Loch Spean. In doing this, I must entreat attention to the state of appearances in that part of the mutual valley of the Roy and Spean united, which crosses in a semicircular line, from the south-western corner of Ben-y-vaan on the one hand, to the northern projecting point of Aonach-more on the other. From the same species of reasoning which I employed to establish the barrier of Loch Roy, it appears evident, that the barrier of Loch Spean, could not have existed above the semicircular line I have just described, since the two abrupt ends of Shelf 4th, indicating the former existence of Loch Spean, come, if not quite up to the two extreme points of it, at least to within a very short distance of them; nor is it to be supposed, that this barrier could have been much to the

 south-west

south-west of these points, since not the slightest vestige of Shelf 4th, has been discovered any where in that direction. But as, in the case of Loch Roy, this also actually appears on an examination of the ground, to be by far the most natural and probable position for the barrier of Loch Spean, since the semicircular range of little hills, or what I have called the elevated moor, which exactly follows the supposed semicircular line I have sketched out, rises even now, nearly, and I believe in some places entirely, to the level of Shelf 4th, so that if the ravine at Highbridge were closed up, and the deficiencies in the elevated moor supplied, the perfect barrier for the confinement of the water of Loch Spean, would be reproduced. I say the *perfect* barrier,—because I believe that the lake had no outlet here at all, but that this was its upper end, and that as in the other cases, the former loch and the present valley have changed extremities. The primary Loch Spean, then, must have stretched from a point a little above Highbridge, all the way to the summit-level of the bottom of the Pass of Muckul, a distance of not less than twenty-four miles. There the level of Shelf 4th sufficiently shows, that the surface of the lake had such a relation to the ground at that end of it, that it must have discharged the River Spean (or *Little Spey*, for such is the interpretation of its name), through the Pass of Muckul, by a straight and natural course, carrying it to direct union with the Spey, which at that time brought along with it the Gluoy and the Roy, in addition to the waters supplied by its present source. Whilst matters were in this situation, the river Pattaig must have entered near the eastern end of the lake, to be immediately afterwards discharged by it through the Pass, along with the rest of the water passing from Loch Spean, and in a course much more natural to it than that in which it now runs. Loch Treig must then have been a great southern limb of Loch Spean, and the

tops

tops of the little hill of Tom-na-Fersit must have formed two small islands; and it would depend upon the circumstance, whether Mealderry was, or was not, a portion of the Loch Roy barrier, (which, by the bye, I am rather inclined to think it was not,) whether its top was also an island in the primary or independent state of Loch Spean, or whether it only became so afterwards. A reference to Plate VIII. fig. 1. will explain what I suppose to have been the primitive state of Lochs Gluoy, Roy, and Spean. I conceive that Loch Gluoy always remained an independent lake up to the period of its final evacuation: but it is evident, that some intermediate changes took place as to the circumstances of the other two lakes; and these will now fall to be considered.

I believe it will be readily admitted, that it is much easier to suppose the existence of former barriers, than to discover the means which operated in their removal; but it must be also granted, that the difficulty of accounting for the destruction of such large masses, does not by any means imply that they never had any being at all, particularly where a number of facts remain to lead us to an opposite conclusion. From all the present appearances, it is extremely probable, that the barrier of Loch Roy, was not only very thin, but of soft materials, at the two parts which have been removed. When we consider in addition to these circumstances, that the level of Loch Roy was about two hundred and eighty feet above that of Loch Spean, and that, consequently, the pressure against this weak barrier must have been very great, it will not appear by any means very improbable, that some partial rupture may have taken place at one, or perhaps both of the narrow necks A and B, Plate VIII. fig. 1., so as suddenly to reduce the level of Loch Roy to Shelf 3d, where it continued to remain for some time. It is proper to remark here, what I

 trust

trust will appear sufficiently evident, if the explanatory diagram I have employed, Plate VII. fig. 5. be examined, that the operation of the waves of a lake, in eating out a shelf on the side of a mountain, will be much more powerful when the surface of the mountain is yet entire, than it will continue to be afterwards, when a certain proportion of sloping beach has been formed, over which it may in some degree waste the fury of its waves. We see that the natural shelves now existing around the borders of our Highland lakes, do not appear to have been very much, if at all increased, beyond the breadth of those remaining from the lakes which we suppose to have been emptied at so very remote a period. The depth, therefore, of the indentation of a shelf, does not form any criterion whereby we may judge of the length of time expended in its formation. Shelf 4th furnishes an excellent example of this observation, for it is as deeply indented, and as well defined, in many parts of Glen Roy, as it is any where in Glean Spean, although it is evident, that the lake which formed it, must have existed much longer in the latter glen than it did in the former. It does not therefore appear to be absolutely necessary, that Loch Roy should have remained long at the level of Shelf 3d, before its second subsidence took place; but it is not very material to the theory whether it did so or not. It is evident, that one material change must have taken place in it, in consequence of the sudden fall of its level. The whole extent of Upper Glen Roy must have been laid dry, and, consequently, it would now no longer discharge the united streams of the Gluoy and Roy, by the channel of the river running from the point at Loch Spey; but leaving the stream from that little residuary lake to pursue its own course, it would now, in the first instance, become tributary to the great Loch Spean, and would be carried by means of its river through the Pass of Muckul,

Muckul, to join the lower part of its former run. This secondary state of matters is represented in Plate VIII. fig. 2. Although it is not very easy to conceive what might be the exact effect of this change, in the course of so very considerable a body of running water, yet there can be no doubt that its power would in time be felt, directed, as it now came to be, against a thin barrier, composed of soft materials, and already so much weakened, as it must have been, by so great a rush of water, as that which pressed over it during the sinking of Loch Roy from the level of Shelf 2d to that of Shelf 3d. Indeed the very circumstance of admitting the possibility of such a breach having ever taken place once, implies that the causes for its happening a second time must have been greatly multiplied; nor can any one hesitate in believing, that if the destruction once began, it would likewise be now proportionably much more sudden and tremendous. Be it remembered, too, that although the perpendicular height to be swept away, was greater upon this second occasion than it was in the first instance, yet it was not necessarily very great,—not certainly of necessity more than about two hundred feet, the difference of elevation between Shelf 3d and Shelf 4th. We see, indeed, by the appearances remaining in Glen Collarig, where there has been little or no change since that rupture, which, during the second subsidence of Loch Roy, let off a portion of its waters there, that the opening which took place in the barrier between the Gap and it, did not extend to half that depth, otherwise the united Lake of Roy and Spean would have gone entirely through there, and would have made an island of the hill of Bohuntine. But where the Roy now flows on the eastern side of that hill, the depth of barrier destroyed must have been at least equivalent to that of the depth of Shelf 4th below the level of Shelf 3d. But as I shall afterwards exhibit causes for the

the subsequent deepening of the present mouths of the glens, by means of their rivers alone, it is unnecessary to suppose at present, that the barrier was destroyed by the second subsidence of Loch Roy, to a depth much under that which was merely necessary to reduce Loch Roy to the level of Loch Spean, of which it now became an immense arm, as represented in Plate VIII. fig. 3.

The consideration of what I suppose to have been the grand cause which operated in producing the sudden and contemporaneous evacuation of the independent Loch Gluoy, and the great, and by this time united Loch Spean and Roy, again leads me to the Glen-mor-na-Albin, or Great Glen of Scotland. To those who have travelled throughout the extent of this remarkable valley, it seems to me hardly necessary to point out the various circumstances that lead to the supposition of its being an immense rent across the island, produced by some extraordinary and powerful convulsion. Indeed the whole of its appearance is more strikingly convincing to the eye when examined, than any detailed description can be to the mind, however minutely conveyed in words. But if we consider the vast depth of its lakes,—the almost rectilineal straightness of its direction,—its uniform narrowness,—the uniformity also of the general shape of the abrupt and lofty fronts of its bounding mountains,—the seeming adaptation of those on opposite sides to each other,—the wonderful equality of its level from one sea to the other,—and the lowness of its summit-level,—which, as it is composed of vast beds of alluvial matters, must have been even raised by time greatly above its original state,—if all these circumstances, I say, be considered, it will at least appear possible, that it may have owed its origin to some such unusual event. But as I believe the evacuation of the lakes to have been owing to no less magnificent a cause than this, I am am also inclined to think, that the evidence which they have left behind them, will reflect some strong rays of probability upon the theory I have adopted as to the formation of this very singular glen; and that the Shelves of Lochaber, and the Glen-mor-na-Albin, will be found upon examination, mutually to elucidate the history of each other.

Let us suppose, then, that the lochs were brought to the state which is represented in Plate VIII. fig. 3., and that the Glen-mor-na-Albin having as yet no existence, the whole country to the north and west of what was then their upper extremities, was a solid and undivided mass. An examination of the map of Scotland would at once show, that in such a situation of things, the discharge of the combined waters, generated in all of them, towards the Eastern Sea, by the channel of the River Spey, would have been then much more natural, than it even is now to the Western Sea by their present courses, under the circumstances that exist. Nor can it be doubted that the opening of this vast fissure, would produce all the effects necessary to explain the seeming difficulties, and to reconcile the various incongruities that otherwise encounter us, and perplex our speculations on this interesting subject. The terrible convulsions attending the creation of such a yawning crack, running through ground previously unbroken, although it might not cut exactly across in the very line between the lakes and their south-western boundaries, so as to allow the whole body of the water to escape from each of them in one moment, would certainly so rive and shatter the country, that the weight of the water itself would almost instantly complete the annihilation of any thing that remained to prevent its escape. From the appearances which still exist indeed, this would seem to have been the very manner in which it must have operated with respect to the Spean lake, since

since we see that the middle of the crack, runs nearly in the line of the river Lochy, whilst the western termination of the supposed Loch Spean must have been above Highbridge. It is therefore probable, that the small hills that are scattered like an elevated moor, in a semicircular form, from Ben-y-vaan, by Highbridge, to the projection of Aonach-more, are the remains of the shattered barrier, towards the destruction of which the discharge of the lake added the immediate assistance of a tremendous rush of water. The appearances at the Mouth of Glen Gluoy, and particularly the manner in which the shelf of that glen suddenly stops, on the south-east side, whilst it comes farther down on the north-west side of the valley, would rather seem to indicate, that a smaller crack, (of which there would naturally be several,) branching off from the great rent, had taken a zigzag direction, somewhat in the bent line formed by the mouth of Glen Gluoy and the Glen of Fintack; and indeed the whole appearance of this tributary glen would induce one to espouse such a supposition.

If it be at all admitted, that these lakes ever had existence, which I presume to suppose can hardly be doubted, I have already shown, that the whole water discharged from them, must have run towards the Eastern Sea. If this was the case, it appears to me to be impossible to account for the disappearance of the *terra firma* which shut in their western or upper extremities, in any other way than by the means I have suggested;—means which were fully adequate to produce at once the discharge of the united Loch Spean and Roy, and of the independent Loch Gluoy. It even appears to me to be not unlikely, (though I do not consider the aid of such a supposition to be absolutely necessary to my theory), that in a country where such a great convulsion was to happen, some previous throes might have manifested themselves, which might have even

even had some share in weakening the barrier dividing Loch Roy from Loch Spean.

The present depth of the Glen-mor-na-Albin, is more than enough to have accounted for the escape of the waters of these glens towards either sea; it is, however, evident, that it has been once much deeper, since the Caledonian Canal is now cutting through great beds of alluvial, to which the debris of the mountains brought down by torrents are every day adding, so much so indeed, as to produce an evident diminution in the extent of the higher lakes. And then Loch Ness itself is so very deep;—though I am rather disposed to think, that the abyss containing it, may have been produced by some of the last pangs of the convulsion, which perhaps operated with greater violence there than elsewhere. A belief is very prevalent, that Scotland, to the northward of this glen, was once insulated from the rest of the kingdom, by a narrow strait of the sea running through it; but from the circumstance of the early disappearance of all marine exuviæ, in the course of the cut of the canal, from the sea, through the flat ground near Inverness, this notion appears rather improbable. It would, however, be a highly interesting experiment, to bore for nearly a hundred perpendicular feet, at some point about the summit-level of the Canal, in order to discover, what substances would offer themselves. Some very curious geological speculations might be awakened by such a trial, and some additional and unexpected light might thus be thrown, upon the theory of the ancient Lochaber lakes. It is very likely, that much evidence bearing upon this last subject, might also be gleaned, by extending our inquiries to the two extremities of the Glen-mor-na-Albin, as well as to the appearances at the mouth of the river Spey. The few investigations I have made as to these points, have been much more superficial than I could have

 wished,

wished, nor can I pretend to found much upon them. The western end of the Great Glen of Scotland, is flanked by such rocky mountains, as to render it impossible to conceive that the portion of water which escaped that way, however great might have been its body, or however violent its discharge, could have produced much effect, so as to leave traces of its action; and the sea also, on this side of the island, being so much nearer the immediate scene of the catastrophe, would naturally counterbalance the violence of the flood, by the sudden influx of its waters. Accordingly, I was not conscious of observing any thing on the west coast, that could lead to any conclusion, favourable to the theory I have ventured to hazard. But, upon the east coast, I thought I discovered appearances that seemed in a very material degree to illustrate and strengthen the views I entertain. In the neighbourhood of Inverness, there are great hills of rounded gravel, and sand, in what may be called the Mouth of the eastern end of the Glen-mor-na-Albin. The *Hill of Tom-na-hiurich*, near the Town of Inverness, in particular, is extraordinary both for its structure, its shape, and its situation; being found standing nearly in the middle of the alluvial flat, like the inverted hull of a ship in form, and presenting the end of its long diameter towards the Great Glen, in such a way, and being so shaven off on the two sides, as to leave little room for doubt, that it stands as a living witness of that terrrible flood of water, which resulted from the sudden opening of the Glen-mor-na-Albin.

It remains for me now, to endeavour to trace out the changes which have taken place in the glens left by the lakes, and which may be considered as the secondary effects of the grand catastrophe;—and, first, as to those in Glen Gluoy. The chief streams of this glen are three,—one running from Glen Fintack, and the other two coming from the hills on the north and

and south sides of its present upper extremity. Whilst Loch Gluoy existed, the water of these streams was all discharged by the High Glen, into Glen Turret. But no sooner was the lake broken up at its other extremity, than the water would cease to flow in that direction, and would instantly rush into that which it follows at present. An attention to the southern branch of the river, at the head of Glen Gluoy, (to which, in the map, as well as in my description, I have given the name of the *River Gluoy*), as well as a remembrance of its various accompaniments in that quarter, will afford matter for some curious remark. It is discovered to descend from the hill, by a fall, upon that broad part of the shelf which must have been formerly a gently shelving bay of the ancient lake; where, whilst the water existed, its force would be immediately broken, and the stream would then have no effect in cutting, but would rather add to the shoal, by the deposition of the debris brought down with it from the mountain. But no sooner was the lake evacuated, than all check to the full exertion of the force of its descent would be removed, its powers of excavation would be brought into perfect action; and the violence of its descent would soon cut open the deep ravine which I have described, and marked in the map, as dividing the shelf across its whole breadth; and its power would continue undiminished, as long as any material difference existed, between the degree of declivity of the bottom of the ravine, and that of the lower part of the glen into which it issues. I therefore conceive, that this part of Glen Gluoy is particularly interesting, because it displays in a most satisfactory manner the mode in which running-water always operates, in bringing its course to a regular equality of fall, throughout all its parts. The present depth of Glen Gluoy, at its lower end, cut as it is also into a deep ravine, furnishes no proof that the

 original

original lake was nearly so profound in that quarter. The sudden burst of the water must have done much to scoop it out almost instantaneously, and the river itself would continue active in reducing it, in a proportion exactly equal to the quantum of its deviation from a regular declivity, counterbalanced as it might be, by the various degrees of hardness of the materials through which it had to work. These last observations apply equally to the effects which must have been produced by the rivers of all the glens, after the evacuation of their lakes. We see how the rocks have been cut in the descent of the stream from the *High Glen*, which must have been done in the same manner I have just described, after the water escaped from the *Bay of Turret.* So, after the subsidence of Loch Roy, which laid dry all Upper Glen Roy, the stream would, in the same way, begin to cut the ravine, to the south of the rock, dividing Upper and Under Glen Roy; and the operations there, would be increased by the farther reduction of Loch Roy, to the level of Loch Spean. The inclined shelves opposite to the mouth of Glen Turret (See the diagram, Plate VII. fig. 6.) are evidently the effect of the water of Loch Roy, rushing off at successive elevations, during its final evacuation; or perhaps, indeed, some of the lower ones may have been owing entirely to the after operations of the river. Generally towards the mouth of Glen Roy, and particularly to the eastward of the Hill of Bohuntine, the valley has been much deepened by the river, and the rocks are more and more cut, as it proceeds in its progress down the glen; we are not, therefore, to decide upon the depth of the ancient lake at this point, by what we now see. The same deepening of the channel of the river takes place in the common valley of the united Roy and Spean, as is exemplified in the wild scenery at Highbridge, to which direction the river Pattaig was turned, and whither the whole water of these

these valleys was then sent and discharged, instead of going as formerly through the Pass of Muckul towards the East Sea. The state which matters had now assumed, will be understood at one view, by a reference to Plate VIII. fig. 4. Glens Gluoy and Roy were now completely evacuated of their stagnant water. But of the Glen Spean lake, besides those remnants that remain to this day under the name of *Lochs Treig* and *Laggan*; there were then three smaller portions, as represented in fig. 4. These must have long survived the great catastrophe, since the name of *Kenmuir*, or The End of the Lake, given to each of the rocky necks of land, which served as barriers to confine their western or lower extremities, sufficiently denotes that these minor lakes, must have continued to exist after the Gaelic language was in use. It is a remarkable coincidence, and worthy of notice, that the little valleys remaining after the discharge of these smaller lakes, exhibit the same ravines and falls, that accompany all those on the greater scale in this neighbourhood, and that also appear in the case of the analogous example of Subiaco in Italy. The causes which produced the evacuation of these smaller lakes, were evidently slow in their operation; it must have been gradually effected by the river alone working in obedience to that invariable law, by which running-water has a constant tendency to reduce the course over which it flows, to one uniform and regular declivity.

From all that has come under my observation in the course of this interesting investigation, I am satisfied, that the district of Lochaber, and the country connected with it, will be found to merit frequent and minute inspection; and that it will be considered as affording many facts, from which important geological inferences may be drawn. It appears to me, that the evidence displayed by its different parts, is admirably calculated to illustrate all the varied mechanical operations of stagnant and

and of running water, under every modification; and that perhaps, these could be no where so well established. But this is not all;—for if, as I am inclined to believe, it shall ultimately be decided, that the Glen-mor-na-Albin, not only elucidates the mode in which the ancient lakes of Lochaber were evacuated, but that the shelves left by these lakes also, throw a reciprocal light upon the origin of the Glen-mor-na-Albin, then the science of geology will have reaped no inconsiderable advantage, by the attention of its followers having been directed, as I hope it will be, to such a field of inquiry.

NOTE.

The descriptive part of this paper, was written from my notes, soon after returning from my last visit to Glen Roy. I have just had (January 1818), an opportunity, of reading for the first time, Dr MacCulloch's learned and ingenious essay "*On the Parallel Roads of Glen Roy*," which was read at the Geological Society of London, nearly about the time that the Royal Society of Edinburgh did me the honour of listening to my first remarks on the same subject. I observe, that I have the misfortune to differ very materially from Dr MacCulloch, as to the height of Shelf 2d, or the uppermost line of Glen Roy, when considered with reference to Loch Spey. As will be seen by looking at the text, (page 33, of the foregoing), I conceive that this line may be traced to within about 200 yards of Loch Spey, and that, from the present level of the ground there, having been increased by the accumulation of a mossy stratum, I believe the level of the shelf to be actually

tually somewhat *lower*, than the surface of the moss lying between it and Loch Spey. In Dr MacCulloch's *Tabular View of Elevations*, he makes the highest parallel of Glen Roy to be 1266 feet, and Loch Spey 1203 feet, above the German Sea, and, consequently, the shelf to be 63 feet above the loch. Although my own observations have led me to form so very different an opinion about this matter, and although this opinion has been since borne out by the highly respectable testimony of Mr Macdonald of Inch, yet I should have almost hesitated in supposing, that so very accurate and philosophical an observer as Dr MacCulloch could have been mistaken, did he not himself seem to imply a doubt in his own mind of some error having arisen in the measurement of this very elevation. This he expresses in a note which I hope Dr MacCulloch's consideration will forgive me for quoting, as I doubt not his liberality will pardon me for thus expressing my difference of opinion with regard to the state of a fact, of which I feel convinced. The words of this note are as follows:

"Whatever doubt we may have respecting the general value of the method by which the elevation of the upper line of Glen Roy was ascertained, I must here remark, that this principal measurement receives confirmation, to a certain extent at least, by comparison with the height of that land which is the common division of the Truim and the Garry. This point has been found, by levelling, to be 1460 feet, and it appears probable, from comparing the course of the former river and that of the Spey to their common junction, that the source of the Spey cannot be materially different in elevation, a circumstance confirmed by the barometric observations. The other measures in the Table scarcely admit of any material errors."—*Geological Transactions*, Vol. iv. Part ii. p. 327.

The

The height of the source of the Truim is here stated to be 1460 feet; and it is supposed by Dr MacCulloch not to be materially different from that of the source of Spey, which, however, is only 1203 feet by his measurement. According to this statement, therefore, the source of Truim is 257 feet above that of Spey, which, in a question of so much nicety as the present, must be considered as constituting a very material difference indeed. But the difference between Dr MacCulloch and me, is only about 63 feet, which, if it can be allowed me, will bring the height of the sources of the Truim and Spey so much nearer to an equality, and will at the same time make the altitudes relating to Glen Roy, in perfect harmony with the view of the state of matters which my observations have led me to entertain.

II.

PLATE I.

Sketched by Thomas Lauder Dick

Engraved by W^m. Miller Edin^r.

VIEW down GLENGLUOY from the hills at its upper extremity from point *a* in the map.

a. *Ben Nevis seen at a distance* — b. *Mouth of Glen Fintack.*

PLATE II.

Sketched by Thomas Lauder Dick. Engraved by W^m Miller Edin^r

VIEW of the mouths of GLENROY and GLENSPEAN taken from above Inch from point *b* in the map.

a *Glen Collarig* — **b** *the Gap* — **c** *hill of Bohuntine* — **d** *Glen Roy* — **e** *the high plain* — **f** *Crag dhu* — **g** *inclined plain* — **h** *Meaddery* — **k** *proper point of division between the two Glens* — **m** *Mullroy.*

Fig. 1.

The GAP as seen from GLENCOLLARIG taken from point *c* in the map.

a *is the hill of Bohuntine*

Sketched by Thomas Lauder Dick *Engraved by W^m. Miller Edin^r.*

Fig. 2.

The GAP as seen from GLENROY taken from point *e* in the map.

a *is the hill of Bohuntine*

PLATE II.

Sketched by Thomas Lauder Dick

Engraved by W^m Miller Edin^r

VIEW up GLEN ROY taken from the GAP from point d in the map

The foreground represents a shelf, with a rock in the interior angle

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Sketched by Thomas Lauder Dick

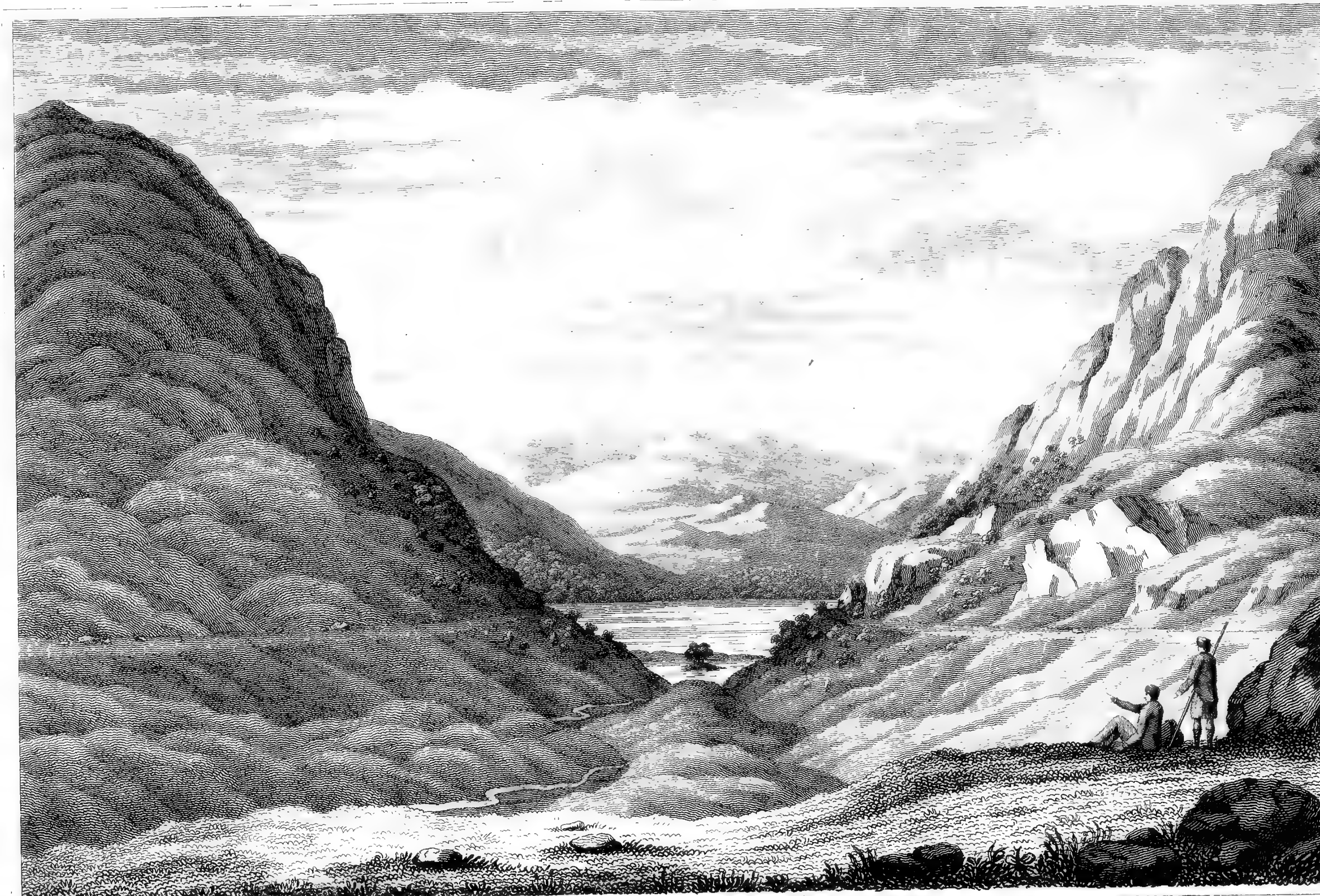
Engraved by W^m Miller Edin^r

VIEW of the head of GLENROY taken from point *f* in the map

the foreground is a portion of Shelf 3d

a *Mountain of Tombhran* – b *isolated rock dividing upper and under Glen-Roy* – c *ravine through which the Roy comes*

PLATE VI.

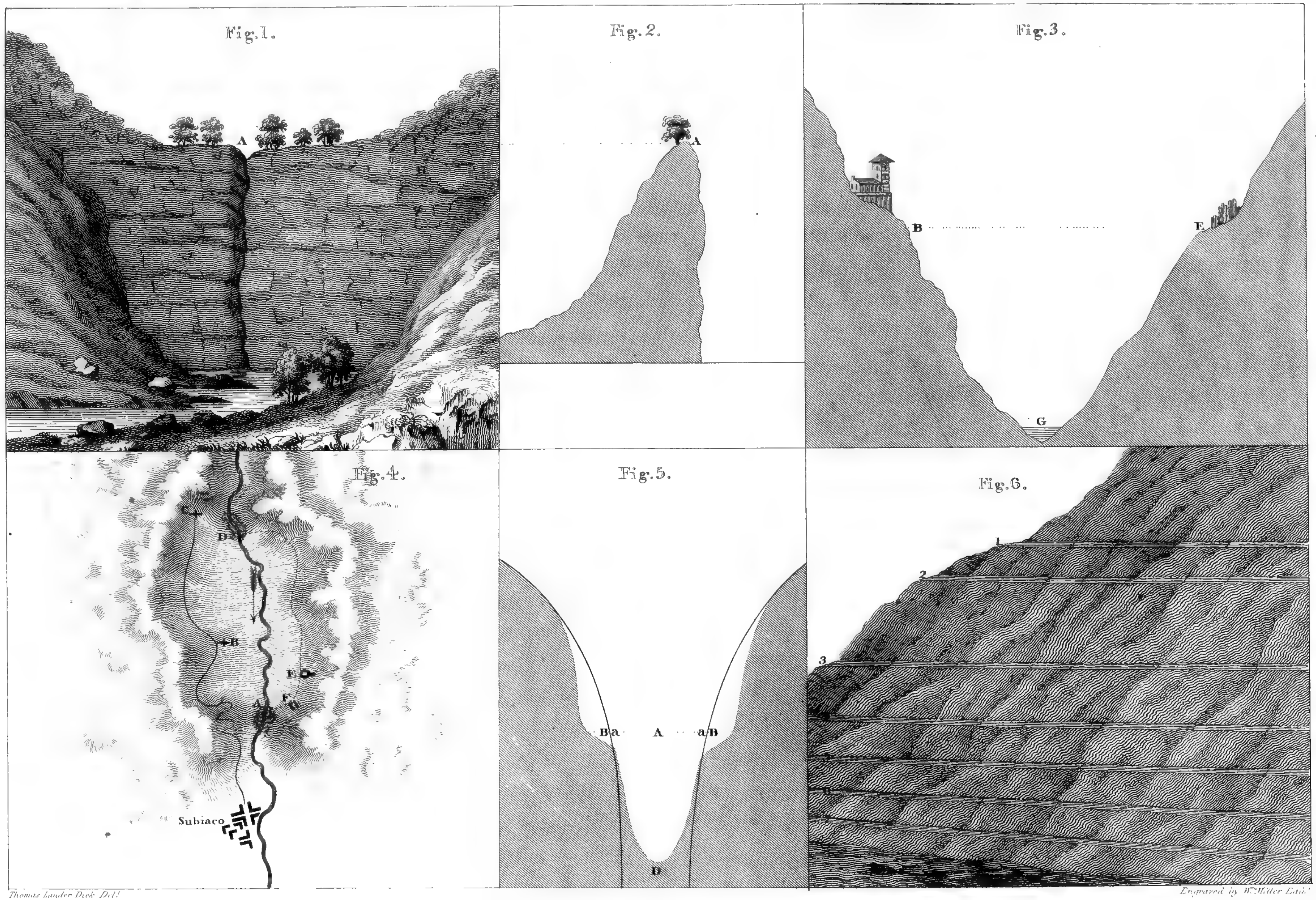


Sketched by Thomas Lauder Dick

Engraved by Wm. Miller Edin.r

VIEW of the Entrance to LOCH TREIG taken from the top of Tom-na Fersit in GLEN SPEAN from point g in the map.

PLATE VII.



DIAGRAMS

Fig 1 The barrier rock of the Valley of Subiaco_Fig 2. Section of the barrier rock_Fig 3. Section of the Valley of Subiaco_Fig 4. Map of the Valley of Subiaco_Fig 5. Theory of the formation of a Shelf_Fig 6. Glen Roy pseudo shelves.

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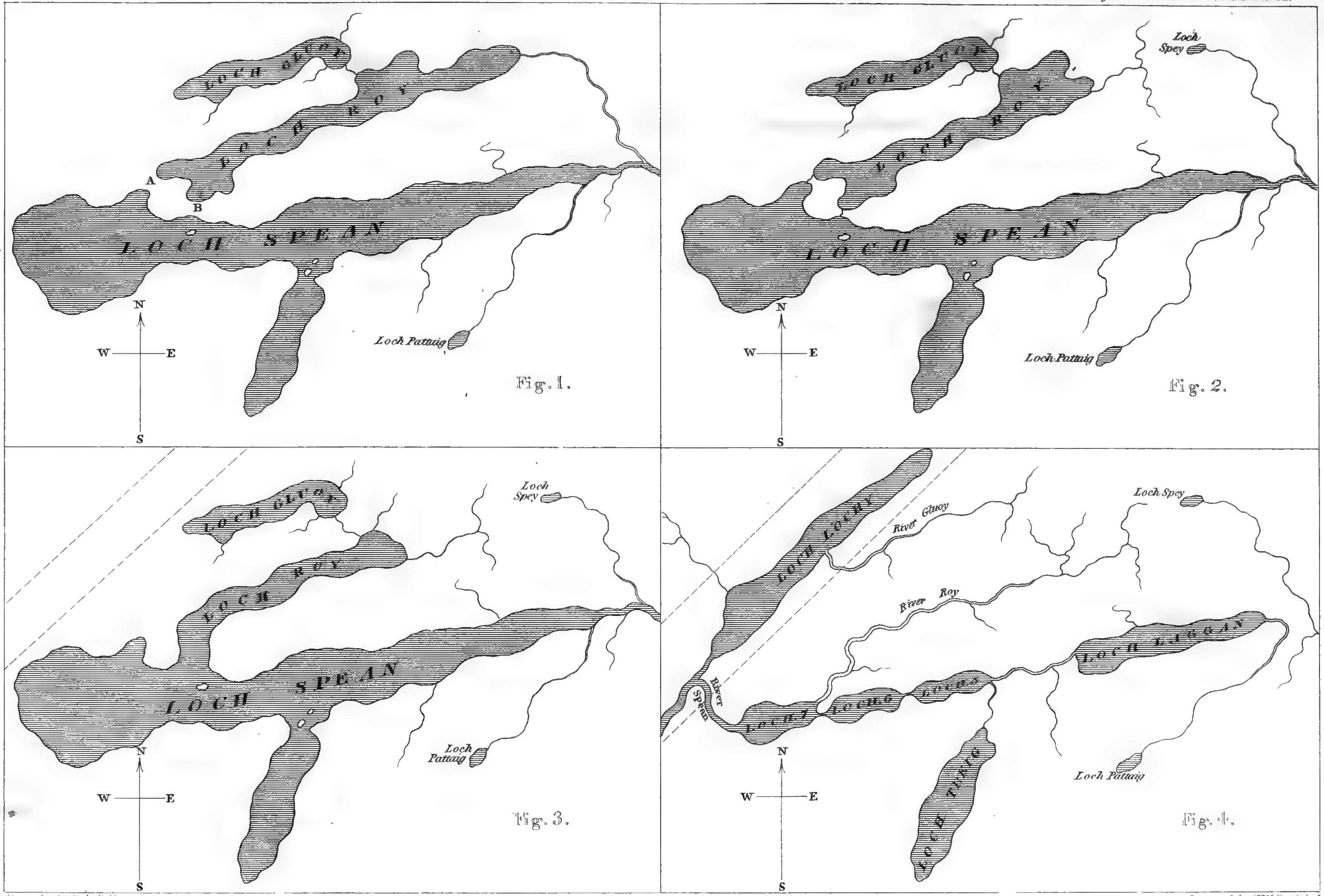


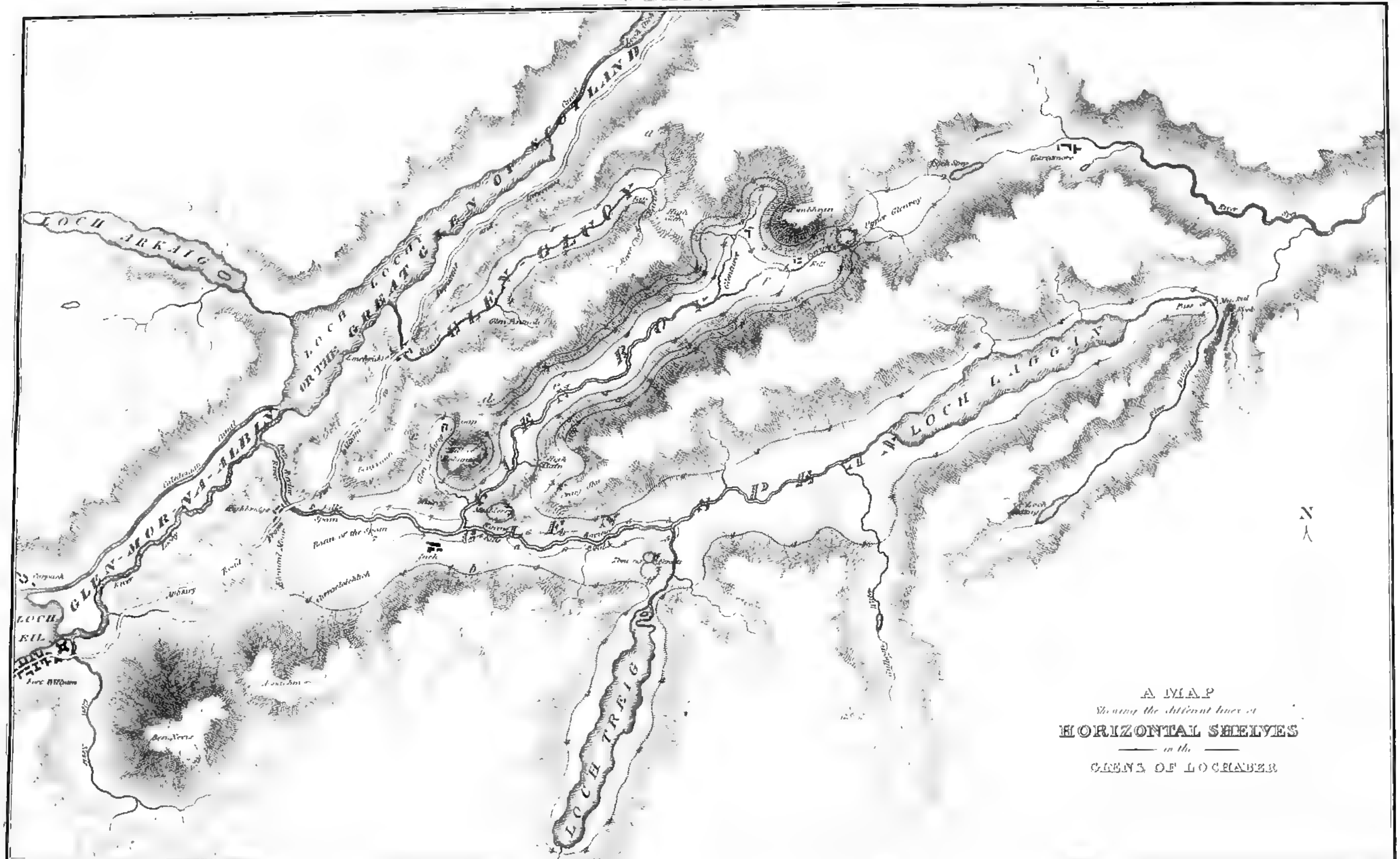
Thomas Lauder Dick, Del.t

Engraved by W.m Miller Ed.r

DIAGRAMS to illustrate the theory of the four different states of the LAKES

Fig 1. Primary state of all the lakes_ Fig 2. State of Loch Roy after its first subsidence. Fig 3. State of matters after the second subsidence of Loch Roy_ Fig 4. Change produced by the opening of the Glenmorna albin.

Trans. Royal Soc. Edin. Vol. IX.



II. *On the Poisonous Fishes of the Carribbee Islands.* By WILLIAM FERGUSON, M. D. F. R. S. EDIN.

(Read Jan. 18. 1819.*)*

THE subject of poisonous fish has long been a source of puzzle and speculation to the inhabitants of the West Indies. Much has been conjectured upon it, and numerous tests and theories been proposed, which have had for a time their believers and advocates; but all have been found to be equally baseless. The author of this paper, by a narrative of what he has himself seen and observed on the subject, proposes rather to shew to the Society what it is not, than what it actually is, and thereby to clear the way for the future successful investigation of this curious and interesting phenomenon, by dissipating many erroneous notions that stand in the way of the discovery of truth.

Throughout the greater part of the West Indies, the accident of meeting a poisonous fish is a rare and extraordinary occurrence. At Barbadoes, for instance, it happens so seldom, that the majority of even the best informed inhabitants can scarcely be made to believe, that it has ever taken place

amongst

amongst them. On the coasts of St Domingo, where I served during the years 1796, 1797, and 1798, and where the British troops, under the scarcity of fresh provisions, always depended much on the sea for subsistence, only two well-authenticated instances of the kind came within my personal observation. Had there been others in the army, it is most probable that I would have heard of them. The nature of the accident, and of the morbid phenomena consequent upon it, was so very similar to what I had much more recent opportunity of witnessing at Guadaloupe, in the year 1815, as to render it unnecessary to trespass on the time of the Society with a detail of both occurrences. I shall therefore proceed to lay before them an account of the last, as being the best within my memory, as well as being officially authenticated by documents that will be referred to in the course of this paper.

Shortly after the last capture of that island, under circumstances much the same as at St Domingo, while the British troops were daily making use, without scruple, of whatever fishes were offered to them in the markets of the island, the Quartermaster-General, attracted by the appearance of a particularly fine horse-eyed cavallo *, purchased it for his family, the members of which, including servants, were numerous (not fewer than twenty). All partook of it, and all, without exception, were taken ill within a few hours afterwards. The symptoms in some were cholera morbus, with florid patches on the skin, not unlike what is seen in phlogistic scarlatina, only the parts affected were more swelled and raised; and, in all, great and most distressing pains over the thinly covered bones, more particularly the bones of the face, with great febrile

* *Harang aux gros yeux* of the French, and *Scomber* of naturalists.

brile disturbance, much painful numbness of the soles of the feet, and more or less of spasmodic twitchings and tremors. All the Negro servants were more severely affected than the white members of the family, and the black cook died from the effects of the poison; confirming the popular opinion, from the fatality thus falling, as in other instances, upon the blacks, of their constitutions being more amenable to the action of the fish-poison than those of the whites. But it ought here to be remarked, that these last suffered exactly in proportion as they had partaken of the fish, and the General's lady, who had dined almost entirely upon it, felt the effects of the poison for many months afterwards. The numbness of the feet, with the peculiarly painful sensation of the soles, continued for a very long time. So little danger was apprehended by the inhabitants from the use of this fish, though all of them knew it to be occasionally poisonous, that, two days after the accident, I saw a very large one cut up, and distributed in the market-place amongst a number of purchasers, all of whom treated my interference with merriment, and jeered good humouredly at my warnings against it.

Though the majority of the British Medical Staff had long been resident in the West Indies, the accident in the Quarter-master-General's family was so new to most of them, that we hesitated not to call in the aid of the French Faculty of the place, who prescribed (the necessary evacuations having been premised) the sulphuret of potash in the first instance, in as large and frequent doses as the stomach could bear, and then the saccharine mucilages, in every shape that could be offered; and this treatment, more particularly that of the saccharine regimen, appeared to be very effectual. It did not appear that the alkaline remedy produced much effect. A very short time after this occurrence, a shoal of the green-backed cavalloes (a much smaller fish) beset the shores and wharfs of Basseterre, the capital of the island, in such numbers, that they were taken in all kinds of ways by the common people, and an English merchant, attracted by the sight of this fishery, could not resist the temptation of a remarkably fine one, which he purchased for a trifle, and carried home to his family. They were taken ill after eating it, much in the same manner as the Quartermaster-General's, though not so severely *. His lady only had alarming symptoms; but, amongst the many thousands of these fish that had been eaten in the town, this one alone was ascertained to have possessed any poisonous quality. The British Medical Staff was in the closest communication with the French Faculty on the subject, in consequence of the first accident, and if any others had occurred, it is next to impossible that they could have been concealed from us †.

These casualties strongly excited the attention of the Governor-General, Sir James Leith, who directed me to call officially upon all the French Faculty, (some of them men of much knowledge and experience) for information on the subject; and from them we learnt, that sixteen different species of fish had been found more or less poisonous, at different times, in Guadaloupe; but that in all, with one exception (that of

* The fish is, comparatively to the horse-eyed cavallos, a much smaller one, and consequently a small portion only could fall to the share of each member.

† Let it not be here supposed, that this fish-poison bears any analogy to the affections that are sometimes induced upon particular constitutions in this country, from eating some particular kinds of shell-fish. The fish-poison affects all who receive it, as generally, and as certainly, as opium or arsenic. In the year 1797, at Cape Nicholas Mole, in St Domingo, almost every officer in the Army and Navy suffered from it, from eating of one large fish, on the occasion of a garrison dinner, and several of the black domestics died.

of the yellow-billed sprat *), it was so perfectly an accidental occurrence, that it never had been deemed necessary to impose any prohibition, beyond what the fears and experience of the people naturally dictated, more particularly, as the best part of their food was at all times derived from the sea. From their information, however, it was clearly ascertained, that the most dangerous fishes were the small yellow-billed sprat, the baracoota †, and horse-eyed cavallo, which three were forbidden under penalty of confiscation of the fishing-boats, to be ever exposed for sale; and the other thirteen kinds were directed, under a severe pecuniary penalty, to be gutted as soon as caught, (the black fishermen having expressed much confidence in that precaution) and never to be brought to the markets except in that state. No accident occurred after these regulations were adopted, during the remaining nine months that the British continued in possession of Guadaloupe. From the black fishermen we also obtained the curious information, that the deadly yellow-billed sprat was never poisonous when caught in the immediate Bay of Basseterre, even at the time when it would be almost certainly fatal to eat them if taken at a very short distance on either side of the roadstead, and that, at some seasons of the year, they could be eaten with impunity everywhere; the most dangerous times with them being from the month of April till the end of the summer months. They also amply confirmed, what we had previously taken for granted, that the larger fishes followed and preyed upon them at all times with avidity, and that there was no bait they could use more tempting than the yellow-billed

* *Sardine doré* of the French, and *Clupea Thryssa* of naturalists.

† *La Bechune* of the French, and *Perca major* of naturalists.

billed sprat. Indeed they might be seen by any who would take the trouble to attend to them, selecting from their sprat-nets the yellow-billed for bait, reserving the *balahoo*, a fish not unlike the sprat, but about the size of a pilchard or small herring, and the common white sprats of the same size, caught in the same net, of the same shoal, and on the same ground, for market; which last were never known, under any circumstances, to prove poisonous.

The importance and obscurity of the subject, on which so little light had been obtained from our inquiries at Guadaloupe, called for further investigation, and by direction of Sir James Leith, I circulated the following queries, amongst the faculty of all the colonies:

"1. What fish have you knowledge of, as possessing, when eaten, a poisonous quality, in the West Indies?

"2. Were these fishes poisonous in all places and seasons, or only at particular times, and in particular places? Did they prove poisonous to the majority of those who ate them, or only to particular individuals?

"3. Did the other fishes inhabiting the same places, exhibit, when eaten, more or less of the same poisonous quality, or was it found in only one or two particular species, or only in one or two individuals of the same species?

"4. Can it be ascertained whether any species of food, that fishes incidentally eat, can communicate this poisonous quality?

"5. It has been seen, that fishes such as the King Fish *, and the different kinds of cavalloes, can be eaten with safety when

* *Xiphias* of naturalists.

when of the ordinary size, but become sometimes poisonous, when they grow very large. What do you suppose can be the reason of this? Do these fish live on a different kind of food when arrived at this gross state, from what they did when smaller? Does the poisonous quality reside in the fat that has accumulated under the skin? or what is the change induced upon the fish in consequence of his increased bulk, that renders him poisonous?

" 6. Are not fishes that are found to be poisonous generally in the highest season, and of superior flavour?

" 7. Has any thing remarkable ever been detected in regard to the liver or other viscera of poisonous fishes, or are there any marks by which they can at all be distinguished from others of healthy quality?

" 8. Is any faith due to the test of boiling a piece of silver in the same pot with the suspected fish, when cooked; and will not all fishes that abound with dark-coloured fats under the skin, imbue silver, more particularly when long boiled, with a tint of the same? Have not these fishes been eaten with impunity after they had stained the silver that had been used for the above test?

" 9. Has the existence of copper-ore at the bottom of the sea, so as to constitute what is called a *copper-bank*, in contact with the waters, ever been ascertained; and if ascertained, have the fishes caught there proved more remarkably poisonous than in other places?

" 10. Do fishes eat any species of marine plants, weeds, or mosses, for food, and can any of those that fishes eat have the effect of rendering them poisonous?

" 11. Are eels, mud-fish, and other species that live stationary in a great degree, amongst the weeds at the bottom of the sea,

sea, ever poisonous, or more remarkably so than the other species of fish that prey abroad throughout the waters?

"12. The poison of the yellow-billed sprat has been found particularly deadly in the month of May, at the time when, according to the vulgar saying of fishermen, coral is in blossom. Can it be ascertained, what is the food of these fish at that time? What particular species of marine insects abound, and sea plants flourish, at that period, in the places where he inhabits?"

N. B. It is said that the yellow-billed sprat can be eaten with impunity at all seasons, when taken in the road of Basseterre, Guadaloupe.

"13. Do not all the larger fishes that are found to be poisonous, prey upon the yellow-billed sprat, in common with any other kind of smaller fish they can master? May not the larger fishes, that prey directly upon the yellow-billed sprats, thereby acquire a highly poisonous quality, or one of less intensity, by preying at a farther remove on those fishes that have done so; or is this disproved, by the fact of the larger fishes of some species only being poisonous, while the smaller of the same kind, that may be supposed to prey more immediately on the yellow-billed sprat, can be eaten with impunity?"

N. B. The poisonous quality of the *Baracoota* is in no respect modified by his size.

"14. Fish of the larger kinds are never poisonous at Barbadoes, and some other places. Is the yellow-billed sprat found on these coasts?

"15. Is any credit due to the common opinion, that fish are rendered poisonous by eating the gally fish or stinging blubbers?"

N. B.

N. B. These blubbers are found in great quantity at Barbadoes, and abound prodigiously on some of the coasts of Europe, where fish are never known to be poisonous.

"16. What are the symptoms of fish-poison? Do they bear any resemblance to those of the poison of copper or other mineral poison, or poison from the vegetable kingdom? Is there any antidote against it that can be used at table, such as oil, lime-juice, vinegar, wine, spirits, or spices, and what are the best remedies and modes of treatment after the poison has taken effect?"

The replies from the majority of even the oldest residenters in the West Indies professed total inexperience of the subject, so rare it seems is the accident; but from others of them some valuable information was obtained. From the account of my friend Dr Nugent of Antigua, it would appear that the yellow-billed sprat is at times the strongest native unprepared poison probably in existence, Negroes having fallen down dead when in the act of eating it, with part of the fish, though a very small one, in their mouths; and the same effect has been produced on a dog, from giving him a single fish to eat. It is even recorded by Dr Chisholm of Grenada *, that a white person, having unwarily, when eating sprats, put one of the yellow-billed into his mouth, and immediately spit it out again, when informed of his mistake, without swallowing any portion, but only masticating it, died nevertheless from the effects of the poison. These accounts were confirmed by Mr Griffin, staff-surgeon of St Kitt's, who stated a remarkable

 occurrence

* In the Number for October 1808 of the *Edinburgh Medical and Surgical Journal.*

occurrence of the kind that had lately taken place in that island. Dr Osborne of Antigua, by whom all the above was fully admitted, professed, nevertheless, much confidence in the precaution of gutting the fish, and stated an instance of a Creole lady, who would venture to eat the yellow-billed sprat at all times, when she could depend on the fishermen cleaning them out as soon as caught; but this must in all probability have been owing to peculiar idiosyncrasy in the person, as no cleaning out of the fish, however promptly and perfectly performed, rendered them safe to others. It was proven at the same time, by a report from an eminent physician at Martinique, transmitted through Staff-surgeon Woulfe, that not even salting the fish after cleaning it, could at all times do away the poisonous quality; a family in that island having just been severely poisoned by eating a baracoota that had been in salt twenty-four hours. The blacks always profess the utmost dread for the yellow-billed sprat, during the months when, according to their vulgar saying, the coral is in blossom, but at other times they eat them without scruple, and with impunity, giving no other reason but that the season of danger is past. I see no room to doubt of the madrepore being in particular activity at certain seasons of the year, and that fishermen are more sensible of the growth of coral at these times than at others; but I think there is much reason to doubt of this growth at all affecting the quality of the fish that feed upon the corallines, seeing that Barbadoes, which is a coral formation in all its coasts and shores, is of all the islands in the West Indies, the one, I believe, where poisonous fish are most rarely seen. Besides, it is not on the coasts of coral formation where these animals are commonly found. Antigua may be a partial exception; but their more favourite resort would appear to be the shores of the volcanic islands of the West Indies,

dies, such as the leeward shore of Guadaloupe, immediately under the great Souffriere, where hot boiling springs are found within the high-water mark, or in the channel between the volcanic promontories of St Kitt and St Eustatia, where the fish are so remarkably poisonous, that fishermen rarely exercise their trade in that part of the sea. It abounds, I have heard, in a particular manner, with the yellow-billed sprats, and no inhabitant will venture to eat a baracoota or other large fish taken thereabout.

Most of the accounts agreed in what I had myself observed, of the fish that proved poisonous being always in the very best condition, and generally the largest of their species, without marks of disease of any kind in any part of them, and I never heard of a single exception to this, the sufferers having always been induced to eat heartily, from the peculiar excellence of the fish; and all who were capable of examining the subject, were convinced of the inutility and frivolity of the tests usually employed, such as boiling a piece of silver, &c. with the fish, adducing instances where the severest poison had been received when the test declared security, and *vice versa;* the only test hitherto discovered, in the least to be depended on, being that of giving a portion of the fish, the offal in preference, to a cat, a duck, or a pig, and witnessing its effects upon them, before proceeding to make use of it.

The commonly received opinion, too, of copper banks at the bottom of the sea, that is to say, uncovered and insoluble copper ores in contact with the waters, the very existence of which is a most improbable gratuitous supposition, communicating a poisonous quality, such as that found in the yellow-billed sprat, to the wandering fishes that roam in the waters, I need scarcely say to the Society, was refuted and shewn to be impossible; as well as another opinion, almost as general,

 that

that the stinging blubbers (the *Medusæ* and *Holothuriæ*) which we have no reason to suppose that fishes ever eat, communicated the poisonous quality. Another article in the creed of the French Creoles on this subject, viz. that fish were made poisonous by eating the deadly manchineal apples that were carried by the rivers into the sea, was too absurd to be investigated, as its obvious refutation was at once conveyed, in the fact of no poisonous fishes having ever been found in any of the numerous rivers that flowed or stagnated amongst groves of the manchineal tree; but they believed it from the curious circumstance which induces me to mention their opinion here, of the sea-water being an excellent remedy against the manchineal poison; and they therefore believed, that from having the remedy so perfectly at hand, the fish could eat with impunity what made him so dangerous an article of food to those who catched him.

From the whole of our inquiry, I think it was established, that no fish, with the exception of the yellow-billed sprat, which, from its small size, is fitted to be the prey of almost every other, could be called regularly or certainly poisonous at any time; but that with all the rest it was an accidental variety, communicated from some particular kind of food. That in the larger fishes of prey, the poisonous quality most probably arose from their having recently preyed upon the yellow-billed sprat (these fishes being found most frequently poisonous where the yellow-billed sprat abounds), but in all of that description, it would appear to be a transitory quality, communicated to the animal from the food he had just eaten, and passing away soon after its digestion was completed;—a supposition the less improbable, when we consider the quickness of the process of digestion, that, from the shortness of the alimentary canal, and great size of the liver, must take place in these

these voracious animals. How else are we to account for the fact so often witnessed by ships crews, or in fleets, of two dolphins caught on the same line, the one proving wholesome, the other poisonous; or, amongst other species, for one or two only of a shoal, caught in the same net, proving dangerous to eat; or for the chances being so much greater, of falling in with the larger poisonous fishes, where poisonous prey abounds, yet the poisonous quality of the former never being sure or permanent? I have laid so much to the account of the yellow-billed sprat, that I was long much puzzled to account for well authenticated instances of the larger fishes having more than once, though certainly very rarely, been found poisonous at Barbadoes, on the coasts of which I believe that the yellow-billed sprat is never seen; and it was not till after I had been a long time in the island, I ascertained beyond all doubt, that the smaller *Jack fish*, a species of the *Perca marina*, well fitted from their size to serve the same purpose of prey to the larger fish as the sprats, were occasionally poisonous in some of the bays at the north-east end of the island.

Could we ascertain what it is that communicates the poisonous quality to the smaller fishes mentioned in this paper, the question, in respect to discovery of cause, might be considered as at rest. The existence of a local marine poison, when eaten by the fish, communicating noxious impregnation, or inherent poisonous quality, in these little animals, may both be inferred and disproved on nearly equal grounds. The first would seem very probable, from the local and temporary nature of the quality in regard to place and season, were it not that the dreadful potency of the impregnation renders it most unlikely that it could be derived from any species of food whatever, or be otherwise than inherent in the fish, to say nothing of its incommunicability, in the case of the yellow-billed sprat,

sprat, to other fishes of the same size and genus, such as the white sprat, which is always found in the same place, and may be supposed to feed in the same way.

The subject is of great importance, for no misfortune can be conceived more terrible, even when death does not ensue, than being served with this undistinguishable poison in the shape of the edible fishes, the best and most delicious, as well as the most common food by far, which the Caribbee islands afford. Most pitiable cases were related to me in the French settlements, by persons worthy of credit, where the patients, after escaping with difficulty, from imminent death, suffered during the rest of their lives all the miseries of exfoliation of the bones with hideous ulcerations, or paralysis, and all its distressing accompaniments; and the same accounts are confirmed by Dr Thomas, who practised long in the West India colonies, in the 2d edition of his *Practice of Physic.* For these secondary symptoms no adequate remedy could of course be found; but as an antidote to the poison, before it could have time to operate in this baneful manner, there could be no doubt of the astonishing efficacy of sugar, more particularly in the form of the expressed cane juice. This fact was established by a great body of evidence, and to my mind it in some degree explained the curious circumstance of white guests generally escaping better from the fish-poison than their black domestics, at the same entertainment; the former making use of punch, sweet liqucurs, &c. which seldom fall to the lot of the latter, for we had no clear proof of any spice or seasoning, or vinous or spiritous liquor, that did not contain sugar, possessing any efficacy as an antidote.

I feel that I owe an apology to the Society for having thus offered a paper to their notice, which proves so little; but the subject belongs to an element into which we cannot enter, and all familiar knowledge of its inhabitants must consequently be impossible.

III.

III. *Account of a Mineral from Orkney.* *By* Thomas Stewart Traill, M. D. F. R. S. Edin.

(Read April 21. 1817.*)*

WHILE examining an abandoned lead-mine in the vicinity of Stromness, in the year 1803, I found a mineral which, from its weight and appearance, I supposed to be carbonate of barytes. A few hasty experiments soon convinced me that it was a different substance; but circumstances occurring which prevented a more accurate investigation, the mineral lay neglected among the duplicates of my collection till last autumn, when having mentioned my doubts and conjectures respecting it to my friend Dr Murray of Edinburgh, I was strongly urged by that gentleman to undertake its analysis. During his short visit to Liverpool, a few preliminary experiments were begun, from which it appeared, that the mineral contained carbonate of strontia, and I have since completed its chemical examination.

I may here observe, that a specimen having previously been submitted to several very able mineralogists, they were unable, from its external characters, to ascertain its nature; a circumstance which affords a fresh proof of the necessity of uniting chemical investigations to a knowledge of the external appearance of mineral bodies.

 External

External Characters of the Mineral.

Its colour in the fresh fracture is greyish-white, passing into pale yellowish-white, where it approaches the surface of the specimen, which is weathered.

It occurs in masses, of various sizes, dispersed, along with lead-glance, in a species of coarse slate, which may perhaps be considered as shale passing into clay-slate *. This rock appears to rest on mica-slate, which is in connection with gneiss and small-grained granite, rocks which occur in no other part of the Orkney Islands constituting mountain masses. The mineral perhaps may occur crystallised, for it has a distinct crystalline texture; but the specimens I found were so much acted on by the weather, that no trace of crystalline figure is discernible.

The lustre is shining and pearly in the principal fracture; glistening and resinous in the cross-fracture. The weathered surface is earthy and dull.

The principal fracture is radiated, somewhat diverging; the cross fracture is uneven, approaching to splintery. The mineral is translucent where fresh, but opake externally.

It is soft; so as easily to be scratched by a knife; it scratches calc-spar, but not fluor-spar.

It is rather brittle, and easily frangible.

It is heavy. Its specific gravity is 3.7, or more accurately 3703, to water as 1000.

Chemical

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* I here state my own impression at the time when the mineral was found: but Professor Jameson, to whose authority I pay the greatest deference, has observed, in a work long ago printed, that the rocks in that neighbourhood consist of a mineral "*intermediate between shistose and indurated clay.*"—*Mineralogy of the Scottish Isles*, vol. ii. p. 233.

Chemical Characters.

It is insoluble, or nearly so, in water.

It effervesces briskly with acids, and is partly dissolved.

It is infusible before the common blowpipe, and resists the ordinary temperature of a smith's forge, when subjected to it in a crucible; but loses in weight, becomes white, and more hard than before. This process rendered it partly soluble in water, to which it imparted an acrid taste, alkaline qualities, and the odour of sulphuretted hydrogen.

A fragment of the mineral, thrown into strong sulphuric acid, effervesced, and formed a white powder of little solubility.

With concentrated nitric and muriatic acids there was, at first, a brisk effervescence, which soon ceased; but was repeatedly renewed, on successive additions of small quantities of water. In both cases a portion was dissolved; the solution was transparent and colourless, and crystallizable on evaporation.

On adding prussiate of potassa and iron to the muriatic solution, no change was at first perceptible; but after some time, a faint bluish tinge might be distinguished. By digesting muriatic acid on the insoluble residue, a deep blue colour was obtained on the addition of the same re-agent.

Chemical Examination of the Mineral.

The preliminary experiments by which its chemical characters were ascertained, shewed that it was resolvable by the action of muriatic acid into gaseous, liquid, and solid substances, each of which became the subject of investigation.

A.

The gas disengaged was found by experiment to be carbonic acid.

B.

1. The muriatic solution, when separated by the filter from the undissolved residue, was evaporated to dryness, and crystallised from a fresh solution in water *. The crystals were slender prisms, with two of the lateral planes broader than the rest; were persistent in the air, and had all the chemical characters of muriate of strontia. Their solution was not precipitable by ammonia, but potassa separates a portion of the earth with the peculiar phenomena detailed in Dr Hope's valuable paper in volume iv. *Phil. Trans. Edin.*

2. The nitric solutions gave small brilliant crystalline flakes; and these were also formed on the addition of nitric acid to the muriatic solution, but were speedily dissolved on the addition of water.

3. In order to satisfy myself still farther that the muriatic salt had a base of strontia, a very dilute solution of sulphate of soda was dropt into a concentrated muriatic solution of the mineral; but no precipitate was formed: when the sulphate was less diluted, a precipitate fell, though less copious than when added to a similar solution of muriate of barytes, but more abundant than with muriate of lime.

4. After separating, by successive crystallizations, the crystals from the muriatic solution, a small quantity of an acrid and

* The first addition of water caused a considerable evolution of caloric.

and very deliquescent salt remained in the bottom of the capsule. It was decomposed by oxalate of potassa, when a highly insoluble substance, not soluble in excess of oxalic acid, was obtained. Calcination, and the action of sulphuric acid, proved that the oxalate of lime had been formed.

5. The greyish-white powder, which remained after the calcination of the oxalate, was wholly soluble in water, and formed a bulky precipitate with sulphuric acid. The washings of this precipitate were not rendered turbid by phosphate of ammonia, nor was any change produced by the muriate of ammonia. These experiments shew that the muriatic solution of the mineral contained no magnesia, nor argil, nor any appreciable quantity of iron.

The peculiarity attending the action of concentrated nitric and muratic acids on the mineral is worthy of notice, as affording an additional diagnostic mark between carbonate of strontia and carbonate of barytes. It will be recollected that those acids acted *at first* upon the mineral from Orkney, but that the effervescence soon ceased, unless water were added. In order to compare the two carbonates more accurately, the following experiments were instituted.

a. A fragment of native carbonate of strontia from Strontian was thrown into muriatic acid; a strong effervescence ensued, but soon ceased: it was however immediately renewed on the addition of water; just as had happened with the mineral from Stromness.

b. Into a portion of the same acid was dropt a fragment of carbonate of barytes from Anglezark, which had been entirely freed from loose particles; no effervescence took place, until water was added; but when a portion of the same specimen, reduced to powder, was thrown into a fresh portion of the acid, effervescence instantly commenced.

c. A

c. A solid fragment of Carrara marble was attacked and dissolved by a portion of the same acid, without the addition of water.

Hence we may consider carbonate of strontia intermediate, in its habitudes with this acid, between carbonate of barytes and carbonate of lime; and these peculiarities afford an easy method of distinguishing these three native carbonates from each other.

From the preceding experiments we may conclude, that the portion of the mineral from Orkney, which is soluble in muriatic acid, consists of carbonate of strontia, a little carbonate of lime, and a minute trace of iron.

C.

The undissolved residue of the former experiments had a yellowish-white colour, and was totally insoluble in water. The calcination of a portion of the mineral had shewn that sulphur entered into its composition, as sulphuretted hydrogen was given out on the addition of water. The probable origin of this had been the decomposition of a sulphate. No trace of a sulphate had appeared in the acid solutions, and therefore we may conclude that the sulphate exists in the insoluble residue.

1. A portion of this residue was boiled with a concentrated solution of carbonate of potassa in a silver vessel. It was then washed to free it from alkali; and on finding that it had become partly soluble in muriatic acid with effervescence, the process was several times repeated, and thus the greatest part of the residue was rendered soluble in muriatic acid. What remained in the last process, was soluble in boiling sulphuric acid, from which it separated on cooling in acicular crystals.

2. The

2. The water employed to wash the powder C. 1. was evaporated, and crystals of sulphate of potassa were formed.

3. The muriatic solution (C. 1.) obtained by decomposing the sulphate by carbonate of potassa, when evaporated, yielded tabular crystals, persistent in the air, which, placed in the wick of a candle, tinged its flame of a yellow or greenish-yellow hue; and when dissolved in water afforded an instant precipitate with sulphuric acid, and with the most diluted solutions of sulphate of soda.

4. Another portion of the insoluble residue was boiled with eight parts of concentrated sulphuric acid in a platina cup, and was wholly dissolved; but on cooling, it separated in acicular crystals around the edge of the containing vessel. These crystals were acidulous, even when dipt into water, which resolved them immediately into an insipid powder which was a neutral sulphate. When exposed to the air this powder was more slowly formed.

5. A third portion of the insoluble residue was digested with muriatic acid, under the idea that its colour indicated the presence of iron. The acid became of a yellowish colour, and afforded a rich blue precipitate with prussian alkali.

These experiments prove, that the residue consists chiefly of Sulphate of Barytes. In C. 1. the process of Klaproth was employed; and at each successive step, fresh portions of the sulphate were decomposed, by the united affinities of sulphuric acid for potassa, and of carbonic acid for barytes. In C. 4. Moretti's process was followed *, and, to verify his results, comparative experiments were tried.

a. Artificial sulphate of strontia was boiled in a platina crucible with 8 parts of concentrated sulphuric acid; a perfect solution

* See Thomson's *Annals*, vol. iv. 395.

lution took place; the liquor was poured into a glass capsule, and put aside in a cool place; no crystals appeared in 12 hours; but after several hours a thin ring of amorphous sulphate was deposited around the margin of the liquid, probably owing to the absorption of water from the air. The insoluble neutral sulphate was however immediately precipitated from the solution by the addition of water.

b. Artificial sulphate of barytes was treated in the same manner; a perfect solution was obtained; and the liquid soon began to form crystals around the edge of the capsule. When the air of the room is dry, the crystals though small are pretty distinct prisms, promiscuously aggregated. They are supersulphates, agreeing in their properties with what is stated above (*a*).

c. Fragments of a transparent crystal of sulphate of strontia from Bristol, reduced to powder, presented exactly similar results with the artificial sulphate (*a*); and a portion of a colourless crystal of sulphate of barytes from Dufton near Appleby, was acted on precisely as the artificial sulphate (*b*).

In the mineral from Orkney, the whole of the residue insoluble in nitric and muriatic acids, was dissolved by boiling sulphuric acid; which shews that there is no silica present.

The blue precipitate, by prussian alkali, from the muriatic acid digested on the residue, shews that oxyde of iron is united to the sulphate.

The mineral, then, consists of *carbonate of strontia*, *carbonate of lime*, *sulphate of barytes*, and a *little oxyde of iron*. We have yet to ascertain the proportions in which these ingredients enter into its composition.

D.

To ascertain the quantity of carbonic acid is important, as it will enable us to verify the other results.

100

100 grains carefully selected from the purest and most solid parts of the specimen were broken into small fragments, and dropt in succession into a flask, containing a cubic inch of muriatic acid diluted with two parts of water, which had been previously poised in a delicate balance. Each fragment was suffered to part with its carbonic acid before another was added, lest the violence of the effervescence should dissipate any portion of the liquid in the flask. After all effervescence had ceased for some hours, the flask was again accurately weighed; when it was found to have lost 21.1 grains. As this part of the process requires peculiar attention, the experiment was repeated; and the average of three trials gave 21 grains as the quantity of Carbonic Acid in the mineral.

This result cannot be far from the truth, as it was the same when nitric acid was employed.

E.

To ascertain the quantity of strontia and lime, several experiments were undertaken.

1. The muriatic solution D. was evaporated to dryness, in order to expel the excess of acid. The saline mass was dissolved in water, and slowly evaporated; the crystals of muriate of strontia were successively separated; but the results of several repetitions of the process not coinciding, a different method was employed to separate the muriates of strontia and lime.

2. The nitric solution of the mineral was evaporated to dryness, dissolved again in water, and slowly crystallized. The crystals were digested with strong alkohol, by which nitrate of lime is dissolved, but not nitrate of strontia. The crystals were washed by the affusion of alkohol; and thus the two salts were completely separated.

3. The quantity of strontia in the mineral could be ascertained by weighing the nitrate; but there appears to me less certainty in weighing crystals which contain water, and which are very soluble, than in reducing the earthy or other base to the state of an insoluble compound, that may be moderately heated without loss of weight, and the constituents of which are well known. Sulphuric acid was therefore added, in excess, to precipitate all the strontia, and the liquid being evaporated to dryness in the capsule in which the precipitation was effected, and heated in a platina crucible to expel excess of acid, and water, afforded 84.6 grains of sulphate of strontia, which, by Dr WOLLASTON's excellent scale, is equivalent to 68.6 grains of Carbonate of Strontites.

4. The alkoholic solution (E. 2.) was evaporated, and afforded a tenacious paste, which, when dissolved in water, precipitated by carbonate of soda, washed and dried, weighed 2.6 grains; this, then, gives us the quantity of the Carbonate of Lime which enters into the composition of the mineral.

When we compare these results, with the quantity of carbonic acid in the mineral, we find an agreement as exact as the nature of such researches will permit: for

68.6 carbonate of strontites contains	19.60 carbonic acid;
2.6 carbonate of lime contains -	1.14 carbonic acid
	20.74

or the difference amounts only to 0.26 *per cent.*

F.

The examination of the insoluble residue was attempted, by boiling it with carbonate of potassa, in a silver vessel; but as only a portion was thus decomposed at each boiling, I thought it best to attempt it in the dry way.

Having

Having found in some previous experiments that some iron adhered to the insoluble residue,

1. It was digested with muriatic acid, which became of a yellowish hue, and along with the iron took up a portion of the earthy matter; but this was precipitated on the addition of water. Its solution was concentrated, and precipitated by succinate of potassa. The precipitate, washed, dried, and heated to redness in a platina crucible, afforded 0.1 grain, or nearly so, of red Oxyde of Iron.

2. The residue of the mineral was now mixt with three times its weight of lamp-black, made into a paste with oil, and subjected in a black-lead crucible for two hours, to the heat of a smith's forge. The contents of the crucible were then thrown into muriatic acid, which produced a brisk effervescence: the muriatic solution was precipitated by sulphuric acid; it was then evaporated and heated, to expel the excess of acid, and what water might adhere to it, and when weighed = 27.5 grains.

The residue then consists of	27.5	sulphate of barytes,
And -	0.1	oxyde of iron.
	27.6	

In 100 grains, therefore, of the mineral from Orkney, we have

68.6	carbonate of strontites.
27.5	sulphate of barytes.
2.6	carbonate of lime.
0.1	oxyde of iron.
98.8	
1.2	loss (probably water).
100.0	

A question may here arise, whether these ingredients are chemically combined, or only in a state of mechanical admixture in the mineral? The homogeneous appearance, and crystalline texture of this substance, and the nearly uniform proportions of the ingredients obtained from it, by different experiments, would lead to the conclusion that the mineral in question is a chemical compound. These, however, may be the result of an intimate mechanical mixture of the earthy salts of which it is composed.

The iron appears to be united by affinity to the sulphate of barytes, as it is not separated in any considerable degree during the solution of the carbonates in diluted muriatic and nitric acids; but requires for its separation from the sulphate of barytes, digestion in one of those acids, after the separation of the more soluble ingredients.

The existence of carbonate of lime in this mineral is enteresting. In this particular it accords with what has been observed by SCHMEISSER, THOMSON, and STROMEYER, in native carbonate of Strontia. It is remarkable, that the portion of carbonate of lime in the Orkney mineral, is not very different from the quantity of carbonate of strontia in Arragonite; a circumstance which renders it probable, that the carbonate of lime is in a state of chemical union with the carbonate of strontia.

Should this substance be regarded as a variety of Strontianite, or as a distinct mineral species? If the latter conjecture be entertained, it will be necessary to give it a name; which may be derived, either from its composition, as BARY-STRONTIANITE, or from its locality, as STROMNITE.

IV.

IV. *Extract from Inspection Report of the Island of Trinidad, made in the year* 1816, *by the Inspector of Hospitals, in conjunction with the Quarter-Master General and Chief Engineer for the Windward and Leeward Colonies of the West Indies. By* William Ferguson, M. D. F. R. S. Edin.

(*Read Dec.* 1. 1817.)

Having heard at Port-of-Spain of an appearance that went by the name of the *Mud Volcanoes*, we took the opportunity when surveying the southern quarter of Trinidad, to examine them. They are situated near Point Icaque, the southern extremity of the island, on an alluvial tongue of land, that has been appended to the primitive rocks, where no doubt the land originally terminated. This appendage is several miles in length, and points directly into one of the mouths of the Oronoko, on the mainland, about twelve or fifteen miles off.

We landed nearly opposite to where we were told we should find the mud volcanoes, and after making our way about five miles through the woods, across the sandy isthmus, we came upon two plantations very pleasantly situated, amidst a group

of

of remarkable round little hills, each from eighty to a hundred feet in height. Our path on leaving these led us through some very thick wood of tall trees, till we found ourselves again upon a pretty steep regular ascent, which had nothing remarkable in it, except the diminishing height of the trees as we went up. Only the tops of these trees, which were of the kind that usually grow near lagoons and salt marshes, at last appeared above the ground, as we opened a perfectly uniform round bare platform, of several acres, with different chimneys in the shape of truncated cones, the highest of them not exceeding three feet, some of which were throwing out, with a strong bubbling noise, salt water, about as salt as that of the Gulf of Paria, loaded, as much as it could be, to preserve its fluidity, with argillaceous earth. In some of the chimneys this went on slowly, or not at all; in others it might be called a pretty active cold ebullition. The surface of the platform round the chimneys was perfectly firm, and one of our party picked up a white sea shell, of the turbinated kind, in the act of being thrown out along with the mud.

We afterwards procured various pyritic fragments that had been picked up in a similar manner; but the inhabitants of the quarter assured us, that the ebullition, even during its greatest activity, was quite cold. The smooth circular platform of the chimneys was bounded by a perfectly regular parapet of clay, about three feet in height, propped up, as it were, by the tops of the trees, that, like shrubs, were shooting out of the ground immediately behind it. This appearance was most likely to be referred to the buried trees around having had time to shoot out in the interval between the two last great eruptions, which take place only during the hottest months of dry seasons, and then the noise is described to be like the loudest cannon, the mud being thrown up to the height of at least thirty

thirty feet in the air, and the theatre of the eruption being unapproachable within fifty paces.

Close to the first volcano, but in a much more low and sunk situation, is another of precisely the same appearance and character, with only a narrow ravine between the two.

Such an extraordinary phænomenon induced us to examine the neighbouring mounts of the cleared country, close to the nearest of which stands the residence of Monsieur Chancelier, a French planter, and we found them all, (bating only the eruption) to possess the same form and composition in all respects as those we had just quitted. The platform and parapet were easily distinguishable, the chimneys only were gone, but small pits were left in their places, filled with mud, from which air-bells rose even under our own observation, and our conductor, the intelligent manager of the estate, told us, that when these rose in salt-water, a fresh eruption was to be apprehended. He pointed out the former site of his master's residence, half-way up the mount, which had been destroyed by one of these eruptions, after a period of cessation so long, that no record remained of the one that had preceded it, and he assured us, that during the period he had lived there (fourteen years) the largest mount now in activity had gained a very considerable increase of height.

I have been thus particular in detailing (though at most irrelevant length, in a military report) this curious phænomenon, from a belief that it has not been treated of by any author, and that, when investigated by scientific men, new light may be thrown on the original formation of argillaceous hills in situations where it might otherwise be difficult to account for their appearance.

The magnificent isolated mountain of Tamanaa, in the centre of the great eastern marsh, unconnected with any chain of hills, and at an immense distance, on every side, from what may

may be called *terra firma*, may be supposed, till examined, to have arisen from the plain, through the means of some similar elaboratory in the works of nature. I have said, till examined,—for its approaches are so barred by the thickest woods, and deepest swamps, where the boa *, the alligator, and all the venomous reptiles of the parent continent, still retain the sovereignty of the soil, that the most determined and enterprising have never yet been able to penetrate to its base.

* Even the rattlesnake, we were assured, was found here, one having been killed on the banks of the Guanapo the day before we visited it. The no less venomous mapapi (*lance du fer* of the French) more formidable on account of his irritable nature, and greater size (one was killed in the Napoareme eleven feet long), comes occasionally into the cultivated country, as well as the smaller poisonous coral snake and others. I have not heard that the dangerous viper of St Lucia and Martinique has been seen in Trinidad; but the abundance of the boa and alligator was manifested to a degree that could not otherwise have been believed, when the great savanah of the eastern marsh, and the underwood of the grand lagoon, were fired during a very dry season several years ago. This brought all to light from their different hiding places, and the dead carcases, as marked by the hovering of the vulture and carrion crow, were so numerous, that the air was infected for miles with the stench

V. *Memoir on the Repeating Reflecting Circle.* *By* Major-General Sir THOMAS BRISBANE, F. R. S. E. Corresponding Member of the Academy of Sciences.

(Read Feb. 15. 1819.*)*

HAVING had frequent opportunities, during my residence in France, of seeing a great many Repeating Reflecting Circles, several of which I have observed with, and having found much consistency in the results deduced from observations made with them, it occurred to me, that if I could engage Mr TROUGHTON to execute one for me, it would be a most perfect instrument. This he accordingly did; and I trust that the observations made with it, which I am about to communicate, will perfectly justify the opinion I had formed of its precision. The instrument is only of about six inches radius, divided in gold to 20″. I have always been in the habit of choosing for latitudes 30 repetitions, when the weather would permit, divided into three series of 10 each, and reading the angle or arc run through during the series, which completely destroys every imperfection of the division, or reading. In order to determine the time, I have always found six repetitions quite sufficient to give it as correct as equal altitudes. Of these I also generally observe three series, in order to take the mean. These observations I have repeatedly verified by equal alti-

 tudes,

tudes, and found the results the same. I have also ascertained the accuracy of the instrument from latitudes determined by a sixteen inch repeating circle with a moveable axis, and level of Reichenbach's, with which I had frequently observed at Valenciennes, Blandecques, &c.; and it is but justice to say, that in these instances, Mr Troughton's circle gave the same results to a second. I beg to be permitted tobe a little more particular than I otherwise should, as to the mode I have pursued in calculating and deducing latitudes from this instrument, as it is not by any means as yet generally known in England, although I have no doubt, that when quite understood, it will be found to surpass all other instruments of its size, for simplicity and accuracy, and I am desirous that amateurs may profit from the experience I have had for some years of its advantages.

In order to determine the apparent time by the clock or chronometer, I generally begin two, three, or four hours before noon, to take the three series of repetitions, and from the observed angles I infer the time, as pointed out in my former memoir on the sextant. If the altitudes corresponding to these can be obtained in the afternoon, I prefer equal altitudes, or otherwise the simple repetitions made both before and after noon combined, and the mean taken.

I generally begin to repeat about 7′ before the sun's passage over the meridian, which leaves ample time for the three series, the middle one of which I generally contrive to be divided by noon, by which means the errors are compensated, should any exist in the determination of the time, or in the reductions.

The third series is also finished about the 7′ past noon; and, although it is not what I would recommend except in extreme cases, I have been induced to begin 20′ before noon, and, provided

vided I compared that repetition with one made at nearly the same distance past noon, I have found the mean perfectly agree with the truth ; although, taken separately, neither would have been considered as good observations.

It now remains for me to point out the most accurate mode of inferring the latitude from these different series of repetitions. The most extensive Tables for these reductions are given by the Baron DE ZACH. M. BIOT has also given a very valuable Table for this purpose.

Type of the most simple and most accurate mode for determining latitudes by the Repeating Reflecting Circle.

1. Determine the angle from the arc run through during a series of repetitions which must always consist of equal numbers, divided by double the number of repetitions.

   The angle being a reflected one, determine by subtraction each horary angle, and the corresponding quantity of correction, by M. DE ZACH's Tables, in his work, *Attraction des Montagnes.*
2. Determine the apparent altitude and zenith distance.
3. Determine the refraction diminished by parallax.
4. Form for each series the sum of the horary angles. This sum is composed sometimes of the difference of the sums before and after noon.
5. To form the sum of the quantities corresponding to the horary angle, from the Tables, which is always the sum, and never the difference.
6. When there are several different series of repetitions of ten to calculate together, they become then but as one series, viz. of 20, 30, or 40 observations; therefore

 there

there is nothing else to be attended to than observing the rules stated in articles 4 and 5.

7. Calculate the variation in declination for the quantity corresponding to the sums No. 4. This may either be done simply by proportions, worked by logarithms, or taken from Tables calculated for the purpose.

8. Form the apparent declination which will be equal to the true declination $\pm$ (the refraction — parallax) + the variation in declination for the difference of meridians, $\pm$ the variation of declination for the middle of the series that you propose to calculate. If the series is composed of 10, 20, 30, or 40 observations, the result will be the $\frac{1}{10}$th, $\frac{1}{20}$th, $\frac{1}{30}$th, or $\frac{1}{40}$th of the quantity indicated by the sum No. 4. The sign + is applied when these quantities augment the declination, and the sign — when they diminish it.

9. Prepare the constant factor

$$= \frac{\text{Cosine apparent declination. Cosine latitude}}{\text{Sine apparent zenith distance}}.$$

10. Add the logarithm of the constant factor to the logarithm of the sum No. 5., which gives the logarithm of the meridian correction.

11. Subtract the correction from the apparent zenith distance.

12. To the result of No. 11. add or subtract the apparent declination (No. 8.) which gives the distance from the zenith to the equator, or the Latitude of the place of observation.

It is almost unnecessary to add, that my artificial horizon has always been quicksilver, (when the situation would permit me to us it), covered with one of TROUGHTON's glass roofs, as I have

have pointed out in my former communication to the Society, on ascertaining time. I have also invariably observed alternately the upper and lower limb of the sun during the repetitions, both for the time and latitude; by which means the true altitude of the centre is obtained, independent of the application of the semidiameter.

Two examples completely worked out accompany this memoir, which it is hoped will render it clear and explicit.

In the communication I had the honour to submit to the Royal Society of Edinburgh on the subject of ascertaining time with accuracy, and which was read on the 2d February 1818, I intimated my intention, if that was deemed worthy of a place in the *Transactions*, to transmit a memoir on the repeating circle, which I now beg leave to lay before them, as I feel confident that the more practical astronomers work with that instrument, so as to understand it perfectly, the more they will be satisfied with the results obtained from it, which I have almost uniformly found to be highly satisfactory. Even a small one of five inches radius, executed for me at Paris by Messrs Jakers, has afforded me additional proofs of the value of this instrument, and the justness of its principle.

There are one or two remarks that I should wish to make on the subject of the adjustments of the instrument, which I have learnt from some years constant practice in observing with it, and which I think may not be deemed unworthy of detailing.

Although the general nature and principle of the adjustments are similar to those of the sextant, there are others which differ. In the first place, in order to ascertain whether the great and small mirrors are parallel, I place the index at zero Φ, and then bring the sun seen direct and reflected in contact,

contact, which I remark. I then move forward the index 90°, and thus I repeat the operation successively through each quadrant of the 720°. Should they appear quite coincident during the whole revolution, it is a proof not only that the two mirrors are parallel, but that the plane of the circle is a true one, which rarely happens. Should I, however, find, that the reflected sun appears sometimes to the right and sometimes to the left of the one seen direct during this operation, it leads me to suspect that one of two causes of error exists; either that the plane of the circle is not just, or that the two mirrors are not parallel. This important point I determine, by examining the adjustment of the great mirror, which, if found correct, I then ascribe to the inaccuracy of the plane of the instrument, which deviation I distribute equally throughout the whole circle.

The next principal adjustment, is to ascertain if the telescope be parallel to the plane of the circle, which is done either by a small proof telescope applied to the circle, when in a horizontal position; and, if the object seen at some distance appear in the centre of that telescope, and the one attached to the circle, it is a proof of its correctness. There are generally two small sights sent with the circle, to ascertain this adjustment.

Having carefully examined these, and corrected any error, if it exists, before each day's observations, we may rest assured that the results will be satisfactory, if no error be committed in determining the time of apparent noon, the observations properly noted, and the calculations rigorously made according to the accompanying formulæ.

Paris, 25th March 1819.

VI.

CALCULATION FOR FINDING THE LATITUDE FROM OBSERVATIONS MADE NEAR NOON WITH THE REPEATING REFLECTING CIRCLE.

TROUGHTON'S Circle. 8th November 1817, very clear. Quicksilver Horizon.

11 49 36.9 Noon by Chronometer. Instrument at 280° 40′ 00″

11 38 23.3	11 13 6	247.57
38 55.3	10 41.6	224.48
39 25.5	10 11.4	208.85
39 47.0	9 49.9	189.77
40 14.6	9 22.3	172.42
40 37.3	8 59.6	158.78
41 8.3	8 28.6	141.07
41 26.7	8 10.2	131.05
41 52.7	7 44.2	117.51
41 17.3	7 19.6	105.39
	92 01.0	1691.89

1st reading 22° 42′ 15″

1691.89 — 1691.89
+ 250.26

1942.15 4th or 1st compound series.
211.86

2154.01 = 5, or 2d compound series.

11 49 36.9

11 44 13.3	5 23 6	57.11
44 38.3	4 58.6	48.62
45 13.3	4 23.6	37.89
45 35.0	4 01.9	31.91
46 5.0	3 31.6	24.42
46 20.3	3 16.6	21.08
47 4.0	2 32.9	12.74
47 30.0	2 06.9	8.79
48 1.5	1 35.4	4.96
48 26.0	1 10.9	2.74
	33 02.0	250.26

2d reading 485° 14′ 25″

11 49 36.9

11 50 36.0	1 02.1	2.11
51 4.3	1 27.4	4.16
51 33.3	1 56.4	7.39
51 53 3	2 16.4	10.15
52 19.4	2 42.5	14.40
52 46.3	3 09.4	19.56
53 16.2	3 39.3	26.23
53 36.5	3 59.6	31.32
54 2.7	4 25.8	38 54
55 3.0	5 26.1	58.00
	30 05.0	211.86

3d reading 227° 45′ 12″

Mean Daily variation sun's declin. = 22′ 36″ Log. 3.132260
92 1 Log. = 3.742018
Log. Ar. Co. 24 hours, = 5.063486

1.937764 = (86″.65

Corr. 1st series 1/10 = 8.66

Var. declin. 22′ 36″ = 3.132260
33 02 = 3.297104
24 hours = 5.063486

1.4928.50 = (31′ 11″

Corr. 2d series 1/10 = 3.11

Var. declin. 22′ 36″ Log. = 3.132260
30 5 Log. = 3.256477
24 Ar. co. Log. = 5.063486

1.452223 = (28″ 33

Corr. 3d series 1/10 = 2 83

Therm. 13.4 = 9.9944
Barom. 743.0 = 9.9900
Z dist. 66° = 2.1145
53.9 = 184

2.1173 = 131″.0
8.1 Parall.

122.9
2′ 2″.9 Refrac. — Parallax.

Therm. + Barom. 9.9844
Z. Dist. 66 — 2.1145
52′.5 = 180

2.1169 = 130″.9 Refr.
8.1 Paral.

122.8
Refraction — Parallax 2′ 2″.8

86.65 } A. M.
31.11 }

1/20)117.76 Sum.

Corr. 4th series 5.88, or 1st compound series.

117.76 Sum A.M.
28.33 P.M.

)89.43 difference.

Corr. 5th series 1/30 = 2.98 or 2d compound series.

Sun's declin. at Noon,	16° 34′ 16″	16° 34′ 16″	16° 34′ 16″	16° 34′ 16″	16° 34′ 16″
Refraction — Parallax,	— 2 2.9	— 2 2.8	— 2 2.8	— 2 2.8	— 2 2.8
Correction of declination,	— 8.66	— 3.11	+ 2.83	— 5.88	— 2.98
Reduction to Meridian,	+ 1 52.54	+ 16.65	+ 14.10	+ 1 4.59	+ 47.76
Sun's declin. corrected,	16 33 56.98	16 32 26.74	16 32 30.13	16 33 11.91	16 32 57.98
Observed Angles,	280° 40′ 0″ + 720 22 42 15 742 42 15 280 40 0 1/20)462 02 15	22° 42′ 15″ 485 14 25 1/20)462 23 10	485° 14′ 25″ + 720 227 45 12 947 45 12 485 14 25 1/20)462 30 47	280° 40′ 0″ + 720 485 14 25 1205 14 25 280 49 0 1/40)924 34 25	280° 40′ 0″ + 1440 227 45 12 1667 45 12 280 40 1/60)1387 5 12
Altitudes,	23 6 6.7	23 7 36.5	23 7 32.35	23 6 51.62	23 7 5.2
Zenith distances,	66 53 53.3	16 52 23.5	66 52 27.65	66 53 8.38	66 52 54.8
Corrected declinations,	16 33 56.98	16 32 26.74	16 32 30.13	16 33 11.91	16 32 57.98
Latitudes,	50 19 56.32	50 19 56.76	50 19 57.52	50 19 56.47	50 19 56.82

Log. Cos. Sun's declin. 16° 34′ 16″ = 9.9815769
Log. Cos. Lat. 50 19 57 9.8050461

Constant factor, 9.7866230
Ar. Co. Sines of Z distances, — 66 5353.3 = 0.0363027
Log. 1691.89 = 3.2283721

3.0512978
1/10) 1125.4

1′ 52″.54

250.26	211.86	1942.15	215401
9.7866230	9.7866230	9.7866230	9.7866230
0.3638832	0.0363793	0.0363429	0.0363540
Log. 2.3983914	Log. 2.3260490	Log. 3.2882828	Log. 3.3332477
2.2216976	2.1490513	3.1112487	3.1562247
1/10) 166.5	1/10) 141.0	1/20) 1291.9	1/30) 1432.9
16″.65	14″.10	1′ 4″.59	47″.76

Table II.

CALCULATION FOR FINDING THE LATITUDE FROM OBSERVATIONS MADE NEAR NOON WITH THE REPEATING REFLECTING CIRCLE.

Troughton's Circle. ♃ 13th November 1817. Quicksilver. Horizon.

11h 50′ 24″.3	Noon by Chronometer.		Instrument at [157° 20′ 26″]
11 45 35.0	4 49.3	45.65	
46 3.3	4 21.0	37.15	
46 35.0	3 49.3	28.67	
47 0.5	3 23.8	22.66	
47 33.0	2 51.3	16.01	
47 58.0	2 26.3	11.68	
48 29.7	1 54.6	7.16	
48 56.0	1 28.3	4.25	
49 31.7	0 52.6	1.51	
49 55.0	0 29.3	0.47	1st Repetition [592° 1′ 5″]
	26 25.8	175.11	

175.11		
229.27		
404.38	1st compound series.	
1374.53		
1778.91	2d compound series.	

11 50 24.3			
11 51 37.5	1 13.2	2.93	
51 59.5	1 35.2	4.94	
52 26.7	2 2.4	8.17	
52 45.5	2 21.2	10.87	
53 18.5	2 54.2	16.55	
53 48.5	3 24.2	22.74	
54 16.5	3 52.2	29.41	
54 39.5	4 15.2	35.52	
55 11.5	4 47.2	44.98	
55 36.5	5 12.2	53.16	
	31 37.2	229.27	2d Repetition [306° 38′ 40″]

11 50 24.3			
11 57 6.5	6 42.2	88.23	
57 28.5	7 4.2	98.13	
57 50.0	7 25.7	108.33	
58 8.5	7 44.2	107.61	
58 33.7	8 9.4	130.62	
58 52.0	8 27.7	140.57	
59 13.7	8 49.4	152.94	
59 35.7	9 11.4	165.81	
59 56.5	9 32.2	178.55	
0 20.5	9 56.2	193.84	
	83 02.6	1374.53	3d Repetition [20° 49′ 24″]

Thermometer = 11°.2 = 9.9980 .... 9.9980
Barometer 74875 = 9.9933 .... 9.9933
Z. Dist. 68° = 2.1561 .... 2.1561
16 = 68′ 17″.5 = 64

	2.1542	2.1538
Refraction,	142.6	142.5
Parallax,	8.2	8.2
	134.4	134.3
Refraction — Parallax,	2′ 14″.4	2′ 14″.3

Diurn. var. ⊙ dec. 16′ 0″.5 = 2.982497
26 25.8 3.300248
Ar. Co. Log. 24 hours, 5.063486

1.346231
$\frac{1}{10}$ [17″.6

Corr. for series 1st, 1.76

31′ 37″.2	83′ 2″.6
2.982497	2.982497
= 3.278113	= 3.697456
5.063486	5.063486
1.324096	1.743439
$\frac{1}{10}$ [21″.1	$\frac{1}{10}$ [55″.4
2d = 2.11	3d = 5.54

17.6 before noon.
21.1 afternoon.
$\frac{1}{10}$ [3 5 difference.
Corr. for .17 4th series.

21.1 } afternoon.
55.4 }
76.5 sum.
17.6 forenoon.
$\frac{1}{30}$ [58.9 difference.
1.96 Corr. for 5th series.

	1st	2d	3d	4th	5th
Sun's declination,	= 17° 58′ 7″	17° 58′ 7″	17° 58′ 7″	17° 58′ 07″	17° 58′ 07″
Refraction — Parallax,	— 2 14.40	— 2 14.30	— 2 14.30	— 2 14.30	— 2 14.3
Correction of declination,	— 0 1.16	+ 2.11	+ 5.54	+ .17	+ 1.96
Reduction to Meridian,	+ 11.45	+ 14.98	+ 1 29.81	+ 13.19	+ 38.76
Corrected declination,	17 56 2.29	17 56 9.79	17 56 28.05	17 56 6.06	17 56 33.42

Sun's declination, Cos. 17° 58′ 07″ 9.9782836
Log. Co. Lat. 50 19 57 = 9.8050461

	1st	2d	3d	4th	5th
		........229.27	........1374.53	........404.38	........1778.91
Constant Factor,	= 9.7833297	9.7833297	9.7833297	9.7833297	9.7833297
Ar. Co. sin. zen. Distances,	= 0.0320246	0.0319667	0.0319491	0.0310204	0.0319969
Log. 175.11	= 2.2433109	2.3603472	3.1381542	2.6067897	3.2501539
	2.0586652	2.1756436	2.9534330	2.4211398	3.0654805
	$\frac{1}{10}$ [1146	$\frac{1}{10}$ [149.8	$\frac{1}{10}$ [8981	$\frac{1}{20}$ [263.9	$\frac{1}{30}$ [1162.7
	11″.45	14″.98	1′ 29″ 81	13″.19	38″.76

	1st	2d	3d	4th	5th
	157° 20′ 26″	592° 01′ 05″	306° 38′ 40″	157° 20′ 26″	157° 20′ 26″
	592 01 05	720 + 306 38 40	720 + 20 49 24	720 + 306 38 40	1440 + 20 49 24
	20 [434 40 39	$\frac{1}{10}$ [434 37 35	$\frac{1}{10}$ [434 10 44	$\frac{1}{20}$ [869 18 14	$\frac{1}{30}$ [1307 28 58
Altitudes,	21 44 1.95	21 43 52.75	21 42 32.2	21 43 57.35	21 43 28.97
Z. Distance,	68 15 58.05	68 16 07.25	68 17 27.8	68 16 04.65	68 16 31.03
Declination,	17 56 2.29	17 56 9.79	17 56 28.05	17 56 6.06	17 56 33.42
Latitudes,	50 19 55.76	50 19 57.46	50 19 58.75	50 19 56.59	50 19 57.61

N. B. In the preceding calculations, the Centigrade Thermometer and the Metrical Barometer are employed.

VI. *Description of a Fossil Tree found in a Quarry at Niteshill, the Property of* Colonel DUNLOP *of Househill. By the* Rev. PATRICK BREWSTER, *one of the Ministers of the Abbey Church, Paisley.*

(*Read Feb.* 1. 1818.)

THE quarry of Niteshill, from which this very interesting petrifaction was taken, lies about three miles south-east of Paisley, and is part of a coal formation. It consists of white sandstone, which in many parts is deeply stained by an impregnation of iron. Two very thin seams of excellent coal occur immediately under the sandstone, with the intervention of a few feet of till or blaize. The strata dip to the south, and crop out about a hundred yards north of the spot from whence the tree was taken. At this spot the face of rock is about sixteen feet; fourteen feet above the tree, and one under; another foot being occupied by the stem itself.

The part which has been detached from the rock consists of stem and roots, five feet of stem, and two of roots, different views of which I have endeavoured to represent in figures 1, 2, & 3.

The tree was found in contact on every side with the solid rock. Its direction was nearly north and south; the root end pointing

pointing to the north, and the line of the trunk inclining with the strata to the south ; the dip being one foot in seven.

When it was first disengaged from the surrounding mass, it had a complete envelope of coal, incrusting its whole surface: but this interesting portion had been removed by the workmen before I had an opportunity of examining it. Deprived of the coal, the surface still bears a considerable resemblance to bark.

From the fracture of the stem downwards, the lines or furrows are pretty regular; but as they approach the root, they meet and run into each other. On one side the space between them is slightly convex, while on the opposite it is concave, and somewhat of a fluted appearance.

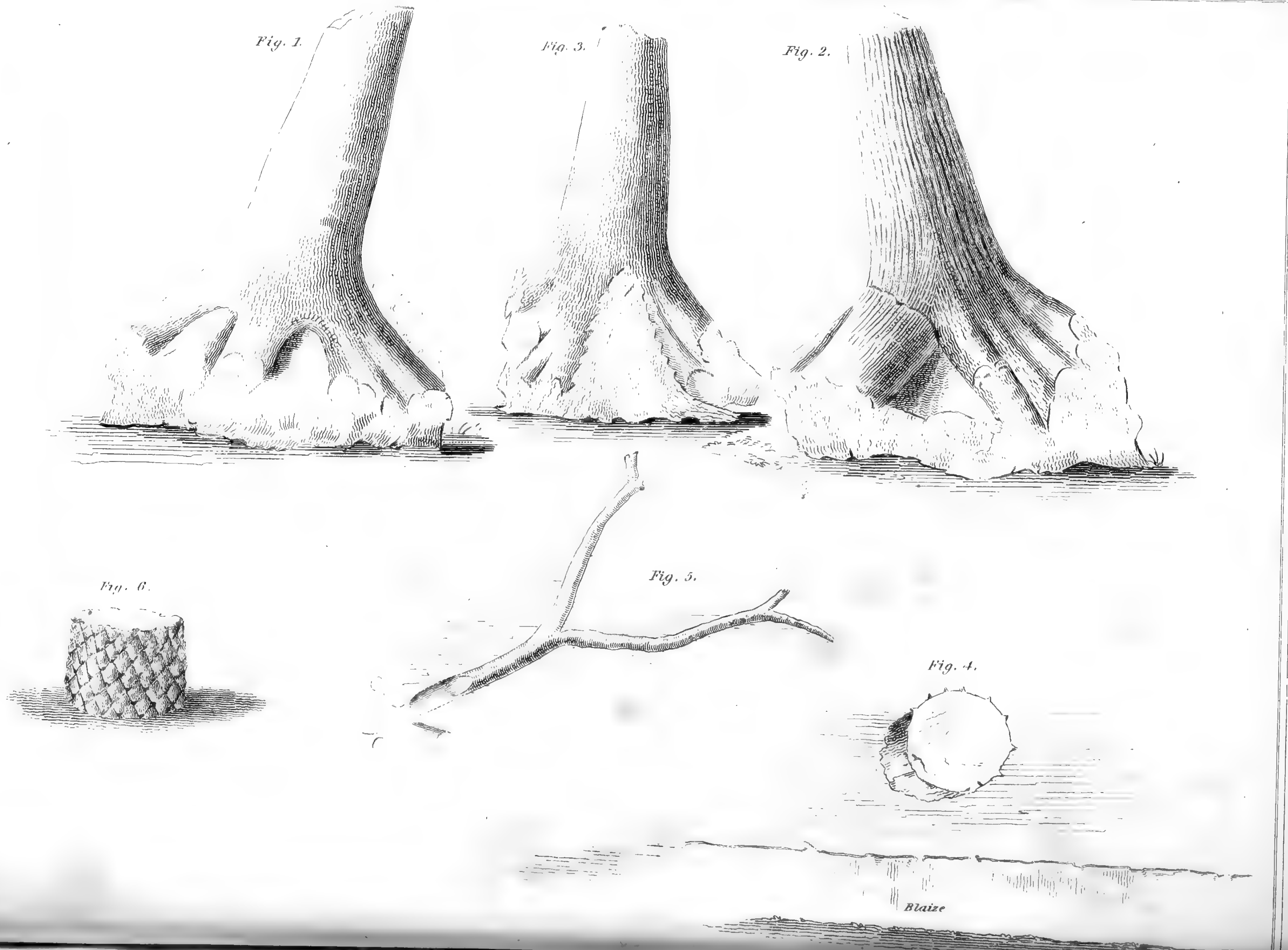
Internally there cannot be perceived the slightest vestige of any ligneous structure. The stone of the tree, however, is in some respects different from that of the circumjacent rock : it is in general more compact, and contains more iron, and is of course specifically heavier.

Owing to the impregnation of iron, the colour is in some parts so much deepened, that the workmen mistook it for whin. This difference of colour and of gravity, however, is partial, and does not extend equally through the whole mass of the petrifaction. In some of the roots particularly, the stone is as pure as in any part of the quarry.

For the following dimensions I am indebted to Colonel Dunlop of Househill the proprietor, who, with that kindness and liberality which distinguishes him, has afforded every facility towards the examination and description of this singular fossil.

The trunk, independent of the roots, is *five* feet in length. There are four principal roots, each of which measures *two feet.*

PLATE IX.



feet. The circumference, taken close by the root, is *five feet seven inches and a half:* In the middle of the stem *four feet and a half;* and at the top or fracture *three feet nine inches.*

In the immediate neighbourhood of the above tree, and in the same rock, there are four converging branches, which have once been united; three of which penetrate the rock in different directions, and the fourth runs along its surface. They are evidently of a different species, and belong, I suspect, to the fragment of another stem which was found some time ago near the same spot. The species to which they belong is well known among this class of petrifactions, and occurs in some of the neighbouring quarries. The length of the exposed branch, from the fracture to the point of division, is 15 inches; the ascending branch is 26 inches, and the other is 35.

Description of the Figures, PLATE IX.

Figs. 1, 2, 3, are different views of that part of the tree which has been detached from the rock, and which is now at Househill.

Fig. 4. represents that part of the quarry in which the remainder of the tree is still lodged.

Fig. 5. represents four converging branches of a different species of tree, found near the former.

Fig. 6. is a section of a trunk found near the above branches, and supposed of the same species.

VII. *Account of a non-descript Worm (the Ascaris pellucidus) found in the Eyes of Horses in India. In Letters from* Alexander Kennedy, M. D. F. R. S. Edin. *to* Professor Russell *and* Dr Hope. *With a Description of the Animal, by* Captain Thomas Brown, F. R. S. E. & F. L. S.

(*Read Feb.* 5. 1816, *and Nov.* 9. 1818.)

Dear Sir, *Edinburgh, 5th February* 1816.

WHEN I lately mentioned to you in conversation, the disease in the eyes of horses in India, occasioned by the presence of a worm within the ball of the eye, I thought that you might probably have heard of it before; but as you had not, and are desirous of further information upon the subject, I now take this method of mentioning the circumstances to you, so far as I know them.

The animal occasioning this disease, is termed by the natives about Madras, the "*Worm*" in the Horse's Eye, by using the corresponding words in their respective languages. I have been told that in Bengal it is called the "*Sānp*," or the Snake in the Horse's Eye. As it seems more to resemble a fish or an aquatic insect, it might perhaps with more propriety be regarded as an eel.

This disease often follows blows or external injuries; but also frequently occurs without this previous cause. After weakness, watering, and inflammation of the horse's eye, it assumes a whitish look, and then the worm may be plainly observed, of a white colour, swimming with great briskness and activity through the aqueous humour. The cure depends upon its being extracted, without which, I believe, that the eye is always lost by suppuration. I have known several medical gentlemen attain much dexterity in performing this extraction. The mode of proceeding is as follows: Being provided with a common lancet, armed at the shoulders by being wrapped round with tow, the operator places himself by the horse's head, next to the diseased eye, and moving his hand gently up, so as not to alarm the horse, he thus watches the opportunity of the eye's being well open, and then suddenly plunges the lancet through the lower and fore part of the cornea, directing the point across, and at the same time cutting downwards. The aqueous humour being in this manner suddenly evacuated, by a gush, or in a stream, the worm passes out along with it. The eye is then covered up, and kept wetted with a cooling solution. When the extraction has been successfully performed, and the aqueous humour is again restored, the vision is found unimpaired.

The fineness and small size of the worm sometimes prevent its being found, even when the extraction has been successfully performed. It is frequently detected, however, in the track of the aqueous humour over the horse's face. When picked up, it generally appears to be dead, at least I have met with none which retained any appearance of life. I have seen none of them so long as the nail of the thumb. It is of a grey-white colour, very soon lies flat and flaccid, and appears to be not much broader or thicker than a horse's hair. My friend

Dr

Dr Berry, however, who has frequently succeeded in extracting them, informs me that he has not only often met with them considerably longer than I have described, but also that upon his placing them in a tumbler of tepid water, he has seen them swim about for several minutes, and even for a quarter of an hour; and that when viewed in this situation, the shape evidently appears to taper off towards the tail. Had I thought of placing those which I have met with, as Dr Berry did, in tepid water, it seems not improbable, that I might both have found some of them alive, and also of greater length, than when viewed under exposure to the open air.

Upon this occasion, it is both proper and satisfactory to refer to the testimony of that eminent naturalist, the late Dr James Anderson of Madras. Having had occasion, several years ago, to mention this worm, and the disease which it occasioned in the horse's eye, to one of his scientific correspondents, it is believed to Dr Rush of Philadelphia, his letter was at the time given to the public, in one of the Madras newspapers. Though Dr Anderson's correspondence was afterwards collected from the newspapers, and reprinted, it might now be difficult to find a copy of it. But I recollect to have heard afterwards, that the letter now alluded to, had been communicated by Dr Anderson's correspondent to the American Philosophical Society. I remain, &c.

Alex. Kennedy.

To James Russell, Esq.

Dear

DEAR SIR, *Edin.* 17*th Nov.* 1819.

FINDING that my last communication, regarding the worm in the eyes of horses in India, submitted to the Royal Society by Mr RUSSELL, has been mislaid, I shall now do what in me lies, to replace that loss, in the most satisfactory manner I can, from memory.

Immediately after my letter upon this subject to Mr RUSSELL, under date 5th February 1816, I applied to several of my friends in India for a specimen of the worm; and the papers now amissing, consisted of a short letter from myself to Mr RUSSELL, covering the original letter from Mr WILLIAM SCOT, Surgeon of one of the battalions of Madras artillery, along with which he had sent home one of the worms, extracted by himself, and which was presented to the Royal Society at the time his letter was read.

I now regret not having preserved a copy of that letter, but am willing to believe, that in the following recapitulation of its contents, there can be no material error.

The worm was discovered in the eye of a horse belonging to Lieutenant-Colonel FREESE at St Thomas's Mount, on the 5th of May 1818, and was extracted next day by Mr SCOT, in presence of Colonel FREESE, Dr M. S. MOORE, and a third person, whose name I do not now recollect. Mr SCOT's letter was dated 7th May. In it he described the appearance of the eye, much as I had done, in my letter to Mr RUSSELL, and noticed its milky appearance, and the lively motion of the animal in the aqueous humour, comparing the mode of its progress to something resembling leaping, which it seems to me might be no inapt comparison, when the worm was fore-shortened, by moving nearly in the line of vision of the spectator.

In this instance, it was found necessary to throw down the horse, an attempt to operate while he was standing having failed. The worm was received among tepid water, in a China

China saucer, where it continued to move about briskly, until a little cold water was added, when it fell dead instantly, and was afterwards with difficulty detected at the bottom of the vessel.

This may be the most proper place to mention, that I have lately received three more of these worms from Mr Scot, which were extracted by Mr Berridge, who keeps a livery stable at Madras. Having presented two of these to the University Museum, they are now in the custody of Professor Jameson. I have the honour to remain, &c.

Alex. Kennedy.

To Dr T. C. Hope, F. R. S. E. &c.

Ascaris *pellucidus.*—Head slightly subulate, with the extremity somewhat obtuse; body smooth, pellucid, of a bluish-white colour; thickest at the centre, and gradually tapering towards the head, and abruptly towards the tail, which terminates in a sharp point; its diameter not being more than a fourth of the head. Length an inch and a quarter.

Inhabits the aqueous humour of the eyes of horses in India; in which it may be seen swimming about with great activity. Is said to be generally produced by external injuries; though in some instances it has occurred without any known cause.

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VIII. *Memoir relating to the* Naval Tactics *of the late JOHN CLERK, Esq. of Eldin; being a Fragment of an intended Account of his Life. By* John Playfair, F. R. S. Lond. & Edin. *Professor of Natural Philosophy in the University of Edinburgh.*

(Read April 6. 1818.*)*

* * * * * * * * * *

THE author of the *Naval Tactics* is one of those men who, by the force of their own genius, have carried great improvements into professions which were not properly their own. The history both of the sciences and of the arts furnishes several remarkable examples of a similar nature. Fermat the rival, sometimes the superior of Descartes, one of the most inventive mathematicians of a most inventive age, was by profession a lawyer, and had only devoted to science the time that could be spared from the duties of a counsellor or a judge: about fifty years earlier, also, his countryman Vieta had made a like digression from the same employment, and hardly with inferior success.

Perrault, who, in the façade of the Louvre, has left behind him so splendid a monument of architectural skill and taste, was a physician, and not only practised, but wrote books on medicine. Dr Herschell too, who has made more astronomical

mical discoveries than any individual of the present age, betook himself to the study of the heavens as a relaxation from professional pursuits. Mr Clerk is to be numbered with these illustrious men, having made great improvements in an art to which he was not educated, and in which early instruction, and long practice, would seem more indispensable than in any other.

Two reasons may perhaps be assigned for the success which often attends men who thus take a science by assault, without making their approaches regularly, and according to the rules of art. They are inspired by genius, and impelled by the highest of all motives, the pleasure they derive from their exertions. They are also free from the prejudices, and the blind respect for authority, which constitute so strong a barrier against improvement both in the sciences and the arts.

A young man, who had been bred in the service of the Navy, who had seen the Commanders he was taught to respect most highly, bring their fleets into action constantly in a certain way, and who had naturally made that manœuvre the great object of his study, would not be apt to deviate from a practice, in the accurate and successful application of which the greatest merit of a Naval Officer was supposed to consist. Indeed no man learns his art, as it actually exists, more completely than a seaman; but no man learns it in a way more likely to preclude improvement. A landsman, therefore, sitting in his study, and thinking only of the abstract principles, mechanical or tactical, of the naval art, provided he be well instructed in them, and have a mind sufficiently powerful to combine those principles, and appreciate their different results, may be expected to give valuable lessons to the most able and experienced seamen.

Mr

Mr Clerk was precisely the man by whom a successful inroad into a foreign territory was likely to be made. He possessed a strong and inventive mind, to which the love of knowledge, and the pleasure derived from the acquisition of it, were always sufficient motives for application. He had naturally no great respect for authority, or for opinions, either speculative or practical, which rested only on fashion or custom. He had never circumscribed his studies, by the circle of things immediately useful to himself; and I may say of him, that he was more guided in his pursuits, by the inclinations and capacities of his own mind, and less by circumstance and situation, than any man I have ever known. Thus it was, that he studied the surface of the land as if he had been a general, and the surface of the sea as an admiral, though he had no direct connection with the profession either of the one or of the other.

From his early youth, a fortunate instinct seems to have directed his mind to naval affairs. It is always interesting to remark the small and almost invisible causes from which genius receives its first impulses, and often its most durable impressions. "I had (says he) acquired a strong passion for nau-"tical affairs when a mere child. At ten years old, before I "had seen a ship, or even the sea at a less distance than four "or five miles, I formed an acquaintance at school with "some boys who had come from a distant sea-port, who in-"structed me in the different parts of a ship from a model "which they had procured. I had afterwards frequent oppor-"tunities of seeing and examining ships, at the neighbouring "port of Leith, which increased my passion for the subject; "and I was soon in possession of a number of models, many "of them of my own construction, which I used to sail on a "piece of water in my father's pleasure-grounds, where there

" was also a boat with sails, which furnished me with much " employment. I had studied *Robinson Crusoe,* and I read " all the sea-voyages I could procure."

The desire of going to sea, which could not but arise out of these exercises, was forced to yield to family considerations; but, fortunately for his country, the propensity to naval affairs, and the pleasure derived from the study of them, were not to be overcome.

He had indeed prosecuted the study so far, and had become so well acquainted with naval affairs, that, as he tells us himself, he had begun to study the difficult problem of the way of a ship to windward. This was about the year 1770, when an ingenious and intelligent gentleman, the late Commissioner Edgar, came to reside in the neighbourhood of Mr Clerk's seat in the country. Mr Edgar had served in the army, and, with the company under his command, had been put on board Admiral Byng's ship at Gibraltar, in order to supply the want of marines; so that he was present in the action off the Island of Minorca, on the 20th of May 1756. As the friend of Admiral Boscawen, he afterwards accompanied that gallant officer in the more fortunate engagement of Lagos Bay.

After the American war was begun, an attention to the narratives of his friend, and still more to the actions which were then happening at sea, served to convince Mr Clerk that there was something very erroneous in the methods hitherto pursued by the British admirals for bringing their fleets into action; insomuch, that, though nothing could exceed the skill with which each individual ship was worked, yet when one whole fleet was opposed to another, the plan followed was uncertain and precarious, and it seemed that the expedient for forcing an enemy to fight, remained yet to be discovered. It appeared, indeed, that very

very little attention had yet been paid to the subject of Naval Tactics.

The oldest work we know of that treats of Naval Tactics, is that of the learned Jesuit PERE HOSTE, Professor of Mathematics in the Royal College at Toulon, and entitled *L'Art des Armées Navales*. It is an elementary and distinct exposition of the ordinary manœuvres at sea, and has no pretensions to any thing more. It was, however, highly regarded at the time: the author, when he presented it to LOUIS the XIV. in 1697, was well received, and had a pension given him.

There was no book on the subject in the English language; and the conduct of our sea-fights, though it had so often proved successful, did not display much extent or variety of resources. It had usually happened that the British fleet was eager to engage, and that the enemy was unwilling to risk a general action; our object, therefore, had almost always been to gain the *weather-gage*, as it is called, of the enemy, or to place ourselves to windward of his fleet. When that fleet was drawn out in line, in the manner necessary for allowing every ship its share in the action, the British fleet bore down from the windward on the enemy, *lying to* as it is termed, or *almost fixed in its position;* the whole line, and also the broadside of each individual ship, being nearly at right angles to the direction of the wind.

Under these circumstances, the British fleet had usually pursued one of two methods of making the attack. The one consisted in forming a line parallel and directly opposite to that of the enemy; after which each ship bore down on that which was immediately opposed to *it*. According to the other method, the British fleet, on the opposite tack to that of the enemy, ran along parallel to it, and within fighting distance,

tance, till the whole of the one line was abreast of the other, and each ship ready to engage her antagonist.

If the first of these methods was pursued, each ship, on coming down, had a very sharp fire to sustain from the broadside of that opposed to her, which she could only return feebly from the *guns on her bow*. The rigging, of consequence, which presented the best mark when seen endwise, was likely to be so much cut, that the ship must be nearly disabled before she arrived at the fighting distance.

If the second method was pursued, the headmost ship had to endure the fire of the whole line before it arrived in its place; the second, the fire of all but one; the third, of all but two, and so on: so that it was not likely that any but the sternmost ships could reach their station without having received considerable damage. This gave to the enemy, who quietly remained on the defensive, a great advantage over the attacking squadron, and enabled him, almost to a certainty, to come off, if not with victory, at least with very little loss.

The disadvantages, however, arising from these two modes of attack, either had not been duly considered, or had been set down among the unavoidable evils necessarily involved in a determination to force the enemy to fight. Perhaps, too, the desire of complying literally with the instructions always given to our admirals, of doing their utmost to take, burn, and destroy, contributed to make it be thought, that a direct and immediate attack, such as has just now been described, was the only means that could properly be resorted to.

Mr Clerk had the merit of pointing out the evils now enumerated, in a manner most clear and demonstrative, and of describing a method by which the attack might be made, without incurring any of the disadvantages that have been mentioned, and almost

almost with a certainty of success. As the evil arose from an endeavour to diffuse the force of the attack, if one may say so, over the whole surface of the line attacked; so the remedy consisted in concentrating the force of the attack, and in bringing it to bear with proportionally greater energy on a single point, or a small portion of the enemy's line. For this purpose the admiral of the attacking and windward squadron, is supposed to come down, not in line, but with his fleet in divisions, so as to be able to support the particular division destined to break through the line of the enemy. The consequence must be, that, if this attack is directed against the rear of the enemy, the ships a-head must either abandon those that are cut off, or must double back, either by tacking or wearing. Here Mr Clerk shews, that if the enemy follow the first of these methods, and make his line either tack in succession, or altogether, such a distance must be left between them and the three or four sternmost ships, that not only must those last be easily carried, but that several more must probably be thrown into such a situation as to subject them almost unavoidably to the same fate. If the enemy attempt the same thing by wearing, his condition will be still worse. The fleet, by falling to leeward, must not only desert the ships attacked altogether, but must leave the sternmost of the wearing ships so much exposed as to render it certain that they will be entirely cut off.

At the time when this method of attack was proposed, it was regarded as a manœuvre quite new, and as having never yet been acted on. Mr Clerk, indeed, has entered into a historical detail, which tends to establish this point, and in which, from the most authentic documents, he traces the plans of most of our remarkable naval actions, from that of Admiral Matthews, off Toulon, in 1744, to that of Admiral Greaves off

off the Cheasapeak in 1781. In most of these actions, though conducted by some of our ablest naval officers, the British fleet being to windward, by extending the line of battle, with a design of disabling or destroying the whole of the enemy's line to leeward, was itself disabled before the ships could reach a situation in which they could annoy the enemy; while, on the other hand, the French, perceiving the British ships in disorder, have made sail, and, after throwing in their whole fire, have formed a line to leeward, where they lay prepared for another attack; and thus has been frustrated that combination of skill and courage which distinguishes our seamen, and has always been so conspicuous in actions of single ships. The analysis of those actions forms a most interesting part of Mr Clerk's book, and furnishes a commentary on the naval history of Britain, such as we seek for in vain in the treatises written expressly on that subject.

In the second part of his work, which, though first written, was last published, the author has considered the nature of the attack from the leeward, or where the fleet which would force the other to action has not the advantage of the weather-gage. Here also he proves, by arguments very clear and convincing, that nothing promises success but the cutting of the enemy's line in two; the leeward fleet on the opposite tack to that of the enemy, bearing up obliquely, so as to pierce the line in the centre, or towards the rear, as circumstances may direct. The ships thus cut off could have no support, and must either save themselves by downright flight, or fall into the hands of the enemy.

The time when Mr Clerk was engaged in these speculations, was a period very memorable in the naval, the military, and political history of this country; and never was there a moment when the communication of the secret he had discovered

vered could have been attended with more important consequences. The contest in which Britain was engaged with the American colonies, so questionable in its principle,—so approved by the nation,—and so obstinately pursued by the Government, had involved the country in the greatest difficulties. A series of great and ill-directed efforts, if they had not exhausted, had so far impaired, the strength and resources of Britain, that neighbouring nations thought they had found a favourable opportunity for breaking the power, and humbling the pride, of a formidable rival. The French Government, desirous of accomplishing an object of which it had never lost sight, and willing also to share in the glory of giving independence to a new State, was yet ignorant of the lesson which it was so soon to learn to its cost,—the danger which a despot runs, who attempts to give that liberty to other nations which he refuses to his own people. Spain also, which we see at this moment exerting every nerve to continue the thraldrom of her own colonies, joined eagerly in the scheme of giving independence to those of England; and by her detail of a hundred grievances, sufficiently convinced the world, that her hostility to Britain proceeded from a cause which she could not venture to avow.—Against this formidable combination, which Holland was preparing to join, Britain stood alone without an ally; and not merely alone, but divided in her counsels, with more than half her force engaged in the operations of a destructive civil war, in which victory would have been more ruinous than defeat. These were circumstances, which, in the mind of every friend to his country, could not but excite anxiety and alarm; yet they were perhaps not the most threatening that distinguished this perilous crisis. In the naval rencounters which took place after France had joined herself to America, the superiority of the British navy seemed almost to disappear; the naval armies of our enemies were every day gaining strength; the number and force of their ships were augmenting; the skill and experience of their seamen appeared to be coming nearer to an equality with our own. Their commanders were completely masters of the art of avoiding a general or decisive action, and at the same time of materially injuring their enemies. In the doubtful conflict off Ushant, which gave the commencement to our hostilities with France, the British admiral, after placing himself between the French fleet and their own coast, continued to manœuvre for several days together, without being able to bring on a general action, and was forced at length to draw off towards his own ports, allowing the French to return to theirs, without the capture of a single ship to support his own claim to victory, or to refute that of the enemy. The year which followed this had witnessed the most inglorious naval campaign recorded in the annals of Great Britain. The combined fleets of France and Spain were seen riding with exultation in the British Channel, capturing our ships close to our own shores, while the naval force of Britain stood aloof, and only ventured to look from a distance on a scene which every British seaman beheld with grief and indignation, while he seemed to read in it the tale of his personal dishonour. Another action in the course of the same year, had no great tendency to console us for the disgraceful caution which our fleet in the Channel had been forced to observe. Admiral Byron attempted to bring the French fleet, off Grenada, to action, and after the greatest gallantry, displayed both by himself and the officers under his command, he entirely failed in his object, and even suffered considerable loss. Indeed when one studies the account of this action, by help of the light which the author of the *Naval Tactics* has thrown on it, he sees with much regret the highest efforts

efforts of valour and seamanship thrown away, from our ignorance of the true principle by which our attack should have been directed; while the French, in their position to leeward, succeeded, with their usual address, in damaging our ships, and in saving their own.

The parallel drawn by Mr Clerk between the unfortunate engagement of Admiral Byng and this of Admiral Byron, is sufficiently striking, and shews but too clearly, that there are many circumstances, besides conduct and valour, that determine the character of a soldier that fights either at sea or land.

The action of Admiral Arbuthnot in the succeeding year, deceived equally the hopes of the nation, and equally demonstrated the skill of the French commanders, in the means of obtaining the end they had in view, and in entirely defeating that of their enemy; and by its unhappy influence on our military operations on shore, may be regarded as the most fatal miscarriage that marked the progress of the British arms. The action of Admiral Greaves off the Cheasapeak, concluded a series of unsuccessful attempts, in which, though no signal disaster fell on the British fleet, no glory was gained, the ultimate object of the expedition was always lost, and, to a power used to boast in its superiority, the entire absence of victory seemed equivalent to defeat. The enemy was acquiring skill and confidence, while we were losing that feeling of superiority on which success so often depends. The circumstances of the nation had never called on every individual to think more seriously of the situation of his country; nothing had ever proved so clearly, that, at sea, the system of offensive warfare was yet but imperfectly understood, nor was there ever a juncture, when such discoveries as Mr Clerk had made, could be brought forward with so great effect. To a man

 who,

who, like him, was a real lover of his country, sincerely interested in its liberty and independence, as well as in the glory of its flag; full also of the enthusiasm of genius, and the love of science; I can hardly imagine any higher or more exquisite delight, than that which he must have felt, when his imagination arose from the despondency into which the actual state of things had thrown every thinking man, to consider the change which the secret which he had in his possession was likely, nay sure to make, in the condition of his country.

There can exist, I think, but one feeling superior to this,—that which must arise on seeing this noble vision realized. This also fell to the share of the author of the *Naval Tactics*, who lived to see his measures carried into effect with unexampled skill and gallantry; saw them lead to victories more splendid than the most sanguine hopes could have ventured to anticipate, and saw himself become one of the great instruments by which Providence enabled his country to weather a more awful tempest than any by which it had hitherto been assailed.

Being fully satisfied as to the principles of his system, Mr Clerk had begun to make it known to his friends as early as 1779. After the trial of Admiral Keppell had brought the whole proceedings of the affair off Ushant before the public, Mr Clerk made some strictures on the action, which he put in writing, illustrating them by drawings and plans, containing sketches of what might have been attempted, if the attack had been regulated by other principles, and these he communicated to several naval officers, and to his friends both in Edinburgh and London.

In the following year he visited London himself, and had many conferences with men connected with the navy, among whom he has mentioned Mr Atkinson, the particular friend of

Sir

Sir George Rodney, the Admiral who was now preparing to take the command of the fleet in the West Indies. A more direct channel of communication with Admiral Rodney was the late Sir Charles Douglas, who went out several months after the Admiral, in order to serve as his Captain, and did actually serve in that capacity in the memorable action of the 12th of April 1782. Sir Charles, before leaving Britain, had many conferences with Mr Clerk on the subject of naval tactics, and, before he sailed, was in complete possession of that system. Some of the conferences with Sir Charles were by the appointment of the late Dr Blair, prebendary of Westminster; and at one of these interviews were present Mr William and Mr James Adam, with their nephew the present Lord Chief Commissioner for Scotland. Sir Charles had commanded the Stirling Castle in Keppell's engagement; and Mr Clerk now communicated to him the whole of his strictures on that action, with the plans and demonstrations, on which the manner of the attack from the leeward was fully developed.

The matter which Sir Charles seemed most unwilling to admit, was the advantage of the attack from that quarter; and it was indeed the thing most inconsistent with the instructions given to all admirals.

Lord Rodney himself, however, was more easily convinced; and in the action off Martinico, in April 1780, the original plan seemed regulated by the principles of the *Naval Tactics*. The British fleet was to leeward, and the first signal made by the Admiral gave notice of his intention to attack the enemy's rear with his whole force. The enemy, however, having discovered this intention, wore, and formed on the opposite tack, and thus the effect of the signal was for the time defeated. The Admiral appeared then to depart from the new system;

tem; for the next signal which he threw out, was for every ship *to bear down* on her opposite, according to the 21st article of the additional fighting instructions. It appears, as we shall afterwards see, that the cause of this change was the mistake of the signals, the captains of the fleet not being sufficiently prepared for the new method of attack. In the two actions which immediately followed this, on the 15th and 18th of the next month, the French succeeded in the defensive system; and it was not till two years afterwards, in April 1782, that Lord RODNEY gave the first example of completely breaking through the line of the enemy, and of the signal success which must ever accompany that manœuvre, when skilfully conducted. The circumstances were very remarkable, and highly to the credit of the gallantry as well as conduct of the Admiral. The British fleet was to leeward, and its van, on reaching the centre of the enemy, bore away as usual along his line; and had the same been done by all the ships that followed, the ordinary indecisive result would infallibly have ensued. But the Formidable, Lord RODNEY's own ship, kept close to the wind, and on perceiving an opening near the centre of the enemy, broke through at the head of the rear division, so that for the first time the enemy's line was cut in two, and all the consequences produced which Mr CLERK had predicted.

This action, which introduced a new system, gave a turn to our affairs at sea, and delivered the country from that state of depression into which it had been thrown, not by the defeat of its fleets, but by their entire want of success.

It was in the beginning of this year that the *Naval Tactics* appeared in print, though for more than a year before copies of the book had been in circulation among Mr CLERK's friends. Immediately on the publication, copies were presented to the

MINISTER

MINISTER and the FIRST LORD of the ADMIRALTY. The Duke of MONTAGUE, a zealous friend of Mr CLERK's system, undertook the office of presenting a copy to the KING.

Lord RODNEY, who had done so much to prove the utility of this system, in conversation never concealed the obligation he felt to the author of it. Before going out to take the command of the fleet in the West Indies, he said one day to Mr DUNDAS, afterwards Lord MELVILLE, "There is one CLERK, a "countryman of yours, who has taught us how to fight, and "appears to know more of the matter than any of us. If "ever I meet the French fleet, I intend to try his way."

He held the same language after his return. Lord MELVILLE used often to meet him in society, and particularly at the house of Mr HENRY DRUMMOND, where he talked very unreservedly of the *Naval Tactics*, and of the use he had made of the system in his action of the 12th of April. A letter from General Ross states very particularly a conversation of the same kind, at which he was present. "It is (says the "General) with an equal degree of pleasure and truth, that I "now commit to writing what you heard me say in company "at your house, to-wit, that at the table of the late Sir JOHN "DALLING, where I was in the habit of dining often, and "meeting Lord RODNEY, I heard his Lordship distinctly state, "that he owed his success in the West Indies to the ma-"nœuvre of breaking the line, which he learned from Mr "CLERK's book. This honourable and liberal confession of "the gallant Admiral, made so deep an impression on me, "that I can never forget it; and I am pleased to think, that "my recollection of the circumstance may be of the smallest "use to a man with whom I am not acquainted, but who, in "my opinion, has deserved so well of his country."

As

As a farther evidence of the sentiments of the Admiral on a subject where they are of so much weight, I have to quote a very curious and valuable document, a copy of the First Part of the *Naval Tactics*, with Notes on the margin by Lord RODNEY himself, and communicated by him to the late General CLERK, by whom it was deposited in the family library at Penicuik. The notes are full of remarks on the justness of Mr CLERK's views, and on the instances wherein his own conduct had been in strict conformity with those views. He replies in one place to a question which Mr CLERK had put (published after the action in spring 1780,) of which mention has been already made, concerning the conduct of that action. The first signal of the Admiral, as we have already seen, was for attacking the rear with his whole force. The French, perceiving this design, wore, and formed on the opposite tack. This made it impossible immediately to obey the Admiral's signal, and the next that he made was for every ship to attack her opposite. Mr CLERK's question was, Why did Sir GEORGE change his resolution of attacking the rear, and order an attack on the whole line?—Sir GEORGE answers to this, That he did not change his intention, but that his fleet disobeyed his signals, and forced him to abandon his plan.

An anecdote which sets a seal on the great and decisive testimony of the Noble Admiral, is worthy of being remembered, and I am glad to be able to record it on the authority of a Noble Earl. The present Lord HADDINGTON met Lord RODNEY at Spa, in the decline of life, when both his bodily and his mental powers were sinking under the weight of years. The Great Commander, who had been the bulwark of his country, and the terror of her enemies, lay stretched on his couch, while the memory of his own exploits seemed the only thing that interested his feelings, or afforded a subject for conversation. In this situation,

tion, he would often break out in praise of the *Naval Tactics*, exclaiming with great earnestness, " JOHN CLERK of Eldin for " ever."

Generosity and candour seemed to have been such constituent elements in the mind of this gallant Admiral, that they were among the parts which longest resisted the influence of decay.

Soon after the victory obtained by Lord RODNEY, the American war was brought to a conclusion, and the world enjoyed some years of repose. The French Revolution disturbed the tranquillity of Europe; Britain was quickly involved in a war more formidable than that in which the principles of Mr CLERK's system was first essayed; one where it was yet to be more severely tried, and was yet to render more important services to the country.

We have seen, that Lord RODNEY had been so convinced by the first explanation he received of Mr CLERK's system, that he declared, that should he meet the French fleet " he would " try his way."—On Lord HOWE, the effect of the first perusal of the same work was quite different, though the result in the end was entirely the same. A copy of the first edition of the *Naval Tactics* was sent to his Lordship, who, after reading it, expressed himself as highly pleased with the ingenuity of the book, and as greatly struck with the circumstance of the author being a landsman; but he nevertheless desired General CLERK to inform his ingenious kinsman, that he would adhere to the old system if ever he had an opportunity of engaging the French fleet. To this Mr CLERK replied, through the same channel, that if his Lordship did so he would infallibly be beaten. His Lordship, however, when it came to the trial, did not adhere to the old system, but, concentrating his force, directed it against one point, precisely on the principles of the

Naval Tactics. His change of opinion may have arisen from the practical commentary by which Lord RODNEY had illustrated the principles of that work; and perhaps, too, a second perusal of the book itself had materially contributed to this effect. That Lord HOWE really consulted it a second time, there is good reason to believe. When he commanded the Channel fleet in 1793, Mr JAMES CLERK, the youngest son of the author of the *Naval Tactics*, a young man of great promise, who, had he lived, would have done honour to the profession on which his father had bestowed so valuable a gift, served as a midshipman on board the Admiral's ship the Queen Charlotte. He possessed a copy of the second edition of his father's book, which was borrowed by Captain CHRISTIAN, no doubt for the Admiral's use. Thus much is certain, that the action of the 1st of June 1794, was, in its management, quite conformable to Mr CLERK's system, and its success entirely owing to the manœuvre of breaking the line.

Lord HOWE was also the first who introduced into the signal book signals directed to the object of cutting off the rear, —of bringing the whole force to bear on one point,—breaking the line, &c. Indeed, if his Lordship's conduct had been contrary to the principles of the *Naval Tactics*, the words of his declaration, that he would still adhere to the old method, is a decided testimony in favour of one of the points which I think it most material to establish. About the utility of the method, after Lord RODNEY's action, no doubt could be entertained. As to its novelty, and its originality, if any difference of opinion could arise, it is completely answered by Lord HOWE's message delivered to General CLERK, as it is a proof that an officer of his Lordship's great skill and experience, considered this manœuvre as new, as opposed to the ordinary practice, and as a thing hitherto unknown. The novelty of the

the system, therefore, can no more be doubted than its utility.

An example of breaking the line, with success, if possible, more brilliant than either of the preceding instances, was afforded by Lord St VINCENT's memorable action on the coast of Spain, when, disregarding, as he said, in his own account of it, the regular system, he attacked the Spanish line of twenty-seven ships with fifteen only, and by carrying a press of sail, intersected and cut off the windward division, of which four were taken before the rest of the fleet could work up to their relief.

Lord ST VINCENT had early been made acquainted with Mr CLERK's book, of which a copy had been sent him by Colonel DEBBIEG of the Royal Engineers, a particular friend of the author. I do not find that his Lordship ever expressed any opinion on the principles of this work.

Lord DUNCAN's victory on the coast of Holland was achieved on the same principle, and carried into effect with singular gallantry. His Lordship, indeed, before going to sea, had many conferences with Mr CLERK, and professed that he was determined to pursue the plan of operations which he had pointed out. His Lordship's attack, accordingly, was directed against the centre of the enemy, in consequence of which the rear division was cut off and taken, with the exception of a single ship. When the first news of this victory, so near to our own shores, and therefore so strongly felt, and so highly appretiated by us all, was brought to Walmer Castle, where Mr PITT was then residing, he, with Lord MELVILLE, Mr FORDYCE, and some others, were sitting at table just after dinner. A man who had seen the action, and had just landed, desired to be introduced, and on coming into the room, gave an account of what he had witnessed; on his mentioning that Lord

DUNCAN had broke through the Dutch line, Lord MELVILLE immediately exclaimed, Here is a new instance of the success of CLERK's system.

The last and greatest in the brilliant series of victories that followed the publication of the *Naval Tactics*, was, like all the rest, obtained by the skilful application of the principles there unfolded; and of this, Lord NELSON's instructions, before the battle, are the fullest evidence. They even contain, in the body of them, several sentences that are entirely taken from the *Naval Tactics*. These instructions were transmitted to Mr CLERK by one of the Commanders in that memorable action, Captain, now Admiral Sir PHILIP DURHAM, with a note, which shews in what light his discoveries were viewed by those most capable to decide. " Captain DURHAM, sensible of the many " advantages which have accrued to the British nation from " the publication of Mr CLERK's *Naval Tactics*, and particu-" larly from that part of them which recommends breaking " through the enemy's line, begs to offer him the inclosed " form of battle, which was most punctually attended to in the " brilliant and glorious action of the 21st of October. Mr " CLERK will perceive with pleasure, that it is completely ac-" cording to his own notions, and it is now sent as a token of " respect from Captain DURHAM, to one who has merited so " highly of his country.

" *H. M. S. off Cadiz, 29th Oct.* 1805."

I must observe, that the Great Admiral, to whose last and most glorious action I have now alluded, had put in practice the same manœuvre in the Battle of the Nile; the line was then broken in the same way, and the discomfiture, by that means, of a fleet at anchor, was the most complete that can be imagined.

From

From the whole of this narrative, therefore, it is plain, that the *Naval Tactics* was acknowledged by professional men, as an original and valuable work, unfolding a new system; the advantages of which were proved by demonstrations founded on the most undeniable principles, and now verified by a series of great and brilliant victories, in consequence of which there has been effected an entire revolution in the offensive part of naval warfare. These truths having been so generally acknowledged and admitted, both by Naval Officers of the highest reputation, and by Statesmen of the greatest power, it cannot but appear extraordinary, that no mark of public favour was ever bestowed on the author, nor any acknowledgment made by Government of merit so distinguished. It was merit of the kind most directly calculated to interest the feelings, and to call forth the gratitude of the Nation; it was an improvement in the art which Britain reckons so peculiarly her own; it was a contrivance for making more effectual the arms in which she most confides; for rendering more impenetrable the Wooden Walls, to which she trusts her safety, her prosperity, and her independence. The name of Mr CLERK, and of the *Naval Tactics*, is in the mouth of every Officer, from the Midshipman to the Admiral.

Whatever was the cause of this strange omission, it is deeply to be regretted,—regretted, however, much less on account of Mr CLERK, than on account of the Nation itself. To a man conscious of having rendered so important a service to his country as he had done,—who might say to himself without vanity, that he was entitled to be numbered with her most useful citizens, and her most eminent benefactors,—who saw that the actions which had immortalized the names of RODNEY, HOWE, DUNCAN and NELSON, had been all directed by a principle

ciple which he had been the first to discover,—and who knew, that he was to go down to posterity as the author of a great and important improvement;—to the happiness of a mind sustained by such reflections, and inspired by the sentiments which must accompany them, what great addition is it in the power of a Monarch, or even of the Nation, to make? what is it that the common badges and titles of honour and distinction can be supposed to add? These may be fit, and even necessary emblems, for marking degrees of merit of an ordinary kind; but when merit is transcendant to a certain point, it can dispense with such conventional symbols; it shines of its own light, and enables its possessor to look down on the neglect or the ingratitude of the world.

But though these considerations may in some measure set us at ease with respect to the author himself, and his own feelings, it must be allowed that they take nothing from the blame incurred by those to whom the Nation had intrusted the power of dispensing its honours and rewards. Neglect of merit will always operate as a discouragement to exertion, and every instance of it tends to extinguish a portion of the fire of genius, of that which often constitutes the sole riches of the possessor, and is always a valuable portion of the patrimony of the State. Every mind is not provided with the power of enduring neglect; ingenious men are often the most sensible of it; and it is hard that the possession of talents should be converted into a source of suffering. If the author of the *Naval Tactics* had not been supported by such enlarged views, and such high sentiments as we have mentioned, the circumstances of his case would have pressed on him with much severity.

That

That it was not ignorance of the facts, or of the chain of evidence now brought forward, that prevented a public acknowledgment of Mr CLERK's services, is altogether certain. The late Lord MELVILLE, who held so conspicuous a situation in the government of this country during the greater part of the period I have been treating of, was early made acquainted by Mr CLERK himself with his ideas on the subject so often mentioned; and in the beginning of his political career, when yet King's Advocate in Scotland, was consulted on the best means of bringing forward those ideas, and gave his advice with the readiness and frankness for which he was remarkable in all situations of life. It is apparent, that he never ceased to hold Mr CLERK's discovery in the highest estimation; and of this, his observation at Walmer Castle (on hearing of Lord DUNCAN's victory above related) is a sufficient proof,—an observation that conveyed a severe censure on himself, and on the Minister to whom it was addressed, unless they both felt that their power of rewarding the merit in question was restrained by some considerations known to themselves, and invisible to the public at large.

Lord MELVILLE had particularly studied the affairs and the interests of the Navy; he had been for a long time at the head of the Admiralty; and there is reason to think, that he was sensible of the improper neglect with which the Author of the *Naval Tactics* had been treated. I have been assured that he had represented this to Mr PITT, but when it was too late, and when that Minister was drawing near the end of life.

If I might venture any conjecture on the cause of an omission which it is impossible to justify, I should be disposed to ascribe it to the fear of giving offence to the Navy, and to consider it rather as resulting from an excess of caution, than from

from direct or intentional neglect. It might seem to derogate from the glory of our Naval Officers, to recognise a Landsman as the author of one of the most valuable discoveries that had been made in their own art,—as the person who had not only pointed out the new principle, but had completely unfolded its advantages, and predicted its effects. If this were the ground on which the reward was withheld, it must at once be considered as very insufficient for the purpose of justification. The man entrusted with the power of rewarding merit, ought no more, than those who have committed to them the office of punishing guilt, to be accessible to any voice but that of truth and justice. The little and mean jealousies that may be excited, by an impartial discharge of their duty, ought never to interfere with the performance of what is imperiously called for. Jealousy, in the present instance, was a weakness that deserves no indulgence; it was vanity and selfishness that ought to have met with no sympathy, no toleration. If, indeed, such feelings any where exist, there is fortunately no reason to think them general; and it is a duty which I most willingly discharge, to say, that the Naval Officers with whom I have had the honour to converse on this subject, have all in the most unequivocal terms expressed their conviction of the importance and originality of Mr Clerk's discovery. That there are exceptions to this rule, I can only state as a conjecture, necessary to explain what is otherwise so difficult to be accounted for.

But to whatever cause the neglect of which I now complain is to be attributed, it is certain that the Government and the Navy have both lost a great opportunity of doing honour to themselves. A National Monument, that would have marked the era of this great improvement, and testified the gratitude of of the Nation to the author, would have been very creditable to the Minister under whose patronage it was erected; and an acknowledgment from the Navy, that this discovery was the work of a Landsman, would have been highly becoming in a profession, of which intrepidity and valour are not more characteristic than frankness and generosity.

IX. *On Circular Polarisation, as exhibited in the Optical Structure of the Amethyst, with Remarks on the Distribution of the Colouring Matter in that Mineral.* By David Brewster, LL. D. F. R. S. Lond. & Edin. *

(*Read November* 15. 1819.)

In plates of Rock-Crystal cut perpendicular to the axis of the prism, an unusual kind of polarisation had been observed in the colours seen along the axis. The phenomena were subsequently analysed by M. Biot, who remarked, that in some specimens of quartz, the succession of tints appeared by turning the doubly refracting prism from *right* to *left*, while in other specimens the same succession was developed by turning the prism from *left* to *right*; and he concluded from his experiments, that the quartz impressed upon the particles of light a *rotatory motion*, and that this property belonged to the ultimate particles of silex, and was independent of their mode of aggregation.

The same species of colours was afterwards observed, about the same time, by MM. Biot and Seebeck, in transmitting polarised light through considerable thicknesses of some essential oils, and solutions of sugar and camphor; and this new

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* The properties of Amethyst, described in this paper, were discovered in 1817; and were announced to the Royal Society on the 18th January 1819.

fact seemed to confirm the supposition that the colours were not dependent upon crystallisation.

My attention was particularly directed to these phenomena, (which we shall distinguish by the name of *Circular Polarisation,)* in consequence of having discovered distinct traces of them in crystals with two axes. The tints appeared at the poles of the resultant axes, and the same crystal seemed to unite the properties of both the varieties of rock-crystal. Another specimen of the same mineral was entirely destitute of these tints, so that I could not avoid drawing a conclusion opposite to that of Biot, and of supposing, that, in this case at least, crystallization had some share in the production of the tints. This conclusion received no slight confirmation, when I discovered the double system of rings in crystallised sugar, and found that they exhibited *none* of the phenomena of circular polarisation, although these phenomena are finely developed in a solution of that substance.

If the property of producing circular polarisation, were essential to the particles of *silex*, it is not easy to understand why it is not exhibited, to a certain degree, by all the siliceous substances, and particularly by *Opal* and *Tabasheer*, the former of which contains above 90 *per cent.* of that earth.

The great resemblance of *Amethyst* to *Quartz*, both in crystallisation and chemical composition, induced me to examine it with particular care. Werner had boldly attempted to draw a distinction between these minerals, which the less practised eye of other mineralogists had confounded; and it will be considered as no ordinary proof of his wonderful sagacity, that this distinction has been fully confirmed by the optical results which it is the object of the present paper to describe.

Having procured above 60 *Amethysts*, principally from the Brazils, some of which were *lilac*, others *yellow*, others *green*, and

and some perfectly *colourless*, I cut various plates of them perpendicular to the axis, and examined them when exposed to polarised light. A structure of a very extraordinary kind presented itself; but in most cases it was so minute, that I was obliged to analyse the emergent light by microscopes of *Agate* and *Tourmaline* *. When the structure was regular, three separate sets of veins were seen, as shewn in Plate X. Fig. 1. which represents a plate cut from the pyramidal summit of a pink-coloured amethyst.

The veins resembled a number of V's inclosed in one another, and each set was opposite an alternate face of the prism, the apex being directed to the centre. Upon examining these alternate veins, I found that the series distinguished by a *faint blue* tint, produced the succession of colours, by turning the prism from *right* to *left*; while the series with a *faint yellow* tint produced the same succession, by turning the prism from left to right †.

Each of these fringes was placed between two of an opposite character, and separated from them by a *black fringe*, where the crystal produced none of the tints of circular polarisation,

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* After I discovered that the *Agate* gave a single polarised image, in consequence of the dispersion, and partial absorption, of the rays which form the other image (See *Phil. Trans.* 1813, p. 102. and 1814, p. 189.), I employed it constantly as a part of my apparatus, as may be seen in the *Phil. Trans.* 1814, p. 203, 206, 208, &c. &c., and when the aid of a microscope was necessary, I cemented a thin plate, with Canada Balsam, upon the plain side of a Plano-convex Lens. By the method described in the *Phil. Trans.* 1819, p. 146, I have extinguished one of the images of *Calcareous Spar* so completely, that the place where it should have been could not be distinguished, even in the strongest lights; and I have accordingly used it as an analysing prism, in preference to the agate and the tourmaline. *Epidote*, *Mica*, and other substances which absorb one of the pencils, may be employed for the same purposes.

† See the description of the figures at the end of the paper.

sation, or rather where these tints were extinguished by the opposite action of the two adjacent veins *.

In many specimens of Amethyst, these veins are distributed with great irregularity, and sometimes they are so extremely thin, that the two circularly polarising structures almost entirely disappear, and leave the crystal with the power of producing a system of rings with the black cross distinctly traversing them. In those specimens where the circular tints are nearly extinguished, the amethyst exhibits, in the most distinct manner, two resultant axes, inclined to one another between *three* and *four* degrees.

The black hyperbolic branches appeared, as is usual in crystals with two axes, in an azimuth of 45°, and different tints, analogous to those of absorbing crystals, were seen within and without these branches. The tints between the convex summits of the hyperbolic branches, were sometimes of a *deep purple*, and in other specimens of a *pink* hue; while the tints within thesame concave summits, were of a *slaty blue* or of a *reddish white* colour. The plane of the resultant axes was always perpendicular to the radius of the sector which exhibited the two axes.

Phenomena similar to those which have been described, are seen likewise in the *olive-coloured* amethysts, and in those which are *colourless* like quartz; and we are therefore entitled to conclude, that the amethyst combines in itself both the structures

* If we consider *Circular Polarisation* as having its origin in a deviation from the usual laws of crystallisation, the parts of Amethyst corresponding to the *black fringe* may be regarded as produced under the influence of the usual laws, while, during the formation of the opposite veins, between which it is interposed, the crystallisation was subject to the unusual laws differently related to the axis, according as the polarisation is *direct* or *retrograde*.

structures of the two optical varieties of quartz; that these two structures are disposed in plates parallel to the axis of the prism; that these plates are inflected into various forms, and that they modify each others action, and are sometimes so minute as to destroy the circular tints which each of them would have produced separately.

The *lilac* tints, from which the amethyst derives its peculiar colour, and its value as a precious stone, generally (though not always) reside in the veined part of the specimen; but when the colour is removed by heat, neither the veins nor their optical actions suffer any change.

In some specimens I have found the red colouring matter arranged in veins corresponding with the dark spaces where the two structures destroy one another.

This phenomenon is finely seen in the amethyst represented in Fig. 1. which has the appearance shewn in Fig. 2. when narrowly examined with common light, and also with polarised light, the colour of the veins varying in different positions, according to the quantity and nature of the tint, absorbed in different azimuths *. In order to explain the distribution of the colouring matter in this and similar specimens, let *a*, *a*, *a*, *a*, *a*, *a*, &c. Fig. 3. be the black lines which separate the two structures, and let *b*, *b*, *b*, *b'*, *b'*, *b'*, &c. be the lines where the one structure has begun to affect the tint of the opposite structure, then the colouring matter begins at the line *b*, *b*, *b*, and gradually increases till it is a maximum at *a a a*, from which it again diminishes, and becomes a maximum at *b'*, *b' b'*, and so on, increasing and diminishing in a similar manner. These tints vary in different azimuths, being sometimes purple in

* See *Philosophical Transactions*, 1819, p. 11.

in the plane of primitive polarisation, and pale-red in a plane at right angles to it.

In another amethyst, shewn in Fig. 4. the portion A gave the retrograde tints, and B the direct tints: the *direct* veins were *lilac;* the *retrograde* veins *brownish-red;* and the *dark lines yellowish-white.*

In other crystals the colouring matter affects the largest masses of the structure, such as those left white in Fig. 1. which separate the veined sectors. In a very interesting specimen, shewn in Fig. 5. the lines AE, BF, DG, which divide the hexahedral crystal into triangular prisms, are distinctly seen by common light; and one of these prisms, BCD, is alone tinged with the red-colouring matter. Upon exposing this crystal to a polarised ray, I found that the sector BCD, consisted of two opposite structures *a*, *b*, separated by the curved vein *m n*, where their opposite actions were *in equilibrio;* and hence it follows, that the colouring matter affected all the three structures of the specimen. This subdivision of the crystal into hexahedral prisms, seems to indicate that the dodecahedron may be formed by two intersecting rhomboids, to which the two structures may be related.

In a large white amethyst, tinged with masses of yellow, I found that the yellow-colouring matter resided in three unequal sectors, A, B, C, Fig. 6. all the rest of the crystal, consisting of narrow veins of the opposite structure, which became so minute as to destroy one another almost entirely in the sector D, which exhibited in the highest perfection the two axes and the hyperbolic branches. The sectors A and C were, as it were, expansions of direct veins, while B was the expansion of a retrograde vein, and B and C were separated by a dark line, from which the tints ascended to a green of the second order.

Among

Among the numerous amethysts which I prepared for examination, there was one of a very interesting nature. One half of it was *yellow*, and the other *lilac*. The *yellow* half exhibited the tints of circular polarisation; but the *lilac* half seemed entirely destitute of them. The application of the microscope, however, displayed in the lilac portion a sort of *rippled* structure, like that of the agate *, and I distinctly saw various remaining specks of the two structures, by whose opposing agencies the circular tints had been extinguished. This specimen is shewn in Fig. 7. where B is the yellow, and A the lilac portion, separated by a sharp line *m n*.

In another specimen, represented in Fig. 8. but without any natural faces, the one half A had the *direct* circular polarising structure, while the other half B had the *retrograde* structure, and the junction of these opposite tints was marked by a black line *m n*, from each side of which the colours ascended in the scale to the Greenish Pink of the second order. The part of the crystal corresponding with the black line was colourless, while both the portions A and B had a dark-yellow tinge. This black space constantly occurs between the two opposite structures; though I have various specimens, such as that in Fig. 11. where the same structure appears to exist on both sides of it. I have always found, however, upon minute examination, that in this case the *second structure exists in the middle of the irregular black space, having nearly exhausted itself in neutralising, to a certain extent, the opposite structure which encircles it.*

Although the veined structure, when it is regular, most commonly resides in the alternate sectors of hexahedral pyramids of amethyst, yet I have found specimens in which it is placed in a different manner. In a colourless, and also in

* See *Phil. Trans.* 1814, p. 192; and Pl. V. Fig. 1, 2.

an olive-coloured amethyst, the whole of the specimen is occupied with the veined structure, as shewn in Fig. 9. each system of veins covering a sector of 120°. In another specimen, shewn in Fig. 10. the veined sectors were four in number, two of them corresponding, as at B and D, with opposite sides of the hexagon, and the other two corresponding, as at A and C, with two of its opposite angles. In this last specimen the veined part was tinged with pink, and the crystal was foul near its axis. In another specimen, Fig. 11. which contained part of the pyramid, and part of the prism, of a very fine crystal, the veined structure occupied all the half ABCDA, which was nearly colourless; and the other half AFEDA, which had circular polarisation, was of a yellow colour, excepting in the two places where the opposite tints had extinguished one another. In the parts *a* and *c* the tints were retrograde, and in *b* direct.

The finest specimen of amethyst which I have ever seen, is shewn in Fig. 12. which is drawn of the natural size, and which represents a section of part of the pyramid and part of the prism. On the three alternate sides of the prism, viz. MN, OP and QR, are placed sectors M *c* N, O *d* P, Q *a* R, which are divided into two parts by dark lines *c c'*, *d d'*, *a a'*, which separate the direct structures of A, C, and E from the retrograde structures of B, D, and F. On the other three alternate faces of the prism are placed the three veined sectors M *c b a* R, N *c b d* O, and P *d b a* Q, which meet at *b* in angles of 120°, and consist of veins of opposite structures alternating with each other, and so minute, that in many places the circular tints are almost wholly extinguished by their mutual action. The direct sectors A, C and E are all connected together by the three radial veins *b a*, *b c*, *b d*, and are therefore to be considered as the expanded terminations of these veins.

veins. The retrograde sectors B, D and F are expansions of the first retrograde veins next to *d b e*, *d b a* and *a b c*; and the lines *c c′*, *d d′* and *a a′* are continuations of the dark or neutral lines which separate the first retrograde vein from the direct radial veins.

All the sectors A, B, C, D, E and F, are of a *yellowish-brown* colour, and all the rest of the crystal is of a *pale lilac* colour; the lilac tints being arranged in the manner previously described. The phenomena which I have now mentioned as existing in this specimen are very common in the amethyst; and I have never yet found a specimen in which the *yellow* tints were not confined to those portions which formed the expanded termination of veins, a fact which indicates that this would have been the colour of the crystal, whether its action were direct or retrograde, and that the lilac colour affects in general those portions which are composed of opposite veins.

Hitherto we have considered the appearances exhibited by amethyst in a direction coincident with the axis of the prism. When we examine it in a direction transverse to the axis, we receive no assistance from the phenomena of circular polarisation, as the force by which they are produced extends only to a *very small* distance from the axis; but the structure of the crystal is fortunately rendered obvious by other means. In Fig. 13. we have represented a section of the pyramid of amethyst, cut by a plane parallel to one of the faces of the pyramid, in order to explain the several phenomena which it displays. The upper pyramidal layer ABC is commonly pink, but often brownish or bluish, and composed of strata of different shades of colour. The next layer is yellowish white; the third layer DE is pink like the first; the fourth layer is yellowish-white; and the fifth layer FG is like the first and third, being succeeded by a

 yellowish-

yellowish-white one. All these strata are sections of the planes of the primitive rhomb, the third plane being perpendicular to the eye. These layers are crossed by the veins *a b*, *c d*, turning away from the axis at their summits, so as to fall more perpendicularly upon the faces AB, AC as they approach to B and C. Each alternate vein is pink where it traverses the pink layers, and of a deeper yellow where it traverses the yellowish-white layers. I was now anxious to ascertain whether there was any difference in the mechanical state of those parts of the veins which gave the black fringes, and those which produced circular polarisation, as the veins were often visible in common light, an effect which could arise only from a difference of mechanical or of refractive density. With this view, I cut a plate about $\frac{1}{50}$th of an inch thick, out of a large amethyst, by planes passing through the axis. Having divided this plate into two parts, I placed the one above the other, so as to counteract its polarising and doubly refracting forces, and exposing it to polarised light, I had a system of rectilineal tints M, N, Fig. 14. of opposite characters, separated by the black fringe AB, all of which were perfectly free from the tints of circular polarisation*. Upon examining them with an analysing microscope, I distinctly observed, that they were crossed with the veins of the amethyst, though these veins were entirely invisible either in ordinary or polarised light previous to the super-position of the plates. The tints produced by the ordinary polarising force were always a *minimum* at the lines corresponding with the black fringes

* Plates of Rock-Crystal cut and arranged in this manner, form the best combination for exhibiting the different orders of colours.

ges which separated the direct and retrograde structures, and increased to the centres of these structures, from which they again diminished to the adjacent limit of the next vein. Hence we deduce the important fact, *that the direct and retrograde veins in Amethyst have a greater polarising force, and consequently a greater force of double refraction than the interval between them, corresponding with the black fringe.* As the two structures pass into one another, through this line as their node, by insensible gradations, we cannot avoid concluding, that the cause, whatever it may be, which gives to the particles of Quartz the peculiar arrangement that produces circular polarisation, gives them at the same time, when thus arranged, an increase of polarising and doubly refracting force.

These results, considered merely as optical facts, would have entitled mineralogists to separate Quartz and Amethyst; and it is highly probable, that the two varieties of quartz, and the amethyst, will be found to exhibit some remarkable difference in their crystalline structure, to which the difference in their optical properties may be ascribed. It is fortunate, however, that the optical structure which we have pointed out displays itself by precise mineralogical characters. The combination of veins may be seen even in common light. They appear cropping out, as it were, upon the alternate faces of the pyramid, as shewn in Fig. 1. at A, C, and E; or on all the faces when the whole prism is pervaded by the veined structure, and the fracture across the veined portions, exhibits a beautiful, and sometimes a regular rippled structure, not unlike the engine-turning on the back of ornamental watches. This rippled structure, which I have attempted to represent in Fig. 15. is an infallible proof that the specimen is amethyst, whether it is *yellow*, *orange*, *olive-green*, *lilac*, or perfectly *colourless*.

lourless. The fracture in the direction of the black fringe is *rough*, and along the two opposite veins *polished;* so that in specimens that have been injured, we can see even ina direction transverse to the axis, as in Fig. 13. the veined structure distinctly marked by a succession of opaque and transparent lines.

During the preceding experiments, I remarked the following property of circular polarisation, which enables us to ascertain whether the structure is direct or retrograde, without employing an analysing prism.

Let AB, Fig. 16. be a plate of amethyst, one half of which APQ has the *direct* circular polarising structure, and the other half BPQ the *retrograde* structure. Let the plane of primitive polarisation MN coincide with PQ. If we now take a plate of sulphate of lime, which polarises a white of the first order, and place its axis parallel to MN, it will not affect the tints in either half of the plate AB, which we shall suppose to be a white of the first order. If the axis of the sulphate of lime is shifted to CD, it will raise the white tint of the direct portion to a *yellow*, growing brighter as it moves round, and becoming *orange*, *red*, *pink*, and *blue;* the *blue* becoming fainter, and terminating in *white*, when CD reaches the position BA. If the axis of the sulphate of lime moves from MN to *c d*, the white tint of the direct portion will become faint *blue*, then more *blue*, then *pink*, *orange*, and *yellow*. The effect on the retrograde structure is quite the reverse of this, the one becoming *blue* when the other is *yellow;* but the resulting tint is always the same, whether a plate of sulphate of lime crosses the direct or the retrograde circular tint.

The properties of amethyst which have now been described, render a plate of this substance a valuable addition to our apparatus

paratus for conducting experiments on the polarisation of light. If we wish to place the principal section of the analysing prism exactly in the plane of primitive polarisation, we have only to interpose a thin plate of amethyst, like that shewn in Fig. 1., and if the tints of both sets of veins are exactly similar, the analysing prism will have the required position. If the one set of tints is bluer or whiter than the other, or if there is the slightest difference between them, the position of the prism must be altered, till that difference is no longer perceptible.

If we wish to place a plate of sulphate of lime, or any other crystal, so as to have its principal section in the plane of primitive polarisation, the interposition of the amethyst plate will give us the same assistance, by indicating that the circular tints are not affected by it; whereas if we wish to place the axis of the sulphate of lime at an angle of 45° to the primitive plane, the amethyst will point out this position, when the opposite circular tints suffer an equal change.

The observations contained in the preceding pages are the results of an immense variety of experiments, which accidental circumstances put it in my power to make upon this interesting mineral. Having had access to whole bagfuls of amethystine pyramids from the Brazils, in the possession of Mr Alexander, lapidary in Edinburgh, I have examined some hundred specimens; and though I have not been able to represent one-tenth part of the varieties of arrangement assumed by the colouring matter and the veins, yet I have given the most general, and, I trust, the most interesting of them. I have purposely omitted the different appearances which are produced by crossing the veins of different specimens, because they are deducible from established principles, and likewise other phenomena of colour, which arise from the action of a number of minute strata upon light, when it is made to pass between them.

DESCRIPTION OF THE FIGURES IN PLATE X.

In all the Figures of this Plate, which have been coloured in order to represent the two structures, the *direct* and *retrograde* veins are distinguished by a slight difference of tint,—a difference which is actually produced by turning the principal section of the analysing prism a slight degree out of the plane of primitive polarisation. When the principal section of the analysing prism is exactly in the plane of polarisation, the tints of the two structures are perfectly alike, when the veins are of the same size.

Fig. 1. Is a plate cut out of a pyramid of Amethyst, and about $\frac{1}{10}$th of an inch thick. The blue and yellow veins are separated by a black fringe, towards the middle of which the tints gradually shade off, and no direct vein ever passes into a retrograde one, without the interposition of a black fringe. The veined structure appears on the alternate faces of the pyramid, as shewn in the Figure.

Fig 2. Shews the arrangement of the colouring matter in the veined sectors.

Fig. 4. Shews a form of the veins which is not very common.

Fig. 5. In the sector GCF of this Figure, I have shewn an arrangement which the double structure sometimes assumes; though it did not occur in the specimen represented in the Figure, and already described.

Fig. 6. Shews the structure of an Amethyst perfectly colourless, excepting in the three coloured sectors, which were yellowish by common light. The thickness is about 0.32 of an inch.

Fig. 7. In this specimen the half *m* AC *n* shews imperfectly the veined structure in the part A, while in the part C small specks of the two structures may be seen with a microscope.

Fig. 8. Is a specimen which has no veins, but merely the two structures, as previously described.

Fig. 9. Is a specimen 0.47 of an inch thick, consisting wholly of direct and retrograde veins. This Amethyst developes tints entirely different from any that I have described.

Fig. 10. Is a remarkable specimen, and the only one of the same kind that I have met with.

Fig. 11. In this specimen the retrograde portions *a* and *c* were, as usual, separated from the direct portion *d* by the black fringe *m*. The two portions *a*, *c* were also separated by a black fringe; but I found that the remains of a direct structure existed among the black masses between *a* and *c*.

Fig. 12. I consider this specimen, and the one shewn in Fig. 1. as exhibiting the most general structure of well crystallised Amethysts.

Fig. 13. Represents the pyramidal strata of a pink colour, seen by common light in a direction transverse to the axis.

Fig. 15. Shews the fracture of Amethyst.

X.

Fig. 1.

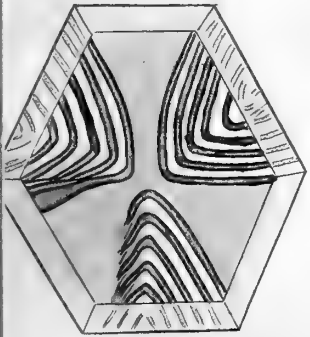


Fig. 2.

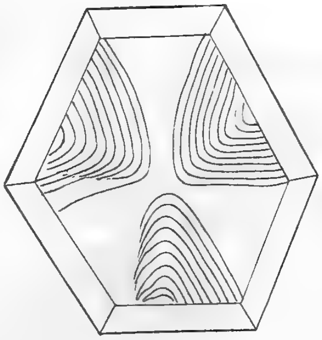


Fig. 3.

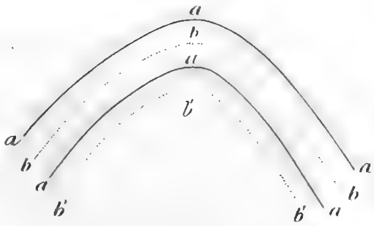


Fig. 4.

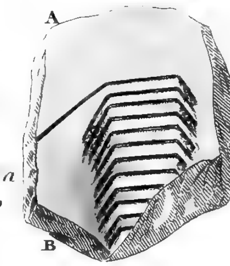


Fig. 8.

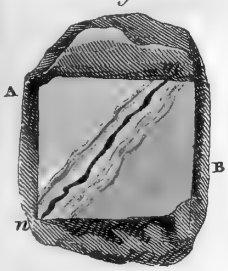


Fig. 7.

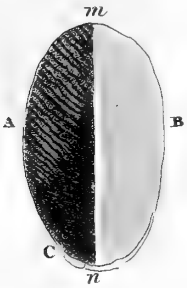


Fig. 6.

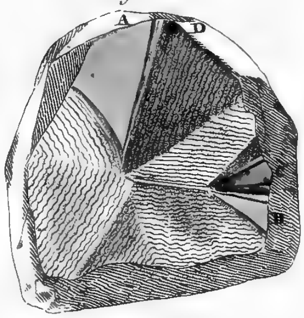


Fig. 5.

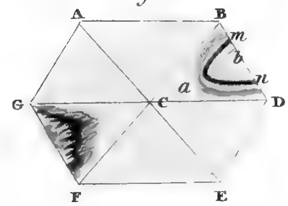


Fig. 9.

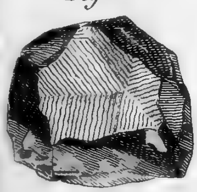


Fig. 12.

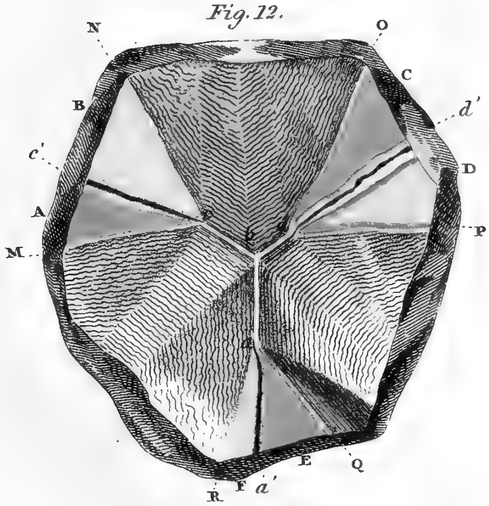


Fig. 10.

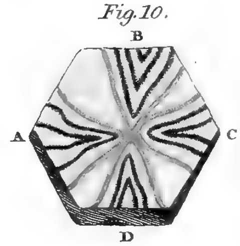


Fig. 15.

Fig. 14.

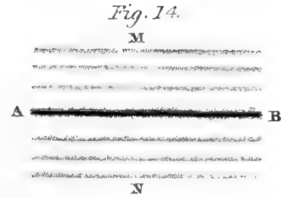


Fig. 11.

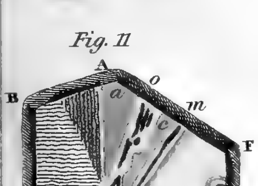


Fig. 16.

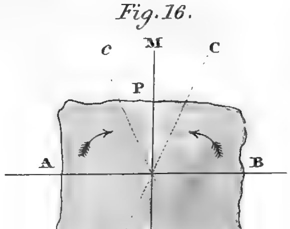
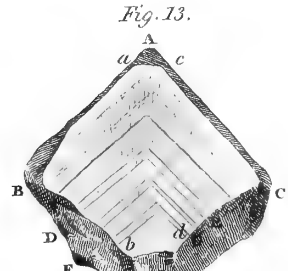


Fig. 13.



X. *An Examination of some Questions connected with Games of Chance.* *By* CHARLES BABBAGE, Esq. F. R. S. LOND. & EDIN.

(Read March 21. 1820.*)*

THE questions which I propose to examine in the following paper, although not themselves dependent on chance, have arisen entirely from games in which it predominates. To determine some method of betting upon a number of successive events, (and the probability of each of which is either equal to, or less than one-half,) by which a profit shall be realised after a considerable number of them have been decided, is a problem which has occupied the attention, and exhausted the efforts, of one set of speculators, as completely as that of the quadrature of the circle has defeated the labours of another. The first and most simple plan, is that of doubling the stake whenever a loss occurs. This is well known, and has been so frequently practised, as to have acquired a peculiar name; it is technically called the *martingal;* it requires for its success, that the person who employs it have the power of leaving off whenever he please, and that he have the command of an unlimited capital. If the chance of the events happening is one-third instead of one-half, the stake must be tripled. Suppo-

 sing

sing a player adopt this system in betting on a number of independent events, the chance of occurring of each of which is one-half, he would naturally desire to know, if possible, before he began, what would be his profit or loss, supposing p of the events decided in his favour, and q against him. In this particular plan of playing, it so happens, that he cannot, from the mere knowledge of the number of favourable and of unfavourable events, arrive at the conclusion he desires. I shall presently show, that these data alone are insufficient, and that, in order to determine the question, not merely the number, but the order of succession must be given.

It is probable that this difficulty, in the case of most frequent occurrence, has deterred many from attempting other similar problems. Indeed, on the first view of such questions, it is by no means apparent, that any of them can be solved without reference to the order in which the events take place. The mode of inquiry which I shall point out, will show that in many cases their mutual arrangement is not required amongst the data, and will furnish a criterion by which we may determine, in any given case, whether it is necessary.

I shall first examine the case of the martingal, which, although the results it leads to are of a negative nature, will introduce us to the method of treating these questions, and from its frequent practice is rather interesting.

Let us suppose a gamester bet a certain sum $2u$, upon an event whose chance of happening is one-half; whenever he wins he repeats the same bet; but whenever he loses, he doubles his last stake. If he should win p and lose q times, it is required to ascertain how much he will have won or lost.

The first stake being $2u$, which may either be gained or lost, we may represent the gamester's profit after one event is decided

decided by $2u(-1)^a$, a being any whole number; for since the nature of the number a is left undecided, whether it is an even or an odd one, the expression just given will represent either a profit or a loss. First, if a is an even number, his next stake remains the same as it was before, or equal to $2u$, if it is an odd number, his second stake must be $4u$. We must therefore endeavour to find some function of a which shall be equal to $2u$, when a is an even number, and become $4u$, when a is an odd one. A great variety of functions may be found satisfying this condition; such are $2u \times 2^{\frac{1-(-1)^a}{2}}$, $2u\left(\frac{3+\cos a\pi}{2}\right)$, &c. and many others. Our choice amongst the infinite variety which present themselves, must be directed by the ulterior operations of the gamester; and, first, I remark, that every stake must be equal to the constant quantity u, multiplied by some power of 2. The next remark which may guide us in this choice of a proper function is, that the index of that power of 2 is determined by the number of times (in immediate succession) the event has been unfavourable, reckoning back from the event about which the stake is proposed: if, therefore, at any period, all the preceding determinations have been unfavourable, the amount of the next stake will be influenced by them all. It may also be noticed, that the successive powers of 2 can be formed by the addition of all the preceding ones, together with unity, thus,

$$1,\ 2^0,\ 2^1,\ 2^2,\ 2^3,\ 2^4,\ 2^5$$

$$1+2^0=2,\ 1+2^0+2^1=4,\ 1+2^0+2^1+2^2=8, \text{ and so on:}$$

From these considerations it appears, that the function we require may consist of a series of functions, each multiplying the

 successive

successive powers of 2. In order to determine these, let us suppose that at some point of the game, the last event has proved favourable; then, by the conditions, the next stake is $2u$; and whatever be the course of succeeding events, $2u$ will always form part of the stake; therefore it need not be multiplied by any function of a, b, c, &c. the letters which determine the winning or losing of the subsequent events. We may therefore assume $2u$ as the constant part of every stake, without reference to any particular order in their occurrence. If the failure or happening of this event is represented by $(-1)^a$, a being an odd number in the first, and an even number in the second case, we must multiply the next power of 2, or 2^1, by some function of a which shall vanish when a is an even number, and become unity when it is an odd one. Such a function is easily found, and one of the simplest is $\frac{1-(-1)^a}{2}$. The next stake is therefore $u\left(2+\frac{1-(-)^a}{2}2\right)$, whatever be the form of a.

The failing or happening of this event may be represented by $(-1)^b$, and the profit of the player by this event is then represented by $u\left(2+\frac{1-(-1)^a}{2}2^1\right)(-1)^b$.

The third stake must comprehend the second power of 2, and will be of the form

$$u\left(2+2^1 f(a,b)+2^2 f_1(a,b)\right).$$

If b is an even number, or the second event is favourable, in that case, the new stake would be $2u$; and therefore both $f(a,b)$ and $f_1(a,b)$ must vanish. This will take place if each has a factor of the form $\frac{1-(-1)^b}{2}$, and the new stake in consequence

sequence becomes

$$u\left\{2+2^1\frac{1-(-1)^b}{2}f(a,b)+2^2\frac{1-(-1)^b}{2}f_1(a,b)\right\};$$

f and f_1 not being the same functions as before. If a had been an even number, we may consider the first bet as not having been made, since it has no influence on the succeeding ones; and in this case the expression ought to reduce itself to

$$u\left\{2+2^1\frac{1-(-1)^b}{2}\right\};$$

$f(a,b)$ must therefore equal unity, and $f_1(a,b)$ must vanish when a is an even number. This gives

$$u\left\{2+2^1\frac{1-(-1)^b}{2}+2^2\frac{1-(-1)^b}{2}f_1(a,b)\right\}.$$

This expression is reduced to $2u$ if b is an even number, and to

$$4u+4uf_1(a,b)$$

when b is an odd one; $f_1(a,b)$ must therefore be such a function of a, that when a is odd, it shall become unity, and when even, equal zero; $\frac{1-(-1)^a}{2}$ is such a function, and we then have for the third stake

$$u\left\{2+2\frac{1-(-1)^b}{2}+2^2\frac{1-(-1)^b}{2}\cdot\frac{1-(-1)^a}{2}\right\}.$$

The law by which we may represent the stake to be ventured, after the determination of any number of events, is now apparent; had it not been sufficiently so, the same reasoning which has been already explained at some length would have assigned it for the fourth stake,

$$u\left\{2+2\frac{1-(-1)^c}{2}+2^2\frac{1-(-1)^b}{2}\cdot\frac{1-(-1)^c}{2}+2^3\frac{1-(-1)^a}{2}\cdot\frac{1-(-1)^b}{2}\cdot\frac{1-(-1)^c}{2}\right\}.$$

We

We can now represent the profit or loss on each event, without determining which of the two it is:

On the 1st he gains $u \left\{ 2 \right\} (-1)^a$

2d $\quad u \left\{ 2 + \overline{1-(-1)^a} \right\} (-1)^b$

3d $\quad u \left\{ 2 + \overline{1-(-1)^b} + \overline{1-(-1)^a} \,.\, \overline{1-(-1)^b} \right\} (-1)^c$

4th $\quad u \left\{ \begin{array}{l} 2 + \overline{1-(-1)^c} + \overline{1-(-1)^b} \,.\, \overline{1-(-1)^c} + \overline{1-(-1)^a} \\ \quad .\, \overline{1-(-1)^b} \,.\, \overline{1-(-1)^c} \end{array} \right\} (-1)^d$

5th $\quad u \left\{ \begin{array}{l} 2 + \overline{1-(-1)^d} + \overline{1-(-1)^c} \,.\, \overline{1-(-1)^d} + \overline{1-(-1)^b} \,.\, \overline{1-(-1)^c} \,.\, \overline{1-(-1)^b} \\ \quad + \overline{1-(-1)^a} \,.\, \overline{1-(-1)^b} \,.\, \overline{1-(-1)^c} \,.\, \overline{1-(-1)^d} \end{array} \right\} .\, (-1)^e$

&c. &c. &c.

The sum of all these is the object sought: with respect to that part which multiplies $2u$, it is easily found; it is

$$2u \left\{ (-1)^a + (-1)^b + (-1)^c + \ldots \&c. \right\};$$

but we know that he has gained p, and lost q times; consequently p of the quantities a, b, c, &c. are even numbers, and q of them odd ones; therefore the sum of the series, multiplying $2u$, is $p-q$, and the value of the part alluded to is

$$2(p-q)u.$$

So far, then, we can proceed by means of the data furnished in the question; but they are insufficient for its complete solution, on attempting to find the sum of that part of the expression

sion in which (—1) has only one index, it appears to be

$$u\left\{1(-1)^b+2(-1)^c+3(-1)^d+\&c.\right\};$$

and the knowledge that p of the letters a, b, c, &c. represent even, and q of them odd numbers, will not assist us in determining the sum of this series; we must also be acquainted with the order of succession of the even and odd numbers. Another reason will afterwards be assigned, why it is not sufficient merely to be acquainted with the number of favourable and of unfavourable events, which may with more propriety be stated, when some other questions of a similar nature have been examined.

Let us now consider another case, in which the amount of the sum staked on each event follows a different law, we will suppose the following problem:

A gamester begins a series of bets on an event whose chance of occurring is one-half, by staking the sum u. Whenever he wins he makes the next succeeding stake less than his last by the quantity v; but if he lose, he then increases his stake by the same quantity. Supposing he should win p times, and lose q times, what will he have gained or lost on the whole number $p+q$.

His first stake being u, his first profit may be expressed by $u(-1)^a$, which will be won or lost according as u is even or odd; in the first case his next stake would be $u-v$, and in the second it would be $u+v$. These two cases may be combined into one, and thus expressed $u-v(-1)^a$, and his second profit will be $\left\{u-v(-1)^a\right\}(-1)^b$; his next stake will be $u-v(-1)^a-v$ if b is even; but it will be $u-v(-1)^a+v$

if

if that number is odd. These may be represented thus: $u - v \left\{ (-1)^a + (-1)^b \right\}$, and his third profit will be

$$\left[u - v \left\{ (-1)^a + (-1)^b \right\} \right] (-1)^c;$$

the succeeding stakes are easily represented in the same manner, and his profits stand thus:

$$u(-1)^a$$
$$u(-1)^b - v\left\{(-1)^a\right\}(-1)^b$$
$$u(-1)^c - v\left\{(-1)^a + (-1)^b\right\}(-1)^c$$
$$u(-1)^d - v\left\{(-1)^a + (-1)^b + (-1)^c\right\}(-1)^d$$
$$u(-1)^e - v\left\{(-1)^a + (-1)^b + (-1)^c + (-1)^d\right\}(-1)^e,$$

&c. &c.

the value of the part multiplying u, or

$$(-1)^a + (-1)^b + (-1)^c + \&c.$$

is easily found, since we know that p of the quantities $a, b, c,$ are even numbers, and q of them odd numbers. The first part of the expression is therefore

$$(p - q)\, u.$$

In order to determine the second part, we must observe, that the expression

$$(a')\, b' + (a' + b')\, c' + (a' + b' + c')\, d' + (a' + b' + c' + d')\, e' +, \&c.$$

is equal to the sum of all the combinations, two by two of the quantities a', b', c', &c.; and, moreover, that if these latter are the

the roots of an equation, then the expression just written is equal to the co-efficient of its third term. If we change a' into $(-1)^a$, b' into $(-1)^b$, c' into $(-1)^c$, &c. it becomes the same as the one whose value we are seeking. Hence then it appears, that the sum of all the quantities, multiplying v, is equal to the co-efficient of the third term of an equation whose roots are $(-1)^a$, $(-1)^b$, $(-1)^c$, &c. or of the equation

$$o = x - (-1)^a \,.\, x - (-1)^b \,.\, x - (-1)^c \ldots.$$

but we know that p of the quantities a, b, c, &c. are even numbers, and q of them odd ones; therefore this equation has p equal roots of the form $+1$, and q equal ones of the form -1, or the equation is

$$o = (x-1)^p \; (x+1)^q;$$

and the quantity which multiplies v, is equal to the co-efficient of the third term of this expression, which is

$$\frac{p \,.\, \overline{p-1}}{1 \,.\, 2} - \frac{p}{1} \,.\, \frac{q}{1} + \frac{q \,.\, \overline{q-1}}{1 \,.\, 2} = \frac{(p-q)^2 - (p+q)}{2};$$

so that the profit of the gamester is

$$W = (p-q)\,u - v\,\frac{(p-q)^2 - (p+q)}{2}. \qquad (1)$$

This result is entirely independent of the order in which the events occurred; and we may learn from the method that has been employed for its solution, that whenever the sum of all the winnings or losings is a symmetrical function of the quantities $(-1)^a$, $(-1)^b$, $(-1)^c$, &c. the final conclusion will not depend on the order in which the events succeed each other, but on the actual number of favourable and unfavourable events.

In the instance we are now considering, if the number of successful and of unsuccessful cases are equal, the gamester who adopts this system of play will always win, for in that case $p = q$, and $W_1 = p v$; as a numerical example of the formula just investigated. Let us suppose

A person stakes 100 shillings on the event of a piece of money thrown into the air falling with one of its faces uppermost, in preference to the other; whenever he wins he diminishes his stake five shillings, and whenever he loses he increases it by the same sum. Supposing he makes 800 successive bets, and wins p, and loses q of them.

If p and q are equal, each being 400, his profit will be $400 \times 5 = 2000$ shillings.

From this it appears, that he will win even though a smaller number than one-half of the events prove favourable. In order to determine how many times he must win, that he may neither lose nor gain on the whole number, we must make the value of W equal to zero, putting $p + q = a$; this gives for the required value of p

$$p = +\tfrac{1}{2}\left(a + \tfrac{u}{v}\right) \pm \tfrac{1}{2}\sqrt{\tfrac{u^2}{v^2} + a};$$

in the present instance, $a = 800$, $u = 100$, $v = 5$, which gives

$$p = \tfrac{1}{2}(800 + 10) \pm \tfrac{1}{2}\sqrt{100 + 800} = 405 \pm 15;$$

the lower sign being employed, we have $p = 390$.

In fact, on substituting this number in the formula (1) we find that he neither wins nor loses money, although the number of unfavourable events has been greater by twenty than the number of favourable ones. The other root of the equation points

points out another limit, beyond which if the number of favourable events increase, he will lose money.

In the problem just examined, each stake depends on that which immediately precedes it. Others may be proposed, in which it is made to depend on the result of two or more of the events which immediately precede, such is the following one:

A gamester begins by staking a given sum u, and regulates his succeeding bets in this manner; if one of the two immediately antecedent to that which he is at any time making, have been gained, and the other lost, the new stake is the same as that last made; but if both those bets have been gained, he diminishes his stake by the sum v; and if both have been lost, he increases it by the same sum v. The first stake being u, the first gain may be represented by $u(-1)^a$; and as there has only been one bet yet made, the second cannot be affected by the law prescribed; it will therefore be the same as the first, and the profit arising from it will be $u(-1)^b$. The third stake depending on the two former, we must add to the quantity u some function of a and b multiplied by v, which shall vanish if a and b are one odd and the other even, and which shall become -1 when they are both even, and $+1$ when they are both odd. Such is the function $-\frac{(-1)^a+(-1)^b}{2}$;

the profit from the third stake may therefore be represented by

$$\left\{u - v\left(\frac{(-1)^a+(-1)^b}{2}\right)\right\}(-1)^c;$$

 and

and in a similar manner, we may find that which arises from the fourth is expressed by

$$\left\{u - v\left(\frac{(-1)^a + (-1)^b}{2} + \frac{(-1)^b + (-1)^c}{2}\right)\right\}(-1)^d.$$

The mode of continuation is sufficiently obvious, and by arranging all these profits together, we have

$$u\left\{(-1)^a\right\}$$

$$u\left\{(-1)^b\right\}$$

$$\left\{u - v\left(\frac{(-1)^a + (-1)^b}{2}\right)\right\}(-1)^c$$

$$\left\{u - v\left(\frac{(-1)^a + (-1)^b}{2} + \frac{(-1)^b + (-1)^c}{2}\right)\right\}(-1)^d$$

$$\left\{u - v\left(\frac{(-1)^a + (-1)^b}{2} + \frac{(-1)^b + (-1)^c}{2} + \frac{(-1)^c + (-1)^d}{2}\right)\right\}(-1)^e$$

$$\left\{u + v\left(\frac{(-1)^a + (-1)^b}{2} + \frac{(-1)^b + (-1)^c}{2} + \frac{(-1)^c + (-1)^d}{2} + \frac{(-1)^d + (-1)^e}{2}\right)\right\}(-1)^f.$$

&c. &c.

The part which depends on u is easily determined to be $(p - q)\,u$, where p and q are the number of successful and of unsuccessful cases, the remaining part consists of $-\frac{v}{2}$ multiplied by a function of the quantities a, b, c, &c. In order to abridge as much as possible, I shall write a instead of $(-1)^a$, b instead of $(-1)^b$, and so on; so that $a\,b$ will represent $(-1)^a \times$

$(-1)^a \times (-1)^b$, or $(-1)^{a+b}$; observing this, the factor multiplying $-\frac{v}{2}$ will be expressed thus:

$$
\begin{array}{l}
a\,c + b\,c \\
a\,d + 2\,b\,d + c\,d \\
a\,e + 2\,b\,e + 2\,c\,e + d\,e \\
a\,f + 2\,b\,f + 2\,c\,f + 2\,d\,f + e\,f \\
a\,g + 2\,b\,g + 2\,c\,g + 2\,d\,g + 2\,e\,g + f\,g, \\
\quad \&c. \qquad \&c.
\end{array}
$$

If to these were added the two series $a\,b + b\,c + c\,d +$ &c. and $a\,(b + c + d + e +$ &c.) the sum would be equal to twice the sum of all the products, taken two by two of the quantities a, b, c, &c. (and since these quantities represent $(-1)^a$, $(-1)^b$, &c. we have found in the last problem that it is equal to $\left(\frac{(p-q)^2 - (p+q)}{2}\right)$. The part depending on v is therefore

$$
-\frac{v}{2}\left\{(p-q)^2 - (p+q) - (-1)^{a+b} - (-1)^{b+c} - (-1)^{c+d} - \&c. \right.
$$
$$
\left. - (-1)^a \left((-1)^b + (-1)^c + (-1)^d + \&c.\right)\right\}
$$

The second of these series is evidently equal to

$$
(-1)^a \left(p - q - (-1)^a\right) = (-1)^a\,(p-q) - 1\,;
$$

the other series

$$
(-1)^{a+b} + (-1)^{b+c} + (-1)^{c+d} + (-1)^{d+e} + \&c.
$$

cannot be determined merely by knowing how many of the numbers a, b, c, &c. are odd, and how many are even.

Still,

Still, however, the knowledge of the order in which the events take place is not absolutely required. It will be sufficient to know how many changes from odd to even, and *vice versa*, occur between the quantities $a, b, c, d, e,$ &c.; for if there is no change in going from a to b, the first term will be $+1$; but if there is a change it will be -1; and generally -1 will occur as often as there is a change from odd to even, or from even to odd in the series

$$a, b, c, d, e, \&c.$$

If, therefore, k denote the number of transitions, since the number of terms is $p+q-1$, the value of the series will be

$$p+q-2k-1;$$

and the whole value of the part dependent on v will be

$$-\frac{v}{2}\left\{(p-q)^2-(p+q)-(p+q)+2k+1-(-1)^a(p-q)+1\right\}$$

and the profit on the whole number of bets is

$$W=(p-q)u-\frac{v}{2}\left\{(p-q)^2-2(p+q)+2k+2-(-1)^a(p-q)\right\} \quad (2)$$

if $p=q$, then

$$W_1=+v(2p-k-1) \quad (3)$$

k in the first of these expressions may vary from 0 to $p+q-1$, and in the second from 1 to $2p-1$.

In order to compare this with an example, let the following series

series of bets be made *plus* or *minus*, denoting their success or failure:

$$\begin{array}{r} +\ 100 \\ +\ 100 \\ +\ 90 \\ -\ 80 \\ +\ 80 \\ +\ 80 \\ +\ 70 \end{array}$$

The profit is 440. Here $p=6$, $q=1$, $k=2$, $v=10$, $u=100$; and these values being substituted in (2) give

$$W = 440.$$

The next case I shall examine is one in which the amount of each stake depends on the result of the three preceding events.

Let the law by which the stakes are regulated be such, that when the three preceding have been won, a certain sum v is taken from the last stake; if they have been lost, the sum v is added to the last; but if only two of these three have been gained, or only two lost, in the first case one-third of v is subtracted, and in the second case is added to the last stake.

The first stake being u, the three first bets will be represented by $u(-1)^a$, $u(-1)^b$, $u(-1)^c$. In order to fulfil the conditions of the question, the fourth must be increased by the quantity $-v\frac{(-1)^a+(-1)^b+(-1)^c}{3}$; and the profit resulting from it is represented by

$$\left\{u-v\frac{(-1)^a+(-1)^b+(-1)^c}{3}\right\}(-1)^d$$

that of the fifth is equally expressed by

$$\left\{u-u\left(\frac{(-1)^a+(-1)^b+(-1)^c}{3}+\frac{(-1)^b+(-1)^c+(-1)^d}{3}\right)\right\}(-1)^e$$

The

The succeeding terms need not be written down, as the law is obvious. In this, as in the former questions, the co-efficient of u is $p - q$; and if we employ the same abridgment of a for $(-1)^a$, &c. as in the last, the co-efficient of $-\frac{v}{3}$ is

$$\begin{array}{l} ad + bd + cd \\ ae + be + 2ce + de \\ af + 2bf + 3cf + 2df + ef \\ ag + 2bg + 3cg + 3dg + 2eg + fg \\ \qquad \&c. \quad \&c. \end{array}$$

This series, which only differs from three times the sum of all the products, two by two of the quantities a, b, c, &c. by the omission of certain parts, may be called Q. On examining what parts are omitted, it will be found that

$$Q + 2a\Big(S(a+b+..) - a - b - c\Big) + bd$$
$$+ b\Big(S(a+b+..) - a - b - c\Big)$$
$$+ (ce + df + cg + ..) + 2(cd + de + ef + ..)$$
$$+ 3(ab + ac + bc) = 3\,S(ab + ..)$$
$$= 3\,\frac{(p-q)^2 - (p+q)}{2}.$$

This equation becomes, by the mutual destruction of certain terms

$$Q + 2a\,S(a+b+..) + b\,3(a+b+..) + (ac + bd + cc + ..)$$
$$+ 2(bc + cd + ..) - 3 = 3\,\frac{(p-q)^2 - (p+q)}{2}$$

Hence

Hence

$$Q = 3\,\frac{(p-q)^2-(p+q)}{2} - 2\,(-1)^a\,(p-q) - (-1)^b\,(p-q) + 3 -$$
$$-\,(a\,c + b\,d + c\,d + \ldots) - 2\,(b\,c + c\,d + \ldots).$$

The latter of these series is

$$\left\{(-1)^{a+b} + (-1)^{b+c} + (-1)^{c+d} + \ldots\right\} - (-1^{a+b} =$$
$$= p + q - 2\,k - 1 - (-1)^{a+b},$$

as we found in the last question, k being the number of changes from even to odd, or *vice versa*, in the series $a, b, c, \ldots$ The value of the series

$$(-1)^{a+c} + (-1)^{b+d} + (-1)^{c+e} + \ldots$$

is not determined without some other data. If, however, we are acquainted with the number of alterations from odd to even, and the contrary, in the series

$$a\,c \quad b\,d \quad c\,e \quad d\,f \quad \ldots$$

we can assign its value; let the number be l, then the series in question is equal to $p + q - 2\,l - 2$: These substitutions and the necessary reductions being made, we have

$$Q = (p-q)\left\{3\,\frac{p-q}{2} - 2\,(-1)^a - (-1)^b\right\} - (p+q)\,\frac{q}{2}$$
$$+ 7 + 2\,l + 4\,k + 2\,(-1^{a+b}$$

and W the profit on $p + q$ events is

$$W = (p-q)\left\{u - \frac{v}{3}\left(3\,\frac{p-q}{2} - 2\,(-1)^a - (-1)^b\right)\right\}$$
$$-\,\frac{v}{3}\left\{7 - (p+q)\,\frac{q}{2} + 2\,l + 4\,k + 2\,(-1)^{a+b}\right\} \qquad (4)$$

if $p = q$

$$W_1 = -\,\frac{v}{3}\left\{7 - 9\,p + 2\,l + 4\,k + 2\,(-1)^{a+b}\right\} \qquad (5)$$

In

In the first of these expressions, k may vary from 0 to $p+q-1$, and l from 0 to $p+q-2$; in the second k may vary from 1 to $2p-1$, and l may vary from 0 to $2p-2$.

The last question which I shall examine is one in which each stake depends on all those which precede it.

A gamester stakes a certain sum u on an event whose chance of happening is one-half. He regulates each succeeding stake in this manner: To the constant sum u he adds the nth part of all his previous winnings; or if he has lost by the previous stakes, he subtracts the nth part of his loss, it is proposed to find his profit * at the termination of $p+q$ bets.

The first stake being u, the profit is $u(-1)^a$; the nth part of this added to u, or $u+\frac{u}{n}(-1)^a$ will constitute the second, and the profit will be $u(-1)^b+\frac{u}{n}(-1)^a(-1)^b$, the nth part of these two, or $\frac{u}{n}\left((-1)^a+(-1)^b\right)+\frac{u}{n^2}(-1)^a(-1)^b$ added to the quantity u, will be the third stake, and the profit on the determination of the third event will be

$$u(-1)^c+\frac{u}{n}\left((-1)^a+(-1)^b\right)(-1)^c+\frac{u}{n^2}(-1)^a(-1)^b(-1)^c;$$

the

* The language of analysis is so much more general than that in which we usually convey our thoughts, that it is almost impossible to make the latter keep pace with the former. This is more particularly manifest when we are treating of games of chance. The words profit, winning, gain, &c. must, if we wish to avoid perpetual repetition, frequently be understood to comprehend their very opposites.

the nth part of the sum of these three profits added to u, and multiplied by $(-1)^d$, gives for the profit on the fourth event

$$u(-1)^d + \frac{u}{n}\Big((-1)^a(-1)^d + (-1)^b(-1)^d + (-1)^c(-1)^d\Big)$$

$$+\frac{u}{n^2}\Big((-1)^a(-1)^b(-1)^d + (-1)^a(-1)^c(-1)^d + (-1)^b(-1)^c(-1)^d\Big)$$

$$+\frac{u}{n^3}(-1)^a(-1)^b(-1)^c(-1)^d.$$

From these expressions, continued a few steps further if necessary, it appears that the sum of all the profits W is equal to

u multiplied by the sum of all the quantities

$$(-1)^a,\ (-1)^b,\ (-1)^c, \ldots$$

$+\frac{u}{n}$ multiplied by the sum of all the products, two by two of those quantities.

$+\frac{u}{n^2}$ multiplied by the sum of all the products, three by three of the same quantities.

$+\frac{u}{n^3}$ multiplied by the sum of all the products, four by four of the same quantities.

&c. &c.

Hence $\frac{1}{n}$ W = the sum of all the co-efficients, except the first of the terms of an equation, whose roots are $\frac{(-1)^a}{n}$, $\frac{(-1)^b}{n}$, $\frac{(-1)^c}{n}$, &c. multiplied by u; but by the conditions of the pro-

 blem

blem, p of the quantities a, b, c, are even, and q of them odd numbers, or p of the roots of the equation are of the form $\frac{-1}{n}$, and q of the form $\frac{+1}{n}$, and the equation itself is the developement of $\left(x+\frac{1}{n}\right)^p \left(x-\frac{1}{n}\right)^q = 0$,

the sum of all its co-efficients except the first may be found by making $x = 1$, and subtracting unity, this gives

$$\frac{1}{n} \text{W} = \left(1+\frac{1}{n}\right)^p \left(1-\frac{1}{n}\right)^q u - u,$$

$$\text{or} \quad \text{W} = n \left(\frac{n+1}{n}\right)^p \left(\frac{n-1}{n}\right)^q u - n u; \tag{6}$$

if $p = q$ this becomes

$$\text{W} = \frac{(n^2-1)^p}{n^{2p-1}} u - n u \tag{7}$$

if $n = 1$, whatever be the numbers p and q, the loss will be equal to u (unless at the same time $q = 0$), for in that case as soon as the first unfavourable event happens, the player loses not only all he had previously won, but also the sum u besides; and since, by the conditions of the play, he must subtract from u the nth part of all his former loss, which since $n = 1$ is $-u$, his next stake must be $u - u$, or zero; so that in fact if $n = 1$, the first unfavourable decision terminates the game.

I shall now proceed to show how a similar mode of reasoning may be applied to cases where the number of events which happen at each step are more than two.

Suppose a person draw a number of balls in succession from an urn, containing balls numbered 1, 2, 3, 4, . . k, there being many of each kind: he begins by staking the sum u, and if he draw

draw a ball marked one, he receives n_1 times his stake, if the ball be marked two, he receives n_2 times his stake, and so on. The next stake is thus regulated, supposing the ball last drawn to have been marked i, he adds to the last stake the sum $v\,n_i$: any of the numbers n_1 n_2, . . may be negative, if he has drawn p balls marked n_1, q marked n_2, r marked n_3, and so on, what is the amount of his winning?

Let $\alpha, \beta, \gamma, \ldots$ be the kth roots of unity, the expression

$$S_a = \frac{\alpha^a + \beta^b + \gamma^a + \ldots}{k}$$

is always equal to zero, except when a is a multiple of k; also let

$$P_a = n_1\,S_a + n_2\,S_{a+1} + n_3\,S_{a+2} + \ldots + n_k\,S_{a+k-1};$$

then P_a will in every case reduce itself to one of the quantities $n_1, n_2, n_3, \ldots n_k$.

With the aid of these considerations, we can express the amount of the stake at any particular step; his first is u, and whatever be the kind of ball drawn, his profit is always expressed by $u\,P_a$, according to the form of a. In consequence of this first determination, he adds to u the quantity $v\,P_a$, which sum $u + v\,P_a$ forms his second stake; the number of the second ball determines the amount of his second profit, which may be expressed thus:

$$(u + v\,P_a)\,P_b,$$

without at all determining the form of a, the third stake will be $u + v\,P_a + v\,P_b$ and the profit arising from it is

$$(u + v\,P_a + v\,P_b)\,P_c;$$

that in the fourth event is

$$(u + v\,P_a + v\,P_b + v\,P_c)\,P_d.$$

the

the sum of all the profits will be

$$u\,P_a$$
$$u\,P_b + v\,(P_a)\,P_b$$
$$u\,P_c + v\,(P_a + P_b)\,P_c$$
$$u\,P_d + v\,(P_a + P_b + P_c)\,P_d$$
$$u\,P_e + v\,(P_a + P_b + P_c + P_d)\,P_e.$$

It is easily perceived that the co-efficient of u is equal to that of the second term, and the co-efficient of v is equal to that of thethird term of the equation

$$(x + P_a)\,(x + P_b)\,(x + P_c)\,(x + P_d)\ldots = 0;$$

but of the quantities* P_a, P_b, P_c, . . p are equal to n_1, q are equal to n_2, r are equal to n_3, &c. this equation is therefore

$$(x + n\ )^p\,(x + n_2)^q\,(x + n_3)^r\ldots = 0;$$

and the co-efficient of the second term, in its developement, is

$$p\,n_1 + q\,n_2 + r\,n_3 + \ldots$$

whilst that of the third term is

$$\frac{p.p-1}{2}\,n_1^{\,2} + \frac{q.q-1}{2}\,n_2^{\,2} + \frac{r.r-1}{2}\,n_3^{\,2} + \ldots$$

$$+ \frac{pq}{1}\,n_1\,n_2 + \ + \frac{pr}{1}\,n\ \ n_3 + \frac{qr}{1}\,n_2\,n_3 + \ldots$$

so

* This notation has been employed by Mr Herschel, in a paper in the Philosophical Transactions for the year 1818 on circulating functions.

so that the whole profit is

$$W = u\,(p\,n_2 + q\,n \;+ r\,n_3 + \ldots) + v\left\{\frac{p \cdot p-1}{2}\,n_1^{\,2} + \frac{q \cdot q-1}{2}\,n_2^{\,2} + \ldots\right.$$

$$\left. + \frac{pq}{1}\,n_1\,n_2 + \frac{pr}{1}\,n_1\,n_3 + \ldots\right\} \qquad (8)$$

in the case of $n_1 = 1$, $n_2 = -1$, $n_3 = 0$. This formula reduces itself to (1).

Supposing the urn in the last question filled with the same balls, and a person drawing out one receives $n_1, n_2, n_3, \ldots$ times the sum u, according to the number of the ball drawn; and on the second drawing he receives $n_1, n_2, n_3, \ldots$ times the sum of $u +$ the profit by the last drawing: and generally on extracting any ball he receives $n_1, n_2, n_3, \ldots$ times the sum of $u +$ the amount of the profit on all the preceding events, if the number of times each of the balls marked 1, 2, 3, .. are drawn, be respectively denoted by $p, q, r, \ldots$ what is the whole profit?

Adopting the same notation as in the last problem, $P_a = n_1\,S_a + n_2\,S_{a+1} + n_3\,S_{a+2} + \ldots$ will represent either $n_1, n_2, n_3, \ldots$ and the first profit is $u\,P_a$, the second is $(u + u\,P_a)\,P_b$; that in the third is $(u + u\,P_a + u\,P_b + u\,P_a\,P_b)\,P_c$, and the sum of all the profits is

$$\begin{array}{l} u\,P_a \\ u\,P_b + u\,P_a\,P_b \\ u\,P_c + u\,P_a\,P_c + u\,P_b\,P_c + u\,P_a\,P_b\,P_c, \\ \qquad \&c. \qquad \&c. \qquad \&c. \end{array}$$

On

On comparing this with the fourth problem which was solved, it appears that

$$W = u \times \text{ the sum of all the co-efficients except the first of the equation } (x + P_a)(x + P_b)(x + P_c) \ldots = 0,$$

or $$W = u(1 + P_a)(1 + P_b)(1 + P_c) \ldots - u;$$

but p of the quantities $P_a, P_b, P_c, \ldots$ are equal to n_1, q of them to n_2, r of them to $n_3, \ldots$ This equation, therefore, becomes

$$W = u(1 + n_1)^p (1 + n_2)^q (1 + n_3)^r \ldots - u \qquad (9)$$

if $n_1 = \frac{1}{n}$, $n_1 = -\frac{1}{n}$, $n_3 = 0$, and $u = n u$. This coincides with (6).

As an example, suppose an urn filled with balls of three colours, white, black, and red, and that the person who draws them out may name any sum he chose prior to each extraction; if he draw a white ball, the sum he named is paid to him; if a black, he loses one-half of it; and if a red one, he loses one-third of that sum. And suppose he regulates the sum named in the following manner, beginning with naming u whenever he has drawn a white ball, he adds the whole of his previous winnings to the sum u; but if he has drawn a black one, he adds only half his profits to the sum u; and if the ball last extracted from the urn was red, he adds one-third of all his profits to the same sum u. He has drawn out p white, q black, and r red balls, what is the amount of his profit or loss?

In

In this case $n_1 = 1$, $n_2 = -\frac{1}{2}$, $n_3 = -\frac{1}{3}$, $n_4 = n_5 = \ldots = 0$

and we have

$$W = u\,2^p \cdot \frac{1}{2^q} \cdot \frac{2^r}{3^r} - u = \frac{2^{p-q+r}}{3^r} u - u.$$

The questions examined in the preceding pages afford an instance of the immediate application of some very abstract propositions of analysis to a subject of constant occurrence, which being as far as I have been able to discover, hitherto untouched, and also requiring reasoning of rather an unusual nature, I have preferred treating in particular instances, instead of investigating it in its most general form. The principles on which similar problems should be attempted, are first by means of some combinations of the roots of unity to represent the stake after the decision of any number of events, and then by means of any known theorems respecting the roots of equations, to ascertain the sums of the series which present themselves in the result.

XI. *On the Radiation of Caloric. By* The Reverend THOMAS CROMPTON HOLLAND.

(Read Feb. 7. 1820.)

THE various facts concerning the radiation of caloric present a very interesting subject of inquiry, and various theories have been formed, with a view to their explanation. The principal difficulty has been to explain the facts of the apparent radiation of cold. The most simple theory with respect to these, is that proposed by M. PREVOST of Geneva. He supposes, that all bodies are always radiating caloric in proportion to their temperature, and that those surfaces, which radiate least, make up for the deficiency, by reflecting most; so that the combination of reflection and radiation from any surface, when *in æquilibrio* with the surrounding bodies, is the same. When a body is heated, its radiation is increased, and therefore, when placed near a thermometer, it radiates more to the thermometer than it receives from it, and therefore elevates its temperature. When, on the other hand, a body is cooled, it intercepts from the thermometer near it part of the radiation of the surrounding objects, and it radiates less than it receives. The thermometer must therefore sink. The principal objections that have been urged against this theory, are de-

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rived from the apparent reflection of cold by concave mirrors; and from the circumstance, that a blackened surface, which, when heated, produces more heat than a polished one, when cooled, produces more cold, though in the latter case it must be supposed to radiate most caloric. In THOMSON's *Annals*, vols. v.—viii. are given various papers by M. PREVOST and Mr DAVENPORT, which appear to me to afford a complete explanation of these facts; but, from the conciseness of their statements, and from their not being illustrated by calculations or diagrams, they are not easily comprehended, and appear not to have been generally understood. Mr DAVENPORT's statement is, "Fill a canister, of which one side is polished, and the other black, with a freezing mixture. Has not the black surface lost a part of its intensity of radiation? This cannot be denied. Has the polished surface lost its power of reflection? The answer must be in the negative. It follows then, that unequal diminutions have been imposed on those powers of returning heat to the thermometer, which before were equal. The radiating surface has lost more than the reflecting one, and its thermometer receives less return, than that on the reflecting side." This appears to me a satisfactory explanation; but from the difficulty of comprehending the reasoning, without reducing it to calculation, it seems not to have been generally understood. Dr MURRAY, after admitting both the premises, objects to the concluion. He says, "The clear surface has also had its intensity of radiation proportionally reduced. And at any temperature, the blackened surface radiates more caloric than the clear surface does at the same temperature. The former, therefore, returns more caloric to thethermometer than the latter, or at least, allowing all the effect that can be ascribed to difference of reflection, no cause is assigned why it produces a greater degree of cold."

From

From considering the subject, before I had seen Mr Davenport's papers, the following explanation occurred to me. It is in principle the same with his, and only differs from his, in being, I think, more easily understood, and in showing from the calculation, how Dr Murray's objection may be completely obviated. Plate XI. Fig. 4, let P be a polished body, and B a black one. Let their combined powers of radiation and reflection, when *in æquilibrio* with the thermometer, be represented by 1. In P, let the reflection be $\frac{3}{4}$, the radiation $\frac{1}{4}$. In B, let the reflection be $\frac{1}{4}$, the radiation $\frac{3}{4}$. Now, it is only the radiation which can be affected by changing their temperature. Let their temperature be raised, till their radiating power is doubled. Then,

	reflects,	radiates,	sum,	excess above the equilibrium,
P	$\frac{3}{4}$	$\frac{2}{4}$	$1\frac{1}{4}$	$\frac{1}{4}$
B	$\frac{1}{4}$	$\frac{6}{4}$	$1\frac{3}{4}$	$\frac{3}{4}$

Now, as it is only the excess above the equilibrium that can affect the thermometer; B, which radiates 3 times as much as P, will affect the thermometer 3 times as much. Now, let each body be cooled, till it radiates only $\frac{1}{2}$ as much as when *in æquilibrio*. Then,

	reflects,	radiates,	sum,	defect from the equilibrium,
P	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{8}$
B	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{5}{8}$	$\frac{3}{8}$

But it is the defect from the equilibrium only that can affect the thermometer; and therefore B, which, when heated, produces 3 times as much heat as P, when cooled, produces 3 times as much cold; though in all cases it radiates 3 times as much

much caloric. This reasoning will be much confirmed, by considering the circumstances which will occur, when the surface of the thermometer is supposed to be changed. Fig. 5, let P be a thermometer with a surface of polished metal, and B a blackened thermometer, and their radiating and reflecting powers as above. Let A be any body. Then while they are all *in æquilibrio*, A acts as 1, of which

$$\left\{\begin{array}{l} P \text{ - - } \frac{3}{4} \\ \quad\text{reflects,} \\ B \text{ - - } \frac{1}{4} \end{array}\right\} \begin{array}{r} \text{- - } \frac{1}{4} \\ \text{radiates,} \\ \text{- - } \frac{3}{4} \end{array}\Bigg\}.$$

Now, if the temperature of A be changed, it is the reflection from the thermometers that will be proportionably altered; their radiation will remain the same till their own temperatures are changed. Let A be heated till its action is as 2. Then,

$$\left\{\begin{array}{l} P \text{ - - } \frac{6}{4} \\ \quad\text{reflects,} \\ B \text{ - - } \frac{2}{4} \end{array}\right\} \begin{array}{r} \text{- - } \frac{1}{4} \\ \text{radiates,} \\ \text{- - } \frac{3}{4} \end{array}\Bigg\} \begin{array}{r} \text{- - } 1\frac{3}{4} \\ \text{sum,} \\ \text{- - } 1\frac{1}{4} \end{array}\Bigg\} \begin{array}{r} \text{- - - - - } \frac{1}{4} \\ \text{defect from 2,} \\ \text{- - - - - } \frac{3}{4} \end{array}\Bigg\}.$$

But it is this last quantity, namely, the difference between the action of the thermometer and that of the heated body, which operates to raise the temperature of the thermometer; and therefore, that with the blackened surface will shew 3 times the sensibility to heat that the polished one does.

Next let A be cooled till its action is as $\frac{1}{2}$. Then,

$$\left\{\begin{array}{l} P \text{ - - } \frac{3}{8} \\ \quad\text{reflects,} \\ B \text{ - - } \frac{1}{8} \end{array}\right\} \begin{array}{r} \text{- - - } \frac{1}{4} \\ \text{radiates,} \\ \text{- - - } \frac{3}{4} \end{array}\Bigg\} \begin{array}{r} \text{- - } \frac{5}{8} \\ \text{sum,} \\ \text{- - } \frac{7}{8} \end{array}\Bigg\} \begin{array}{r} \text{- - - - - - - } \frac{1}{8} \\ \text{excess above } \frac{1}{2}, \\ \text{- - - - - - - } \frac{3}{8} \end{array}\Bigg\}$$

But it is this last quantity, the difference between the action of the thermometer and that of the cold body, which affects the temperature of the thermometer, and therefore the blackened

ened surface will be 3 times as sensible to cold as the polished one.

Thus this theory explains why those surfaces which radiate the most caloric, produce the greatest cold when cooled, and are most sensible to the impressions either of heat or cold from surrounding bodies. It is equally applicable to the apparent reflection of cold. In Fig. 1, 2, 3, let DEFG be the section of a room. In Fig. 1. let the thermometer T be near a plane mirror AB. This prevents the radiations from the wall DE from reaching T. But this is compensated by its reflecting on T a part of the rays which proceed from the space HGFI. Of these the cold body C intercepts the portion KL, and therefore the plane mirror will increase the cold, but in a very minute degree, in the proportion of KL to HGFI. Fig. 2., AB is a concave mirror. This also intercepts the same radiation DE, and, if the thermometer be in the focus of parallel rays, the mirror reflects on it rays proceeding from HI, and these are rendered equivalent to those from HGFI in the former case, because the plane reflects only some of the rays on T, while the concave mirror concentrates at its focus all the rays from HI. But when the cold body is introduced, it intercepts the same space KL as before. The degree of cold, therefore, from one concave mirror, should be as KL to HI, that is, evidently much greater than in the last case. This is supposing the thermometer to be placed exactly in the focus of parallel rays. But if it be placed so that all rays proceeding from C would be converged upon it, then only such rays as MCB, which pass through C, will be reflected on T. When the cold body is introduced at C, it will therefore intercept all these rays, and a much greater cold will be produced.

Fig. 3. represents the action of 2 concave mirrors. Here AB intercepts the radiation from DE, and KL that from HI, and

and it also prevents any of the rays from HI reaching the mirror AB. This is compensated for, because all such rays, as MCL or NCK, from MDEN which pass through C, and fall on KL, are by it reflected in parallel lines to AB, and by the second mirror are concentrated at T. But when the cold body is introduced at C, it intercepts the whole of these rays, and therefore great cold is produced. This explanation of the apparent reflection of cold is precisely the same with that given by Mr Davenport; but, from his having attempted to express it without using diagrams, his statement is not easily understood.

In this paper, therefore, the part which is absolutely new, is that which relates to the sensibility of different surfaces to the impressions either of heat or cold. I hope, however, that I have succeeded in making the other parts more easily understood than former writers have done. This explanation of these facts on the theory of all bodies always radiating caloric in proportion to their temperatures, appears to me to furnish a decisive confirmation of that theory, as it shows, that the circumstances which have been supposed to be the strongest objections against it, are in fact necessary consequences from it.

Fig. 4.

Fig. 1.

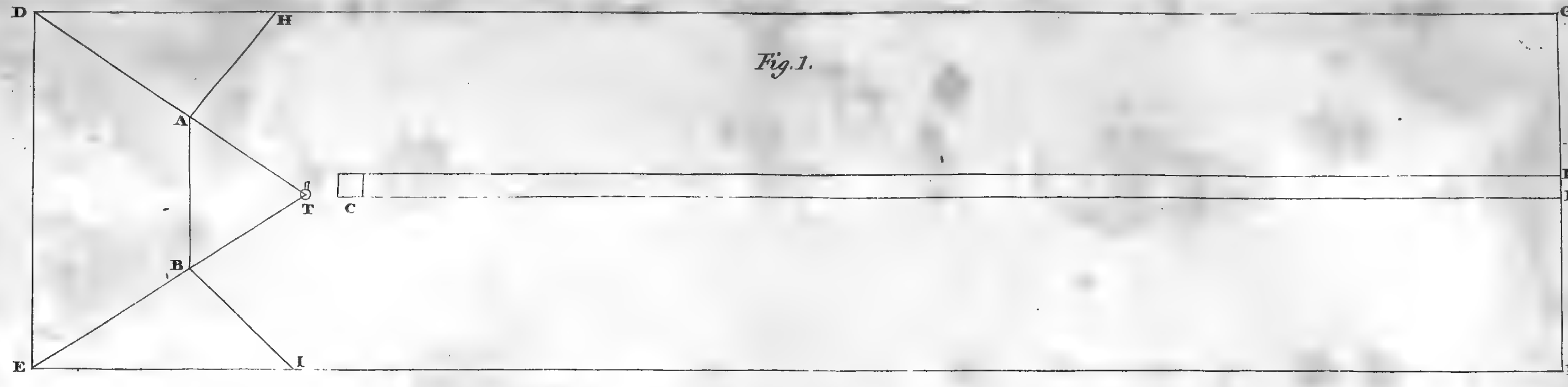


Fig. 2

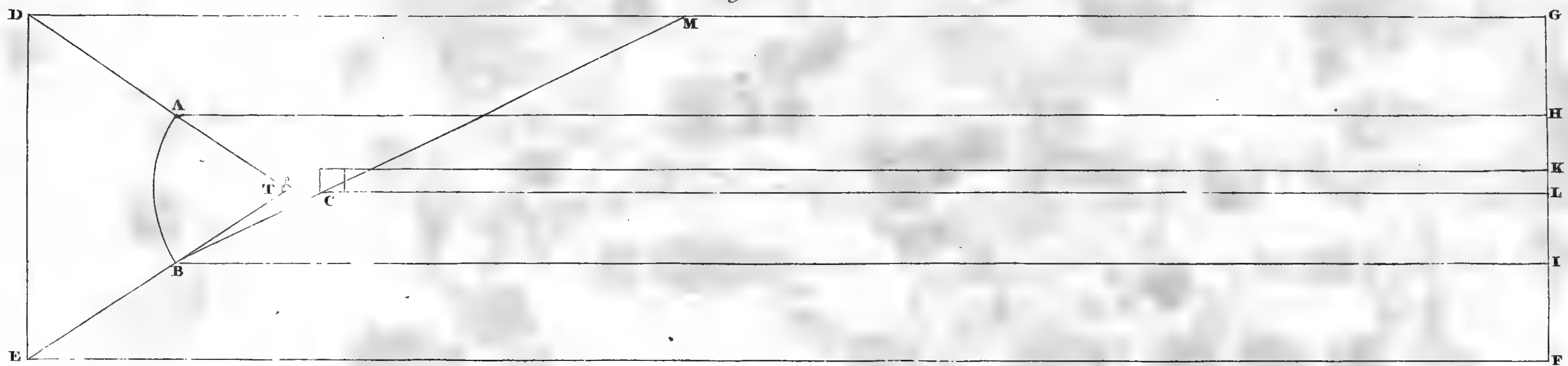
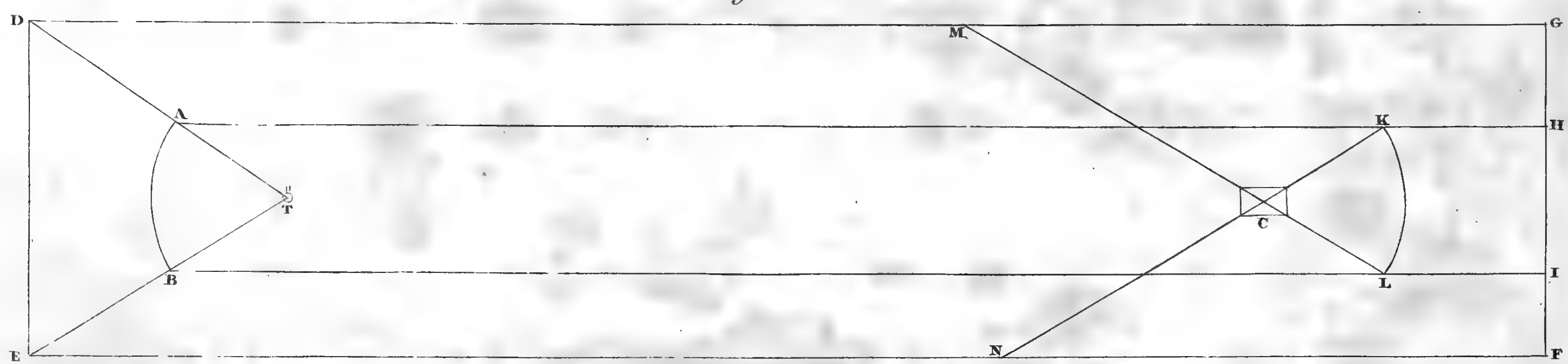
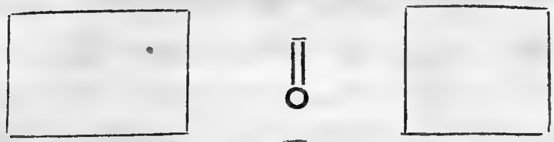


Fig. 3



W. H. Lizars Sculp.

Fig. 4.



In æquilibrio.

	reflects	radiates
P	$\frac{3}{4}$	$\frac{1}{4}$
B	$\frac{1}{4}$	$\frac{3}{4}$

When heated.

	reflects	radiates	sum	excess above the equilibrium
P	$\frac{3}{4}$	$\frac{2}{4}$	$1\frac{1}{4}$	$\frac{1}{4}$
B	$\frac{1}{4}$	$\frac{6}{4}$	$1\frac{3}{4}$	$\frac{3}{4}$

When cooled.

	reflects	radiates	sum	defect from the equilibrium
P	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{8}$
B	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{5}{8}$	$\frac{3}{8}$

Fig. 5.

In æquilibrio.

	reflects	radiates	
P	$\frac{3}{4}$	$\frac{1}{4}$	A acts as 1
B	$\frac{1}{4}$	$\frac{3}{4}$	

When A acts as 2.

	reflects	radiates	sum	defect from 2
P	$\frac{6}{4}$	$\frac{1}{4}$	$1\frac{3}{4}$	$\frac{1}{4}$
B	$\frac{2}{4}$	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{3}{4}$

When A acts as $\frac{1}{2}$.

	reflects	radiates	sum	excess above $\frac{1}{2}$
P	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{8}$
B	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{3}{8}$

XII. *Notice respecting a Remarkable Shower of Hail which fell in Orkney on the 24th of July* 1818. *By* Patrick Neill, F. R. S. E., F. L. S. & Sec. Wern. Soc.

(Read March 1. 1819.*)*

THE notice which, at the suggestion of Dr Brewster, is now to be laid before the Society, respecting a remarkable shower of hail which lately fell in Orkney, has been drawn up partly from conversations with Richard Caithness, a plain but intelligent country man, who possesses a small farm at Hunday in the island of Stronsa, and whose property suffered severely from the shower; and partly from subsequent correspondence with the Reverend William Taylor of Stronsa, whose house lay in the track of the cloud, and with Mr Robert Lindsay, Student of Divinity, who had an opportunity of witnessing the effects of the hail at Lopness, on the neighbouring island of Sanda, when the shower was nearly exhausted. They agree in all important particulars; but even at the risk of some repetition, their own words shall, as often as possible, be employed.

The morning of the 24th of July 1818, was, in Orkney, clear and warm, with a slight air of wind at due south. About midday the atmosphere became overclouded, and somewhat agitated; the wind about this time veering a point or two to the west

west of south, and occasionally rising into a breeze. Between twelve and one o'clock, thunder and lightning began; and after these had continued with little intermission for about an hour and a half, a very dense jet-black cloud forcibly attracted attention by its foreboding appearance. Mr Taylor was in the upper part of his house when he first observed this black cloud, apparently rising from the sea, at the distance, he thinks, of about five or six miles. It then seemed of no great dimensions; but its magnitude was gradually developed, as it approached steadily, and apparently with increasing velocity, from the southward, in a direct line toward the centre of the island. It now assumed a dismally ominous aspect, and occasioned a considerable degree of darkness. The lightning became proportionally more vivid, and the peals of thunder were tremendous. Mr Taylor remarked one flash of lightning to be not only brighter than the rest, but to exert a more extensive influence on the cloud, which seemed as if cleft asunder, and presented a momentary opening of the prospect between the Mainland of Orkney and the island of Stronsa. The thunder-bolt on this occasion seemed to strike the surface of Stronsa Frith in the manner of a solid body dashing into the sea.

Richard Caithness was engaged in the making of kelp on the shore, when he perceived the cloud advancing fast towards his own farm-steading. He immediately hurried home. At this time the wind began to rise; the surface of the sea was greatly ruffled; and darkness like that of night threatened to come on. Just as he reached his house, the cloud overtook him. The lightning was now instantaneously followed by noises, like the firing off of "guns in Stronsa Caves." Hailstones of very uncommon magnitude began to fall. The first large hailstone which Mr Caithness saw, came

came through the glass of one of his windows, and struck the floor violently: it was, to use his own phrase, "really like a "goose-egg." In two or three minutes more, the wind increased almost to a hurricane; and instead of hailstones of the usual shape, "pieces of ice," of almost all forms, were precipitated with the utmost violence. Not only was every pane of glass in the windows of the house, fronting the south, speedily broken, but the cabbage-plants in the garden immediately adjoining, and which could be seen from the windows, seemed as if suddenly cut over, and strewed about the ground *. The "clattering noise" of the hail which fell in the sea at this time, is described by Mr CAITHNESS as quite terrific; and, having been induced by this strange noise to look particularly in the direction of the sea, he adds, that not only did the hail keep the water as it were boiling, and covered with white foam, but he repeatedly saw the lightning striking from the cloud into the sea, and the water, where it was struck, "dashing up as high as masts of ships." The lightning was not forked or zig-zag, but rather in the form of balls or masses of fire. The whiteness of the foam of the sea was rendered more evident, and the brightness of the fire more intense, by the contrast of the surrounding darkness.

The farmer and his family had not recovered from the consternation excited by such an extraordinary event, when the wind and hail ceased, and the sky began to clear. When they ventured to look abroad, the fields presented a scene of perfect desolation. In the "close" or farm-court, surrounded by offices, the hailstones had accumulated, and lay a foot and a half deep! In the open fields, although they did not perhaps exceed the

* These cabbages, it may be remarked, were of the large red Aberdeen sort, well known to be the strongest and coarsest of the tribe.

the half of this depth, yet not only were the crops of every kind utterly beaten down, but not a vestige of them was for some time to be seen. The astounded farmer saw only " fields of rough " ice." All this destructive change had been accomplished in less than ten minutes.

Alarmed by the " horrid cries," very different from the usual bellowing, of some black cattle, which had been grazing on pasture-land at some distance, CAITHNESS attempted to wade out among the hailstones in the direction of the cattle. The " loose ice," he says, slipped below his feet, and sometimes reached to his knees. In this way his legs were so much cut by its sharp edges, that he was soon obliged to desist, and to wait till the ground began to appear, by the melting of the hail. The pieces of ice he describes as of various shapes: most of them were round like eggs; many were flattened, and not unlike " thick clumsy oyster-shells;" some were nearly smooth on the surface, others very ragged and jaggy. Some of these appearances probably arose from the hailstones being partly dissolved. Mr TAYLOR likewise remarks, that some " were as finely polished as marble-bowls, " while others were irregular, and apparently made up of pie- " ces of conglomerated ice." Mr TAYLOR regrets that he did not immediately weigh some of the largest balls, before they began to melt; for he was unluckily not provided with a graduated jar, with which to ascertain the liquid contents. He adds, however, that he " had presence of mind to measure " some of the largest lumps," and that several of them were about six inches in circumference. Mr CAITHNESS thinks, that the largest pieces of ice which he lifted, might weigh from four ounces to nearly half a pound: but he adds, what was extremely natural, that, at the moment, he thought only of the damage his farm had suffered, and it never entered into his mind

mind to weigh the instruments of destruction. He describes the hailstones as being generally of a greyish-white colour, not unlike fragments of light-coloured marble.

The terrified black cattle and horses, which had broken their tethers, and been observed, at the beginning of the fall of hail, running violently backward and forward, galloping and flinging, had now collected together in a herd. CAITHNESS at length made his way to them through the half-melted ice: they still trembled exceedingly; some of the horses had lain flat down on the grass, with their heads stretched out; and all of the animals were more or less cut, and bleeding. Some of the weaker horses, the farmer says, will never recover: the milch cows, he adds, were "struck *yeld*," or gave no more milk, and indeed would not suffer the people to attempt to milk them any more.

On the links or downs, at some distance from CAITHNESS's house, a large flock of tame geese had been feeding: these, he remarked, seemed to remain motionless on the turf; and on proceeding to the place, he found no fewer than sixty wholly deprived of life; a few were still living, but so much injured, that all of them pined away and died in a short time. Some of these poor birds had their bills split; others had an eye struck from its socket, and hanging by the nerve; and the brains of some were fairly knocked out: many had either a leg or a wing broken.

The weather being warm, the ice soon disappeared; and CAITHNESS's fields, which, less than an hour before, had been covered with corn-crops * just beginning to come into ear, and superior in luxuriance to what had been seen in Orkney for many

* Grey oats, Avena strigosa, L.; and bigg, a small variety of Hordeum tetrastichon; which are the only kinds of white crop cultivated with success in these islands.

many years, seemed (to use the farmer's expression) to have been "absolutely plowed black."

It may be remarked, that the sudden production of cold, and consequent congelation, had taken place at a considerable elevation in the atmosphere, for, as Mr CAITHNESS observed, the hailstones must have fallen with great force, since many of those which fell first were sunk in the corn-fields from three to four inches deep; and even in the firm old pastures, each of the first-fallen hailstones had made a hole in the sward exactly of its own size and shape, to the depth generally of about two inches. In some of these holes the balls of ice lay unmelted, long after the others had disappeared. Mr TAYLOR says, that the surface of the ground all around his house was every where perforated as with the "broad point of a "country man's staff;" and it retained this appearance for several days.

It may further be remarked, that the hailstones had fallen not only from a great height, but, owing to the strength of the wind, at a very considerable angle. Mr TAYLOR was obliged to flee from one room to another in his house, in order to avoid the fragments of glass, which were driven to the farther side of the apartment. In Mr TAYLOR's bed-room, the wash-hand bason, although standing at some distance from the window, was shivered in pieces by a hailstone.

As the ice melted away, great numbers of small birds, particularly skylarks, *stares* or starlings, corn-buntings, and *chacks* or wheat-ears, were found dead, and were collected "in heaps" by the boys belonging to CAITHNESS's farm. On the shore, near to a point called Torness, were observed numbers of rock-pigeons, hooded crows, *tysties* or guillemots, and *stock-ducks* or mallards, which had been killed at sea by the hail, and were left by the receding tide. Many wounded gulls and

picktarneys

pictarneys or sea-swallows, were seen floating on the sea, occasionally attempting to fly, but unable to raise themselves.

Owing to the fortunate circumstance of the thunder and lightning having for some time preceded the great fall of hail, the people at work in the fields, and on the "kelp-shore," in the track of the cloud, had all taken shelter. One boy alone, named PETER STEVENSON, suffered from exposure: he was at a distance from any house when the hail began; he threw down a bundle which he was carrying, and ran towards a projecting crag at the sea-beach for protection; but before he could reach it, he received a severe blow on the back of the neck, which stupified him, and produced a contusion, from the effects of which he had not recovered after the lapse of six months. Four men in a boat, at some distance from land, were exposed to a part of the shower, and had their hands much cut and bruised by the hailstones. Had they been subjected to its full violence, they would probably have perished.

It does not appear that the electric fluid had any share in killing the geese or other birds, at least no marks of discoloration or singeing were observable on the feathers, and the palpable blows which the animals had received, were fully sufficient to account for their death. The cows being "struck "*yeld*," as CAITHNESS expresses it, seems a curious circumstance; it is ascribed by him to the dreadful fright they got. The wounds received by the cattle and horses were all evidently inflicted by the hailstones. It is proper to add, however, that, in some places, CAITHNESS observed the surface of the pasture-grass to be much discoloured and scorched-like; and a good deal of the broken straw of the grain-crops likewise "coloured white by the fire, as if it had been sudden-"ly ripened." Mr TAYLOR informs me, that when he first went abroad, immediately after the cloud had passed over, he was not only sensible of a sulphureous smell, but that it was so strong that he had speedily to return for a draught of water, in order to remove the disagreeable sensation in the throat. He observed that the cattle afterwards avoided certain scorched parts of the pasture, which did not recover their verdure till repeated showers had refreshed them.

Richard Caithness was not the only farmer whose crop and farm-stocking were injured. George Foulis, tenant of the farm of Holland, a possession of much greater extent and value, was equally involved in the devastation. This farm, lying to the southward of Hunday, was of course to the windward; and Mr Caithness told me, that the "dismal yells" of Foulis's wounded cattle, on the high grounds between the two farms, and which reached him, notwithstanding the noise of the hail, produced a feeling of horror which he could not describe,—but that the cries seemed still to sound in his ears. These two, however, were the only farmers who suffered severe damage; although many families of *cottars*, or humble dependants, had their patches of corn and potato crops completely destroyed.

The meeting-house and manse of the Reverend Mr Taylor were in the line of the cloud. In both, the south windows were wholly shattered, not only the glass, but the wooden astragals being broken. Mr Taylor observed by his watch the duration of the violent wind and heavy hail, and states it to have been little more than eight minutes.

Both Mr Taylor and Mr Caithness concur in describing the thick layer of ice or hail as forming a tolerably well-defined belt across the island, in a direction from S. S W. to N. N E., passing through the centre of the old parish of St Nicolas. This belt, they think, might be about a Scots mile broad, —perhaps nearly a mile and a half English; and beyond this line,

line, on each side, the ground appeared "spotted with ice," to the extent of about half a mile more. In confirmation of the accuracy of their observations regarding the extremely local nature of the shower, it may be mentioned, that persons who had been employed the whole day in digging turf in a peat-moss near Rothiesholm Head, which supplies the island with fuel,—at the distance of little more than two miles in a direct line westward from CAITHNESS's house, though considerably to the southward,—were wholly exempted from its influence, and wondered very much when, in passing homewards in the evening, they witnessed the devastation which had been produced within the track of the hail. They had indeed observed a very thick black cloud shooting past the high rocks of Rothiesholm Head in the afternoon; they had seen bright lightning, and heard loud thunder; but they had not been touched by the hail. The same thing happened to the eastward; the farm of Cleat, situated only about a mile and a half distant in that direction, having scarcely been affected by the shower. But even to the southward, (the direction from which the cloud came,) the range of the storm was very limited. The peninsula of Deerness, belonging to the Mainland of Orkney, was directly in the line, about seven or eight miles to the S. S W.; yet it remained untouched. Mr CAITHNESS indeed mentions, that he had spoken to some "Deerness men," who were that day fishing off the Moul Head, the most northerly point of Deerness, and who told him, that they observed the cloud thickening and blackening as it rolled on towards Stronsa.

It would appear, therefore, that the accumulation of electric matter came to a crisis over the sea, at the distance of about three or four miles only, to the S. W. of Stronsa. The cloud swept up Rothiesholm Bay, and crossed the island in the way already described. When nearly in an exhausted state, it

 touched

touched the north-east corner of the island of Sanda. Mr Lindsay (already mentioned) happened at this time to be at the house of Mr Strang of Lopness, situated in that part of Sanda. Although the main force of the shower was now spent, the effects were still formidable; a good deal of the glass in the windows having been shattered. As the cloud was passing off, it occurred to Mr Lindsay to observe the state of Mr Strang's barometer; and he found the mercury sunk so low, that it was necessary to mark its place on the wooden frame, the scale, as is not uncommon in old barometers constructed for this country, not being graduated lower than 28 inches. Lieutenant Baikie, R. N. has since extended the scale, and found Mr Lindsay's mark to indicate 27.76. When the cloud had completely passed, Mr Lindsay, having gone into the garden, observed that the "cabbages were perforated as if musket-bullets had been shot against them."—"About an hour afterwards," he adds, "I picked up some that still remained undissolved, and found that they measured $1\frac{3}{20}$th inch in diameter. They were for the most part of a spheroidal form, consisting of a nucleus resembling common hail, occupying about one-third of the diameter, encrusted by a coating of transparent ice. Some of the stones, however, were irregularly formed into a sort of crystallized mass." Mr Strang's house is situated about twenty feet above the medium level of the sea.

The last remains of the shower, it may be added, were slightly felt on the south-east point of the island of North Ronaldsha.

The whole extent of the course of the hail-storm, from S. W. to N. E., was thus little more than twenty miles; and, as nearly as I can learn, it travelled this space in less than half an hour, or at the rate of a mile in a minute and a half, as it required between eight and nine minutes for its passage over

Mr

Mr TAYLOR's house. The cloud, when at its highest pitch of accumulation, appears to have extended at once between five and six miles in length.

In the afternoon the sky was clear, the wind hushed, and the air warm and genial.

Being aware that at all the Northern Light-houses, registers of the state of the barometer and thermometer are regularly kept, (an attention to the interests of science which is highly praiseworthy,) I applied to Mr STEVENSON, Engineer to the Commissioners, for an extract of the register at the light-house at the Start Point, or eastern extremity of Sanda; which he most readily granted me. It appeared that the hail had not at all touched the light-house, although, as already mentioned, it had broken the glass of the windows of the house of Lopness, not an English mile distant. Mr CHARLES NISBET, the principal light-keeper, writes thus to Mr STEVENSON. "I was at work in the field, putting up some hay at the time: the sky was very black to the south-west, with thunder. In a short time rain began to fall heavy, with a sharp breeze of wind, but not the least appearance of hail. I was therefore surprised the next day, when I heard of the mischief done by the hail at Lopness. The fall of rain at the farm-house of Selibuster" (situated as far to the west of Lopness as Start Point is to the east) "was very heavy, and was followed by some hail."

The following is an extract from the Start Point register, from 20th to 30th July 1818.

STATE

State of the Barometer and Thermometer in the Start Point Light-house, the instrument being situated a hundred feet above the medium level of the sea.

	Rain in Inches.	Winds.			Time of Noting.	Therm. in degrees.	Barometer in inches.
1818.					8 A. M.		
July 20.	—	South	Light airs	Clear	—	53	30.07
21.	—	do.	Breeze	do.	—	55	29.72
22.	.10	do.	do.	do.	—	57	29.70
23.	—	West	do.	do.	—	57	29.92
Hail storm. 24.	—	South	Gale	Foggy	—	57	29.68
25.	.23	East	Breeze	Clear	—	57	29.72
26.	—	South	do.	do.	—	57	29.83
27.	.45	West	Light airs	do.	—	59	29.98
28.	—	N. W.	Breeze	do.	—	55	30.12
29.	—	S. E.	do.	Hazy	—	56	30.02
30.	.27	North	do.	do.	—	55	29.70

From this extract, it appears, that at 8 in the morning of the day of the shower, the mercury in the barometer stood at 29.68, and that on the following morning, at the same hour, it was at 29.72. The effect of the hail-storm, in producing, for a short time, a more attenuated state of the atmosphere, was therefore very remarkable; the mercury, as observed by Mr Lindsay, having sunk two inches, or to 27.76, during the passage of the cloud, or immediately after its passage.

Such are the particulars of this remarkable meteoric occurrence which have come to my knowledge. I am aware, that accounts of similar hail-storms are upon record, particularly in the *Philosophical Transactions*. But I have not thought it necessary at this time to examine these, nor to institute any comparison; my only object being to add to the stock of facts.—

For

PLATE XII.

Engraved for the Royal Society Trans. Vol. IX. page 199

Drawn by G. C. Scott Mr. Stevensons Office.

W.H. Lizars Sculpt.

For the same reason, I have considered it unnecessary to advert to any of the hypotheses which have been suggested by philosophers, in order to account for such hail showers; for the sudden coalescing of the watery vesicles, and their almost simultaneous conversion into ice.

On the accompanying little Map, Plate XII., traced from Murdoch Mackenzie's General Chart of the Orkney Islands, the track of the hail-shower is pretty accurately laid down, and its very local nature is thus exhibited in a more striking manner.

XIII.

XIII. *Observations on the Mean Temperature of the Globe.*

By David Brewster, LL. D. F. R. S. Lond. & Sec. R. S. Edin.

(Read February 7. 1820.*)*

If no provision has been made by the Great Author of Nature, for equalising the light and heat projected upon the different bodies of our system, we may consider the earth as receiving, from the direct action of the solar rays, a degree of heat, intermediate between the condensed radiations sustained by Mercury and Venus, and the attenuated warmth which reaches the remoter planets. The heat which our Globe thus acquires from its locality in the system, is again tempered by the obliquity of its axis, and is distributed over the same parallels of latitude by its daily rotation. When the Sun is in the Equator, his rays, beating on the Earth with a vertical influence, impart to it the full measure of their action; and as his meridian altitude decreases, their intensity suffers a corresponding diminution. The burning heat at the Equator becomes moderated in higher latitudes. In passing through the temperate zone, it declines with great rapidity, and between the Arctic Circle and the Pole, the rays of the Sun are unable even to temper the piercing cold which reigns in these inhospitable regions.

 This

This gradation of temperature, so obvious to the sensations of those who have visited southern climates, is still more distinctly indicated by its physical and moral influence. The arid plains of a tropical climate, where vegetable life is almost extinguished by excessive heat, gradually shades into the more luxuriant regions of the vine and the olive. The mild and uniform temperatures of Spain and Italy, are again followed by the variable climate, and the more verdant kingdoms in the north of Europe. Then succeeds the region of blighted vegetation, where nothing can exist but the birch and the pine, and the chain of vegetable life terminates in the hoary desolation of the Arctic Zone.

The progression of climate is no less distinctly marked by the developement of the human faculties. Indolent and impatient of thought under the debilitating influence of a sultry atmosphere, man begins to unfold his capacities as he is removed from the Torrid Zone. In more temperate climates, he cultivates those faculties which do not lead to very rigorous application; and under the invigorating influence of a colder sky, the mind attains that maturity of its powers, which fits it for the most abstract and profound speculations. From this region, distinguished as the seat both of ancient and modern civilisation, the mind again sinks under the torpor of extreme cold, and the distinctive characters of our species disappear among the diminutive inhabitants of the Polar latitudes.

The investigation of the mean temperature of the Earth, connected, as it thus appears to be, with many interesting inquiries of a moral and physical nature, has not been pursued with the same zeal as other branches of knowledge. Long after the invention of the thermometer, no attempt had been made to apply it to meteorological purposes; and though, for more than half a century, its indications have been registered

in

in many parts of the world, yet the observations with it have commonly been guided by no settled principle, and are, therefore, frequently unfit for the purposes of generalisation. Philosophers were satisfied with deducing a law of temperature from theoretical considerations; and disdained the humbler and more laborious task of interrogating the mass of facts which had been accumulated by zealous and active observers.

The first person who attempted to deduce from observation a general expression for the mean temperature, at all latitudes, was the celebrated astronomer TOBIAS MAYER of Gottingen. Assuming that the heat varies as the square of the sine of the latitude, he obtained the formula $T = 58 + \overline{26 \times \text{Cos. } 2\,\text{Lat.}}$, in which 58 is the mean temperature of 45° of north latitude, and 26° the difference between the temperature of that parallel and the Equator. M. LICHTENBERG, the editor of MAYER's posthumous works, applied this formula to 13 observations of mean temperature made between the Cape of Good Hope and Stockholm, and their agreement was considered at that time to be remarkable. The sum of all the errors was 26°.8, or a little more than 2° on each observation; but as the errors in excess amounted to 22°.3, while those in defect were only 4°.5, it should have been obvious that the formula was founded upon an incorrect assumption.

The formula of MAYER was implicitly adopted by KIRWAN, in his able work *On the Mean Temperature of the Earth*; and has been more recently brought forward, as connecting together, "in a most harmonious manner," the results of distant temperatures, although the fine series of observations, collected by HUMBOLDT, had demonstrated its inaccuracy, and proved, that even in the parallel of 63°, it erred in excess no less than 9° of Fahrenheit.

 The

The beautiful memoir of HUMBOLDT on the *Isothermal Lines*, or lines of equal temperature, and on the distribution of heat over the globe *, has given a fresh impulse to this fundamental branch of Meteorology, and will, no doubt, introduce a new degree of precision into those loose and indefinite records of temperature which have been so generally accumulated in every part of Europe. In attempting to reconcile the formula of MAYER with the observed results as given by this celebrated traveller, I expected to succeed, at least for the western regions of the Old World, by the adoption of more correct co-efficients; but as I proceeded in the inquiry, I saw that the principle of the formula was entirely irreconcileable with well established facts, and I therefore sought for a law different from the duplicate ratio of the sines.

In comparing the temperature of the Equator with that of 45°, and with that of the highest latitude in HUMBOLDT's series, it was obvious that the cold increased much more rapidly towards the poles than had been believed; and upon extending the comparison to the intermediate temperatures, I found that the mean heat of any place was well represented by the radius of its parallel of latitude, or, in geometrical language, that the temperatures varied with the cosine of the latitude. In expressing this law I have assumed $81\frac{1}{2}°$ as the mean temperature of the Equator, the very same number which HUMBOLDT has preferred as the mean of various results under distant meridians. The formula therefore becomes

$$T = 81\tfrac{1}{2} \text{ Cos. Lat.}$$

The

* This Memoir has been translated into English, and published in the *Edinburgh Philosophical Journal*, vol. iii. and iv.

The following Table contains the observed mean temperatures of thirty-one places, situated between the Equator and the parallel of 70° of north latitude, together with the calculated results, as given by the preceding formula, and by that of Mayer, in its latest form.

TABLE OF MEAN TEMPERATURES.

	Latitude.	Observed Mean Temp.	Calculated Mean Temp.	Difference.	Mayer's Formula.	Difference.
Equator, ...	0° .0′	81°.50	81°.50	0°.00	84° .2	2°.7 +
Columbo, ...	6 .58	79 .50	80 .90	1 .40 +	83 .4	3 .9 +
Chandernagore, ...	22 .52	75 .56	75 .10	0 .46 —	76 .3	0 .74 —
Cairo, ...	30 .2	72 .82	70 .56	1 .76 —	71 .1	1 .31 +
5 Funchal, ...	32 .37	68 .54	68 .62	0 .08 +	69 .0	0 .46 +
Rome, ...	41 .54	60 .44	60 .66	0 .22 +	60 .7	0 .36 +
Montpellier, ...	43 .36	59 .36	59 .03	0 .33 —	59 .4	0 .04 +
Bourdeaux, ...	44 .50	56 .48	57 .82	1 .34 +	59 .0	2 .52 +
Milan, ...	45 .28	57 .18	58 .28	1 .10 +	57 .7	0 .52 +
10 Nantes, ...	47 .13	54 .68	55 .35	0 .67 +	56 .10	1 .42 +
St Malo, ...	48 .39	54 .14	53 .85	0 .29 —	54 .80	0 .66 +
Paris, ...	48 .50	51 .89	53 .65	1 .76 +	54 .60	2 .71 +
Brussels, ...	50 .50	51 .80	51 .47	0 .33 —	52 .90	1 .10 +
Dunkirk, ...	51 .2	50 .54	51 .25	0 .71 +	52 .70	2 .16 +
15 London, ...	51 .30	50 .36	50 .74	0 .38 +	52 .30	1 .94 +
Bushey Heath, ...	51 .37¾	51 .2	50 .58	0 .62 —		
Kendal, ...	54 .17	46 .02	47 .58	1 .56 +	49 .8	3 .78 +
New Malton, ...	54 .10	48 .28	47 .53	0 .75 —	49 9	1 .62 +
Lyndon, ...	54 .34	48 .90	49 .37	0 .47 +	49 .5	0 .60 +
20 Dublin, ...	53 .21	49 .10	48 .65	0 .45 —	50 .6	1 .50 +
Copenhagen, ...	55 .41	45 .68	45 .95	0 .27 +	48 .6	2 .92 +
Edinburgh, ...	55 .57	46 .23	45 .64	0 .59 —	48 .32	2 .09 +
Carlscrona, ...	56 .16	46 .04	45 .46	0 .58 —	48 .2	2 .16 +
Fawside, ...	56 .58	44 .30	44 .26	0 .04 —	47 .5	3 .20 +
25 Kinfauns, ...	56 .23½	46 .20	45 .12	1 .08 —	47 .9	1 .70 +
Stockholm, ...	59 .20	42 .26	41 .57	0 .69 —	45 .5	3 .24 +
Upsal, ...	59 .51	42 .08	40 .94	1 .14 —	45 .1	3 .02 +
Abo, ...	60 .27	40 .00	40 .28	0 .28 +	44 .6	4 .60 +
Umeo, ...	63 .50	33 .08	35 .96	2 .88 +	42 .1	9 .02 +
30 Uleo, ...	65 .3	33 .26	34 .38	1 .11 +	41 .3	8 .04 +

This

This singular agreement between the observed and calculated results, and the equilibrium of the positive and negative errors, shews that the formula embraces the leading causes which affect the mean temperature of the west of Europe. The sum of all the positive errors is 13°.12, and the sum of the negative errors 9°.11; and their total amount is 22°.23, which gives only an average error of $\frac{8}{10}$ths of one degree of Fahrenheit upon each observation.

The results of Mayer's formula give all the errors positive except one, and their sum is no less than 70°.7, being 2°.3 for each observation. The error of the formula becomes so great as 9° between the parallels of 60° and 70°, which proves, in the most convincing manner, that the temperature of 32°, which Mayer assigns to the North Pole, is very far above the truth. The formula which I have given above makes the polar temperature so low as *zero*, or 0° of Fahrenheit's scale, differing 32° from the preceding measure; but the circumstance of its representing with accuracy the mean temperatures at very high latitudes, inspires us with some confidence even in this extreme result.

In this state of uncertainty respecting the probable temperature of the North Pole, and of the accessible parallels between 70° and 80°, I proposed to examine the most northern meteorological journals, with the view of finding some general rule by which the mean temperature of the year might be deduced from one or two months observations. I had previously communicated my formula to Mr Scoresby, and requested from him some information respecting the temperature of the Greenland Seas; and I had the satisfaction of finding, that this subject had engaged his most particular attention, and that he had actually deduced the mean temperature of the parallels of

76° 45,

76°.45′, and 78°, from a series of 650 observations made by himself, in *nine* successive years *.

In the latitude of 76° 45′ he found the mean temperature to be 18° $\frac{86}{100}$dths. My formula makes it 18° $\frac{68}{100}$dths, deviating only $\frac{16}{100}$dths of a degree.

In the latitude of 78°, Mr Scoresby found the mean temperature to be 16° $\frac{99}{100}$dths. My formula makes it 16° $\frac{95}{100}$dths, deviating only $\frac{4}{100}$dths of a degree. Mayer's formula makes the mean temperature of these parallels above 34°, erring no less than 33° upon both observations, whereas the error of my formula is only $\frac{1}{5}$th of a degree.

It appears, then, from the evidence of direct observation, that the temperature of the North Pole must be considerably lower than 16° $\frac{99}{100}$dths, and must therefore be more correctly indicated by the new formula than by that of Mayer. Mr Scoresby has attempted, by a very ingenious analogical process, to deduce the temperature of the Pole from that of 76° 45′. He considers the difference between the actual temperature of that parallel, viz. 18°.86, and the temperature given by Mayer's formula, or 33°.8′, as an anomaly produced by the frigorific influence of the ice; and having found what this anomaly should be at the Pole, he subtracts it from Mayer's polar temperature, in order to obtain the real polar temperature, which he thus finds to be 10°. This result, however, is obviously too great, upon Mr Scoresby's own principle; for since Mayer's formula errs greatly in excess in those parallels where there is no accumulated ice to produce an anomaly, it must give at least an equal error in excess for the parallel of 76°.45′. Now, this error in the latitude of 63° and 65° in Lapland

* This interesting investigation is now published, in Mr Scoresby's excellent *Account of the Arctic Regions*, vol. i. p. 356.

land is 8° ; and therefore calling it also 8°, which is far too low for the latitude of 76° 45′, we have for the mean temperature, uninfluenced by the ice, 33°.8 — 8°.0 = 25°.8 ; from which subtracting the polar anomaly of 21°, as computed by Mr Scoresby, and we obtain 4°.8 for the mean temperature of the Pole.

In the preceding paragraphs, we have compared the results of the formula with the temperatures of individual places, which must often be influenced by local causes. We shall therefore compare the formula with the temperatures of the four parallels of 30°, 40°, 50°, and 60°, which Humboldt has deduced from a great variety of observations, and which he considers as well established.

	Lat. N.	Observed Mean Temp.	Calculated Mean Temp.	Differences.
	30°	70°.52	70°.56	0°.04 +
	40	63 .14	62 .43	0 .71 —
	50	50 .90	52 .39	1 .49 +
	60	40 .64	40 .75	0 .11 +
Scoresby	76 45′	18 .86	18 .68	0 .18 —
Do.	78	16 .99	16 .95	0 .04 —

The differences between the observed and calculated temperatures, both in this and the preceding Table, are frequently owing to the circumstance of the thermometer having been observed at two periods, the average of which does not give the mean temperature of the day. The Reverend Mr Gordon has found, from a series of very accurate observations, that the mean temperature will be obtained most correctly in this country, when self-registering thermometers are not used, by observing at 10 o'clock in the morning and evening; and it is highly to be desired that this principle should be adopted in all our meteorological journals. Another source of difference arises from local causes, which often

often occasion a difference of temperature under the same latitude. In the case of Edinburgh, for example, the mean temperature, deduced from Mr PLAYFAIR's observations, is 47.8 *, differing considerably from the formula, while the mean

* As Mr PLAYFAIR's observations were made in Windmill Street and Buccleuch Place, where the thermometer must have been influenced by the heat reflected from the opposite sides of these streets, I consider the mean of his annual temperatures, viz. 47°.8, as erring in excess, and have therefore preferred 46°.23, the result of Messrs MILLER and ADIE's observations.

This opinion respecting the temperature of Edinburgh is strongly confirmed by the following valuable and accurate observations, made and communicated to me by my friend Mr JAMES JARDINE.

TEMPERATURE of the CRAWLEY SPRING, situated 564 feet above the level of the sea.

1811, 30th January,	-	46°.5	Fahrenheit.
21st March,	-	46.0	
18th April,	-	46.2	
19th August,	-	46.7	
Mean,		46.35	
Add for 334 feet above Merchant Court,		1.00	
Mean Temperature at Edinburgh,		47.35	

TEMPERATURE of the BLACK SPRING, situated 882 feet above the level of the sea.

1815, 12th January,	-	44°.8	Fahrenheit.
1811, 31st January,	-	45.0	
1818, 4th February,	-	44.6	
1811, 18th April,	-	44.8	
1810, 17th September,	-	45.0	
1819, 8th October,	-	44.8	
1810, 31st December,	-	45.0	
Mean	-	44.86	
Add for 652 feet above Merchant Court,		1.95	
		46.81	

Mean

mean temperature, according to the observations of Messrs Miller and Adie, is 46°.23 *, agreeing very nearly with the calculated results.

Hitherto we have considered only the temperature of the Old World, as determined under meridians passing through the west of Europe; and previous to actual observation, it was reasonable to infer, that under other meridians the heat would follow a similar law of distribution. The testimony of travellers, however, soon corrected this hasty inference; and as the condition of more distant climates was better known, the severity of a Canadian and a Siberian winter became proverbial. Notwithstanding this evidence, Mayer, and Kirwan, who adopted his formula, have considered it as universally applicable; and Mr Leslie has maintained, on the authority of a few insulated facts, that the average temperature of the Old and New World will be found the same †.

These speculations, however, have been completely overturned by the researches of Humboldt. He has shewn, that though the temperature of the Equatorial regions is nearly the same under all meridians, yet in higher latitudes it declines rapidly in the New World, and under the eastern meridians of Asia.

Mean Temperature at Edinburgh from Black Spring, - -	46 .81
Mean Temperature at Edinburgh from Crawley Spring, - -	47 .35
General Mean Temperature of Springs at Edinburgh, - -	47 .08

* These observations were made in Merchant Court, 230 feet above the level of the sea.

† *Edinburgh Encyclopædia*, Art. America, Sect. *Climate of America*, vol. i. p. 614.

Asia. In the three first columns of the following Table, he has given the differences of temperature for the Eastern and Western Hemispheres, under the parallels of 30°, 40°, 50° and 60° of north latitude.

Lat.	Temp. Old World.	Temp. New World.	Difference between Old and N. World.	Temp. of N. World calculated.	Diff. between obs. & calcul.
30°	70°.52	66°.92	3°.60	69°.07	+ 2°.15
40	63 .14	54 .50	8 .64	54 .04	— 0 .46
50	50 .90	37 .94	12 .96	38 .06	+ 0 .12
60	40 .64	23 .72	16 .92	23 .02	— 0 .70

The difference of temperature of the Old and New World is nearly 4° in the parallel of 30°; 9° in the parallel of 40°; 13° in the parallel of 50°; and 17° in the parallel of 60°.

It would have been desireable to have expressed these differences, by adding to the preceding formula a co-efficient depending on the longitude; but the observations are not sufficiently numerous for this purpose, and I have contented myself with the following simple expression, which enables us to calculate the temperatures of the New World.

$$T = 81\tfrac{1}{2}^{\circ} \text{ Cos.}^2 \text{ Lat.} \times 1.13.$$

This formula makes the Equatorial and Polar temperature of the New World the same as those of the Old World, while in intermediate latitudes the calculated and observed results do not differ upon an average so much as 1°, as will be seen from the two last columns of the preceding Table.

The determination of the temperature of North America, enables us to approximate with more certainty to the degree of cold which exists at the North Pole; and as this question must always possess considerable interest in relation to any attempt that is made to explore these icy regions, I would request the attention of the Society to the nature of the argument by which I conceive that we may ascertain the *maximum* limit of the Polar temperature.

In the Old Continent, the mean heat at 60° of latitude is 40°. In 78° of latitude, Mr SCORESBY makes it 17°, and thence infers that it must be 10° at the Pole. Now, if Mr SCORESBY had approached the Pole in a meridian passing through the New World, he would have encountered a cold of 24° in the latitude of 60°; and in the parallel of 78° this cold would have increased to 4°, as deduced from the formula. If we then subtract from this an anomaly calculated after Mr SCORESBY's ingenious process, we shall find that the Polar temperature computed in this way is many degrees below the *zero* of Fahrenheit's scale. Or, to state the argument more popularly, since the cold at the Pole is 10°, as inferred from observations made in the *mildest* meridian, it must fall greatly below this, and even *below zero*, if inferred from observations made in the *coldest* meridian. The winds which blow from the continent of Greenland,—from the northern extremities of America,—and from the frozen coast of Siberia, must produce at the North Pole an influence which is scarcely felt in the Spitzbergen Seas.

From all these considerations, we are entitled to infer that the formula, which represents the actual temperatures with such accuracy from the Equator, and through all the varieties of climate in the Temperate Zone, even to the parallel of 78°, where the fixed ice acts with its full influence, is not likely to fail in its accuracy when extended to its limit; and, therefore, that the temperature of the Pole itself is not far from 0° of Fahrenheit *.

THE

* As this reasoning is founded on the assumption that the Pole is the coldest point of the Globe, the results given above will admit of considerable modification, if

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The Meteorological observations which have been recently made in Lancaster Sound by Captain Parry, confirm in a very remarkable degree the general Formula, and the opinions respecting Polar temperature, which I have endeavoured to establish in the preceding pages*. Instead of giving too great a degree of cold to the Arctic latitudes, as every person supposed the Formula to have done, it errs on the opposite side, and ascribes to the parallel of $74\frac{3}{4}°$ a temperature of about 6°, whereas Captain Parry found it to be so low as 1°.33.

This intrepid and skilful navigator, whose important discoveries in the Arctic Regions do equal honour to the heroism of the men under his command, and to the liberality of the British Government, observed the temperature of the regions which he visited, with peculiar care, and by means of the finest instruments. The observations were made every two hours; and as the expedition continued nearly twelve months in the Parallel of 74° 45′, and in the Meridian of 110°, we may consider the mean annual temperature of that point of the globe as established by means of above 4300 observations.

The following abstract of this valuable Journal has been kindly communicated to me by Captain Parry, with the permission of the Lords of the Admiralty.

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if that supposition shall be found improbable, as will be shewn in the subsequent part of this paper.

* This part of the Paper was read before the Royal Society on the 4th December 1820.

" *ABSTRACT*

"*ABSTRACT of the* HECLA's *Meteorological Journal for Twelve Kalendar Months, during which Period she was within the Parallels of* 74° *and* 75° *of North Latitude.*

MONTHS.	Mean Temperature of Air in Shade.			REMARKS.
	Max.	*Min.*	MEAN.	
1819, September,	+ 37°	— 1°	+ 22°.54	"During the time that we were in Winter Harbour, it was always found that the thermometer on board stood from 2° to 5° higher than the one on shore, from the warmth created by the fires, &c. The *minimum* temperature for February was — 50° on board, but — 55° on the ice. On the ice, 14th and 15th of February, the thermometer was at — 54° for seventeen hours.
October,	+ 17 .5	— 28	— 3 .46	
November,	+ 6	— 47	—20 .60	
December,	+ 6	— 43	—21 .79	
1820, January,	— 2	— 47	—30 .09	
February,	—17	— 50	—32 .19	
March,	+ 6	— 40	—18 .10	
April,	+ 32	— 32	— 8 .37	
May,	+ 47	— 4	+ 16 .66	
June,	+ 51	+ 28	+ 36 .24	
July,	+ 60	+ 32	+ 42 .41	
August,	+ 45	+ 22	+ 32 .68	The mean annual temperature may be fairly considered as 1° or 2° below zero."
Annual Temperature,		-	+ 1°.33	

The intense cold which is thus proved to exist in the latitude of $74\frac{3}{4}$°, indicates, when compared with that in 78° in the Spitzbergen Seas, a very singular state of the Isothermal lines at the Pole itself. The thermometric curve of 17°, which rises in the meridian of Spitzbergen to the 78th degree of north latitude, descends in the meridian of Melville Island to the 65th degree, and unless we suppose that the climate of these regions is subject to no law, we are forced to conclude that the Pole of the Globe is not the coldest point of the Arctic hemisphere, and that there are *two points of greatest cold* not many degrees from the Pole, and in meridians nearly at right angles to that which passes through the west of Europe.

Observations are still wanting to determine the exact positions of the Isothermal Poles; but they appear to be situated in about 80° of N. Lat., and in 95° of East and 100° of West Long.; the Transatlantic one being nearly 5° to the N. of Graham

Graham Moore's Bay in the Polar Sea; and the Asiatic one to the north of the Bay of Taimura, near the North-East Cape.

This view of the distribution of temperature within the Frigid Zone, suggests, or rather renders necessary, a New Law of the Progression of Climates. The gradation of heat on the Transatlantic Meridian is so essentially different from that in the west of Europe, that it is impossible to represent the two classes of phenomena by one Formula, in which the limiting temperatures are found at the Equator and the Pole. No attempt, indeed, has been made to include them in the same law, and still less to refer them to a principle which embraces all intermediate meridians.

As we are not acquainted with the cause of the anomalous distribution of heat in high latitudes, observation alone must guide us in determining the form of the Isothermal lines. From their general resemblance to the Isochromatic Curves, I tried to calculate the temperatures by the product of the sines of the distance of the place from the two Isothermal Poles; but this law did not represent the facts, and I found that they might be more accurately expressed by the Formula

$$\text{Mean Temp.} = 82^\circ.8 \text{ Sin. D}$$

upon the supposition that the greatest cold is 0° of Fahrenheit, or

$$\text{Mean Temp.} = 86^\circ.3 \text{ Sin. D} - 3^\circ\tfrac{1}{2}$$

upon the more probable supposition, that the greatest cold is $-3\frac{1}{2}^\circ$ of Fahrenheit, 82°.8 being the Mean Temperature of the Equator in the Warmest Meridian, and D the distance of the place from the nearest Isothermal Pole *.

By

* The distance D from the Isothermal Pole is in the coldest meridian $D = 80^\circ - \text{Lat.}$; and in the warmest meridian $\text{Cos. D} = \text{Cos. } 10^\circ \times \text{Sin. Lat.}$

In

By applying this last Formula to the results obtained by HUMBOLDT, and to the observations of Captain SCORESBY and Captain PARRY, we shall have the following observed and calculated temperatures *:

	Mean Temp. of Old World.			Mean Temp. of New World.		
Lat.	Observ.	Calc.	Difference.	Observ.	Calc.	Difference.
30°	70°.52	71°.61	+ 1°.09	66°.92	62°.61	— 4°.31
40	63 .14	63 .31	+ 0 .17	54 .50	51 .97	— 2 .53
50	50 .90	53 .16	+ 2 .26	37 .94	39 .65	+ 1 .71
60	40 .64	41 .55	+ 0 91.	23 .72	26 .02	+ 2 .30
$74\frac{3}{4}$	Captain Parry,	-	-	- 1. 33	4 .39	+ 3 .06
78	17 .00	19 .66	+ 2 .66	Captain Scoresby.		

The differences in the *fourth* and *seventh* columns are far from being considerable; and when we reflect upon the uncertainty in the position of the Poles, and the range of the annual temperature at any given place, the coincidence of the observed and calculated results is greater than could have been expected.

In the preceding comparison, the places to which the mean results belong, are supposed to be situated either in the warm meridian which passes through the west of Europe, or in the cold meridian which passes through North America. In comparing, however, the theory with observation, we shall proceed to put it to the severe test of contrasting it with observations made in intermediate meridians, both in the Old and the New World;

In all intermediate meridians we have $\text{Cos. D} = \frac{\text{Cos. } l\,(\text{Cos. L} - \theta)}{\text{Cos. } \theta}$, and

$\text{Tang. } \theta = \text{Cos. M. Tang. L}$, where M is the difference of longitude between the place and the Pole, L the co-latitude of the Isothermal Pole or 10°, and l the co-latitude of the place.

* The calculation for the Old World is founded on the supposition, that the meridian to which the mean results of HUMBOLDT belong is at right angles to the cold meridian in 100° West Longitude. The greater number of places, however, from which the mean was taken, are nearer the Asiatic than the American Pole. Hence we see the reason why the differences are all positive.

World; and in this comparison we shall begin with the ASIATIC POLE, and suppose it to have a temperature of —3°½, and to be placed in 80° N. Lat. and 95° of East Long. from Greenwich.

	Distance from the Asiatic Pole.	Mean Temperature. Observed.	Calculated.	Difference.
Enontekies,	20° 39′	31°.03 *	26°.93	—4°.10
Uleo, -	23 16	33.08	30.59	—2.49
Umeo, -	25 06	33.26	33.11	—0.15
St Petersburg,	27 11	38.84	35.92	—2.92
Stockholm,	29 44	42.30	39.30	—3.00
Moscow, -	29 55	43.16	39.54	—3.62
Warsaw, -	36 06	48.56	47.35	—1.21
Astracan, -	37 25	49.08	48.94	—0.14
Vienna, -	40 37	51.76	52.68	+0.92
Pekin, -	40 56	54.86	53.04	—1.82
Nangasaki,	48 57	60.80	61.58	+0.78
Seringapatam,	68 04	77.00 †	76.55	—0.45
Columbo, -	73 12	79.50	79.12	—0.38

From these differences, which are almost all negative, it appears that we have assumed too great a degree of cold for the Asiatic Pole. If we make it 0° of Fahrenheit, we obtain the following results:

	Mean Temperature. Observed.	Calculated.	Difference.
Enontekies,	31°.03	29.20	—1.83
Uleo, -	33.08	32.71	—0.37
Umeo, -	33.26	35.12	+1.86
St Petersburg,	38.84	37.83	—1.01
Stockholm,	42.30	41.07	—1.23
Moscow, -	43.16	41.30	—1.86

Warsaw,

* Reduced to the level of the sea by HUMBOLDT's rule.

† The mean temperature in 1814 was 78°.25, and in 1816 75°.75. No correction is applied for its elevation above the sea.

	Mean Temperature. Observed.	Calculated.	Difference.
Warsaw, -	48.56	48.79	+ 0.23
Astracan, -	49.08	50.31	+ 1.23
Vienna, -	51.76	53.90	+ 2.14
Pekin, -	54.86	54.25	— 0.61
Nangasaki,	60.80	62.44	+ 1.64
Seringapatam,	77.00	76.81	— 0.19
Columbo, -	79.50	79.26	— 0.24

The differences in this Table (amounting at an average to $1^\circ\frac{1}{10}$) are far within the limits of the errors of observation; but being negative in general, they may be reduced still farther to an average of 1°, by supposing the Asiatic Pole to have the temperature of + 1° of Fahrenheit, which is $4\frac{1}{2}^\circ$ warmer than the Transatlantic Pole. The Formula in this case becomes

$$T = 81.8^\circ \text{ Sin. } D + 1^\circ,$$

from which we obtain the following results:

	Mean Temperature Observed.	Calculated.	Difference.
Enontekies,	31°.03	29.85	— 1.18
Uleo, -	33.08	33.31	+ 0.23
Umeo, -	33.26	35.70	+ 2.44
St Petersburg,	38.84	38.37	— 0.47
Stockholm,	42.30	41.57	— 0.73
Moscow, -	43.16	41.80	— 1.36
Warsaw, -	48.56	49.20	+ 0.64
Astracan, -	49.08	50.70	+ 1.62
Vienna, -	51.76	54.25	+ 2.49
Pekin, -	54.86	54.59	— 0.27
Nangasaki,	60.80	62.69	+ 1.89
Seringapatam,	77.00	76.92	— 0.08
Columbo, -	79.50	79.33	— 0.17

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In comparing the theory with observations made round the Transatlantic Pole, the results are equally satisfactory. The third column of the following table is calculated from the formula $T = 86^{\circ}.3$ Sin. $D - 3^{\circ}\frac{1}{2}$, and the Pole is supposed to be situated in 80° N. Lat. and 100° West Long. *, and to have a temperature of $-3^{\circ}\frac{1}{11}$.

	Distance from the American Pole.	Mean Temperature. Observed.	Calculated.	Difference.
Melville Island,	5° 15′	1°.33	4°.39	+ 3°.06
Upernavick,	12 15	16.34	14.81	— 1.53
Omenak,	13 58	16.60	17.33	+ 0.42
Godhavn,	17 08	22.04	21.92	— 0.12
Godthaab,	20 19	26.07	26.46	+ 0.39
Fort Churchhill,	20 58	25.34	27.38	+ 2.04
Julianæshaab,	24 25	30.33	32.17	+ 1.84
Eyafiord,	24 08	32.16	31.78	— 0.38
Nain, -	25 16	30.03 †	33.34	+ 3.31
Okkak, -	24 47	31.00 ‡	32.68	+ 1.68
Quebec,	34 44	41.90	45.67	+ 3.77
Cambridge,	39 04	50.36	50.89	+ 0.53
New York,	39 53	53.78	51.84	— 1.94
Philadelphia,	41 08	53.42	53.27	— 0.15
Williamsburg,	43 40	58.10	56.09	— 2.01
Orotava,	60 00	70.11	71.24	+ 1.13
EQUATOR { W.L. 100,	80 00	81.50	81.5	0 .0
EQUATOR { E. long. 95.			81.56	+ 0.06

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* If we suppose that the observations in West Greenland, and those about Hudson's Bay and Labrador, are best fitted to give the position of the Pole, it is obvious, that it should be removed a little from the former, and brought nearer the latter, so as to be placed a degree or so farther South. This change would also produce a greater coincidence with Captain PARRY's observations.

† For 1779—80. See *Phil. Trans.*

‡ For 1779—80. See *Phil. Trans.*

In the reasoning from which HUMBOLDT estimates the mean temperature of the Equator, he appears to me to have taken for granted a very material fact. Having found a coincidence between the mean temperature of equinoctial America and equinoctial Asia, he concludes that the mean temperature of the Equator is 81°.5, and is uniform in every point of that great circle; but as these are the very regions under the line where the temperature should be the same, in consequence of being similarly situated with regard to Canada and Siberia, no conclusion can be drawn until a similar temperature has been found on the African coasts of Benin and Loango. The heat under the Equator being thus supposed to be uniform, HUMBOLDT felt himself entitled to conclude, that the colds of Canada and Siberia did not extend their influence to the equatorial plains *, and that between the tropics, the isothermal lines are parallel to the equinoctial.

The theory which I have explained above, requires a different distribution of heat at the Equator. The *maximum* mean temperature of that circle should be 82°.8 in Africa, in order to give 81°.5 as the equinoctial temperature in America and Asia; and the difference of these values, or 1°.3, must be regarded as a measure of the influence which the colds of Canada and Siberia extend to the equatorial plains. Nor is this a mere theoretical result. I consider it as fairly deducible from facts furnished by HUMBOLDT himself; and this distinguished traveller seems to have drawn from these facts the same conclusion, before he had deduced the uniformity of the equatorial temperature

* *Edinburgh Philosophical Journal*, vol. iii. p. 263.

perature from a comparison of Asiatic and American observations.

In his *Political Essay on New Spain*, he makes the following remarks: " On the eastern coast of New Spain, the great " heats are occasionally interrupted by strata of cold air, " brought by the winds from Hudson's Bay towards the parallels of the Havannah and Vera Cruz. These impetuous " winds blow from October to March; they are announced by " the extraordinary manner in which they disturb the regular " recurrence of the small atmospherical tides, or horary varia- " tions of the barometer, and they frequently cool the air to " such a degree, that at Havannah, the centigrade thermome- " ter descends to 32° of Fahr., and at Vera Cruz to 60°.8 Fahr. " —*a prodigious fall* for countries in the torrid zone."—Vol. I. p. 65. Eng. edit. " The great breadth of the New Continent, " —the *proximity of Canada,—the winds which blow from the* " *north, &c.* give the equinoctial regions of Mexico and the " island of Cuba a particular character. One would say, that " in these regions the temperate zone,—the zone of variable " climates,—*increases towards the south, and passes the tropic of* " *Cancer*," &c.—Vol. II. p. 410. " On the east coast of Mexi- " co," he elsewhere remarks, " the north winds cool the air, " so that the thermometer falls to 62°.6 Fahr; and at the end " of the month of February, I have seen it remain for whole " days under 69°.8; while, during the same period, the air be- " ing calm, at Acapulco, it is between 82°.4 and 86°. The " latitude of Acapulco (16° 50′) is 3° farther south than that " of Vera Cruz; and the high Cordilleras of Mexico shelter it " *from the currents of cold air which rush in from Canada upon* " *the coast of Tabasco*," (Lat. 18°)—Vol. II. p. 148. *

From these quotations, it appears, that the cold winds from Hudson's Bay produce a very striking effect upon the climate even

* See also, vol. I. p. 75.

even of the tropical regions. Rising in the parallel of 60°, and sweeping over the whole continent of North America, through an extent of 2600 miles, they retain their gelid influence even in the latitude of 18°. Can we suppose, then, that such winds as these cease all at once to impart their cooling energies to more southern zones. Acting with such power in the parallel of 18°, will they not refresh the opposite shores of the Pacific Ocean, and temper even the burning heats of the Equinoctial Line? Whatever law of progression we may adopt to represent the decreasing influence of these northern currents, in their passage towards the Line, there is none which allows them the influence described by HUMBOLDT on the coast of Tabasco, that will not extend that influence to the Equator itself.

Although the preceding views, respecting the distribution of heat within the Polar Circle, make the temperature much lower than had previously been supposed, yet when taken in conjunction with the results of the expedition under Captain PARRY, they rather encourage the hopes which have been so reasonably entertained, of reaching the Pole itself.

Upon the supposition that there are *two* Isothermal Centres in 80° of latitude, and that their temperature is $-3\frac{1}{2}°$ of Fahrenheit, the mean temperature of the Pole of the Globe will be about 11°, incomparably warmer than the regions in which Captain PARRY spent the winter. If an expedition, therefore, were to set out for Spitzbergen, and remain there for one or more seasons, till an opening should be found through the icy barrier which stretches from that island to the Greenland coast, there is every reason to believe that it would ultimately succeed.

If the Pole is placed in an open sea, the difficulty of reaching it entirely ceases; and if it forms part of a frozen continent, those intrepid individuals who sustained the rigorous cold

cold of Lancaster Sound, could experience no hardship under a comparatively milder climate.

Hitherto we have supposed the two Isothermal Poles to have the same temperature, and to be situated on nearly opposite Meridians; but this supposition is not rendered necessary by any of the phenomena, and we may obtain a better expression of the temperatures, by placing the Poles at different distances from the Equator, and ascribing to them different intensities. The existence of a cold and a warm meridian, is a proof that there are causes which powerfully influence the annual temperature, independent of the position of the Earth's axis with respect to the Sun; so that the effects which they produce can have no symmetrical relation to the Pole either in position or intensity.

The two Northern Poles of the terrestrial magnet, for example, are situated, the one 4° and the other 20° from the Pole, and they have neither equal intensities, nor opposite positions. Imperfect as the analogy is between the Isothermal and the Magnetic centres, it is yet too important to be passed over without notice. Their local coincidence is sufficiently remarkable, and it would be to overstep the limits of philosophical caution, to maintain that they have no other connection but that of accidental locality. The revolution of the two Magnetic foci round the Pole, the one in 1740 years, and the other in 860, has been recently deduced by HANSTEEN from numerous observations, and if we had as many measures of the mean temperature, as we have of the variation of the needle, we might determine whether the Isothermal Poles were fixed or moveable.

The idea of such a motion suggests an explanation of some of the most remarkable revolutions on the surface of the Globe. There is no fact in the Natural History of the Earth better ascertained, than that the climate of the west of Europe was

was much colder in ancient than in modern times. When we learn that the Tyber was often frozen;—that snow lay at Rome for forty days;—that grapes would not ripen to the north of the Cevennes;—that the Euxine Sea was frozen over every winter in the time of Ovid;—and that the ice of the Rhine and the Rhone sustained loaded waggons;—we cannot ascribe the amelioration of such climates to the influence of agricultural operations.

The cold Meridian which now passes through Canada and Siberia, may then have passed through Italy; and if we transfer the present mean temperatures of these cold regions, to the corresponding parallels in Europe, we shall obtain a climate agreeing in a singular manner with that which is described in ancient authors.

It is not, however, in the altered condition of our atmosphere merely, that we are to seek for proofs of a periodical rotation of climate. The impressions of the plants of warm countries, and the fossil remains of land and sea animals, which could exist only under the genial influence of the Temperate Zone, are found dispersed over the frozen regions of Eastern Asia; and there is scarcely a spot on the solid covering of the Globe, that does not contain indications of a revolution in its animal and vegetable productions.

This interchange of the productions of opposite climates, has been ascribed to some sudden alteration in the obliquity of the Ecliptic, and even to a violent displacement of the Earth's axis; but Astronomy rejects such explanations, as irreconcileable with the present condition of the system, and as incompatible with the stability of the laws by which it is governed.

HAVING

Having thus endeavoured to establish a new law of the distribution of heat over the surface of the globe, it might be no uninteresting inquiry to investigate the causes which have modified, in so remarkable a manner, the regular influence of the solar rays. The subject, however, is too comprehensive, and too hypothetical, to be discussed at present. How far the general form and position of the continents and seas of the northern hemisphere may disturb the natural parallelism of the isothermal lines to the Equator.—To what extent the current through Behring's Strait, transporting the waters of warmer climates across the Polar seas, may produce a warm meridian in the direction of its motion, and throw the coldest points of the globe to a distance from the Pole.—Whether or not the magnetic, or galvanic, or chemical poles of the globe, (as the important discoveries of M. Oersted entitle us to call them), may have their operations accompanied with the production of cold, one of the most ordinary effects of chemical action.—Or whether the great metallic mass which crosses the globe, and on which its magnetic phenomena have been supposed to depend, may not occasion a greater radiation of heat from those points where it developes its magnetic influence?—are a few points, which we may attempt to discuss, when the progress of science has accumulated a greater number of facts, and made us better acquainted with the superficial condition, as well as the internal organization, of the globe.

XIV.

XIV. *Method of determining the Latitude, by a Sextant or Circle, with simplicity and accuracy, from Circum-meridian Observations, taken near Noon.* *By* Major-General Sir THOMAS BRISBANE, C. B. F. R. S. E. and Corresponding Member of the Institute of France.

(Read November 20. 1820.*)*

AS it very frequently happens that an observation may not be obtained for the latitude, at the precise instant of noon, it becomes a most desirable object to supply that loss by every possible means. The method which I am about to detail, I have long practised, and from the experience of many hundred trials, I can recommend it, as combining much simplicity with the greatest accuracy; since one day's observations may be equal to those derived from the chances of three weeks of the ordinary course of weather in our climate. This method consists in merely reducing to noon these observations, the same as if made when the sun's centre was on the meridian, by the means of a very simple calculation, which I shall detail, and illustrate with the observations for two days, in order to shew the accuracy of the results thus obtained. Having previously ascertained the time of noon, either by equal altitudes, or from simple ones, in the manner I had the

 honour

honour to detail in a former communication to the Society, "*On the Mode of determining Time with the Sextant,*" I begin nearly 10′ from noon to observe the sun's altitude, from an artificial horizon of oil, or quicksilver, and continue making as many observations as I can accomplish until the sun has nearly the same altitude as when I began, which will be the case about as long past noon, during which an expert observer will easily take 20 altitudes, which, in most cases, will be sufficient to enable him to retain all those that appear to be consistent, and to reject those that differ much from the mean. The error of the instrument is to be carefully determined * ; and the barometer and thermometer must be noted, and their results deduced, agreeably to the two examples that accompany this memoir.

I have always found it the readiest mode to correct the noon declination, as given at Greenwich, first, for the difference of meridians, and next for the time of the observations, which is most readily done by calculating what the change in one minute of time will produce, and then multiply that by the number of minutes required for the given observation †.

Having

* At sea, or where it is not required to proceed with the greatest accuracy, the mean refraction may be used, without having recourse to the correction for atmospherical pressure and temperature.

† If the place of the observer is west of the first meridian, it becomes necessary to add the proportional part to the noon declination, for the difference of meridians, from the Vernal Equinox until the Summer Solstice, and from the Autumnal Equinox to the Winter Solstice; but for the rest of the year it must be subtracted. If the observer is situated east of the first meridian, it must be subtracted during the spring and autumn, but added during summer and winter. Had the sun no motion in declination during the time that the observations continue, it would be unnecessary to apply any correction, as in the case of observing by the stars; but although the quantity is very small during so short a period of time, still

Having thus determined or corrected the declination for each observation, there remains nothing to be done but to apply it according to its sign, either to the zenith distance or altitude, according as it is north or south, in order to obtain the latitude corresponding to each observation.

That most justly celebrated astronomer M. Delambre, to whom all practical astronomers are most deeply indebted, favoured me with the following formula, for correcting or reducing to noon these observations,

$$f = -\frac{2\,\text{Sine}^2\,\tfrac{1}{2}\,P}{1''}\left(\frac{\text{Cos H Cos D}}{\text{Sine}\,(H \pm D)}\right) + \frac{2\,\text{Sine}^4\,P}{\text{Sine}\,1''}\left(\frac{\text{Cos H Cos D}}{\text{Sine}\,(H \pm D)}\right)^2 \text{Co-tan}\,(H \pm D).$$

This correction appears to be tedious to compute, but, by the help of the Tables of $\frac{2\,\text{Sine}^2\,\frac{1}{2}\,P}{\text{Sine}\,1''}$ and $\frac{2\,\text{Sine}^4\,P}{\text{Sine}\,1''}$, the calculation will be much abridged.

The second factor of the first term requires to be computed only to five places of decimals, and the looking out of three logarithms. The second factor of the second term is formed from the preceding one, $\frac{\text{Co-sine H Co-sine D}}{\text{Sine}\,(H \pm D)}$ being squared, and then multiply it by the Co-tangent $(H \pm D)$.

The second part of the above I have omitted, as in observations taken nearly 15′ from noon, I have never found the correction resulting from it amount to half a second; but I have been

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still it is requisite to pay attention to it. For this purpose the proportional part of the declination, corresponding to the horary angle of the observation, is to be added to the declination at noon, in order to have it for the instant of observation, when the observation is made before noon, and the declination is diminishing. If the observation is made in the afternoon, the proportional part must be subtracted.

been induced to give it, in order that those who are desirous may avail themselves, to the full extent, of the correction, which for the Pole Star may become requisite, when the observations are extended from 15′ to 20′ or longer after its passage over the meridian. The product of these quantities give a logarithm termed *f*, which, added to the logarithm of $\frac{2 \text{ Sine}^2 \frac{1}{2} P}{1''}$ taken from the Table, corresponding to the horary angle, gives the logarithm of the correction to be added to the altitude, or subtracted from the zenith distancc; from whence their apparent ones are to be determined.

The accompanying Table, valuable for many purposes of astronomy, viz. $\frac{2 \text{ Sine}^2 \frac{1}{2} P}{1''}$ is extended to 11′ from noon, which is generally sufficient; but those who are desirous of observing further from noon, may continue it agreeably to the above formulæ. This Table, with Lalande's small volume of Logarithms *, are all that is required for the determination of the latitude by this method. The above correction, or Log. *f*, is equally applicable to the repeating circle as to the sextant, with this difference only, that the number of repetitions must be multiplied by that number, or in other words, the logarithm of the number must be added, in order to obtain the reduction to noon for their sum. I have been induced to compute for my own observatory logarithm *f* for

* No astronomer should be without this little work, or Callet's tables, both of which, from their value, and universal use in calculations, have been stereotyped in France, and abridge, in a most wonderful degree, the proportions required in all astronomical computations. As the one term is invariaby constant, viz. 24 hours, the change that takes place in declination, the sun's longitude, or Æ, serves for all the calculations of one day; so that in fact there are but two logarithms to look out, in the most complicated proportion.

for every 10′ of the sun's declination, both north and south of the equator, with a column of differences, so that Ican determine, almost by inspection, the numbers for the intermediate minutes; and this I would recommend to any one who means to prosecute these observations for a considerable time, or in a fixed observatory, as this Table is equally applicable for the corrections of observations made on the fixed stars or planets, whose declinations do not exceed the limits of the Table; otherwise it will be necessary to extend it to a greater range in declination. By pursuing this simple process, I am of opinion, that the latitude of any place may be determined to within a few seconds from a single day's observations; and I have further discovered, that those taken at a distance from the meridian afford just as satisfactory results as if they were taken at the instant of noon; and this I have confirmed by a variety of trials.

TABLE OF $\frac{2 \text{ Sine}^2 \frac{1}{2} P}{\text{Sine } 1''}$

For Reductions to the Meridian Observations made with the Circle or Sextant near Noon, for determining the Latitude, and is constructed agreeably to the above Formula. Argument the Horary Angle in Time.

	0′	1′	2′	3′	4′	5′	6′	7′	8′	9′	10′	
0	0.00	1.96	7.85	17.67	31.41	49.09	70.68	96.20	125.65	159.02	196.32	0
1	0.00	2.03	7.99	17.87	31.68	49.41	71.07	96.66	126.17	159.61	196.97	1
2	0.00	2.10	8.12	18.07	31.94	49.74	71.47	97.12	126.70	160.20	197.63	2
3	0.00	2.16	8.25	18.27	32.21	50.07	71.86	97.58	127.23	160.79	198.29	3
4	0.01	2.23	8.39	18.47	32.47	50.40	72.26	98.04	127.75	161.39	198.94	4
5	0.01	2.30	8.52	18.67	32.74	50.74	72.66	98.51	128.28	161.98	199.60	5
6	0,02	2.38	8.66	18.87	33.01	51.07	73.06	98.97	128.81	162.58	200.26	6
7	9.03	2.45	8.80	19.07	33.27	51.40	73.46	99.44	129.34	163.17	200.93	7
8	0.03	2.52	8.94	19.28	33.54	51.74	73.86	99.90	129.87	163.77	201.59	8
9	0.04	2.60	9.68	19.48	33.82	52.07	74.26	100.37	130.41	164.37	202.25	9
10	0.05	2.67	9.22	19.69	34.09	52.42	74.66	100.84	130.94	164.97	202.92	10
11	0.07	2.75	9.36	19.90	34.36	52.75	75.07	101.31	131.48	165.57	203.58	11
12	0.08	2.83	9.50	20.11	34.64	53.09	75.47	101.78	132.01	166.17	204.25	12
13	0.09	2.91	9.65	20.32	34.91	53.43	75.88	102.25	132.55	166.77	204.92	13
14	0.11	2.99	9.79	20.53	35.19	53.77	76.29	102.72	133.09	167.37	205.59	14
15	0.12	3.07	9.94	20.74	35.46	54.12	76.70	103.20	133.63	167.98	206.26	15
16	0.14	3.15	10.09	20.95	35.74	54.46	77.10	103.67	134.17	168.58	206.93	16
17	0.16	3.23	10.24	21.17	36.02	54.81	77.51	104.15	134.71	169.19	207.60	17
18	0.18	3.32	10.39	21.38	36.30	55.15	77.92	104.63	135.25	169.80	208.27	18
19	0.20	3.40	10.54	21.60	36.59	55.50	78.34	105.10	135.79	170.41	208.95	19
20	0.22	3.49	10.69	21.82	36.87	55.85	78.75	105.58	136.34	171.02	209.62	20
21	0.24	3.58	10.84	22.03	37.15	56.20	79.17	106.06	136.88	171.63	210.32	21
22	0.26	3.67	11.00	22.25	37.44	56.55	79.58	106.55	137.43	172.24	210.98	22
23	0.29	3.76	11.15	22.48	37.72	56.90	80.00	107.03	137 98	172.86	211.66	23
24	0.31	3,85	11.31	22.70	38.01	57.25	80.42	107.51	138.53	173.47	212.34	24
25	0.34	3.94	11.47	22.92	38.30	57.61	80.84	108.00	139.08	174.09	213.02	25
26	0.37	4.03	11.63	23.14	38.59	57.96	81.26	108.48	139.63	174.70	213.70	26
27	0.40	4.13	11.79	23.37	38.88	58.32	81.68	100.97	140.18	175.32	214.38	27
28	0.43	4.22	11.95	23.60	39.17	58.68	82.10	109.46	140.74	175.94	215.07	28
29	0.46	4.32	12.11	23.82	39.47	59.03	82.53	109.95	141.29	176.56	215.75	29
30	0.49	4.42	12.27	24.05	39.76	59.39	82.95	110.44	141.85	177.18	216.44	30
31	6.02	4.52	12.44	24 28	40.05	59.76	83.38	110.93	142.40	177.80	217.12	31
32	0.56	4.62	12.60	24.51	40.35	60.11	83.81	111.42	142.96	178.42	217.81	32
33	0.59	4.72	12.77	24.74	40.65	60.48	84.23	111.91	143.52	179.05	218.50	33
34	0.63	4.82	12.94	24.98	40.95	60.84	84.66	112.41	144.08	179.68	219.19	34
35	0.67	4.92	13.10	25.21	41.25	61.21	85.09	112.90	144.64	180.30	219.89	35
36	0.71	5.03	13.27	25.45	41.55	61.57	85.52	113.40	145.20	180.93	220.58	36
37	0.75	5.13	13.44	25.68	41.85	61.94	85.96	113.90	145.77	181.56	221.27	37
38	0.79	5.24	13.62	25.92	42.15	62.31	86.39	114.40	146.33	182.19	221.97	38
39	0.83	5.35	13.79	26.16	42.45	62.68	86.82	114.90	146.90	182.82	222.66	39
40	0.87	5.45	13.96	26.40	42,76	63.05	87.26	115.40	147.46	183.45	223.36	40
41	0.92	5.56	14.14	26.64	43.06	63.42	87.70	115.90	148.03	184.09	224.06	41
42	0.96	5.67	14.31	26.88	43.37	63.79	88.13	116.40	148.60	184.72	224.76	42
43	1.01	5.79	14.49	27.12	43.68	64.16	88.57	116.91	149.17	185.35	225.46	43
44	1.06	5.90	14.67	27.37	43.99	64.54	89.01	117.41	149.74	185.99	226.16	44
45	1.10	6.01	14.85	27.61	44.30	64.91	89.46	117.92	150.31	186.63	226.86	45
46	1.15	6.13	15.03	27.86	44.61	65.29	89.90	118.43	150.88	187.27	227.57	46
47	1.20	6.24	15 21	28.10	44.92	65.67	90.34	118.94	151.46	187.91	228.27	47
48	1.26	6.36	15.39	28.35	45.24	66.05	90.79	119.45	152.03	188.55	228.98	48
49	1.31	6.48	15.58	28.60	45.55	66.43	91.23	119.96	152.61	189.19	229.69	49
50	1.36	6.60	15.76	28.85	45.87	66.81	91.68	120.47	153,19	189.83	230.40	50
51	1.42	6.72	15.95	29.10	46.18	67.19	92.13	120.98	153.77	190.47	231.11	51
52	1.48	6.84	16.14	29.36	46.50	67.58	92.57	121.50	154.35	191.12	231.81	52
53	1.53	6.96	16.32	29.61	46.82	67.96	93.02	122.01	154.93	191.76	232.53	53
54	1.59	7.09	16.51	29.86	47.14	68.35	93.47	122.53	155.51	192.41	233.24	54
55	1.65	7.21	16.70	30.12	47.46	68.73	93.93	123.05	156.09	193.06	233.95	55
56	1.71	7.34	16.89	30.38	47.79	69.12	94.38	123.57	156.68	193.71	234.67	56
57	1.77	7.47	17.08	30.64	48.11	69.51	94.83	124.09	157.26	194.36	235.38	57
58	1.83	7.59	17.28	30.89	48.43	69.90	95.29	124.61	157.85	195.02	236.10	58
59	1.90	7.72	17.48	31.15	48.76	70.29	95.75	125.13	158.43	195.67	236.82	59

Circum-meridian Observations made at Makerstown, 9th February 1820, in order to determine the Latitude, and with a view of ascertaining the Accuracy that may be obtained by that Mode of Observing.—LONGITUDE in Time West of Greenwich, nearly 10′.4″. Quicksilver Horizon, covered by one of Troughton's Glass Roofs.

Noon by Chronometer. h ′ ″ 0 7 13	Time from Noon.	2 Sine ² ½ P / Sine 1″	Observed Angles. ° ′ ″	Altitudes corrected for error of instrument — 30″	Latitudes.
0 58 30	8.43	149.17	38 31 40	19 15 35	55 34 21.0
0 4	7.09	100.37	32 50	16 10	34 15.5
1 52	5.21	56.20	33 30	16 30	34 22.5
2 45	4.28	39.17	34 10	16 50	34 13.1
3 36	3.37	25.68	34 30	17 00	34 11.6
4 47	2.26	11.63	35 00	17 15	34 05.8
5 57	1.16	3.15	35 10	17 20	34 06.6
6 40	0.33	0.59	35 05	17 17 5	34 11.2
7 49	0.36	0.71	35 00	17 15	34 14.5
8 37	1.24	3.85	34 50	17 10	34 18.3
9 37	2.24	11.31	34 40	17 05	34 20.3
10 33	3.20	21.82	34 30	17 00	34 19.5
11 47	4.34	40.95	34 20	16 55	34 14.3
12 45	5.32	60.11	34 00	16 45	34 14.0
13 45	6.32	83.81	33 40	16 35	34 11.0
14 40	7.27	108.97	33 20	16 25	34 07.1
15 40	8.27	140.18	32 30	16 00	34 15.0
					Mean, 55 34 14.2

$$\text{Log } f = \frac{\text{Co-sine H Co-sine D}}{\text{Sine (H + D)}}$$

Formula for Log f

H	55 34 32	Co-sine	9.75229
D	14 54 51	Co-sine	9.98512
* H + D =	70 29 23	Ar. Co-sine	0.02568
			9.76309

☉ declination at noon Ephemeris, 10° 4″ west of Greenwich,	-	14° 55′ 1″
	-	9.5
Declination corrected for different meridians,		14 54 51.5

For the refraction.

Barometer,	-	29.40 = 0.7469	=	9.9923
Thermometer,	-	47 8.33	=	0.0027
Zenith distance,	-	70		2.2009
		42.7		70
				2.2129
Refraction,	—			163.3
Parallax,	+			8.4
				554.9
	—			2 34.9
Semi-diameter,	+			16 14.0
Correction,	+			13 39.1

Numbers corresponding to horary angles,	149.17	100.87	56.20	39.17	25.68	11.63	3.15	0.59	0.71
Logarithms,	2.17368	2.00160	1.74974	1.59295	1.40960	1.06558	0.49831	9.77085	9.85126
Constant factor, or Log. f,	9.76309	9.76309	9.76309	9.76309	9.76309	9.76309	9.76309	9.76309	9.76309
Constant factor + Log. of numbers,	1.93677	1.76469	1.51283	1.35604	1.17269	0.82867	0.26140	9.53394	9.61435
Corrections,	+ 86.4	58.2	32.6	22.7	14.9	6.7	1.8	0.3	0.4
☉'s declination corrected for different meridians,	D = 14 54 51.5	14 54 51.5	14 54 51.5	14 54 51.5	14 54 51.5	14 54 51.5	14 54 51.5	14 54 51.5	14 54 51.5
Corrections for horary angles,	+ 7.0	+ 5.7	+ 4.3	+ 3.6	+ 2.9	+ 1.9	- 1.0	+ 0.4	— 0.5
D correction,	+ 14 54 58.5	14 54 57.2	14 54 55.8	14 54 55.1	14 54 54.4	14 54 53.4	14 54 52.5	14 54 51.9	14 54 51.0
Altitudes corrected for error of instrument,	+ 19 15 35.0	16 10.0	16 30.0	16 50.0	17 00.0	17 15.0	17 20	17 17.5	17 15.0
Semi-diameter + Parallax — Refraction	+ 13 39.1	13 39.1	13 39.1	13 39.1	13 39.1	13 39.1	13 39.1	13 39.1	13 39.1
Refraction to noon,	+ 1 26.4	58.2	32.6	22.7	14.9	6.7	1.8	3	4
Co-latitudes, or height of equator,	34 25 39.0	25 44.5	25 37.5	25 46.9	25 48.4	25 54.2	25 53.4	25 48.8	25 45.5
Latitudes,	55 34 21.0	34 15.5	34 22.5	34 13.1	34 11.6	34 05.8	34 06.6	34 11.2	34 14.5

Numbers corresponding to horary angles,	3.85	11.31	21.82	40.95	60.11	83.81	108.97	140.18
Logarithms,	0.58546	1.05346	1.33885	1.61225	1.77895	1.92330	2.03731	2.14669
Constant factor, or Log. f,	9.76309	9.76309	9.76309	9.76309	9.76309	9.76309	9.76309	9.76309
Constant factor + Log. of numbers,	0.34855	0.81655	1.10194	1.37534	1.54204	1.68639	1.80040	1.90978
Corrections,	2.2	6.6	12.6	23.7	34.8	48.6	63.2	81.2
☉'s declination corrected for different meridians,	14 54 51.5	14 54 51.5	14 54 51.5	14 54 51.5	14 54 51.5	14 54 51.5	14 54 51.5	14 54 51.5
Corrections for horary angles,	— 1.1	— 1.9	— 2.7	— 3.6	— 4.4	— 5.2	— 5.9	— 6.8
D correction,	14 54 50.4	14 54 49.6	14 54 48.8	14 54 47.9	14 54 47.1	14 54 46.3	14 54 45.6	14 54 44.7
Altitudes corrected for error of instrument,	17 10	17 5	17 00	16 55.0	16 45.0	16 35.0	16 25.0	16 00.0
Semi-diameter + Parallax — Refraction	13 39.1	13 39.1	13 39.1	13 39.1	13 39.1	13 39.1	13 39.1	13 39.1
Refraction to noon,	2.2	6.6	12.6	23.7	34.8	48.6	1 3.2	1 21.2
Co-latitudes, or height of equator,	25 41.7	25 39.7	25 40.5	25 45.7	25 46.0	25 49.0	25 52.0	25 45.0
Latitudes,	34 18.3	34 20.3	34 19.5	34 14.3	34 14.0	34 11.0	34 07.1	34 15.0

Mean of 17 Latitudes = 55° 34′ 14″.2.

Note. * H becomes — D when the Sun or Star is North of the Equator.

(Vol. IX. Part I.—p. 234.)

Table II.

Circum-meridian Observations made at Makerstown, 10th February 1820, in order to determine the Latitude, and with a View of ascertaining the Accuracy that may be obtained by that Mode of observing.—Longitude in Time west of Greenwich nearly 10′ 4″. Quicksilver Horizon, covered by one of Troughton's Glass Roofs.

Noon by Chronometer. h ′ ″ 0 7 5	Time from Noon.	$\frac{2\,\text{Sine}^2\,\frac{1}{2}\,P}{\text{Sine}\,1''}$	Observed Angles	Altitudes corrected for error of instrument — 45″	Latitudes deduced.
12 1 12	5.53	67.96	39° 12′ 00″	17° 35′ 37″.5	55° 34′ 18″0
2 37	4.28	39.17	13 20	35 52.5	34 20.8
3 47	3.18	21.38	13 20	36 17.5	34 07.2
4 42	2.23	11.15	13 25	36 20.0	34 11.3
5 36	1.29	4.32	13 27	36 21.0	34 15.0
6 48	0.17	0.16	13 30	36 22.5	34 16.9
8 03	0.58	1.83	13 30	36 22.5	34 16.9
9 06	2.01	7.99	13 25	36 20.0	34 16.6
9 59	2.54	16.51	13 05	36 10.0	34 22.5
10 49	3.44	27.37	12 50	36 2 5	34 24.3
11 42	4.37	41.85	12 45	36 0.0	34 19.2
12 24	5.19	55.49	12 30	35 52.5	34 19.2
13 06	6.01	71.07	12 00	35 37.5	34 25.8
14 05	7.00	96.20	11 45	35 30.0	34 19.5
14 54	7.49	119.96	11 10	35 12.5	34 23.8
16 16	9.11	165.57	10 20	34 47.5	34 23.3
17 18	10 13	204.92	9 50	34 32.5	34 16.3
					Mean — 55 34 18.6

$$\text{Log.}\, f = \frac{\text{Co-sine H Co-sine D}}{\text{Sine (H + D)}}$$

Formula for Log. *f*.

H = 55 34 32	Co-sine	9.75229
D = 14 35 79	Co-sine	9.98576
* H + D = 70 10 11	Ar. Co-sine	0.02655
	Log. *f* =	9.76460

☉'s declination at noon by Ephemeris,	-	= 14 35 48
10′ 4″ west of Greenwich,	- -	— 8.7
Declination corrected for difference of meridians,		14 35 39.3

For the refraction.

Barometer,	-	29.52 = 0.7495 =	9.9938
Thermometer,	-	46 .3 = 8.0 =	0.0033
Zenith distance,	-	.70	2.2009
		23.6	94
			2.2074
	Refraction,	-	— 161.2
	Parallax,	-	+ 8.4
			152.8
			— 2 32.8
	☉'s semi-diameter,		+ 16 13.8
Semi-diameter + Parallax — Refraction			= 13 41.0

Numbers corresponding to horary angles,	67.96	39.17	21.38	11.15	4.32	0.16	1.83	7 99	16 51
Logarithms,	1.83225	1.59295	1.33001	1.04727	0.63548	9.20412	0.26245	0.90255	1 21775
Constant factor, or Log. *f*,	9.76460	9.76460	9.76460	9.76460	9.76460	9.76460	9.76460	9.76460	9.76460
Constant factor + Log. of numbers,	1.59685	1.35755,	1.09461	0.81187	0.40008	8.96872	0.02705	0.66715	0.98235
Corrections,	+ 39.5	22.8	12.4	6.5	2 5	0.1	1.1	4.7	9.6
☉'s declination corrected for different meridians, D =	14 35 39 3	14 35 39.3	14 35 39.3	14 35 39.3	14 35 39.3	14 35 39.3	14 35 39.3	14 35 39.3	14 35 39.3
Corrections for horary angles,	+ 4.7	+ 3.6	+ 2.6	+ 1.9	+ 1.2	+ 0.2	— 0.8	— 1.6	— 2.4
D corrected,	+ 14 35 44.0	14 35 42.9	14 35 41.9	14 35 41.2	14 35 40.5	14 35 39.5	14 35 38.5	14 35 37.7	14 35 36.9
Altitudes corrected for error of instrument,	+ 19 35 37.5	35 52.5	36 17.5	36 20.0	36 21.0	36 22.5	36 22.5	36 20.0	36 10.0
Semi-diameter + Parallax — Refraction	+ 13 41.0	13 41.0	13 41.0	13 41.0	13 41.0	13 41.0	13 41.0	13 41.0	13 41.0
Reduction to noon,	+ 39.5	22.8	12.4	6.5	2.5	0.1	1.1	4.7	9.6
Co-latitudes, or height of equator,	34 25 42.0	25 39.2	25 52.8	25 48.7	25 45.0	25 43.1	25 43.1	25 43.4	25 37.5
Latitudes,	55 34 18.0	34 20.8	34 07.2	34 11.3	34 15.0	34 16.9	34 16.9	34 16.6	34 22.5

Numbers corresponding to horary angles,	27.37	41.85	55.49	71.07	96.20	119.96	165.57	204.92
Logarithms,	1.43727	1.62170	1.74421	1.85169	1.98318	2.07904	2.21898	2.31158
Constant factor, or Log. *f*,	9.76460	9.76460	9.76460	9.76460	9.76460	9.76460	9.76460	9.76460
Constant factor + Log. of numbers,	1.20187	1.38630	1.50881	1.61629	1.74778	1.84364	1.98358	2.07618
Corrections,	15.9	24.3	32.3	41.3	55.9	69.8	96.3	119.2
☉'s declination corrected for different meridians, D =	14 35 39.3	14 35 39.3	14 35 39.3	14 35 39.3	14 35 39.3	14 35 39.3	14 35 39.3	14 35 39.3
Corrections for horary angles,	— 3.0	— 3.8	— 4.3	— 4.9	— 5.7	— 6.4	— 7.4	— 8.3
D corrected,	14 35 36.3	14 35 35.5	14 35 35.0	14 35 34.4	14 35 33.6	14 35 32.9	14 35 31.9	14 35 31.0
Altitudes corrected for error of instrument,	36 2.5	36 0.0	35 52.5	35 37.5	35 30.0	35 12.5	34 47.5	34 32.5
Semi-diameter + Parallax — Refraction	13 41.0	13 41.0	13 41.0	13 41 0	13 41.0	13 41.0	13 41.0	13 41.0
Reduction to noon,	15.9	24.3	32.3	41.3	55.9	1 9.8	1 36.3	1 59.2
Co-latitudes, or height of equator,	25 35.7	25 40.8	25 40.8	25 34.2	25 40.5	25 36.2	25 36.7	25 43.7
Latitudes,	34 24.3	34 19.2	34 19.2	34 25.8	34 19.5	34 23.8	34 23.3	34 16.3

10th of February, mean of 17 Latitudes, ...55° 34′ 18″.6
9th of February, - 17 Latitudes, ...55 34 14.2

Mean, 55 34 16.4 Lat. of Makerstown.

* *Note.* H becomes — D when the Sun or Star is North of the Equator.

XV. *Description of a Vegetable Impression found in the Quarry of Craigleith.* *By* THOMAS ALLAN, ESQ. F. R. S. LOND. & EDIN.

(*Read January* 22. 1821.)

I SOME time ago had the honour to present to the Royal Society, a specimen of a very singular fossil which had been found in the freestone quarry of Craigleith, near this city. It presented the appearance so commonly met with in the sandstone of the coal-formation,—an impression of what has always been considered as the bark of a vegetable connected with the Palm-tribe; but it differed from any thing I had ever before seen of the kind, by having circular marks ranged in a line along the surface, being apparently the impressions of flowers or fruit. As neither of these grow directly from the stem of any plant now known, except among the Cactus genus, this impression might have been referred to it, had not the regularity of distance between these supposed flowers, pointed out the improbability; and it consequently must be referred to some one, the prototype of which is no longer known.

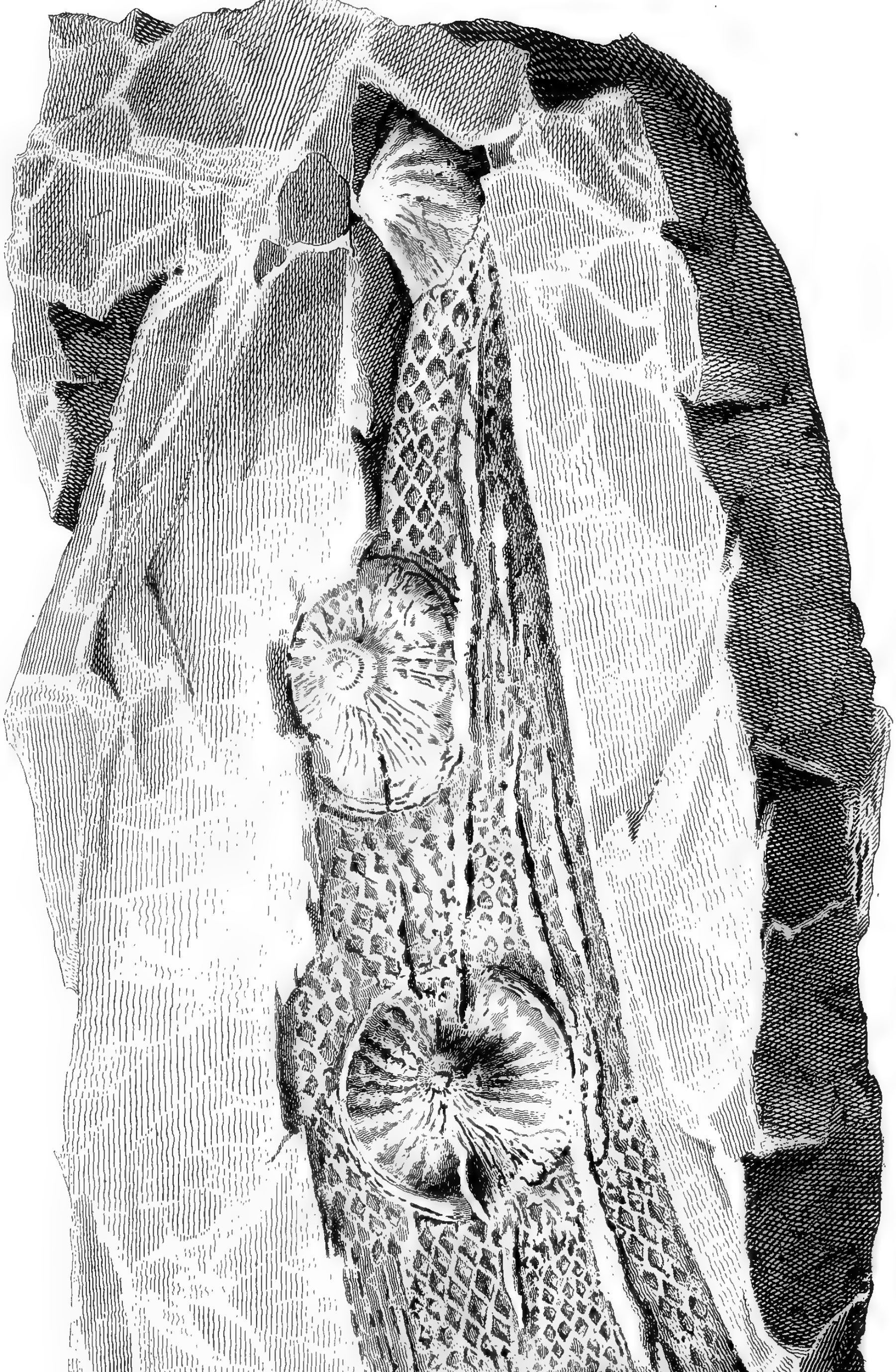
The size of the specimen, of which the annexed engraving is a very exact representation, is twenty-one inches in length,

 and

and about fourteen broad; the widest part of the impression measures four inches, and the diameter of the circles a little more than three. On each edge of the mass there are other impressions of vegetable remains, and in one place some feeble indications of the same kind as those on the principal surface.

I considered this specimen of so much importance, that I was induced to request Mr GREVILLE to make a drawing of it, with the view of communicating it to the scientific world; and I am happy to acknowledge, that to the distinguished abilities of that gentleman, I am indebted for a most beautiful design, from which the annexed engraving has been made by Mr LIZARS. When communicating with Mr LIZARS, on the subject of this engraving, he shewed me a plate he had executed for the *Encyclopædia Edinensis*, representing a specimen belonging to Dr MILLAR, similar to my own, which till then I considered unique. I waited on Dr MILLAR, who politely shewed me his specimen. It presents a string of five buds: they are smaller in dimensions, about an inch, or an inch and a half in diameter, but very distinct, set at regular distances, and in all respects quite analogous. This specimen was found in a quarry belonging to Sir JOHN DALRYMPLE, on the ridge a little south of Dalkeith,—where I learn a great many other fossils, and many curious impressions of plants, are found in great abundance.

It is not my intention to touch upon the interesting speculations which the occurrence of these unknown species of vegetables irresistibly opens to the mind. They give us a glimpse of former periods, which sets conjecture at defiance, and smiles at the vain attempts of theory to unravel. I only wish to call the attention of the naturalist, to the advantage which may be derived from a proper attention to this department of natural



R.K. Greville Delin.

Eng.d by W.H.Lizars

natural history; and when it is known how much this country, I may say our immediate neighbourhood, abounds in fossils of this description, it is rather to be lamented that no extensive collection of them, has been systematically made. In general they are much too bulky for usual sized cabinets; and if some place were appropriated for their reception in the Museum of the Royal Society, I have no doubt they would soon accumulate. For besides in the vicinity of Edinburgh and Dalkeith, they are found in immense abundance all along the coast of Fife, down to St Andrew's. Within high-water mark near Dysart, there are trees equal in bulk to the celebrated fossil lately found in the quarry at Cowcaddens near Glasgow, which has the strongest possible resemblance to an oak; and in the quarry of Cullalo, five or six miles from Burntisland, belonging to Mr Stuart of Dunearn, the whole of the upper stratum of a most extensive field of sandstone, is filled with them to an extent beyond any thing I have ever seen. It was in this locality that a specimen was found, which was sent by Mr Ferguson of Raith to the College; it appeared to be some species of Reed, of a truly gigantic size; its form is elliptic, and it measures about a foot by eight inches in diameter, and is in length seven or eight feet.

Having such stores of these fossils in the immediate neighbourhood, it is no small reproach to us to be without a collection. On the Continent, I am told, an antediluvian *Flora* is now in preparation; and with such means at our disposal, why should we not have an antediluvian *Hortus Siccus?*

XVI.

XVI. *Account of the Native Hydrate of Magnesia, discovered by* Dr Hibbert *in Shetland. By* David Brewster, LL. D. F. R. S. Lond. & Sec. R. S. Edin.

(Read January 8. 1821.*)*

THE Native Hydrate of Magnesia was first discovered, and ranked as a separate Mineral, by the late Dr Bruce of New York. It was found only at Hoboken in New Jersey, traversing serpentine in every direction, in veins from a few lines to two inches in thickness. Its specific gravity was 2.13, and it yielded upon analysis 70 parts of pure magnesia, and 30 of water *.

In the year 1813, I received some fragments of this rare mineral from our late eminent countryman Dr John Murray, and though it exhibited no traces of a crystalline structure, I found it to be a regularly crystallised mineral, with one axis of double refraction perpendicular to the laminæ †. The connection between the primitive form of minerals and their number of axes of double refraction, which I observed at a subsequent period, enabled me to determine that the Native Hydrate of Magnesia belonged either to the *Rhomboidal* or the *Pyramidal* system of Mohs.

In

* See Bruce's *American Mineralogical Journal*, vol. i. p. 26.–30.

† See *Phil. Trans.* 1814. p. 213., and 1818, p. 211.

In this state of our information respecting native magnesia, Dr Hibbert, who has distinguished himself by his excellent mineralogical survey of Shetland, and augmented our national resources by the discovery of Chromate of Iron in large quantities, put into my hands a mineral from Shetland, which had been considered by mineralogists as *White Talc*, but which, he was persuaded, differed materially in the nature of its ingredients from that substance. In consequence of being familiar with the Hoboken Magnesia, I considered the Shetland specimen as the same mineral; and I put this opinion beyond a doubt, by establishing the identity of their optical properties, and also by a chemical examination of the two substances.

Mineralogical Character.—The structure of Native Hydrate of Magnesia is distinctly lamellar. The laminæ sometimes diverge from a central line, and frequently occur in groups, with the laminæ of one group inclined to those of another, like the masses of mica in granite.

The colour of the laminæ is white, and a slight tinge of green is sometimes observed, when we look upon their edges. They are perfectly transparent when separate; but I have noticed in specimens exposed to the weather, a dull and white opacity, which had been induced by the separation of the mineral into a greater number of minute laminæ. This white part has the same relation to the transparent part as *Albin* has to *Apophyllite* *, and, as happens with this mineral, the disintegration follows the crystalline structure of the body. One specimen of this kind exhibited a six-sided prism, the interior of which was undecomposed, while all the external part had a white opacity.

The Native Hydrate of Magnesia scratches *Talc*, from which it may be easily distinguished, as the former marks white paper with a silvery powder, whereas the latter gives only

* See *Edin. Phil. Journal*, vol. i. p. 5.

only a polished line, and leaves none of its own substance. Its hardness seems to be 1.5.

In several specimens I have observed a distinct crystalline structure, in the form of the regular hexahedral prism. The pyramidal form being therefore excluded, it will belong to the *Rhomboidal* system of MOHS.

Its specific gravity is 2.336. It adheres very slightly to the tongue; and it will constitute a new Genus of the 5th Order, or that of MICA in the 2d Class of MOHS' system, unless the order of *Talc-Mica* is modified to receive it.

Locality.—Dr HIBBERT found this substance, in 1817, at Swinaness in Unst, one of the Shetland Isles, traversing serpentine in all directions, being mixed with the Magnesian Carbonate of Lime, and forming veins from half an inch to six or eight inches broad.

Chemical Character.—Hydrate of Magnesia dissolves entirely in muriatic, nitric and dilute sulphuric acids, and I obtained from its solutions in the muriatic and sulphuric acids, the deliquescent salt of *Muriate of Magnesia*, and regular crystals of *Sulphate of Magnesia*. On some occasions a very slight effervescence takes place; but this no doubt arises from adhering particles of carbonate of lime, or from a small quantity of carbonic acid, which may have been absorbed by exposure to the atmosphere.

The following analysis of this mineral has been made by Dr FYFE, since the preceding account of it was drawn up:

Magnesia, - -	69.75
Water, - -	30.25
	100.00

a

a result which differs only a quarter of a *per cent.* from that of Dr Bruce of New York.

Optical Structure.—The Native Magnesia has *One* axis of double refraction perpendicular to the laminæ, and exhibits the single system of coloured rings traversed by a black cross. The character of its action is *Positive* like that of *Quartz*, and the tints which it polarises are different from those of Newton's scale, resembling somewhat those which surround the resultant axes of Selenite *. This mineral is not phosphorescent by heat.

Distinctive Character.—The Hydrate of Magnesia is distinguished from *Talc*, by its having one axis of double refraction, while *Talc* has two axes;—by its lower specific gravity, and greater hardness;—by its marking paper with a polished line, in place of a silvery one, as already noticed; and by its solubility in acids. It is distinguished from the *Common Mica* with two axes, by the elasticity of the latter, as well as by its two axes; and it is equally distinguished from the less flexible *Mica of Kariat in Greenland*, and from other micas that have only one axis, by that axis being positive in the *Magnesia* and negative in the *Mica*, and also by the character of the tints with which the axis is encircled.

It is distinguished from *Selenite*, by its having one axis of double refraction perpendicular to the laminæ, whereas *Selenite* has two resultant axes lying in the plane of the laminæ;—by the want of regular cleavages,—and by its solubility in acids.

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* See *Phil. Trans.* 1818, p. 243.

XVII.

XVII. *Description of a Magnetimeter, being a New Instrument for Measuring Magnetic Attractions, and Finding the Dip of the Needle; with an Account of Experiments made with it.* By William Scoresby, Esq. jun. F. R S. E. M. W. S. *&c.*

(Read January 22. 1821.)

My Dear Sir, *Liverpool*, 9*th Jan*. 1821.

About ten months ago, I had the honour of communicating to the Royal Society, a description of a new instrument for ascertaining the Magnetic Dip. Having made very considerable improvements in the apparatus, by means of which some curious results on the magnetic laws, especially those that relate to the production and annihilation of magnetism in iron, have been obtained,—I now beg leave to submit to the Society a drawing and description of my improved instrument, together with an outline of some of the most interesting experiments made with it. Many of the results appear to me to be new; if so, their importance will be my excuse for repeating some parts of the description given in the former paper. It has been long known that iron might be rendered magnetical by percussion; but I am not aware that the precise effect of position has ever been suggested. I remain, &c.

William Scoresby *Jun.*

To Dr Brewster,
Sec. Royal Soc. Edin.

From a series of observations on the anomalies in the position of the Magnetic Needle on ship-board, made on the coast of Spitzbergen in the years 1815 and 1817, I was led to attribute the *deviation of the compass* to the combined attraction of all the iron in the ship having a vertical position, as it appeared that, in high latitudes, horizontal bars of iron had scarcely any influence on the needle. The result of my investigations, with the several inferences drawn from them about the time of observation, were published in the *Philosophical Transactions* for 1819. In the present paper, therefore, it is my intention only of communicating to the Royal Society some curious facts which have arisen out of a further investigation of the subject.

For examining into the phenomena of the polarity of iron arising from position, &c. I constructed, about the month of December 1819, an apparatus, of which, with improvements recently made, the following is a description. It consists of a small table of brass, A, Plate XIII. Fig. 1., $4\frac{1}{2}$ inches square, and $3\frac{3}{4}$ inches high, having a plate of brass C attached to it by hinges, and moveable by means of the wheel and pinion D, E, through an arch of 250 degrees of a vertical circle. This plate has a small straight groove running from end to end, in the line *a a*, for the purpose of receiving bars of metal, the polarity of which is is to be determined. These bars are readily fixed to the plate, by being slipped through a circular aperture in the end of a spring *b*, which, perforating the moveable plate, and acting downward, firmly embraces any substance laid along the groove. The angular position of the moveable plate is marked by a circle FF, screwed upon the side of the table. It is graduated so as to mark the angle between the moveable plate and the horizontal plane, whether above or below it. To insure accuracy in this angle, the true horizontal position of the table, and with it the horizontal line on the circle, is determined by means of a spirit-level G; and that the movements of the plane may be accurate, and the angle marked true, the pin which passes through the hinges also forms the centre of the wheel D, and terminates exactly in the centre of the graduated circle F. H is a moveable flat plate of brass, divided into rhumbs and degrees: it is furnished with a magnetic needle, having an agate cap traversing on a brass or steel point. The needle can be changed according to the nature of the circumstances; a very light and strongly magnetized one being used in delicate experiments. The compass or plate carrying the needle, being moveable, its distance from the bar resting on the limb C, can be varied at pleasure. The centre of the hinges is one-tenth of an inch above the level of the table; the magnetized needle stands at the same elevation; and the bars in use being one-fourth of an inch diameter, are sunk in the groove of the moveable plate to such a depth, that their axis, or centre, precisely corresponds with the centre of the hinges; hence the middle of the extremity of each bar is at the same elevation, and at the same distance from the needle in every position of the moveable limb. To give firmness to the instrument in making experiments, the table is fixed by the feet to a mass of lead I, of seven or eight pounds weight. By means of this plate of lead, which has a screw *d* at each corner, the whole apparatus is readily put into a horizontal position. As the instrument is put together by screws, it can be easily taken to pieces, so as to become exceedingly portable.

Hitherto this instrument has been principally used for estimating the magnetism of position in iron,—for ascertaining the existence of permanent polarity in iron or steel,—for measuring and comparing magnetic attraction or repulsion, as produced in iron by certain means independent of the magnet,—and for determining the magnetic dip.

From ignorance of, or inattention to, the magnetism of position, various erroneous conclusions have been drawn and propagated respecting the phenomena of the magnet. For instance: In several popular works on this subject, that I have consulted, it is stated, that "if an iron-bar have gained a verticity by being heated red-hot and cooled again, north and south, and then hammered at the two ends, its virtue will be destroyed by two or three smart blows on the middle *." Now there is a particular case in which this may be true; but most generally the statement is inaccurate: for by hammering a bar of iron at the ends, or in the middle, magnetism may be destroyed, produced, or inverted, according to the position in which the bar is held. The effect of position is indeed such, that a bar that has been presented to a magnetic needle, and found free from magnetism, when presented a second time, a quarter of an inch nearer to the needle, or at an angle a degree or two nearer the horizontal, may appear to have gained south polarity,

* See HUTTON's *Math. & Phil. Dict.* &c. article *Magnet.*

polarity, by attracting the north pole of the needle. With this instrument, however, pieces of iron or steel, after having their state as to magnetism determined by it, and being then submitted to any operation capable of affecting their polarity, can be brought a second time to the same precise position, can be presented at the same angle to the needle, and can have any change in their polarity determined in the most satisfactory manner.

As a substitute for the dipping needle, this instrument being much less expensive, and much more portable, may be considered, perhaps, of some importance. The situation in which bar-iron, void of permanent polarity, loses its magnetism of position, is the plane of the magnetic equator. The obliquity of this plane, measured from the horizontal, is, in London, 19° 26′, that is, in the line of its axis coinciding with the magnetic meridian. It dips towards the south, and is horizontal in the east and west. The obliquity of the magnetic equator being the complement of the dip, and my magnetic apparatus enabling us to discover that obliquity, by pointing out the angle of no-attraction in iron, we are furnished with a simple process for determining the dip of the needle *.

By means of this instrument, several curious results, in the phenomena of magnetism, have been obtained. The experiments were chiefly made on small bars of iron and steel, laid in the groove of the moveable plate. As the instrument, at the same time, was placed in a north and south position, according to the compass, the bar, on being elevated or depressed, traversed in the magnetic meridian. The moveable limb was

* The remarks subjoined to No. 2. of the succeeding propositions point out the method of finding the dip, and show what precautions are necessary to be used to insure accuracy in the result.

was usually directed towards the north. Four bars were principally made use of. No. 1., consisting of a piece of iron-wire, softened by heating, a quarter of an inch in diameter, and six and a half inches long. No. 2., another piece of wire, of two-tenths of an inch diameter. No. 3., a cylindrical bar of hardened steel magnetised, of the same dimensions as No. 1. And, No. 4. a similar piece of steel softened by heating to redness. With these, and the instrument already described, a great number of experiments were made; the results of which, in the form of propositions, are annexed; and as almost every experiment was repeated a number of times, I can give the results with the utmost confidence. What is called the Magnetic Axis in the following propositions, is to be understood as the position pointed out by the dipping needle; the Magnetic Meridian is a vertical plane in the line of the magnetic north and south; and the Magnetic Equator is an oblique plane, to which the magnetic axis is perpendicular.

PROPOSITIONS, *&c.*

1. Iron bars become magnetical by position, excepting when placed in the plane of the magnetic equator; the upper end, as regards the position of the magnetic equator, becoming a south pole, and the lower extremity a north pole.

Experiment 1.—Bar No. 1. placed in the groove of the moveable limb, with the compass [H] at the distance of $1\frac{1}{4}$ inches from its extremity, and the instrument north and south, (as in Fig. 3.) did not disturb the needle at the angle of 20°; but raised to an angle of 46°, it repelled the north end of the needle one point, [11° 15′], and at an angle of 73° two points. The north end of the plate being depressed 25° below the horizontal, the bar instantly exhibited an attraction of one point. Though the bar was then changed end for end, still the same results were obtained.

Exp. 2.

Exp. 2.—A bar of cast iron of the same magnitude was found to possess much less magnetism of position than the above. With the compass $1\frac{1}{4}$ inches from the end of the bar, No. 1., produced a deflection of 11°, when elevated 29° above the plane of no-attraction: while the bar of cast iron, though of a soft kind, required to be elevated 68° above the plane of no-attraction, before an equal repulsion was produced. When the bar No. 1., was raised to the angle of 68° above the plane of no-attraction, it repelled the compass-needle 27°.

Exp. 3.—Iron-bars of similar thickness, but of unequal lengths, were found to possess different capacities for magnetism of position. Thus a bar one-fourth of an inch in diameter, and nine inches long, elevated 70°, caused a deflection in the compass-needle of 23° 45′; the same reduced to $6\frac{1}{2}$ inches long, then repelled the needle 18°; and a portion of the same $2\frac{1}{2}$ inches long, only repelled the needle 7° 30′.

2. No attraction or repulsion appears between a magnetised needle and iron-bars; the latter being free from permanent magnetism, whenever the iron is in the plane of the magnetic equator; consequently by measuring the angle of no-attraction, in a bar placed north and south, we discover the magnetic dip.

Exp.—With one end of the bar No. 1. compass $2\frac{3}{4}$ inches distant, the elevation of the plane of no attraction, at Liverpool, was 20°, with the other end of the bar $17\frac{1}{2}$°; the mean or co-dip $18\frac{3}{4}$°; dip $71°\frac{1}{4}$. On the coast of Greenland, in July last, Latitude 70° 36′, Longitude 17° 30′ W. the mean angle of no attraction was 14°, making the magnetic dip 76°.

Remark.—For the purpose of making use of this instrument for finding the dip, it is necessary to employ a very small needle, in comparison of the bar of iron, and to place the needle as far distant as it will conveniently act; otherwise the magnetism infused into the

the bar by the needle, will be mistaken for the magnetism of position, and give an erroneous result. Thus, in the preceding examples of dip, the needle in use being too large and powerful, the results, especially the latter, are probably a little too low. The nature of this error will more particularly appear from the next proposition.

Note.—When a sufficiently small needle is not at hand, the amount of error in the observed dip, occasioned by the magnetic influence of the needle on the bar, may, in all cases, be determined by experiment. For we know that the plane of the magnetic equator coincides with a true horizontal plane, in an east and west magnetic line, consequently, when the instrument is placed east and west, the plane of no-attraction should be horizontal. But, if the instrument be placed in this position, with the compass-needle at right angles to the end of the bar, as in Figure 2. it is found that the infusion of magnetism from the needle makes the plane of no-attraction something above the horizontal. This angle, measured from the plane of the magnetic equator, (instrument E. and W.) is the correction to be applied to the co-dip, observed with the compass-needle at the same distance from the end of the bar, with the instrument N. and S., as in Figure 3. Thus, with the instrument N. and S., and the north-pole of the compass-needle eight-tenths of an inch from the end of the bar No. 1., the mean angle of no-attraction was 26°; and with the instrument E. and W., compass same distance, the angle of no-attraction was 7° 30 above the horizontal. Now, were the magnetic dip 90°, this would be the correction to be made use of; but as, in the present dip, the moveable plate of the instrument, when E. and W., traverses obliquely to the magnetic equator, while in the N. and S. direction it moves perpendicularly to it, the observed correction must be reduced, so as to give the angle formed with the magnetic equator. In this operation, radius is to the sine of the dip, as sine of the observed correction (or angle of no-attraction with the instrument E. and W.) to sine of the true correction, to be applied to the co-dip, observed with the instrument N. and S. Hence the above observed error of of 7° 30′ thus reduced, calling the dip 71° 30′, gives the true correction 7° 6′. This subtracted from 26°, the observed co-dip, leaves 18° 54′ for the inclination of the magnetic equator, which, I believe, is not greatly wide of the truth.

3. Before a magnet can attract iron, that is totally free from both permanent magnetism and that of position, it infuses into the iron a magnetism of contrary polarity to that of the attracting pole.

Exp. 1.—Bar No. 1., with the compass half an inch from it, had no attraction or repulsion when the bar was at a mean angle of $35\frac{1}{2}°$; the same bar, with the compass at $\frac{8}{10}$ths of an inch distance, gave the mean angle of no attraction $27\frac{1}{2}°$; at $1\frac{1}{4}$ inches distance, 24°; at $2\frac{2}{10}$ inches, $20\frac{1}{4}°$; and at $2\frac{6}{10}$ inches distance, the mean angle of no attraction was $19\frac{1}{4}°$. This change, in the angle of no attraction, with the distance, evidently shews that some magnetism of position was necessary to counteract the magnetism communicated by the needle, which was considerable when very near, but became scarcely sensible at the distance of two or three inches.

Exp. 2.—To prove that the magnetic needle, at short distances, comunicates magnetism to the bar, until it is balanced by the magnetism of position, I placed the compass $1\frac{1}{4}$ inches from the bar No. 1. and found the mean angle of no attraction to be 24°; then placing another small needle at the same distance from the bar, with its north pole abreast of the north extremity of the bar, I found the angle of no attraction changed to $20\frac{1}{4}°$. In this case, magnetism was communicated by the needle to the north extremity of the bar, and the same polarity by the other needle to the south end of the bar, so as to counteract the influence of each other; hence, had the magnetic power of both needles been the same, the bar would have been freed from all communicated magnetism but that of position, and would have pointed out the true line of no attraction.

4. A bar of soft iron, held in any position, except in the plane of the magnetic equator, may be rendered magnetical by a blow with a hammer, or other hard substance; in such cases, the magnetism of position seems to be fixed in it, so as to give it a permanent polarity.

Exp. 1.—Bar No. 1. freed from magnetism, and held perpendicularly in the hand, was struck a smart blow over the upper end with a small hammer; though it had previously evinced no attraction for the compass-needle $1\frac{1}{4}$ inch distant, when the elevation of the moveable plate was $21\frac{1}{2}°$, the upper end of it now attracted the north pole of the needle upwards of a point, at the same angle of elevation. The lower end of the bar produced an equal repulsion.

Exp. 2.—The same bar was now inverted, held as before, and a blow again struck on the upper end. The poles of the bar were found to be reversed; that which was before north had become a south pole.

Exp. 3.—Many more experiments were made on the effect of blows, from which it appeared, that when the iron was held in or near the position of the magnetic axis, a blow on any part of the bar, struck in any direction, or with any hard substance, such as a hammer, a piece of copper, brass, or ivory, or even with a bit of wood, invariably rendered the bar magnetical, the upper end becoming a south, and the lower end a north pole. In these experiments, the iron, when struck, was held nearly vertical in the hand, without resting on any thing; yet both ends seemed to acquire an equal degree of magnetism.

Remark.—The fixing of the magnetism of position in iron or steel by hammering, may be employed with advantage in the experiment of producing a magnet, with the use only of unmagnetised bars of steel and two rods of iron. For in the commencement, the bars of iron and steel may have permanent polarity given them by hammering in a vertical position, by which the process will be considerably shortened.

5. An

5. An iron-bar, with permanent polarity, when placed anywhere in the plane of the magnetic equator, may be deprived of its magnetism by a blow.

Exp.—Many experiments were made on the effect of blows on iron in this position: the result was always to diminish the polarity, and generally wholly to destroy it. It commonly happens, that a single blow with a hammer is sufficient for destroying the magnetism of the bar; but if it have been strongly touched with a magnet, it may require two or three blows at each end.

Remark.—For freeing iron of magnetism, it is generally recommended to heat it to redness, and allow it to cool in an east and west position; but as this process oxidizes the metal, and is attended with loss of time, the action of the stroke of a hammer is certainly preferable, and is much more effectual. Where there is no proper instrument for ascertaining the elevation of the magnetic equator, along its north and south axis, the effect of blows on the magnetism of iron, may be shewn with tolerable precision by a common pocket compass, or other small magnetic needle. Place the compass on a table, whose surface is pretty nearly horizontal, with the needle corresponding to the direction of the north and south line of the graduated plate, where there is no card; and then place the iron, the magnetism of which is to be determined, on the table, at right angles to the north extremity of the needle, and an inch or two distant from it, in an east and west position, marking its situation, either by a line drawn on the table, or by two brass pins. The iron being now in the plane of the magnetic equator, will produce no derangement in the needle, if it be free from permanent magnetism; but after being hammered in the magnetic axis, on being brought to the same position again, with regard to the compass, the end of the bar that was upward during the hammering, will be found to attract the north end of the compass-needle: If hammered again, when laid horizontally, and pointing east and west, its magnetism will be annihilated.

 6. Iron

6. Iron is rendered magnetical if scowered or filed, bent or twisted, when in the position of the magnetic axis, or near this position; the upper end becoming a south pole, and the lower end a north pole; but the magnetism is destroyed by the same means, if the bar be held in the plane of the magnetic equator.

Exp.—Numerous experiments were made on the effect of these different kinds of treatment: the result, though varying a little as to the intensity of the magnetism produced, was always the same as to its quality. Any kind of shock, it seems, is sufficient to render iron magnetic. A bar [No. 1.] dropped on its end from the height of three feet on a carpet, became sensibly magnetic; and dropped on a stone received strong polarity, the lower end in each case becoming a north pole: the same bar then dropped horizontally on the floor, in an east and west line, so as to strike the ground in the plane of the magnetic equator, was immediately deprived of its polarity.

7. Iron heated to redness, and quenched in water, in a vertical position, becomes magnetic; the upper end gaining south polarity, and the lower end north.

Exp.—Bar, No. 2. after being deprived of all magnetic virtue, was heated red-hot, and quenched in water, in a vertical position. The lower end was then found to repel the needle of the instrument, when the moveable plate was in the plane of the magnetic equator, 8°; the upper end attracted it about the same quantity.

8. Hot iron receives more magnetism of position than the same when cold.

Exp.—The contrary of this has, I think, been generally assumed. The experiments, however, were most decisive. An iron-bar, No. 2. in a vertical position, at right angles to the north end of the needle, and

and $1\frac{1}{4}$ inches distant, produced a deflection of $27\frac{1}{2}°$. The same heated to redness, and then presented in the same position as before, produced a deflection of 60°. On repeating the experiment with the bar a little nearer to the compass, the mean deflection of both ends of the bar was 15° when cold; but when heated red-hot, the mean repulsion was 77°.

Remark.—On trying the effect of heat on a magnet [bar No. 3.] its power was found to be permanently weakened by heating to 300° or 400°; but, from several experiments, it appeared that the magnet atttacted and repelled as much when hot as cold.

9. A bar-magnet, if hammered when in a vertical position, or in the position of the magnetic axis, has its power increased if the south pole be upward, and loses some of its magnetism if the northend be upward.

Exp.—The compass being placed at the distance of $4\frac{1}{2}$ inches from the south end of the magnetic bar No. 3., while the bar was laid on the moveable plate of the instrument, at an angle of $21\frac{1}{2}°$, the needle was drawn from its meridian 22°. The bar being then struck ten smart blows on the end with a hammer, south pole upward, its attraction was found to be increased to 26°; ten more blows increased it to 28°; twenty more to 31°; after which there was little change produced, though forty more blows were struck. The north end of the magnet was now found to repel the needle $17\frac{1}{2}°$. On striking this end, while held in the hand, north pole up, after ten blows of the hammer, it only repelled 14°; and the south end, which had not been struck, attracted the needle 3° less than before.

10. A bar of soft steel, without magnetic virtue, has its magnetism of position fixed in it, by hammering it when in a vertical position; and loses its magnetism by being struck when in the plane of the magnetic equator.

Remark.

Remark.—The effect produced by hammering iron, occurs also in steel, but with this difference: one blow is generally sufficient to change the poles of iron, that has been rendered magnetic by hammering, or to deprive it of magnetism after it has acquired polarity; but in steel, it frequently requires two or three or more strokes of the hammer, before the effect be fully produced.

11. An electrical discharge, made to pass through a bar of iron, void of magnetism, when nearly in the position of the magnetic axis, renders the bar magnetic; the upper end becoming a south pole, and the lower end a north pole; but the discharge does not produce any polarity, if the iron be placed in the plane of the magnetic equator. The effects appear to be the same, whether the discharge be made on the lower or upper end of the bar, or whether it is passed longitudinally or transversely through the iron.

Exp. 1.—Bar, No. 1. freed from magnetism, and placed in the position of the magnetic axis, received the shock of a Leyden jar, on its upper end from the positive electricity, by which it was rendered magnetic, the lower end being found to repel the north pole of the compass needle of the magnetimeter, about 3°. This experiment varied by giving the shock to the lower end of the bar, and also by passing the discharge transversely, first through the upper end, and then through the lower end, still gave similar results, the lower end of the bar in each case repelling the north pole of the needle 4° or 5°.

Exp. 2.—With the friendly and valuable assistance of Dr Traill, (with whose excellent apparatus all the electrical experiments were made,) several discharges of a battery of sixteen jars were passed through the iron-bar, when in the same position and circumstances as in the last experiment. (1.) The lower end of the bar being connected with the outside of the battery, and the discharge from the inside of the jars being made on the upper end, the magnetism acquired was such, that the lower end of the bar repelled the needle,

needle, in one experiment 10°, and in another 14° or 15°. (2.) The bar, freed from magnetism, and the shock of the battery received on the lower end of it, it repelled the needle 16°. (3.) A discharge taken from the outside of the jars, the lower end of the bar being connected with the positive electricity, gave a repelling power of 15°.

Exp. 3.—The bar was now placed horizontally, pointing east and west by the compass, consequently in the magnetic equator. In this position, the discharge of an electrified jar sent through it, produced no magnetism whatever, and the effect of the battery was scarcely perceptible. The slight deviation of the needle, indeed, after one discharge of the battery, is to be attributed to some accidental circumstance; probably the bar was not accurately in the magnetic equator.

12. A bar of iron possessing some magnetism, has its polarity diminished, destroyed, or inverted, if an electric discharge be passed through it, when it is nearly in the position of the magnetic axis, provided the south pole of the bar be downward; while its magnetism is weakened or destroyed, if it receive the shock when in the plane of the magnetic equator.

Exp. 1.—The bar, No. 1., having such a magnetic influence as to produce a deflection of the compass needle of 10°, was placed in the direction of the magnetic axis, north pole upward. A shock from the battery being then passed through it, the whole of its magnetism was found to be dissipated. The discharge of one jar on the bar, when slightly magnetised, with its north pole upward, had a similar effect; only in some instances, the magnetism, though weakened, was not wholly destroyed.

Exp. 2.—The bar being in the plane of the magnetic equator, and having such polarity as to produce 10° deflection of the needle, had a charge of the battery passed through it, by which its power on the needle was reduced to 2°. The shock of a single jar, produced in some degree a similar effect.

13. Iron

13. Iron is rendered magnetical, if a stream of the electric fluid be passed through it, when it is in a position nearly corresponding with that of the magnetic axis; but no effect is produced, when the iron is in the plane of the magnetic equator.

Exp. 1.—Bar, No. 1., freed from magnetism, and placed upright in the prime conductor, had a silent stream of electricity drawn from it by Dr TRAILL, first with a pointed wire, and then with the point of a cone of wood. In both cases the upper end became a south pole, and the lower end repelled the needle 6°. Sparks drawn from the bar by a piece of metal answered the same purpose.

Exp. 2.—The prime conductor being turned into an east and west position, the bar was introduced into an orifice in the end of it, and consequently obtained the position of the magnetic equator. A stream of electricity drawn from it with a cone of wood, or with a piece of metal, did not render it at all magnetic

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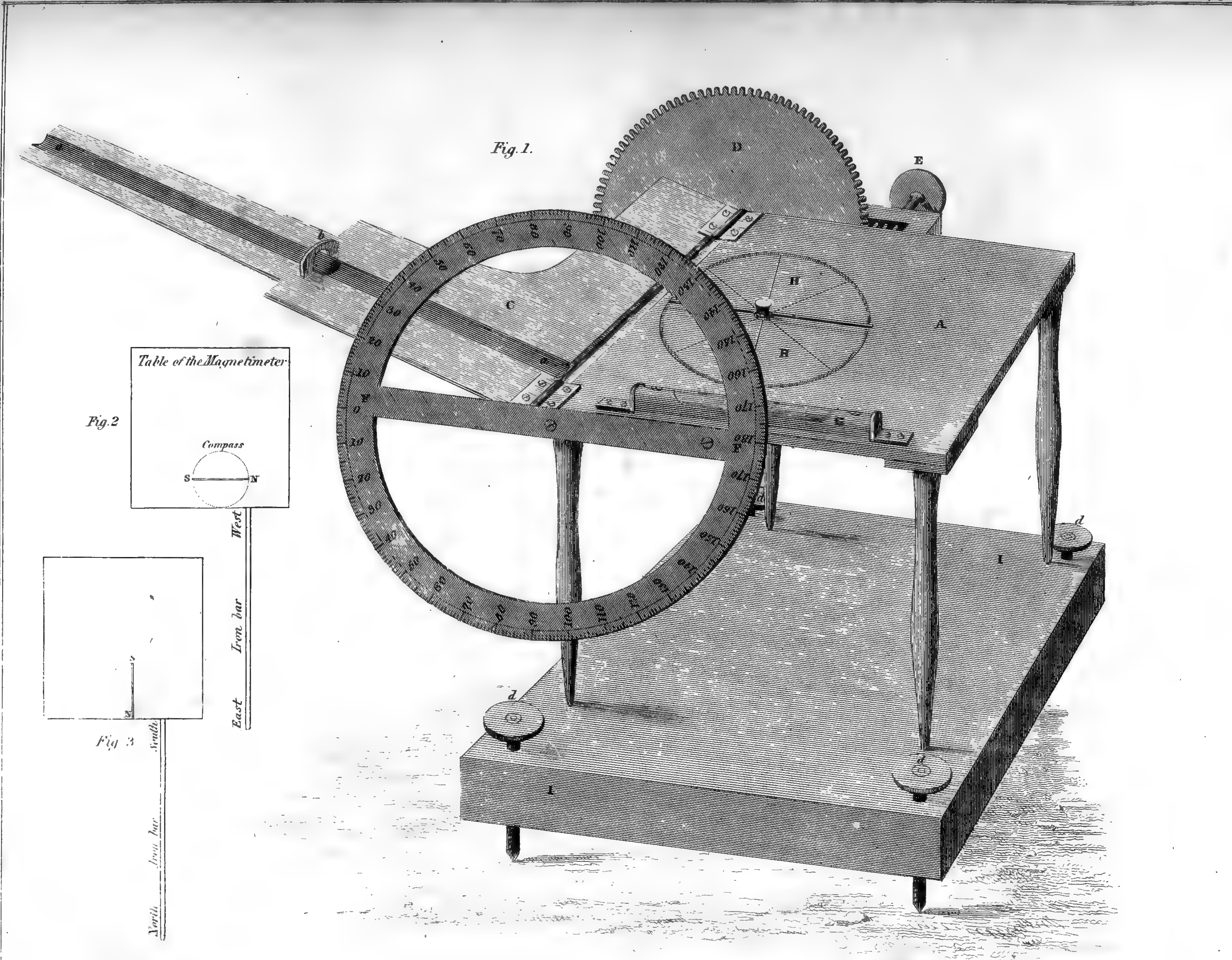
SOME experiments of a similar nature to those which are given in illustration of the last three propositions, were attempted with a galvanic apparatus, for the purpose of ascertaining whether some of the electro-magnetic phenomena, lately observed by Mr OERSTED, be not referable to the position of the iron or steel made use of in his experiments; but the power of the apparatus I employed, though sufficient to produce striking effects on the position of a compass needle, was not capable of magnetising iron; consequently the experiments made with it did not prove satisfactory.

XVIII.

Engraved for the Royal Society Trans. Vol IX page 258



Drawn by W. Scoresby.

Engraved by W.H. Lizars

XVIII. *Account of the Establishment of a Scientific Prize by the late* Alexander Keith, Esq. of Dunottar. *In a Letter from the Trustees to Sir* Walter Scott, Bart. P. R. S. E.

(*Read December* 18. 1820.)

Gentlemen,

It is no doubt already known to you, that the late Alexander Keith, Esq. of Dunottar, bequeathed the sum of L. 1000 for the purpose of promoting the interests of Science in Scotland. Having been appointed Trustees for the Management of this Fund, we have endeavoured to appropriate it in the most advantageous manner for the advancement of Science; and we have the satisfaction of stating, that the plan which has been adopted met with the special approbation of Mr Keith himself, to whom it was communicated previous to his death.

As the Royal Society of Edinburgh is the principal Scientific Establishment in Scotland, we hereby offer to its President and Council the sum of L. 600; the principal of which shall on no account be encroached upon, while the interest shall form a Biennial Prize for the most important discoveries in Science, made in any part of the World, but communicated by their Author to the Royal Society, and published for the first time in their Transactions.

With regard to the form in which this Prize is to be adjudged, we beg leave to suggest, that it may be given in a Gold Medal, not exceeding 15 guineas in value, together with a sum of Money, or a Piece of Plate, bearing the devices and inscriptions upon the Medal.

If, during any of the Biennial Periods, commencing from Martinmas 1820, no discoveries of sufficient importance shall be communicated to the Society, the interest of the Fund may be added to the principal, after paying the incidental expences incurred, from the preparation of the dies and other causes.

Leaving all other arrangements to your judgment and discretion, we have only to express the hope, that this Donation may realize the Patriotic Views of its Founder, and contribute in an eminent degree to advance the honour and interests of our native Country. We have the honour to be,

GENTLEMEN,

Your most obedient,

Humble Servants,

ALEX. KEITH.
J. KEITH.
DAVID BREWSTER.

EDINBURGH,
Dec. 4. 1820.

TO SIR WALTER SCOTT, Bart. PRESIDENT,
and the other Members of the Council
of the Royal Society of Edinburgh.

RESOLVED,

RESOLVED,

That the President and Council of the Royal Society of Edinburgh, cannot forget the zeal with which their late venerable Associate, Mr KEITH of Dunottar, pursued every object that could forward the discovery and the dissemination of knowledge: and they receive the gift which has been announced by his Trustees, under the conditions prescribed, with sentiments of the most respectful remembrance and gratitude, and with the determination that the intentions of Mr KEITH shall be fulfilled, in a manner, it is hoped, which will do equal honour to his Memory, and to the future successful Candidates for the distinction of the KEITH Medals.

RESOLVED FURTHER,

That this resolution be transmitted by the President to the Trustees of Mr KEITH, and that these Gentlemen be at the same time requested, to accept the thanks of the President and Council, for the trouble they have so obligingly taken on the present occasion.

ROYAL SOCIETY HALL,
Dec. 18. 1820.

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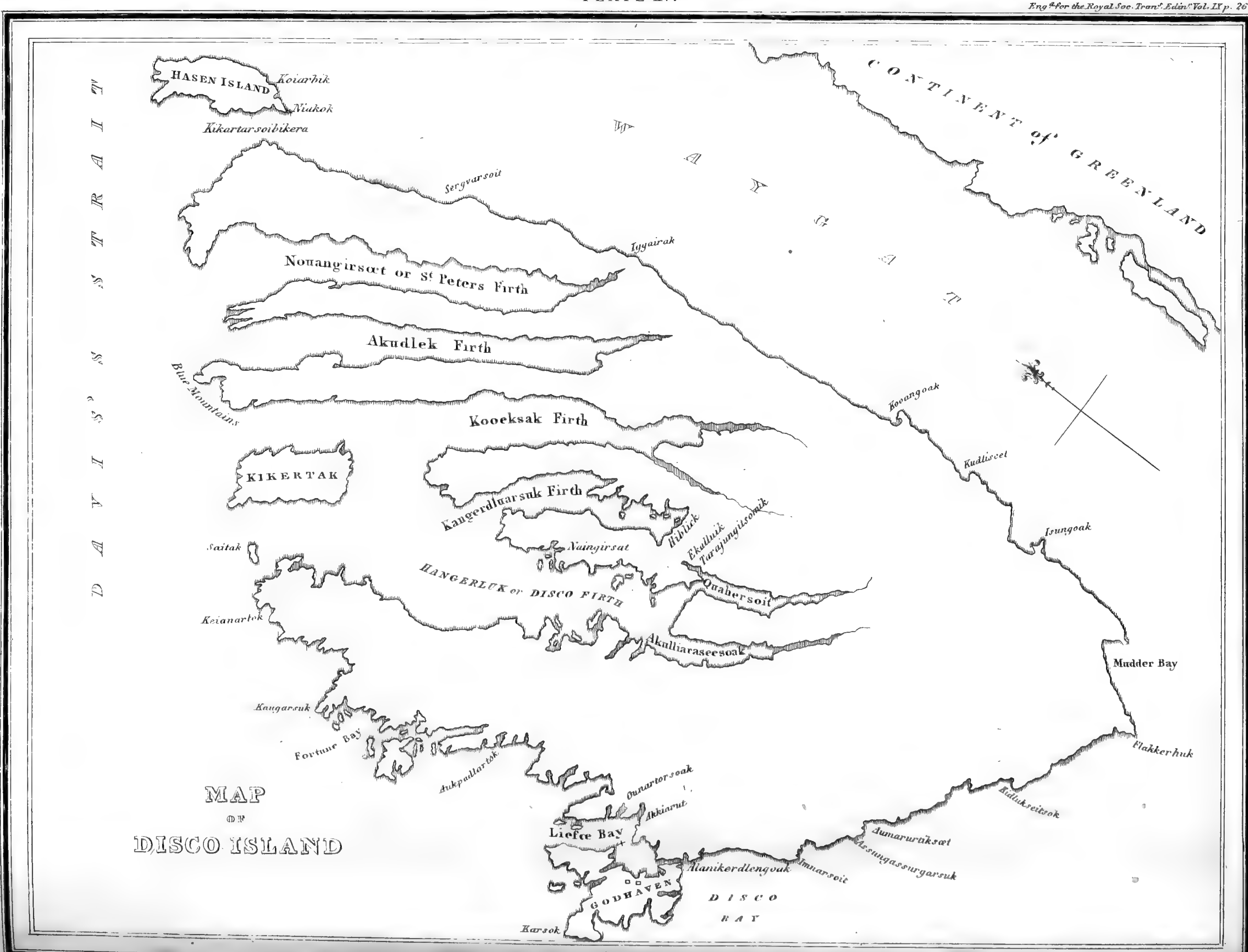
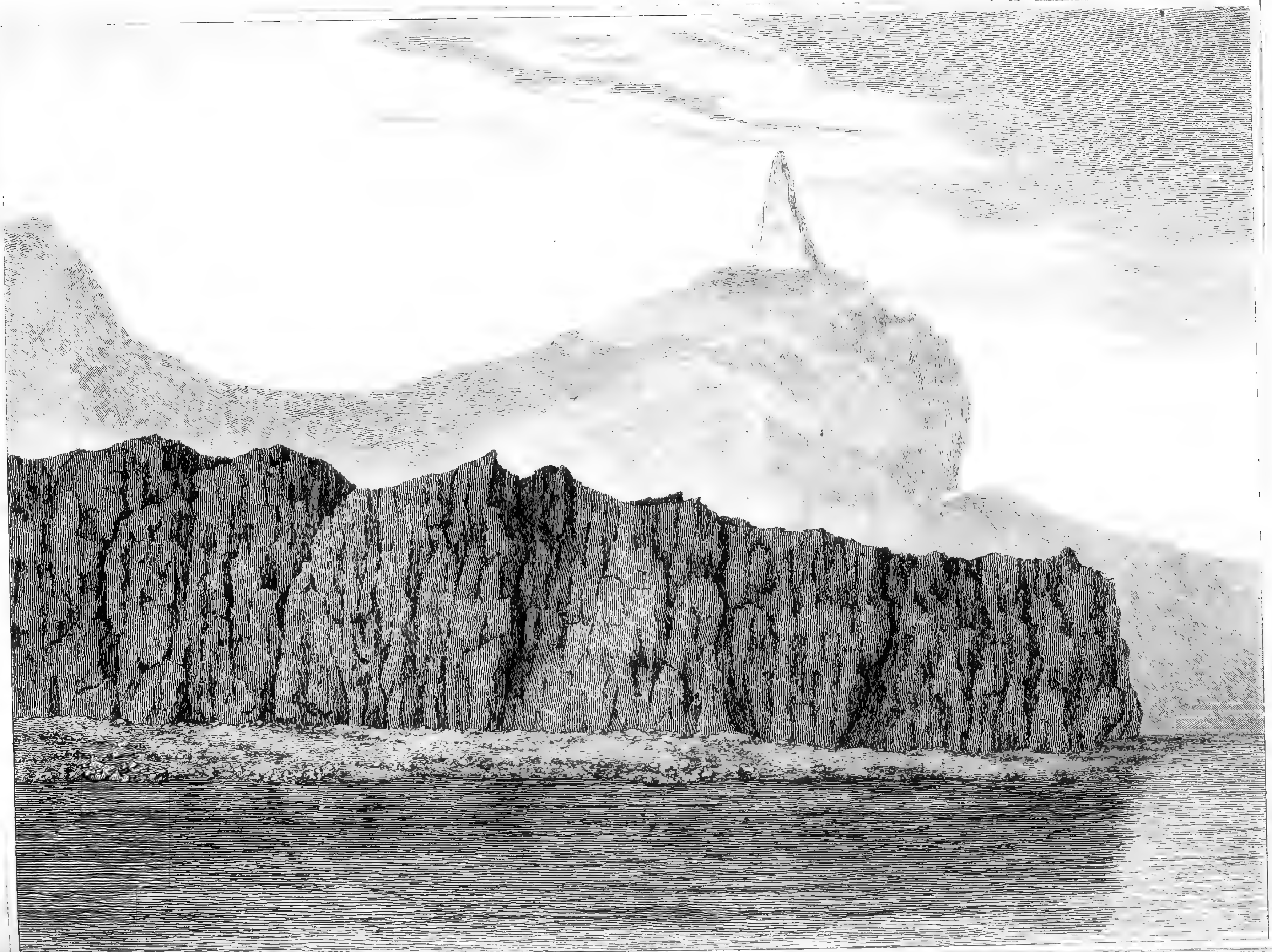


PLATE XVI.

Engraved by W. Miller Edin.r

OUNARTORSOAK ON THE SOUTHERN COAST OF DISKO ISLAND.

PLATE XVII



Engraved by W. Miller Edinr.

MANNIK in the WAYGAT Eastwards from DISKO ISLAND.

XIX. *On the Mineralogy of Disko Island.* By Sir CHARLES GIESECKE, F. R. S. Edin. M. R. I. A, Professor of Mineralogy to the Royal Dublin Society, and Member of the Royal Societies of Copenhagen, Upsal, &c. &c.

(*Read April* 4. 1814.)

DISKO Island, (see Plate XV.), is situated in front of a bay in the continent of Greenland, within Davis' Strait, known by the name of *Disko Bay*, which is sometimes called, particularly in the old Dutch charts, *Sydost Bay*. This name is derived from an immense curvature, screened by innumerable islands, made in the continent by the sea. Disko Island is situated in 69° 14′ of N. latitude. It is distant from the continent towards the south 12 German miles; on the west and north it is surrounded by the sea of Davis' Strait; and on the east, it is separated by a narrow sound, distinguished by the name of Waygat by the Dutch, and by the Greenlanders Ikareseksoak. It stretches northward from 69° 14′ to 70° 24′; and its greatest breadth, which is from Fortune Bay on the west, to Flakkerhuk, so named by the Dutch, on the east, is 10 German miles.

The whole of Disko Island belongs to the flœtz-trap formation, which extends over part of the continent, beyond the Waygat, and shews itself on the other side at 69° 20′ of N. Lat. continuing towards and occupying the peninsula of Noonsoak, which separates Disko Bay from the Bay of St James, called by the Dutch Stikkende Jakob's Bay. On the east end of of this bay, the flœtz-trap disappears under the stupendous glacier or ice-blink of this immense arm of the sea; and on the opposite side of it, not the smallest vestige of flœtz-trap is to be discovered. On quitting the shore, however, towards the north, the same formation occurs, at the island of Upernavik or Spring-Island, which is formed of basalt, with immense beds of sandstone, containing veins of brown and bituminous wood-coal. Two considerable islands situated beyond the Frith, one named Ubekjendte or Unknown Island, and the other Hasen or Hare Island, belong also to the flœtz-trap.

These islands, although now detached, all appear to have originally belonged to the same mass, and to have been torn asunder by the impetuosity of the sea, which, impelled by the winds from every quarter, runs with a force almost beyond belief. During such a tempest, I have myself seen the jaws of the great Greenland whale, *Balæna mysticetus*, thrown to a distance of 200 feet inland upon the beach.

Beyond the Bay of St James, towards the great Northern Cape called Svartenhuk, the flœtz-trap is interrupted, either by the primitive rocks, or by an immense plain covered with alluvial soil. Svartenhuk is composed of a granitic rock, with large beds of micaceous schistus, mixed with small garnets. In the adjacent bay, called Hytten, the flœtz-trap shews itself in small hills, resting on a bed of sandstone, in which bituminous wood occurs. From this point, the continent of Greenland, which consists of granite, stretches away to the east of north, and is covered with an incredible number of small islands, called the *Vrowen* or *Womens' Islands*. The base of these islands is uniformly granite or gneiss; the last sometimes, though rarely, mixed with garnets. Some of the islands are covered with beds of the flœtz formation, particularly Kakarsoak, the largest of the group,

To

To the north of Kakarsoak, in the colony of Upernavik, in Lat. 72° 32′, the flœtz-trap again disappears, and granite, alternating with gneiss, present themselves, and continue to Lat. 73° 32′, at the islands of Udjordlersoak and Tessiursak. Near Cape Nullok, in Sanderson's Hope, the flœtz-trap again appears in large masses of columnar basalt, resting on gneiss; but beyond this place, there is no farther approach, the country being covered by the Great Boreal Glacier,—the Northern Ice-blink.

The direction of the trap-rocks, which are here spread over such an extent of country, is almost entirely similar, being nearly horizontal, stretching from south-west to north-east. The beds of which they are composed are of a very unequal thickness: those of basalt are most prevalent. The hills composed of gneiss and granite are never highly elevated; and the flœtz rocks are placed immediately on the gneiss, which is always slightly decomposed upon the surface, where in contact with the trap. The prismatic basalt of this district, is of that species distinguished in Germany by the name of Basaltic Greenstone, (*Grünsteinartiger Basalt*). It is almost pure, but sometimes contains a few detached specks, perhaps crystals of felspar. I found only in one place some small grains of augite and of hornblende. The massive basalt, on the contrary, often becomes amygdaloidal, by the small globules of mesotype, stilbite and quartz which it contains. It occurs very generally undermost, and touching the primitive rocks, which is very rarely the case with the columnar basalt.

The Trap-tuff, which is very common among the flœtz rocks of Disko, rests also always immediately on the primitive rocks: Indeed, I never found it in any other situation in that island. It appears to me here necessary to mark two varieties of this rock, namely, that which consists almost entirely of fragments of wacke, contained in a paste of the same substance in a state of decomposition; it is of a very fine grain, very soft, and almost friable. The other is composed of fragments of wacke, but more compact, and of globular pieces of basalt. When these globules are broken, the interior is occupied by geodes of crystallised apophyllite, accompanied with capillary mesotype, sometimes decomposed and reduced to powder, in which state it is known by the name of Earthy Zeolite. These are the only minerals I found in this globular basalt. The apophyllite I never observed in the other variety of trap-tuff, in which I discovered no simple mineral whatever, except some very small geodes of radiated zeolite. I shall distinguish the one by the name of Trap-tuff, and the other by that of Basalt-tuff. The last appears to me to be the oldest of the two, and occurs, wherever I saw it, under the other. If the tuff be entirely absent, then the Amorphous Basalt occupies its place, and on it rests the Amygdaloid the paste of which is of a reddish-brown colour. It is the amygdaloid of this colour in which the greatest number of minerals occur, such as stilbite, mesotype, quartz, calcedony, and igloit. When exposed to the action of the weather, this rock becomes extremely fragile, and falls in conchoidal fragments, almost like bole. It occasions, particularly in spring season, by reason of its feeble cohesion, immense devastation. Rent by the effects of the severe frosts of winter, it falls in huge blocks into the valleys, when the basalt, deprived of its support, is precipitated in enormous masses, and to such an extent, that rivers are often impeded in their course, and the whole neighbourhood laid under water. Over this amygdaloid, a mass of ferruginous clay occurs, similar to the Eisenthon of the Germans, which approaches to the jaspery oxide of iron. This is again covered by amorphous basalt, separated from columnar basalt, which usually

usually forms the summits of these hills, by another seam of the same ferruginous substance, of a brownish colour.

The mountain called Ounartorsak, near Godhavn, presents the following proportions in one of its precipices: (See Plate XVI.)

1.	Basalt, columnar.	Basalt, in columns of from three to seven sides, with some crystals of felspar.
2.		Reddish-brown ferruginous clay.
3.	Basalt, amorphous.	Amorphous basalt, with geodes of radiated mesotype.
4.		Reddish-brown ferruginous clay.
5.	Amygdaloid.	Reddish-brown wacke, containing stilbite, mesotype, &c.
6.	Trap-Tuff. Basalt-Tuff.	The last with apophyllite, &c.
7.		Granite, with gneiss.

All the basalt of Disko is magnetic. That found in the most elevated situations is most so; the fallen masses dispersed around the base of the mountains having more power over the needle than the others.

The mountains of Disko are almost all flat at the top, and at a distance present the appearance of large houses. It was only in the Waygat, and in the Bay of St James, (Omenak's Fiord), where I observed pyramidal and conical summits. Mannik, a mountain in Waygat, (see Plate XVII.), is terminated by an immense basaltic pyramid of four sides. On the summits of all the mountains which I ascended, I found numerous rolled masses of primitive rocks, often of considerable size, and of a weight beyond my power to move. These masses consisted either of granite, gneiss, mica-slate, siliceous-schist, quartz, or hornstone. Porphyry-slate is the rarest rock among those of the trap-formation in Greenland. Although I ascended several of the mountains, I found it only in two, Unknown Island and Hare Island, to the north of Disko; and there it occupied only the summit,

summit, in tables split into a thickness varying from six inches to two, affording a clear ringing sound when struck by a hammer. The Greenlanders informed me, that during tempestuous weather, even at the foot of the mountain, they often heard tones resembling those of music, and that Tornarsuk, their good and evil deity, when enraged, was the cause of them. He never, however, happened to be out of humour within my hearing.

At the foot of this immense trap-formation of Disko, considerable beds of Sandstone occur. It makes its appearance at Aukpadlartok, Akkiarut, and Imnarsoit; but the mass of greatest magnitude is at Aumarurtiksæt, where it is accompanied with beds of Coal. From this spot the beds extend along the edge of the sea, by Waygat, and become very considerable at Kudlisæt, where the stratification is disposed in the following arrangement:

Sandstone, sometimes with globules of pyrites.

Brown coal.

Schistose sandstone.

Pitch-coal.

Argillaceous schistus.

Brown coal.

Sandstone, with vestiges of plants.

The sandstone is very light, and sometimes friable, which is also the case with the clay-slate. The vegetable impressions that occur in the lowest bed, seem to be those of the leaf of the Angelica archangelica. The most considerable bed of coal is about 9 feet thick; while some of the seams are not above 7 or 8 inches.

It

It is nearly impossible to render this coal available, as scarcely any shelter is to be found all along the Waygat, for vessels of any description, while a tempest almost continually prevails in the Strait. It is the same case with the coal of Hare Island, generally known on account of the grains of Amber which it contains. There it occurs under an argillaceous wacke, in the following order:

Coarse conglomerate.
Argillaceous wacke.
Brown coal, with amber.
Fine-grained conglomerate.
Sand.

I have now only to mention the Simple Minerals which accompany the flœtz-trap formation of this country, of which the different members of the family of zeolite, its usual companion in all quarters of the globe, are the most remarkable.

1. *Mesotype.*—The most common subspecies of this mineral is the fibrous and radiated. The last is found crystallised in rectangular prisms, truncated, with pyramids of four planes *.

b. Ca-

* Dr Brewster has examined the *Greenland Mesotype*, and has found it to be an entirely different mineral from the Auvergne Mesotype. In its crystalline form it resembles the Auvergne specimens, while, in its optical properties, it resembles the Iceland Mesotypes. It is very remarkable, that the capillary crystals from Sergvarsoit, have been found by Dr Brewster to be different from the large crystals, and to be the same as those from Auvergne.

b. Capillary. Near Sergvarsoit in Disko, there is a small cave covered with capillary mesotype, which the Greenlanders consider as the hair of one of their magicians called Angekok. When this variety is decomposed, it forms the earthy or mealy zeolite.

2. *Stilbite*,—in thin hexagonal tables.
   b. In quadrangular prisms, acuminated by truncated pyramids.
3. *Chabasie*,—crystallised in the primitive rhomb.
   b. In truncated rhombs.
   c. In macles.
4. *Analcime*,—crystallised in the form of the leucite.
5. *Compact Zeolite*, white and red.—This mineral occurs in cavities and veins in all the rocks of the flœtz-trap formation, except the basalt-tuff.
6. *Apophyllite* or Ichthyophthalme, occurs,
   a. In prisms perfectly rectangular.
   b. Also with the solid angles replaced. This variety was mistaken for mesotype, and described as *Mesotype epointé*.
   c. By a curious arrangement of the particles, the crystals of apophyllite are sometimes cylindrical, and being contracted at the extremities, present the shape of a barrel *. They also occur acuminated and diverging, sometimes in the form of a rose. In perfect cubes, the apophyllite occurs in Greenland only in the basalt-tuff, accompanied with delicate capillary mesotype.

* The cylindrical Apophyllite, according to the experiments of Dr Brewster, who has examined some specimens which I transmitted to him, differs in a remarkable manner from the Apophyllite of Iceland, Faroe, Uto, and Fassa. Its optical properties he has found to be of a very curious kind.

type. Notwithstanding, in Faroe and Iceland it is found in wacke. This substance forms an opaque jelly in nitric acid, frothing up and exfoliating. The apophyllite also occurs in a radiated form, similar to stilbite, but with a more brilliant lustre, and presenting on the surface a crystallisation similar to the cock's-comb barytes.

8. *Carbonate of Lime* occurs in all the rocks of this formation, in cavities and veins, of a greyish-white colour, sometimes massive, sometimes crystallised in rhombs, also in pyramids of three and six planes, and in prisms of six planes. I have found it also crystallised in nearly perfect cubes.
9. *Igloite*, the Arragonite of Haüy, and Hard Calcareous-spar of Bournon, occurs fibrous, radiated, and crystallised in pyramids of three planes; also in curvilinear prisms of six planes, terminating by degrees in pyramids.
10. Radiated and concentric globular mineral, of a yellowish-green colour, which I take to be *Wavellite*.
11. *Compact Quartz*, *bacillaire*, and crystallised in prisms, in geodes.
12. *Calcedony*, massive, and very rarely in cubes. Quartz and calcedony occur in all the rocks.
13. *Opal*, *common*, in veins and cavities, white and yellow, particularly in basalt.
14. *Cereolite*, a mineral of a yellowish, brownish, and greenish colour, very similar to compact lithomarge.
15. *Green Earth*, lining cavities, and sometimes filling geodes.
16. *Heliotrope*, in geodes and veins in basalt.
17. *Agate* in geodes in basalt.
18. *Felspar* in small crystals, constituting the basaltic-porphyry and porphyry-slate.

 19. *Fer-*

19. *Ferruginous Clay*, of a reddish-brown colour, the Eisenthon of WERNER.
20. *Bolus*, in small veins.
21. *Bituminous Wood*, very rarely in minute beds, in wacke and basalt.
22. *Brown-coal.*
23. *Pitch-coal*, above described.

The Primitive Rocks, which constitute some small islands on the south side of Disko, are very rarely accompanied with any of the simple minerals. The Felspar of the granite sometimes becomes opalescent; the granite contains occasionally compact and prismatic Epidote, also Diallage and Tourmaline; at Kangek it sometimes, but very rarely, contains some cubes of Pyrites; and in one place, I observed Magnetic Iron, in nodules, mixed with it. In the islets of Fortune Bay, I noticed some specks of the green oxide of Copper in the micaceous schistus.

XX.

XX. *On the Nature and History of the Marsh Poison.* By

William Ferguson, M. D. F. R. S. E. Inspector of Army-Hospitals.

(Read January 3. and 17. 1820.)

In this paper I propose submitting to the Society some observations on the nature and history of the Marsh Poison, which, under the title of *Marsh Miasmata*, or *Malaria*, has ever been acknowledged as the undisputed source of Intermittent Fevers, and is believed, with good reason, to be the exciting cause of the whole tribe of Remittent Fevers;—of Endemic Fever, in fact, in every form, and in every part of the world.

All authors who have treated of the nature of this poison, (and they are most numerous), coincide in attributing its deleterious influence to the agency of vegetable or aqueous putrefaction. So universal a coincidence has caused these opinions to be received with the authority of an established creed. It is my intention in this paper to shew, from a narrative of facts, that they are *unfounded*, and that putrefaction, under any sensible or discoverable form, is *not* essential to the production of pestiferous miasmata.

The marsh poison, happily so little known in this country, and the colder regions of the earth, is notwithstanding by far

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the most frequent and destructive source of fever to the human race, as that form of fever to which it gives rise, rages throughout the world wherever a marshy surface has been exposed for a sufficient length of time to the action of a powerful sun. I have said for a sufficient length of time; because, as will presently be seen, the marsh must cease to be a marsh, in the common acceptation of the word, and the sensible putrefaction of water and vegetables must alike be impossible, before its surface can become deleterious. It will also be seen, that a healthy condition of soil, in these pestiferous regions, is infallibly regained by the restoration of the marshy surface in its utmost vigour of vegetable growth and decay. The previous marshy surface, or rather the previous abundance of water, is, however, an indispensable requisite preliminary, in all situations, to the production and evolvement of the marsh poison. A short review of the circumstances, which, under my own observation, attended our armies on service during the last war, will, I hope, render these seemingly paradoxical opinions intelligible to the Society.

The first time that I saw Endemic fever, under the intermittent and remittent forms, become Epidemic in an army, was in the year 1794, when, after a very hot and dry summer, our troops, in the month of August, took up the encampments of Rosendaal and Oosterhout, in South Holland. The soil in both places was a level plain of sand, with perfectly dry surface, where no vegetation existed, or *could* exist, but stunted heath plants: on digging, it was universally found to be percolated with water to within a few inches of the surface, which, so far from being at all putrid, was perfectly potable in all the wells of the camp. I returned to Holland in the year 1799, with the army under the command of the Duke of York, which

which remained the whole autumnal season in the most pestiferous portion of that unhealthy country, without its suffering in any remarkable degree from endemic fever. Dysentery was almost the only serious disease they encountered. Remittent fever was nearly unknown, and intermittent occurred very rarely; but the preceding summer season had been wet and cold to an unexampled degree; during the whole of the service we had constant rains, and the whole country was one continuous swamp, being nearly flooded with water. In the year 1810, a British army at Walcheren, on a soil as similar as possible, and certainly not more pestiferous, but under the different circumstances of a hot and dry preceding summer, instead of a wet and cold one, suffered from the endemic fever of the country to a degree that was nearly unprecedented in the annals of warfare.

As I intend, in another part of this paper, to treat fully of the nature of the localities in the West Indies, I shall pass over at present my next experience of endemic fever during three years service in the Island of St Domingo, and proceed to state what I observed on this subject in Portugal and Spain: In the course of the Peninsular War, during the autumnal campaign of 1808, our troops, after the battle of Vimeira, were comparatively healthy. The soil of the province around Lisbon, where they were quartered, is a very healthy one, (a slight covering of light sandy soil on a substratum of hard rock, which is almost always so bare, that water can seldom be absorbed into it to any depth, but is held up to speedy evaporation). The season was fully as hot a one as is ordinarily seen in that country, but dysentery was the prevailing disease. Early in 1809 the army advanced to Oporto, for the expulsion of the French under Marshall Soult from Portugal which, during a very cold and wet month of May, (for that country,)

country,) they effected, without suffering any diseases but the ordinary ones of the bivouac; and in June advanced again towards Spain in a healthy condition, during very hot weather. The army was still healthy, certainly without endemic fever, and marching through a singularly dry rocky country, of considerable elevation, on the confines of Portugal. The weather had been so hot for several weeks as to dry up the mountain-streams; and in some of the hilly ravines, that had lately been water-courses, several of the regiments took up their bivouac, for the sake of being near the stagnant pools of water that were still left amongst the rocks. The Staff Officers, who had served in the Mediterranean, pointed out the dangerous nature of such an encampment; but as its immediate site, amongst dry rocks, appeared to be quite unexceptionable, and the pools of water in the neighbourhood perfectly pure, it was not changed. Several of the men were seized with violent remittent fever before they could move from the bivouac the following morning; and that type of fever, the first that had been seen on the march, continued to affect that portion of the troops exclusively for a considerable time. Till then it had always been believed amongst us, that vegetable putrefaction (the humid decay of vegetables), was essential to the production of pestiferous miasmata; but, in the instance of the half-dried ravine before us, from the stoney bed of which, (as soil never could lie for the torrents,) the very existence even of vegetation was impossible; it proved as pestiferous as the bed of a fen. The army advanced to Talavera through a very dry country, and in the hottest weather fought that celebrated battle, which was followed by a retreat into the plains of Estremadura, along the course of the Guadiana river, at a time when the country was so arid and dry, for want of rain, that the Guadiana itself, and all the smaller streams, had

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in fact *ceased to be streams*, and were no more than *lines* of *detached pools* in the courses that had formerly been rivers; and there they suffered from remittent fevers of such destructive malignity, that the enemy, and all Europe believed, that the British host was extirpated; and the superstitious natives, though sickly themselves, unable to account for disease of such uncommon type amongst the strangers, declared they had all been poisoned by eating the mushrooms, (a species of food they hold in abhorrence,) which sprung up after the first autumnal rains, about the time the epidemic had attained its height. The aggravated cases of the disease differed little or nothing from the worst yellow fevers of the West Indies; and in all the subsequent campaigns of the Peninsula, the same results uniformly followed, whenever, during the hot seasons, any portion of the army was obliged to occupy the arid encampments of the level country, which at all other times were healthy, or at least unproductive of endemic fever.

To save further narrative, I shall finish this part of the subject, by adducing some topographical illustrations.

The bare hilly country near Lisbon, where the foundation of the soil, and of the beds of the streams is rock, with free open water-courses amongst the hills, as I have said before, is a very healthy one; but the Alentejo land, on the other side of the Tagus, though as dry superficially, being perfectly flat and sandy, is as much the reverse as it is possible to conceive. The breadth of the river, which at Lisbon does not exceed two miles, is all that separates the healthy from the unhealthy region; and the villages or hamlets that have been placed along the southern bank of the Tagus, for the sake of the navigation, are most pestiferous abodes. The sickly track, however, is not confined to the immediate shore of the river. Salvaterra, for

for example, about a mile inland, is a large village, and royal hunting residence in the Alentejo, which is always reputed to be very healthy till the beginning of the autumnal season, when every person, who has the means of making his escape, flies the place. In their superstitious fear, the inhabitants declare, that even the horses and other animals would be seized with fever if left behind, and therefore they always remove the royal stud. The country around is perfectly open, though very low, and flooded with water during the whole of the rainy season; but at the time of the periodical sickness it is always most distressingly dry; and exactly in proportion to the previous drought, and consequent dryness of soil, is the *quantum* of sickness. I have visited it upon these occasions, and found it the most parched spot I ever saw. The houses of the miserable people that were left behind being literally buried in loose dry sand, that obstructed the doors and windows.

Cividad Rodrigo affords another illustration of the same. It is situated on a rocky bank of the river Agueda, a remarkably clear stream; but the approach to it on the side of Portugal is through a bare open hollow country, that has been likened to the dried up bed of an extensive lake; and upon more than one occasion, when this low land, after having been flooded in the rainy season, had become as dry as a brick-ground, with the vegetation utterly burned up, there arose fevers to our troops, which for malignity of type could only be matched by those before mentioned on the Guadiana.

At the town of Corea, in Spanish Estremadura, not very dissimilarly situated, on the banks of the Alagon (also a very pure and limpid stream,) our troops experienced similar results; with this addition clearly demonstrated, that no spot of the pestiferous savannah below the town, was so much to be dreaded as the immediate shores of the river; so that even the running

running stream itself, which in all other countries has been esteemed a source of health, and delight and utility, in these malarious lands proved only an addition to the endemic pestilence. It is difficult to conceive any thing more deceptious than the appearance of these two towns, particularly the last, which might have been pitched upon by the best instructed medical officer, if unacquainted with the nature of Malaria, as a place of refuge from disease; for the shores of the river, (it had no confining banks,) seemed perfectly dry, and there was not an aquatic weed, nor a speck, nor line of marsh, to be seen within *miles* of the town, nor any thing but dry, bare, and clean savannah. It had, however, been so far the contrary in all past times, that the canons and ecclesiastics of its ancient cathedral had a dispensation from the Pope, of no less than five months leave of absence, to avoid the Calentura, (their name for the endemic fever). In the other ecclesiastical residences of Estremadura, the same dispensation rarely extended beyond *three* months, but almost all had some indulgence of the kind. During the autumnal season, the epidemic prevailed so generally amongst all classes of inhabitants, that even infants at the breast were affected with it, and few of the residents attained to any thing like old age. The oldest person I ever saw in Corea, who was a priest, that had often taken advantage of the dispensation for leave of absence, was only in his 57th year, and he appeared like a man past 70. The inhabitants, nevertheless, seemed always surprised and offended when we condoled with them on the unhealthiness of their country, which they would not admit in any degree; for with them, as every where else, where immemorial experience has shewn that it is impossible to avoid a calamity, it goes for nothing. They contemplated its approach with the same indifference that a Turk does the plague, and patiently awaited its

extinction

extinction by the periodical rains of the winter season, not, however, without some exultation, and self-congratulation, on the greater comparative mortality that occurred amongst the stranger soldiers than amongst themselves.

From all the foregoing, it will be seen, that in the most unhealthy parts of Spain, we may in vain, towards the close of the summer, look for lakes, marshes, ditches, pools, or even vegetation. Spain, generally speaking, is then, though as prolific of endemic fever as Walcheren, beyond all doubt one of the driest countries in Europe, and it is not till it has again been made one of the wettest, by the periodical rains, with its vegetation and aquatic weeds restored, that it can be called healthy, or even habitable, with any degree of safety.

During the years 1815, 1816, and 1817, I was employed in making a topographical health survey of all the West India colonies, which afforded me opportunities, in that diversified, dangerous, and active climate, of improving the observations I had elsewhere made upon pestiferous miasmata, of a kind that I could scarcely have anticipated.

It might *there* be seen, that the same rains which made a deep marshy country perfectly healthy, by deluging a dry well cleared one, where there was any considerable depth of soil, speedily converted it, under the drying process of a vertical sun, into a hot-bed of pestiferous miasmata. Thus, in the Island of St Lucia, the most unwholesome town of Castries, at the bottom of the Carenage, which is altogether embosomed in a deep mangrove fen, became perfectly healthy under the periodical rains; while the garrison, on the Hill of Morne Fortuné, immediately above it, within half cannon shot, began to be affected with remittent fevers. The two localities within this short distance evidently changed places in respect to to health. The top and shoulders of the hill had been cleared of wood, and during a continuance of dry weather, the garrison had no source of disease within itself, but this was amply, though but temporarily supplied, as soon as the rains had saturated the soil on which it stood. Thus an uncommonly rainy season at Barbadoes, seldom failed in that perfectly dry and well-cleared country, to induce for a time general sickness; while at Trinidad,—which is almost all swampy, and the centre of the island may be called a sea of swamp, where it always rains at least nine months in the year,—if it only rained eight, or if at any time there was a cessation of the preserving rains, the worst kind of remittent fevers were sure to make their appearance. General dryness of soil, however, is far from being the ordinary characteristic of our West India colonies. The swamp is too often exposed to the continued operation of a tropical sun, and its approach to dryness is the harbinger of disease and death to the inhabitants in its vicinity. On the whole, it may truly be said, that although excessive rains will evidently cause the acknowledged wholesome and unwholesome soils to change places for a time, in respect to health, a year of stunted vegetation, through dry seasons, and uncommon drought, is infallibly a year of pestilence to the greater part of the West India colonies.

In some other respects, the history of Miasmata in these countries was curious and interesting. Thus at the town of Point au Pitre, Guadaloupe, which is situated amidst some of the most putrid marshes in the world, the stench of which is almost never absent from the streets, the place was far from being *uniformly* unhealthy. Strangers, however much they might be annoyed with the smell, often resorted to it with impunity. No more was its first out-post fort Louis, where the waters are so stagnant and putrid, that it is even more offen-

 sive

sive than Point au Pitre; but at Fort Fleur d'Epeé, the farthest out-post, at the extremity of the marshes, where they approach to the state of Terra Firma, where little or no water is to be seen on the surface, and no smell exists, there cannot be supposed a more deadly quarter, and all white troops considered their being sent there, as equivalent to a sentence of death. It ought to be noted, that the marshes of all these three posts are overgrown with the thickest underwoods, and rankest aquatic vegetation of every kind. A fact of the same kind has been observed in the Island of Tobago. The principal fort and barrack of the colony, has been placed immediately to leeward of the Bacolette swamp, within the distance of less than half a mile, and the strong ammoniacal stench of its exhalations, even at that distance, often pollutes the barracks; but these are so far from producing fever at all times, that when I visited the white garrison there, they had been more remarkably exempt from that form of disease, for several years, than any other troops in the West Indies. I shall not multiply facts and illustrations of the same kind, to prove that putrefaction, and the matter of disease, are altogether distinct and independent elements; that the one travels beyond the other, without producing the smallest bad effect; and that, however frequently they may be found in company, they have no *necessary* connection; but proceed to notice other qualities of the marsh poison, which, until understood, prove extremely puzzling to the observer.

In selecting situations for posts and barracks, it had been observed with surprise, that the border, and even the centre of the marsh, proved a less dangerous quarter than the neighbouring heights of the purest soil, and healthiest temperature; and

and this has never been more strongly exemplified than in the instances I am going to relate.

Port of Spain, Trinidad, the capital of the island, is situated very near the great eastern marsh, with which it is in direct communication, by a marginal line of swamp along the sea-shore. It cannot be called a healthy town, but it is very far from being uninhabitable. On the right are some covering heights, which rise out of the marsh at one extremity. These, unlike the site of the town, which has been built on marshy or alluvial ground, are composed of the driest and most healthy materials,—(pure limestone, the purest and the best in all the West Indies), yet have they proved a residence deadly and destructive in the greatest degree to all who venture to inhabit any part of their diversified surface. No place, however elevated, or sunk, or sheltered, or walled in, gives security against the exhalations from below, only it has been distinctly ascertained, that these prevail with more or less malignity, exactly in proportion to the elevation of the dwelling. The lower, consequently the *nearer* the marsh, the better. The tops of the ridges are uninhabitable. On the highest top, at an elevation of 400 feet, and farther removed from the marsh than the town itself, a large martello tower was built to defend the place. It possessed a fine temperature, but proved so dangerous a quarter, that it was obliged to be abandoned. Not even a creole mulatto Spaniard could sleep in it with impunity for a single night, after a course of dry weather.

The beautiful post of Prince Rupert's, in the Island of Dominica, is a peninsula which comprehends two hills of a remarkable form, joined to the main land by a flat, and very marshy square isthmus to windward, of about three quarters

of

of a mile in extent *. The two hills jut right out on the same line into the sea, by which they are on three sides encompassed. The inner hill, of a slender pyramidal form, rises from a narrow base nearly perpendicular, above and across the marsh, from sea to sea, to the height of 400 feet, so as completely to shut it out from the post. The outer hill is a round-backed bluff promontory, which breaks off abruptly, in the manner of a precipice, above the sea. Between the two hills runs a very narrow clean valley, where all the establishments of the garrison were originally placed; the whole space within the peninsula being the driest, the cleanest, and the healthiest surface conceivable. It was speedily found that the barracks in the valley were very unhealthy, and to remedy this fault, advantage was taken of a recess or platform near the top of the inner hill, to construct a barrack, which was completely concealed by the crest of the hill from the view of the marsh on the outside, and at least 300 feet above it; but it proved to be pestiferous beyond belief, and infinitely more dangerous than the quarters in the valley, within half musket-shot below. In fact no white man could possibly live there, and it was obliged to be abandoned. At the time this was going on, it was discovered, that a quarter which had been built on the outer hill, on nearly the same line of elevation, and exactly 500 yards further removed from the swamp, was perfectly healthy, not a single case of fever having occurred on it from the time it was built. These facts were so curious, that I procured the Surveyor-General of the island to measure the elevations and distances, and I have given them here from his report.

In

* The superficies of the base of the peninsula is exactly 1210 yards in length, by 850 in breadth, exclusive of the isthmus.

In the Island of Antigua, the same results were confirmed in a very striking manner. The autumn of 1816 became very sickly, and yellow fever broke out in all its low marshy quarters, while the milder remittent pervaded the island generally. The British garrison of English Harbour soon felt the influence of that most unwholesome place. They were distributed on a range of fortified hills that surround the dock-yard. The principal of these, Monks Hill, at the bottom of the bay, rises perpendicular above the marshes to the height of 600 feet. The other garrisoned hill, which goes by the name of the Ridge, is about 100 feet lower, but instead of rising perpendicularly, it slopes backwards from the swamps of English Harbour. It was the duty of the white troops, in both these forts, to take the guards and duties of the dock-yard amongst the marshes below, and so pestiferous was their atmosphere, that it often occurred to a well-seasoned soldier mounting the night-guard in perfect health, to be seized with furious delirium while standing sentry, and when carried back to his barracks on Monks Hill, to expire in all the horrors of the black vomit, within less than 30 hours from the first attack; but during all this, not a single case of yellow fever, nor fever of any kind, occurred to the inhabitants of Monks Hill; that is to say, the garrison staff, the superior officers, the women, the drummers, &c., all in fact that were not obliged to *sleep* out of the garrison, or take the duties below, remained in perfect health. The result on the Ridge was not quite the same, but it was equally curious and instructive. The artillery soldiers, (17 in number) never took any of the night guards, but they occupied a barrack about 300 feet above the marshes, not perpendicular above them, like Monks Hill, but a little retired. Not a case of yellow fever or black vomit occurred amongst them, but every man, without a single exception, suffered an attack of the ordinary remittent, of which one of them died; and at the barrack on the top of the Ridge, at the height of 500 feet, and still further retired from the marshes, there scarcely occurred any fever worthy of notice.

Another property of the marsh poison, is its attraction for, or rather its adherence to, lofty umbrageous trees. This is so much the case, that it can with difficulty be separated from them; and in the territory of Guiana particularly, where these trees abound, it is wonderful to see how near *to leeward* of the most pestiferous marshes the settlers, provided they have this security, will venture, and that with impunity, to place their habitations.

The localities of the plantations situated on the windward banks of the rivers that intersect Guiana, and are generally covered by swampy woods in close vicinity, exemplify this fact in a remarkable manner; and at Paramaribo, the capital of Surinam, the trade-wind that regularly ventilates the town, and renders it habitable, blows over a considerable tract of swamp at a short distance, but which, fortunately for the inhabitants, is thickly covered with umbrageous forests. Experience, besides, has shown, that there, as in all other new lands, the cutting down of those trees in the swamps has ever been a fatal operation in itself, and in all probability would be productive of pestilence to the town *.

It would be trespassing wantonly on the time and patience of the Society, to multiply further observations of the same kind,

* The town of New Amsterdam, Berbice, is situated within short musket-shot to leeward of a most offensive swamp, in the direct track of a strong trade-wind, that blows night and day, and frequently pollutes even the sleeping apartments of the inhabitants, with the stench of the marshes, yet it had produced no endemic fever worthy of notice, even amongst the newly arrived, for a period of months and years previously to my visiting that colony.

kind, and I shall therefore proceed to draw some conclusions, which I think are fairly warranted from the facts and narrative I have submitted.

That the marsh poison cannot emanate from vegetable putrefaction, I think must be evident from the fact, that it is found most virulent and abundant on the driest surfaces; often where vegetation never existed, or *could* exist for the torrents, such as the deep and steep ravine of a dried water-course, and that it is never found in savannahs or plains, that have been flooded in the rainy season, till their surface has been thoroughly exsiccated; vegetation burnt up; and its putrefaction rendered as impossible as the putrefaction of an Egyptian mummy. If this be doubted or denied, let us take examples where vegetable putrefaction is self-evident, and examine whether it be productive of disease and death, similar to what emanates from the marsh poison. Surely the evidence of every dung heap, in every part of the world, will answer the question in the negative; or if it be insisted that the poison is generated from a combination of aqueous and vegetable putrefaction, let us resort to the easy familiar illustration of a West India sugar-ship, where the drainings of the sugar, mixing with the bilge-water of the hold, creates a stench that is absolutely suffocating to those unaccustomed to it; yet fevers are never known to be generated from such a combination. These are familiar examples; but I cannot think they should be of less intrinsic value on that account, or be deemed less conclusive. The Italians, to be sure, have published ordonances against the steeping of hemp in stagnant pools, but these resemble many other ordonances relative to health everywhere; in overlooking the leading primary causes of the stagnant pool, the autumnal season, and the malarious lands around,

 and

and having their point directed to a trifling concomitant circumstance of no importance.

Should it be said, that the poison must then emanate from aqueous putrefaction alone, I think this may be disproven by equally familiar examples. The bilge-water in the holds of ships, which at all times smells more offensively than the most acknowledged pestiferous marshes, would in that case infallibly, and at all times, be generating fevers amongst the crew, more particularly in tropical climates. I need scarcely say, that this does not consist with the fact, unless it be in some rare instances, where the bilge-water has become, like that of the marsh, actually dried up, or absorbed into the collected rubbish and foulness of the ship's well, thereby verifying the common saying of the sailors, that a leaky ship is ever a healthy ship, and *vice versa*. Or if it be objected, that the salt may have a preserving power, let us look at the quantity of fresh-water, (not unfrequently the impure water of an alluvial river), laid in for a first-rate man of war proceeding on a long voyage. This is so great as to constitute many floorings, or tiers of barrels, close to which the people sleep with impunity, though it is always disgustingly putrid, and could not fail to affect them, if it contained any seeds of disease *. Examples of the same on land may be found with equal facility. At Lisbon,

* In some ships of our navy, the fresh-water, instead of being put up in casks, has been preserved in bulk, by constructing a large open tank, of tin or lead, at the bottom of the hold, without in the least affecting the health of the crew, though they slept immediately above it. On land, the very same results have been verified under the same circumstances. One of the healthiest officers'-quarters in the West Indies, is the field-officers at Berkshire Hill, St Vincent's, which is built immediately over the garrison water-tank; and a block house at Demerara, similarly situated, was healthier than the other posts on *terra firma*.

bon, and throughout Portugal, there can be no gardens without water; but the garden is almost every thing to a Portuguese family. All classes of the inhabitants endeavour to establish and preserve them, particularly in Lisbon, for which purpose they have very large stone reservoirs of water, that are filled by pipes from the public aqueducts, when water is abundant;—but these supplies are always cut off in the summer. The water, consequently, being most precious, is husbanded with the utmost care for the three months absolute drought of the summer-season. It falls of course into the most concentrated state of foulness and putridity, diminishing and evaporating day after day, but never absorbed, till it subsides either into a thick green vegetable scum, or a dried crust. In the confined gardens of Lisbon particularly, these reservoirs may be seen in this state close to the houses, even to the sleeping places of the household, in the atmosphere of which they literally live and breathe; yet no one ever heard or dreamt of fever being generated amongst them from such a source; though the most ignorant native is well aware, that were he only to cross the river, and sleep on the sandy shores of the Alentejo, where a *particle* of water at that season had not been seen for *months*, and where water being absorbed into the sand as soon as it fell, was *never* known to be *putrid*, he would run the greatest risk of being seized with remittent fever.

From all the foregoing, the deduction appears to be unquestionable, that endemic fevers cannot be generated either from aqueous or vegetable *putrefaction*, singly or combined. It emanates, as we have seen, from the shores of the purest streams, wherever they have been flooded during the rains, through want of confining banks, and it is absent from the most putrid waters. It must be impossible that healthy living water, which

 from

from its current is in a perpetual course of being refreshed and renewed, can ever, by any degree of solar heat, be brought into the state of morbific miasmata; and the evil must therefore reside in the half-dried and drying margin; for the swamp is no more than this margin rolled up under another shape, and it must be brought into the same degree of *dryness*, before it can produce any morbific effects.

One only condition then seems to be indispensable to the production of the marsh poison, on all surfaces capable of absorption; and that is, the *paucity* of water, where it has previously and recently *abounded*. To this there is no exception in climates of high temperature; and from thence we may justly infer, that the poison is produced at a highly advanced stage of the *drying* process;—but, in the present state of our knowledge, we can no more tell what that precise stage may be, or what that poison actually is, the development of which must necessarily be ever varying, according to circumstances of temperature, moisture, elevation, perflation, aspect, texture, and depth of soil, than we can define and describe those vapours that generate typhus fevers, small-pox, and other diseases. The marsh and the stagnant pool will no doubt be pointed out as the ostensible sources from which this poison has ever sprung; but the marsh, it has been seen, is never pestiferous when fully covered with water. At all other times it must present a great variety of drying surface, and both the lake and the marsh must ever possess their saturated, half-dried, and drying margins. It is from these that the poison uniformly emanates, and never from the body of the lake or pool, and I think it may even be fairly presumed that water, for as long as it can preserve the figure of its particles above the surface, is innoxious, and that it must first be absorbed into the soil, and disappear to the eye, before it can produce any mis-

chievous

chievous effects. The most ignorant peasant of Lincolnshire knows, that there is nothing to be apprehended from the ditches of his farm till they have been dried up by the summer heat; and though the inhabitant of Holland may point to the unexhausted foul canal as the source of his autumnal fever, there can be little doubt that he might live upon a sea of the same with impunity, and that it is to the absorbed waters under his feet, which, without the canal, would in all probability be much more pestilential, he ought to attribute his disease. To assert, after all this, that the putrid marsh, which must necessarily, to a certain degree, be a *wet* one, is positively less dangerous than another where no smell exists, will not, I am sure, appear paradoxical to the Society; for it is only saying, that the first has not yet arrived at the degree of exsiccation that has been found most productive of the marsh poison, and that putrefaction, though it may, and must often precede and accompany pestilence, is no part of pestilence itself.

The symbol of vegetable putrefaction, in the decay of the aquatic weeds that cover the pool, constantly meets the eye, and deceives the judgment; and the smell of the putrefying waters combined with it, confirms a delusion which has ever prevented us from discovering, that the action of a powerful sun on its half-dried margin, is adequate to the production of all that could be attributed to the humid decay of vegetables. The greatest danger then may, and does often exist, where no warning whatever is perceptible to the senses, and whoever, in malarious countries, waits for the evidence of putrefaction, will, in all the most dangerous places, *wait too long*, as every one can testify who has seen pestilence steam forth, to the paralyzation of armies, from the bare barren sands of the Alentejo in Portugal,—the arid burnt plains of Estremadura in Spain,—and the recently flooded table-lands of Barbadoes, which have

have seldom more than a foot of soil to cover the coral rock, and are therefore under the drying process of a tropical sun, brought almost immediately after the rains into a state to give out pestilential miasmata.

I shall conclude this paper with a few more observations on some of the qualities not yet noticed of the marsh poison. No experiments hitherto made have enabled us to pronounce whether it be specifically heavier or lighter than common air; but it evidently possesses an uncommon and singular attraction for the earth's surface; for in all malarious seasons and countries, the inhabitants of *ground floors* are uniformly affected in a greater proportion than those of the *upper storeys.* According to official returns during the last sickly season at Barbadoes, the proportion of those taken ill with fever, in the lower apartments of the barracks, exceeded that of the upper by one-third, throughout the whole course of the epidemic. At the same time it was observed, that the deep ditches of the forts, even though they contained no water, and still more the deep ravines of rivers and water-courses, abounded with the malarious poison. At Basseterre, Guadaloupe, a guard-house placed at the conflux of the inner and outer ditch of the fort, infallibly affected every white man with fever that took a single night-guard in it; and the houses that were built in the ravine of the river *aux herbes*, (a clear rapid mountain-stream that runs through the town) or opposite to its " bouchure," proved nearly as unhealthy as the guard-house above mentioned.

Another proof, that from the attraction above mentioned it creeps along the ground, so as to concentrate and collect on the sides of the adjacent hills, instead of floating directly upwards in the atmosphere, is the remarkable fact, *that it is certainly*

tainly lost and absorbed by passing over a small surface of water; which could scarcely happen, unless it came into direct contact with the absorbing fluid. The rarefying heat of the sun, too, certainly dispels it, and it is only during the cooler temperature of the night that it acquires body, concentration, and power. All regular currents of wind have also the same effect, and I conceive it to be through the agency of the trade wind alone, which blows almost constantly from east to west, that the greater part of the West Indies is rendered habitable. When this purifying influence is withheld, either through the circumstances of season, or when it cannot be made to sweep the land on account of the intervention of high hills, the consequences are most fatal. The leeward shore of Guadaloupe, for a course of nearly thirty miles, under the shelter of a very high steep ridge of volcanic mountains, never felt the *sea*-breeze, nor any *breeze* but the night land-wind from the mountains; and though the soil, which I have often examined, is a remarkably open, dry, and pure one, being mostly sand and gravel, altogether and positively without marsh in the most dangerous places, it is inconceivably pestiferous throughout the whole tract, and in no spot more so than the bare sandy beach near the high water-mark*. The coloured people alone

* In our own country, an instance of a pure surface, absolutely destitute of vegetation, proving as malarious as any other spot that I know of in England, may be seen at Dungeness, on the coast of Kent. The point of Dungeness, is a tongue of land appended to the great Romney Marsh, and consists of an extensive bank of shingle or gravel, so dry, loose, and open, that even during wet weather horses sink in it nearly up to the knees. The forts and barracks are at least four miles from what may be called the Mainland, where the grass begins to grow, yet was there no spot of that unwholesome tract of country more prolific of endemic fever during the hot summer and autumn of 1807 than these barracks. In one part of the gravel, but not near the barracks, were some very deep pools, of no great extent, containing a singularly pure pellucid fresh-water.

alone ever venture to inhabit it, and when they see strangers tarrying on the shore after night-fall, they never fail to warn them of their danger. The same remark holds good in regard to the greater part of the leeward coast of Martinique, or the leeward alluvial basis of hills, in whatever part of the torrid zone they may be placed, with the exception probably of the immediate sites of towns, where the pavements prevent the rain-water being absorbed into the soil, and hold it up to speedy evaporation.

For this, if there *be* a remedy, it must be found in the powers of cultivation, ever opening the surface for the escape of pestilential gases, and exhausting the morbific principle by a constant succession of crops; for wherever malaria prevails, the uncultivated savannah, even though used for pasture, becomes infinitely more pestiferous than the plantation, and the depopulated country falls completely under its dominion. With the aid of the purifying sea-breeze, this course at the British colony of Demerara, within six degrees of the equator, has succeeded in rendering the cultivated portion of the deepest and most extensive morass probably in the world, a healthy, fertile, and beautiful settlement. I shall not here enter into a detailed account of the astonishing system of tide and flood-gate drainage by which this delightful result has been established and kept up, but hasten to a conclusion.

It would be unphilosophical to suppose, that the marsh poison, because other distempers, such as dysentery, co-exist with it, ever produces any disease but the specific one of which it is the acknowledged parent, varying, however, in form, and as a modification of effect from the same cause, from the common ague of the fens of Lincolnshire, through all the milder remittent types, up to the aggravated yellow fever, or malignant remittent of the West Indies; and *that* variation, so certain and uniform,

uniform, in proportion to the power of the remote exciting cause, that the varying types of fever might be measured almost to a certainty by the degrees of solar heat, as marked on the thermometer. Thus it is most rare and uncommon to meet with an ague in the West Indies in the swampy alluvial plains at the level of the sea, where the generality of the towns and settlements are placed ;—as rare, or rather as impossible, as it would be to meet with any thing else but a common remittent or an intermittent fever, on the cooler mountain marshy levels of the same country. The highest degree of susceptibility and excitement from solar heat on the part of the *subject*, combined with the highest state of preparation from the same, on the part of the *agent*, appear to be essential in all situations to the production of the dreadful yellow fever, which, luckily for mankind, is incapable of being transported to any locality of lower temperature, or texture of soil different from that which gave it birth. Need I say, that such a disease, however rapid and appalling may be its epidemic current, is not, and cannot, no more than the common ague or remittent fever, be in the smallest degree contagious.

There are very few, indeed, of those that have been compelled to live under its scourge, who have not overcome the prejudices of their education on this head; but, unluckily, a different impression obtains very generally amongst those who have never seen the disease, which deeply affects the peace of society every where, and in some countries has proved subversive of the best interests of humanity. Such opinions, it is the duty of every man, who has had sufficient experience, to combat, by stating the results of personal exposure and investigation, and thereby do his utmost to rescue medical science from the dominion of a prejudice which disgraces it.

I shall now close this tedious paper, wherein I have endeavoured, as much as possible, to avoid all professional disquisitions, or references to authors, or even allusion to any ground on which I have not personally trod. It was my earnest wish to have made it shorter; but amidst the multiplicity of matter and illustration, with which I have been literally oppressed, I found that I could not abridge it farther, and at the same time do justice to the subject.

NOTE.

NOTE.

ON THE NEGRO SKIN.

THE adaptation of the Negro to live in the unwholesome localities of the Torrid Zone, that prove so fatal to Europeans, is most happy and singular. From peculiarity of idiosyncrasy, he appears to be proof against endemic fevers; for to him marsh miasmata are in fact no poison, and hence his incalculable value as a soldier, for field service, in the West Indies. The warm, moist, low and leeward situations, where these pernicious exhalations are generated and concentrated, prove to *him* congenial in every respect. He delights in them, for he there enjoys life and health, as much as his feelings are abhorrent to the currents of wind that sweep the mountain tops, where alone the whites find security against endemic fevers.

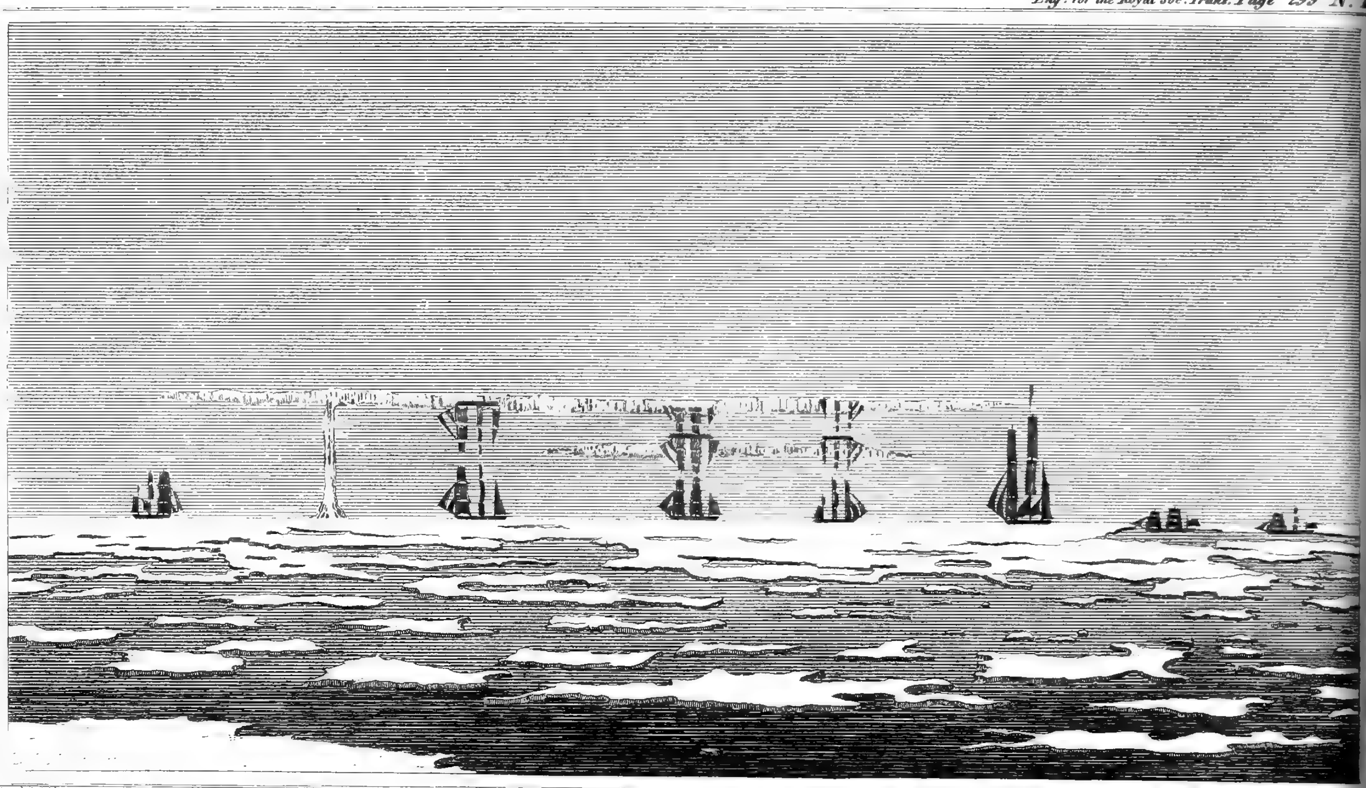
One of the most obvious peculiarities of the Negro, compared with the European, is the texture of his skin, which is thick, oily and rank to a great degree: and from this circumstance the theorist, when he speculates on the mode of reception of the marsh poison into the constitution, whether by the lungs, the stomach, or the skin, may draw a plausible conjectural inference (for it can be no more) in favour of the last. It is certain, that amongst Europeans, the thick-skinned and dark-haired withstand the influence of the marsh poison much better than those of the opposite temperament; and it is equally certain, from the never-failing primary head-ache, that its first impression is invariably upon the brain, as if it had been taken up by the sentient extremities of nerves, of which the skin is so truly an expansion, and conveyed to the sensorium.

Another argument of analogy, in favour of the same opinion, may be derived from a reference to the plague, which is the pestilential endemic fever of the *Levant*, or rather of the arid sandy regions of the southern coasts of the Mediterranean. In that disease, we see reason to believe, that the poison enters by the skin, because swellings of the lymphatic glands are amongst its most prominent symptoms; because oily frictions on the skin are said to be preservative against it, and that carriers or workers in oil do not take the disease.

When the poison is received into the constitution, through whatever channel it may enter, its effects are actually not very dissimilar in some cases to those from the *bite of a serpent*. The aggravated cases of yellow fever at Antigua, mentioned in this paper, and those that have frequently occurred at St Lucia and Martinique, from the bite of the large brown viper of these islands, ran a course not without some resemblance, in the impaired nervous energy, the vomitings, and dissolution of the blood, as marked by the livid discolorations under the skin, (hence the very improper name of Yellow Fever), and its discharge from the internal surfaces previous to the fatal termination.

XXI.

No. I.



Telescopic Appearance of SHIPS, *as observed in the Greenland Sea, during a very peculiar state of the Atmosphere, June 28th. 1820. Latitude 73°. 30′. Longitude 11°. 50′. W.*

No. II.

Telescopic Appearance of the East Coast of GREENLAND, *at the Distance of 35 Miles, when under the influence of an extraordinary Refraction. July 18th. 1820. Lat. 71°. 20′. Long. 17°. 30′. W.*

XXI. *Description of some remarkable Atmospheric Reflections and Refractions, observed in the Greenland Sea.* By William Scoresby, Esq. *jun.*, F. R. S. Edin.

(Read December 18, 1820.*)*

DURING the summer of the present year (1820), while navigating with the ship Baffin, the icy sea in the immediate neighbourhood of West Greenland (the east side), several extremely curious appearances of distant objects, produced by the reflective and refractive properties of the atmosphere, were observed.

The first of these, consisting chiefly of images of ships in the air, occurred on the 28th of June, in latitude 73° 30′, and longitude 11° 50′ W. For two or three days previous, the weather had been intensely foggy, with the wind from the S. E., E. and N. E., blowing fresh. The day alluded to was beautifully clear; not a cloud, excepting the most delicate cirri, having appeared in the sky for twenty-four hours. The thermometer varied between 37° and 42°, and even at this moderate temperature, the sun was so powerful, that its intense light produced a very painful sensation in the eyes, while its heat softened the tar in the rigging of the ship, and melted the snow on on the surrounding ice with such rapidity, that pools of fresh water were formed on almost every piece, and thousands of rills carried the excess into the sea. There was scarcely a breath of wind. The sea was as smooth as a mirror. The ice around was crowded together, and exhibited every variety, from the smallest lumps to the most magnificent sheets. Bears traversed the fields and floes in unusual numbers, and many whales sported in the recesses and openings among the drift ice. About six in the evening, a light breeze at NW. having sprung up, a thin stratus, or "fog-bank," at first considerably illuminated by the sun, appeared in the same quarter, and gradually arose to the altitude of about a quarter of a degree. On this, most of the ships, navigating at the distance of ten or fifteen miles, amounting to eighteen or nineteen sail, began to change their form and magnitude; and when examined by a telescope from the mast-head of the Baffin, exhibited some extraordinary appearances, differing in effect at almost every point of the compass. One ship bearing NW. by W. (Plate XVIII. Fig. *a.* sketch 1.) had a perfect image, as dark and distinct as the original, united to its mast-head in a reverse position; two others (Figs. *b* and *c*), at NW., presented two distinct inverted images in the air, one of them a perfect figure of the original, the other wanting the hull. Two or three more, bearing about north, of which one only is represented in the sketch (Fig. *d*), were strangely distorted, their masts appearing of at least twice their proper height, the top-gallant-masts forming one-half of the total elevation; and, at the same time, some vessels bearing NNE. and E., exhibited an appearance totally different from all the preceding. These, five in number, of which two only (Figs. *e* and *f*) are given in the drawing, were at the distance of twelve or fifteen miles, and consequently considerably beyond the natural horizon; but owing

owing to the influence of some peculiar vapour in the air, they now seemed to advance so near, that they became distinctly visible, and the ice, for some minutes, appeared beyond them. Their masts seemed to be scarcely one-half of their proper altitude, in consequence of which, one would have supposed that they were greatly heeled to one side, or in the position called "Careening." Along with all the images of the ships, a reflection of the ice, in some places in two strata, also appeared in the air. The upper stratum of ice, in which the images of the ships terminated, was fifteen minutes of altitude from the apparent horizon. These reflections suggested the idea of cliffs, composed of vertical columns of alabaster. The stratus, which occupied the space intermediate between the reflection of the ice and the horizon, was, in some positions of the sun, highly illuminated, and shone like a sheet of distant water in a calm; but in other cases, as at the time when the annexed sketch was taken, it was a little darker in colour than the higher region of the atmosphere. To this fog, or stratus, then, it is probable all the reflections were owing; the double images being produced by two or more strata of fog; while a highly tremulous transparent vapour, resembling the steam of water before condensation, which could occasionally be discerned floating across the ice with the breeze from the NW. and N., occasioned, it is likely, the singular distortions observed in the form of every distant object seen through it. Hence, not only ships, but also the ice, was sometimes deformed by the refractive property of this vapour. The verge of the ice, in one place, became a considerable precipice; in another it appeared like distant land clad with snow; and a large hummock on the horizon was reared into the air (Fig. *a*) in the form of an obelisk. The appearances now described occurred between 6 and 12 P. M. The reflected images of the ice

ice continued visible above two hours; of some of the ships about half an hour; and of others, presenting double reflections, about five minutes. The whole of the phenomena represented in the sketch were seen about the same time; but they occupied a much larger extent than could conveniently be given in a drawing. There were some vessels in the SE. quarter, which were not in the least changed from their natural form or dimensions.

The atmosphere was again, in a similar state to that just mentioned, on the 15th, 16th, and 17th of July. Our latitude was then 71° 30′, longitude 17° W. Ice-fields and floes, with many smaller pieces, were in abundance around us. The wind was extremely light, the sky cloudless, and the temperature in the shade between 40° and 48°; the sun, at the same time, was bright, and its rays powerful. On each of these three days, curious reflections from fog-banks, or refractions from tremulous vapour, were observed. The ice in the horizon was reflected in one, two, or three parallel strata, at the altitude, as seen from the deck of the Baffin, of ten to thirty minutes above the verge of the sea; and where water occurred on the horizon, a blackish-grey undulating streak appeared in the atmosphere above it, exactly resembling the slight waves produced by a gentle breeze of wind, of which it was doubtless a reflection. In some places the reflected ice was in narrow faint streaks; in others in bold bright patches, resembling cliffs of white marble, of the basaltic structure. Sometimes the phenomenon extended continuously through half the circumference of the horizon, at others it appeared in detached spots, in various quarters. From the deck of the ship, with a telescope, the inverted images of distant vessels were often seen in the air, while the ships themselves were far beyond the reach of vision. Some ships at the distance of six or eight miles, like those seen

on

on the 28th of June, were elevated to twice their proper height, and others compressed almost to a line. Hummocks of ice here and there were surprisingly enlarged; and every prominent object, in a proper position, was either magnified or distorted. These appearances, though often visible to the naked eye, were not generally very striking; but when examined through a telescope, they presented an ever-varying scene of the most interesting imagery. Most of the phenomena now mentioned were seen on the 16th of July, at five o'clock in the afternoon. A stratus was then observed in the east, extending, north-about, as far as the north-west. In the latter quarter, including the azimuth of the sun, the sky was whitish and resplendent, so that the fog was concealed in the general glare.

Another instance of curious refraction will only be mentioned. This occurred on the 18th of July, under similar circumstances of weather, &c. as those already described. The sky was clear. The tremulous vapour was particularly sensible and profuse, though perfectly transparent. The temperature of the air at 9 A. M., the time when the phenomenon was first noticed, was 42°; but in the evening preceding it must have been greatly lower, as the sea was in many places covered with a considerable pellicle of new ice. Such a circumstance, in the very warmest part of the year, must be considered as very extraordinary, especially when it is known, that ten degrees farther to the north, no freezing of the sea, at this season, that I am aware of, has ever been observed. The latitude of the ship was at this time 71° 20′ N., the longitude 17° 30′ W. Having approached, on this occasion, so near the unexplored shore of Greenland, that the land appeared distinct and bold, I was wishful to obtain a drawing of it; but on making the attempt,

tempt, I found I could not succeed with any degree of accuracy, since the outline changed as fast as I proceeded. The odd form of many of the hills, induced me to examine the land with a telescope from the mast-head, on which, finding it much disfigured by refraction, I contented myself with sketching a few of the most remarkable objects. These, accurately designed, yet disposed without regard to their proper order, or the moment of time when seen, are represented in the sketch, No. II. They afford a tolerable idea of the nature of the scenery then within view. The land, at this time in sight, extended from W. to NNW. (*per* compass); the nearest part at WNW, being about 35 miles distant. It seemed to be a barren and lofty country, abounding in mountainous ridges and peaks. There was much less snow on it than we usually find on Spitzbergen at this season: but in other respects it very much resembles that inhospitable country.

The general telescopic appearance of the coast was that of an extensive ancient city, abounding with the ruins of castles, obelisks, churches, and monuments, with other large and conspicuous buildings. Some of the hills seemed to be surmounted by turrets, battlements, spires, and pinnacles; while others, subjected to one or two reflections, exhibited large masses of rock, apparently suspended in the air, at a considerable elevation above the actual termination of the mountains to which they referred. The whole exhibition was a grand and interesting phantasmagoria. Scarcely was any particular portion sketched before it changed its appearance, and assumed the form of an object totally different. It was perhaps alternately a castle, a cathedral, or an obelisk; then expanding horizontally, and coalescing with the adjoining hills, united the intermediate valleys, though some miles in width, by a bridge of a single

single arch, of the most magnificent appearance and extent. Notwithstanding these repeated changes, the various figures represented in the drawing had all the distinctness of reality; and not only the different strata, but also the veins of the rocks, with the wreaths of snow occupying ravines and fissures, formed sharp and distinct lines, and exhibited every appearance of the most perfect solidity.

XXII. *Account of the Erection of a Granite Obelisk, of a single Stone, about seventy feet high, at Seringapatam.* By ALEXANDER KENNEDY, M. D. F. R. S. EDIN. &c.

(Read December 3. 1821.)

ON the 19th of February last, I had the honour of reading to this Society, some notices of the mode of working and polishing granite, by the natives of India *.

One object of that paper was, from a view of the immense masses, which Indian artists are still in the habit of rendering obedient to their simple instruments, to deduce the probability of the similarity, if not of the identity, of the means now in use among them, with the processes by which the architects of the ancient world, raised the stupendous monuments which we still see in existence; and, as an instance of the very recent exercise of these arts, I mentioned the erection of a granite obelisk near Seringapatam, to the memory of the late JOSIAH WEBBE, Esq. who died in the year 1805. The late Professor PLAYFAIR had expressed to me a desire of procuring information, as to the means by which the erection of this monument had been accomplished; and a wish to bring these to light, as well as my uncertainty regarding the exact length of the

* This Paper will be found in the *Edinburgh Philosophical Journal*, vol. iv. p. 349.

the shaft of the obelisk, induced me to apply to Colonel Wilks, who was upon the spot at the time of its erection, for information as to these particulars. He has, most politely, in the letter which I shall now have the honour of reading, taken the trouble of deducing the materials, even from the quarry; and has also added, very particular and satisfactory details, of the means by which the erection of the obelisk was accomplished. Though the exact length of the shaft is still a *desideratum*, and Colonel Wilks, from recollection, is inclined to think it only sixty feet, instead of seventy-five, at which, from information, I had stated it; yet it appears from his narrative, that accident only, prevented the shaft being formed of a single stone, of the prodigious length of eighty-four feet, which had been actually quarried for the purpose, and the difficulties of erecting which, we can scarcely doubt, would have been surmounted, by the patient perseverance and address of Hindoo workmen.

This stone would have formed a shaft, considerably longer, than that of the obelisk now standing in front of St Peter's, at Rome. Evelyn * states the height of this obelisk, comprehending the base, at 108 feet, and that of the entire stone, which forms the shaft, at 72 feet. He says that it was re-erected, " with vast cost, and a most stupendous invention," by Dominico Fontana, architect to Sixtus the V., and he afterwards mentions (p. 129.) having seen representations of the machines, invented by the architect for this purpose, painted upon the walls and roof of one of the rooms of the Vatican. Evelyn was at Rome in 1645.

Colonel

* *Memoirs*, vol. i. p. 108.

Colonel Wilks, in a subsequent letter, has removed all doubts, as to the abundance of granite in Mysore, by referring to Captain Basil Hall's fine collection, made in India, and which, he says, he had an opportunity of seeing at St Helena, when Captain Hall last returned from India. I shall quote part of that letter. The Colonel says, "That collection, I conclude, is in Edinburgh, and probably in the geological department of the Royal Society. Sevagunga" (one of the Mysore droogs,) "is, I think, the most beautiful red granite I ever saw, and most of the other droogs,—the grey. I am aware, however, that there is a great deal of rock in the eastern ridge of ghauts, not strictly granite; schorl, I think, being sometimes added, and sometimes entirely occupying the place of felspar."

It seems almost superfluous to add, that granite is equally abundant, in many other districts still farther north. The countries of Hyderabad and Beder are well-known instances.

Alex. Kennedy.

Edinburgh, 1st December 1821.

London, Thompson's Hotel, Cavendish Square,

My dear Sir, *5th September* 1821.

Finding, on my return from the Continent, no replies to my several references, which afforded any positive information, regarding the obelisk near Seringapatam, and being able to recover no memoranda of my own, I proceed to answer your letter, as well as I can, from memory alone.

Although I anxiously watched the progress of this interesting work, I as anxiously left it to be exclusively Indian; and the design of the obelisk, was the only aid, afforded by any European to the native workmen.

The

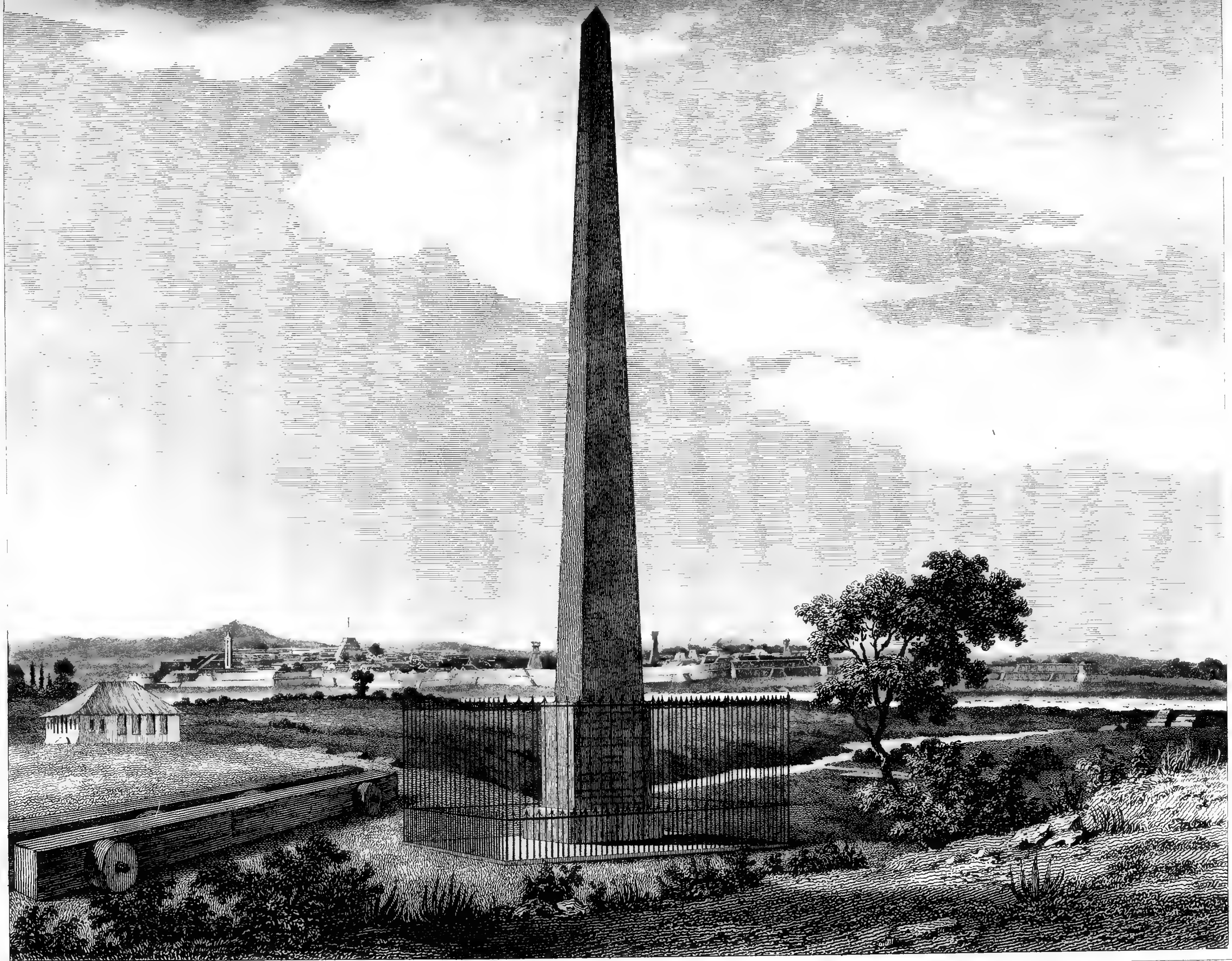
The accompanying sketch, Plate XIX. will obviate much explanation. The obelisk is erected, nearly on the site of the Eedgah Redoubt, which made so determined a defence on the 6th February 1792; and the view is taken from the north, with the Fort of Seringapatam in the back-ground; a bungalo for the accommodation of visitors, and of a gardener, is seen on the left; and more in the fore-ground, the carriage on which the shaft of the obelisk, was conveyed from the quarry, supported by eight wheels or rollers, four without, and as many within, the cheeks of the machine.

The plinth, as exhibited in the sketch, was about 1½ feet thick, of three stones of equal dimensions, accurately cut, and resting on three similar stones at right angles with those under ground; the latter, I think, supported by the solid rock, levelled for their reception.

The pedestal, of a single stone, was nine feet high, and I think seven feet wide; for I distinctly recollect the base of the shaft, to have been six feet diameter. An excavation of that exact diameter, was made in the summit of the pedestal, of about three inches deep, for the reception of the base; which excavation, with a ledge or border, of about six inches wide, between the shaft, and the exterior of the pedestal, would make up the seven feet.

According to my recollection, the length of the shaft is not quite 60 feet; but as every other person who has been referred to, states it from memory, at 70 feet at the least, the point can only be determined by actual measurement.

I well recollect, that the first stone quarried for the purpose was 84 feet, and that it was moved a few yards. It was broken by an explosion of gun-powder, intended to split a detached stone, which stood in the line of its intended removal, and, as the workmen erroneously supposed, sufficiently distant, not



Drawn by Capt. Frazer of the Madras Engineers. Engraved by W. Miller, Edinburgh.

not to affect the shaft by the concussion of the air. The difficulty, however, which they found, in giving a slight degree of motion to this mass, determined the Dewan to contract his views, regarding the height of the obelisk.

The column was quarried about two miles from the place where it was erected. In the process of quarrying granite, two methods are employed.

First method.—The workman looks for a plain naked surface of sufficient extent, and a stratum of the proper thickness, sufficiently near the edge of the rock, to facilitate the separation, or made so, by previous trimming. (I do not speak of *stratified* granite, from any disrespect to the received doctrines of geology, but because I know of no other term to indicate the sort of division in question. I have repeatedly seen quarriers at work, on extensive strata, of various degrees of inclination, and different thickness, from six inches to eight feet.) The spot being determined, a line is marked along the direction of the intended separation; and a groove of about two inches wide, and the same depth, is cut with chisels, or if the stratum be but thin, holes of the same dimensions, at a foot and a half, or two feet distance, are cut along the line. In either case, all being now ready, a workman, with a small chisel, is placed at each hole or interval, and, with small iron mallets, the line of men keep beating on the chisels, but not with violence, from left to right, or from right to left; this operation, as they say, is sometimes continued for two or three days, before the separation is effected. Those who have observed the mode of cutting (as it is called) plate-glass, will not be surprised at their beating from one end, and the fissure also taking place, from one end to the other. This is the mode by which the stone in question was separated.

Second method.—A groove or line of holes being effected as above, a narrow line of fire, of *bratties* (cakes of dried cow-dung) is made; and when the line of rock has been thus thoroughly heated, a line of men and women, with pots full of cold water, suddenly sweep off the ashes, pour the water on the heated line, and the rock immediately splits, but not so correctly as by the former process, which makes a cut as clean as that of a plate-glass manufacturer; but the last method, as the cheapest, is employed where great exactness is not requisite. It is perhaps HANNIBAL's method, and physical reasons are not wanting for the conjecture, that vinegar might possibly be found more effective than water, not for softening, but for rending heated rocks.

The obelisk was first blocked out in the rough, to lighten it, before being placed on its carriage, by means which will easily be conceived, after describing those used for its erection. The carriage, after repeatedly sinking into the hard road, as into a swamp, was ultimately moved, over a succession of balks of timber, placed for its support. Granite is so excessively brittle, that it was thought hazardous to employ draught cattle, or any power less manageable than that of men; and the number employed at one time, on the drag-ropes, as well as I can venture to say, from the picture left on my memory, was about 600 men. The operation of removing it was extremely tedious; but I cannot, from recollection, answer your inquiries with regard to the exact time, or the expence, of the different parts of the process.

To shorten my description, I must anticipate a little, by requesting you to conceive the shaft finished, and placed ready for erection, in a horizontal position, raised to the proper height, and with its base accurately placed for insertion in the top of the pedestal, when it should attain a vertical position.

Then

Then imagine a strong wall, built at right angles with the line of the shaft, and a few feet beyond its smaller end; with two lateral retaining walls, parallel to the shaft, and a fourth, of smaller elevation, near the pedestal, to support the mass of earth, and the workmen to be employed. On such a platform, raised $10\frac{1}{2}$ feet, you will, in the first instance, conceive the shaft to be horizontally arranged. Two lines of timber, plank or balk, were then ranged along the two sides of the shaft, to serve as fulcra, and two lines of men, with hand-spikes, attended by others ready with chocks, or pieces of timber, of different thickness, to be inserted under the shaft, for the purpose of keeping the elevation of the smaller end, effected by the hand-spikes, and distributing the pressure so equally, as not to risk the accidents which would otherwise be inevitable, with this very fragile substance. In proportion as elevation was thus gradually obtained for the smaller end, the space below was filled with rammed earth, and the same process was repeated, with the parallel balks of timber, hand-spikes, and chocks: the small end gradually rising at each successive step, the wall behind increasing in height, and an inclined plane of solid earth gradually increasing its angle with the horizon, until it equalled that at which solid earth could with safety be employed: when the force required being proportionally diminished, timber alone was employed for its elevation. Finally, a scaffolding of timber was erected, embracing three sides of the pedestal, and nearly equal to the ultimate height of the obelisk; ropes were applied to the summit of the shaft, in such directions as to steady and check it; hand-spikes gave the requisite impetus, until it felt the power of the ropes, and was ultimately, and safely lodged, in its shallow receptacle.

There was one part of the process, which greatly arrested my attention, from its extreme simplicity. I was satisfied with the means taken, for insuring a true horizontal surface, for the base of the shaft; but its stability entirely depended, on equal accuracy, in the surface of its receptacle, on the summit of the pedestal; and seeing no mode by which, with their rude instruments, this object was to be attained, I so far departed from my first intention, as to offer them a spirit-level, and instructions for its use. They quickly understood and admired the contrivance, but were afraid of venturing on new methods; their own was (as they affirmed) more slow, but equally certain, and they invited me to inspect it. The surface was rubbed clean and dry, and some water was dropped on it; the water ran! "*You see*" (said the engineer) "*the high and the* "*low.*" He dried up the water, and applied the chisel to the higher portion of the surface, and, by the patience and perseverance of several days, the surface was perfectly polished, and a drop of water remained stationary wherever it was placed.

The whole obelisk received a very fair degree of polish from *corundum.* A piece of plank is overspread with the sort of cement, used for setting sword-blades in their handles: while this substance is still liquid, it is mixed and powdered over, with pulverised corundum, (reduced to a coarse or fine sand, according to the purpose for which it is intended), and left to dry in the sun. These planks, weighted over, are then used, like the slabs of the stone-polisher in England. The knife-grinders wheel, as you probably know, is made of the same materials.

Inscription

Inscription on the Pedestal.

Erected to the memory of

JOSIAH WEBBE, Esq.

BY

PURNEAH DEWAN,

A tribute of respect and veneration,

For splendid talents,

Unsullied purity,

And eminent public virtue.

No tribute to public merit was ever more spontaneous and sincere; and the inscription was made as exact a transcript as possible of the avowed sentiments of the extraordinary Bramin Minister, by whom the obelisk was raised.

It is obvious, that the mode of erecting a column must be very different from that of raising the immense stones which we see in the walls of Indian temples. These stones are moved, end foremost, up an inclined plane of solid earth, of as small an angle with the horizon as circumstances admit, to the spot which they are to occupy in the wall. Long bamboo poles, lashed to the stone, at right angles with its length, and at such distances as merely to admit the efforts of rows of labourers between, constitute the *chief* means of propelling it, by main force, up the inclined plane; and its ascent is facilitated, by means of rollers of small diameter, successively introduced under the stone, and prevented from sinking into the earth, by rows of planks placed on each side of the stone, parallel to the

the line of ascent. When it has ascended the desired height, it is twisted horizontally round, by similar means, into its destined position.

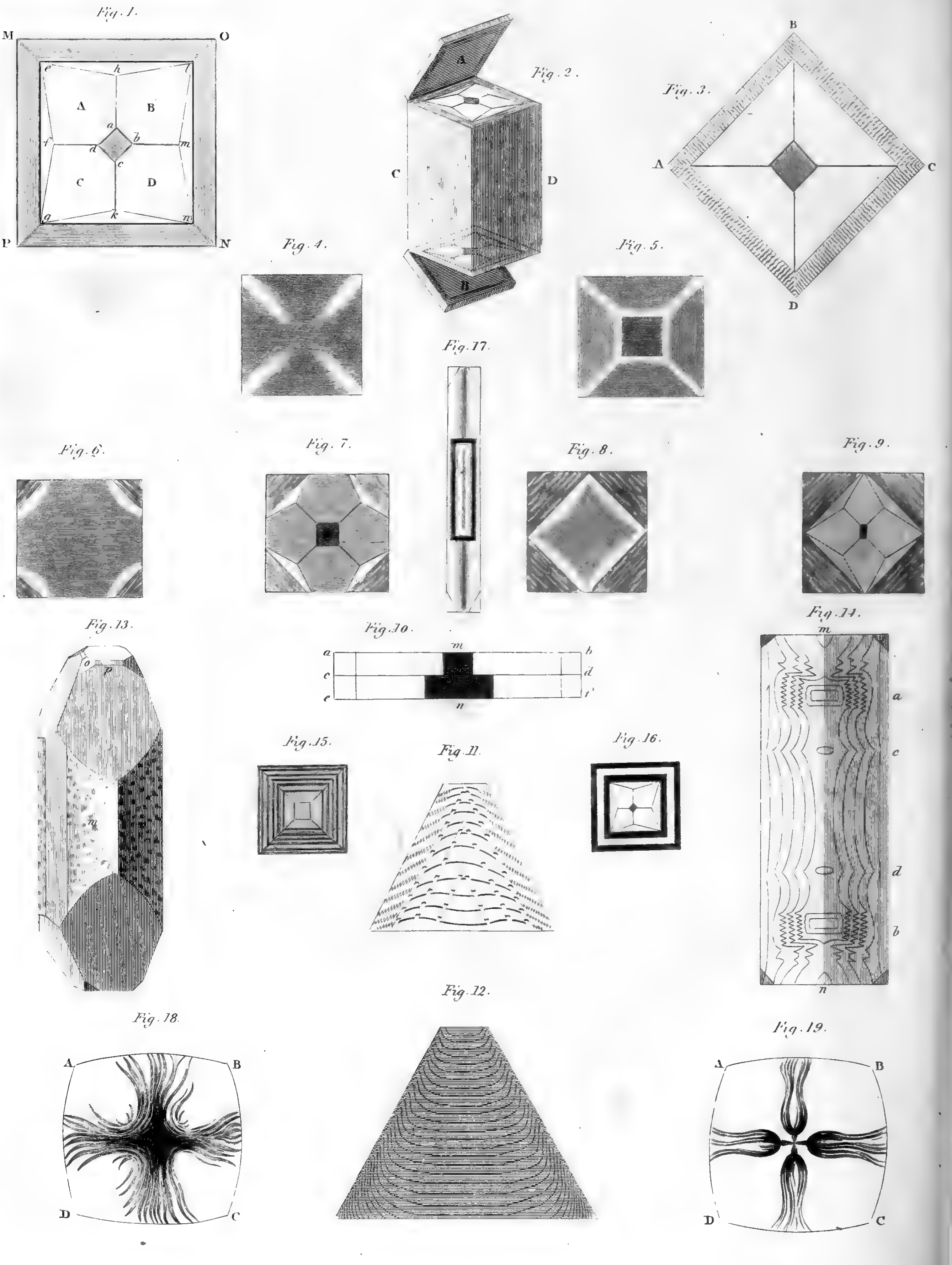
If I have any where been unsuccessful in making my description intelligible, I shall be happy to give any farther explanations in my power. I am, &c.

M. Wilks.

To Dr Kennedy, Edinburgh.

XXIII.

PLATE XX.



Drawn & Engd. by W.H.Lizars.

PLATE XXI.

Engraved for the Royal Soc. Trans. Vol IX page 317.

Fig. 1

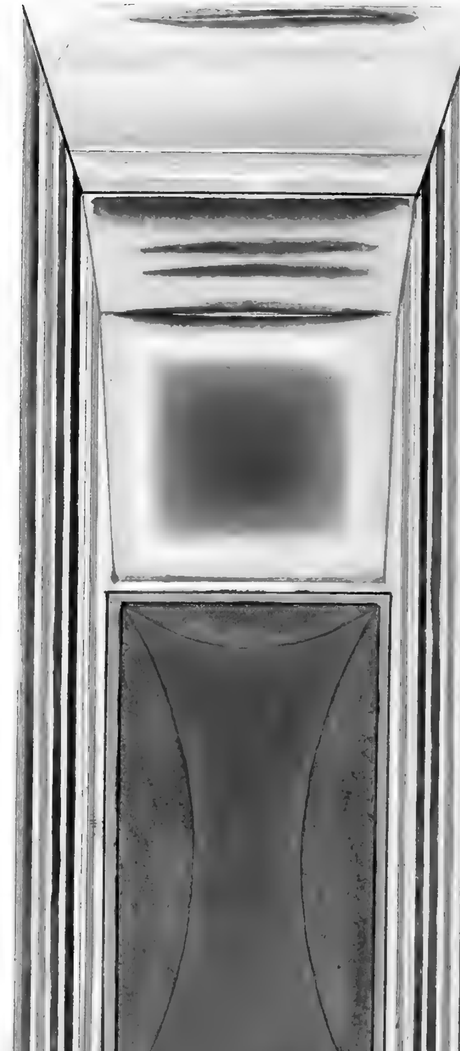


Fig. 3

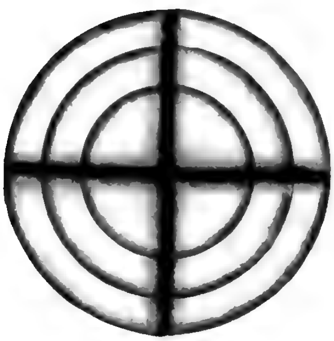
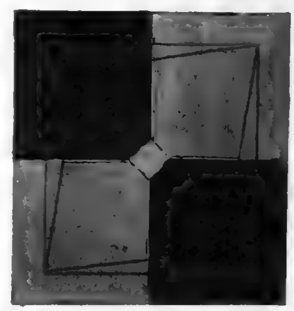


Fig. 2.



Coloured & Engd by W.H.Lizars.

XXIII. *Account of a Remarkable Structure in Apophyllite, with Observations on the Optical Peculiarities of that Mineral.* By DAVID BREWSTER, LL. D. F. R. S. LOND. & SEC. R. S. EDIN.

(*Read 21st April* 1817, *5th March and 17th December* 1821.

THE variety of Apophyllite to which I have given the name of *Tesselite* *, from the beautiful combination of tesselæ which it exhibits in polarised light, is one of the most singular substances in the mineral kingdom. The agency of that species of light, indeed, seemed necessary to the developement of its peculiar structure; but I have since succeeded in confirming and extending my former results, by the application of the microscope; and have been led to observe several new phenomena, which not only throw much light on the structure and properties of this curious mineral, but which affect the fundamental principles of crystallography.

The tesselated Apophyllite from Faroe crystallises in right rectangular prisms, with flat summits, which generally exhibit

at

* My first experiments on Apophyllite are published in the *Edinburgh Philosophical Journal*, vol. i. p. 1.

at the angles very minute truncations, inclined 120° to the edges of the prism *, or 150° to the summit. The sides of the rectangles are nearly equal, and are commonly about $\frac{1}{10}$th of an inch, while the length of the prism seldom exceeds $2\frac{1}{4}$th tenths of an inch. The four faces of the prism have an irregular surface, with longitudinal striæ, but are highly polished; while the flat summits display an inferior lustre, and are variegated with the pearly tints which have given to this mineral one of its most common names †, and which arise from the imperfect contact of the elementary laminæ. These laminæ, whose surfaces are perpendicular to the axis of the prism, may be easily separated, to any degree of thinness, by applying, with the hand, the edge of a sharp knife or lancet; and it is no doubt owing to the laminated structure, and to the imperfect surfaces of the laminæ, that a dilute acid, which will not corrode the polished faces of the prism, will act freely on its less resisting summits.

When we remove the uppermost slice from each of the two summits of the crystal, to the thickness of the 100th of an inch or more, and examine it either by the microscope or by polarised light, we perceive no tesselated structure. A number of veins appear at the edges MO, ON, NP, PM, as shewn in PLATE XX. Fig. 1., or at A, Fig. 2. and these veins gradually diminish in number the nearer we come to the summit, though they never disappear.

If we now remove the next slice, and all subsequent slices, between the two summits, we shall find that they exhibit

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* HAÜY makes this angle 117° 48′.

† Ichthyophthalmite, or Fish-Eye Stone. These pearly tints occur only in one variety of the Tesselite.

bit by the microscope, under favourable circumstances of illumination, the beautiful figure represented in Fig. 1, and 2. The outer case MONP, Fig. 1. which binds the interior parts together, is composed of a great number of parallel veins, which, from their minuteness, display the colours of striated surfaces. This external coating envelopes no fewer than *nine* separate crystals, viz. the central lozenge *a b c d*, the four prisms A, B, C, D, with trapezial bases, and the four triangular prisms *e h l*, *l m n*, *n k g*, *g f e*, all of which are separated from one another by distinct veins. The inflected lines *e h l*, *l m n*, *n k g*, *g f e*, are most easily seen by the microscope. The central lozenge is seen much less frequently, and the radial lines *h a*, *c k*, *f d*, *b m*, require a particular mode of illumination to be distinctly recognised. The colours displayed by one of these plates, when crossed with an uniform plate of sulphate of lime, having a polarised tint of a blue colour, is shewn in Plate XXI. Fig. 2. In some plates the whole of the triangular space *e f g*, Plate XX. Fig. 1. has the same colour and structure as A ; *g k n* the same as C, and so on; while, in other plates, part of the veined border belonging to A, has the colour and structure of C ; but the most common effect is that shewn in Fig. 2. of Plate XXI.

In order to discover if there was any form intermediate between the summit plate and the tesselated laminæ, I have cut up various crystals, but have not been able to observe a gradual transition from the one structure to the other. It must, therefore, take place either *per saltum* *, or the one must pass into the other by a curve, whose vertical branch is less than the 200th or 300th of an inch.

 Although

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* More recent observations have proved this to be the case, as will be seen in a subsequent part of this paper.

Although I have examined some hundred crystals of this variety of Tesselite, I have never yet found one which was transparent across the faces of the prism, or which could be detached from its bed in a complete state. The second or third plate is often very transparent; but the incipient separation of the laminæ which produces the pearly lustre, renders it impracticable to examine the structure of the crystal across the faces of the prism. In one specimen, however I succeeded so far as to determine *, that in it, " and *in several of the Pyramidal crystals*, the maximum tint decidedly varied in different parts of the length of the prism, so as to produce *a succession of coloured bands at the same thickness* †."

A

* See *Edinburgh Philosophical Journal*, vol. i. p. 5.

† In an ingenious memoir, " On certain remarkable instances of deviation from " NEWTON's scale, in the tints developed by crystals with one axis of double refrac- " tion, on exposure to polarised light," published in the *Transactions of the Cambridge Philosophical Society*, vol. i.; and reprinted in the *Edinburgh Philosophical Journal*, vol. iv. p. 334; and vol. v. p. 334, Mr HERSCHEL has, I think, misconceived the full import of this experiment. " This alternation," says he, " or superposition of laminæ of different polarising powers, is no hypothetical case. I have observed its occurrence not only in the instance before us, but in other crystals of perfect regularity in their external forms. Dr BREWSTER has also observed phenomena *referable to this principle* in his paper on the Apophyllite." Upon re-examining the passage in my paper, Mr HERSCHEL will, I am sure, agree with me in thinking, that the phenomena which I observed are not merely referable to that principle, but are a complete demonstration of it, and distinctly prove, that in several crystals there were as many " laminæ of different polarising " powers," as there were " successions of coloured bands at the same thick- " ness." The crystals, indeed, of the specimen which I employed, were the upper portions of those represented in Plate XXI. Fig. 1. The bending and inequalities of the fringes, too, which I have described, and represented in Fig. 7. of my former paper, establish in the clearest manner the alternation, as well as the existence, of different polarising powers in the planes parallel to the faces of the pyramid.

A general idea of the structure of this variety of Apophyllite, may be obtained from Fig. 2., where A and B are the terminal laminæ, raised up in order to shew the tesselated structure of the intermediate portion of the prism.

The fine transparent pyramidal crystals which are found in Iceland, as well as in Faroe, possess a tesselated structure, which differs in several respects from that of the quadrangular prisms. The arrangement of the tesselæ is shewn in Fig. 3., but the border ABCD, which is seen only under favourable circumstances of illumination, appears to be composed of lines or parts at right angles to the sides AB, BC, &c.; and the polarising force of the borders is extremely weak. In order to observe how the tesselæ varied in different parts of the crystal, I took one of the largest I could obtain, and cut it into four different slices. No part of the substance was removed by grinding or polishing, so that I examined the structure of the plates as they were detached in succession from the summit of the crystal: The phenomena which they displayed are shewn in Figs. 4, 5; 6, 7; 8, 9; Figs. 4, 6, 8, containing the appearances when the sides of the crystal were in the plane of primitive polarisation; and Figs. 5, 7, and 9, when they were inclined 45° to it. The Figs. 4, and 5, exhibit the tesselæ in the *first* and *second* slices of the crystal, which had nearly the same structure. In Figs. 6, and 7., the figure exhibited by the *third* slice is shewn. The angles display a veined structure when examined by the microscope; and, what is very remarkable, there are two central squares; the interior one being much darker than the other, and having one axis of double refraction, while the other exhibits the effect of two axes, as if the axis in the plane of the laminæ had a less polarising force than the corresponding one for the rest of the plate. This effect, however, is likely to arise from the juxtaposition of two contiguous laminæ, *a b c d*

 and

and *c d e f*, Fig. 10., the one of which has its central lozenge *n* greater than the lozenge *m* of the other. Hence it follows, that the compound plate will produce such an effect, that the parts of the lozenge *n* surrounding *m* will appear to have two axes of double refraction, while the effect is actually produced by the biaxal structure round the lozenge *m* of the upper plate *a b c d*. In the *fourth* slice, represented in Figs. 8 and 9., the four veined angles now meet one another, and surround the tesselæ with only one central lozenge. The slice from below this, or the *fifth*, exhibited a very irregular structure.

When all the *four* slices were together, they distinctly produced the tesselated structure shewn in Fig. 3. Their united thickness was 0.12 of an inch.

When the crystal was examined across two opposite surfaces of the pyramid, it exhibited the fringes shewn in Fig. 7. of my former paper, and in Fig. 11. of the present one; the fringes being all bent as they approached the edges, where they became serrated, which proves that the polarising force of the outer coats is less than that of the interior ones, and that the different coats near the edges have an alternation of different polarising powers *. Near the base of one of these pyramids, as shewn in Fig. 11., the curves which had been convex towards the summit became concave in the middle, though they still retained their convexity at their junction with the serrated portions, so as to have the form of curves of contrary flexure. Another crystal from Faroe produced the opposite effect, as represented in Fig. 12.; the isochromatic lines being now concave towards the summit, and displaying a very rapid variation of

* See *Edinburgh Philosophical Journal*, vol. i. p. 4., and Plate I. Fig. 7.

of curvature. In this specimen, the isochromatic lines are all curves of contrary flexure, and there is only a small portion of them serrated, between their acute convex summits, and the faces of the pyramid. When some of the Faroe pyramids are examined with high powers, and by light transmitted exactly parallel to their faces, we may recognise frequently three, and sometimes more minute veins parallel to each face, as represented in Fig. 11. In these veins, the doubly refracting and polarising forces suffer an instantaneous change, and portions of the isochromatic curves are displaced, and thrown, as it were, towards the summit of the pyramid, exactly like the dislocations and slips which take place in strata of coal.

Among the pyramidal crystals from Faroe which Major PETERSEN was so good as to present to me, there was one of unusual magnitude, and of a yellowish tinge, which had a number of additional facets, as represented in Fig. 13. These facets, shewn at *o* and *p*, were all inclined 150° to the summit plane. In a great number of the Iceland crystals, I have observed four pair of very singular rounded planes, replacing the angles of the rectangular prism. These planes, which are always rough, with a certain degree of polish, are shewn at *m*, *n* in Fig. 13., and, with the other faces, constitute a twelve-sided prism of a very unusual kind; the mean inclination of the rounded faces being about 150°.

Among the various forms in which the Apophyllite occurs, there is one from Faroe of a very interesting nature. The crystals have a greenish-white tinge, and are aggregated together in masses. The quadrangular prisms are in general below one-twelfth of an inch in width; they are always unpolished on their terminal planes; they have the angles at the summit more deeply truncated than the other quadrangular prisms

prisms from Faroe; they are always perfectly transparent, and may sometimes be detached in a complete state, with both their terminal summits.

In examining this variety of Apophyllite, of which I was favoured with a very fine specimen from the excellent cabinet of Dr Macdonald, I was enabled, by the perfection of the crystals, to study their structure, through the natural planes, and at right angles to their axes. The phenomena which this investigation presented to me, were of a very singular and unexpected nature. In symmetry of form, and splendour of colouring, they far surpassed any of the optical arrangements that I had seen, while they developed a singular complexity of structure, and indicated the existence of new laws of mineral organisation.

When a complete crystal of this variety of Apophyllite is exposed to polarised light, with its axis inclined 45° to the plane of primitive polarisation, and is subsequently examined with an analysing prism, it exhibits, through both its pair of parallel planes, the appearance shewn in Plate XXI. Fig. 1. In turning the crystal round the polarised ray, all the tints vanish, reappear, and reach their maximum at the same time, so that they are not the result of any hemitropism, but arise wholly from a symmetrical combination of elementary crystals, possessing different primitive forms, and different refractive and polarising powers. The difference in the polarising powers is well shewn by the variation of tint; and the difference of refractive power may be observed with equal distinctness, by examining the crystal with the microscope, under favourable circumstances of illumination, when the outlines of the symmetrical forms, shewn in Plate XXI. Fig. 1. will be clearly visible.

In examining the splendid arrangement of tints exhibited in the figure, the perfect symmetry which appears in all its parts is is particularly remarkable. The existence of the curvilineal solid in the centre;—the gradual diminution in the length of the circumscribing plates, in consequence of which they taper, as it were, from the angles of the central square to the truncated angles at the summits; but, above all, the reproduction of similar tints on each side of the central figure, and at equal distances from it, cannot fail to strike the observer with surprise and admiration.

The tints exhibited by each crystal vary of course, according to its thickness *, but the range of tint in the same plate, and at the same thickness, generally amounts, in the largest crystals, to three of the orders of colours in NEWTON'S scale. The central portion, and the two red squares, have, in general, the same intensity, while the four green segments round the central portion, and some of the parts beyond each of the red squares, are also isochromatic †. In the central part, the colours have a decided termination; but towards the summits of the prism their outline is less regular, and less distinctly marked; though this irregularity has also its counter part at the other termination. A part of these irregularities is sometimes owing to the longitudinal striæ ‡ on the natural faces of the

* In comparing the polarising forces of different crystals of this variety of Apophyllite, I have been surprised to observe the great diversity which exists among them; some of the prisms, which are only $\frac{1}{20}$th of an inch thick, having a greater polarising force than others which are $\frac{1}{15}$th of an inch thick.

† In some crystals the two smaller green segments have a different tint from the two larger segments, and the same tint as the central square.

‡ Owing to the feeble polarising power of the apophyllite, these superficial irregularities produce a less degree of derangement in the tints than might have been expected.

the crystal, so that by carefully grinding these off, the beauty and regularity of the figure is greatly improved.

In order to ascertain the order of the colours polarised by the crystal, and observe in what manner they passed into one another, I transmitted the polarised light in a direction parallel to one of the diagonals of the quadrangular prism, and thus obtained, as it were, a section of the different orders of colours, from the zero of their scale. The result of this experiment, which is shewn in Fig. 14., was highly interesting, as it displayed to the eye not only the law according to which the intensity of the polarising forces varied in different parts of the crystal; but also the variation in the nature of the tints, and the connection between these two classes of phenomena. At the points in the diagonal *m n*, opposite to *a* and *b* of the crystal, the tints rose to the *seventh* order of colours; at other two places, opposite to *c* and *d*, they rose only to the *sixth;* while near the summits, at *m* and *n*, they descended so low as the *fourth* order. Hence it follows, that the portions at *a*, *a*, have the maximum polarising force; that the four segments coloured green in Plate XXI. Fig. 1., are next to these in intensity; that the central portions of the red squares are again inferior to these; and that the weakest polarising force is near the summits of the prism. At *a* and *b* the 4th, 5th and 6th fringes, have a singularly serrated outline, exhibiting in a very interesting manner the sudden variation which takes place in the polarising forces of the successive laminæ. Although the variation in the polarising power of the succession of circumscribing plates, is clearly represented by the differences of tint shewn in Fig. 1. of the coloured engraving, yet the exact amount of that variation may be rendered evident, by making the isochromatic lines cross these plates, and observing the serrated outline which is thus produced.

In

In some crystals of this variety of Apophyllite, particularly in the smaller ones, the central portion is only $\frac{1}{5}$th of the whole length of the prism, and the maximum polarising power resides in that central part. This last effect is shewn in Fig. 17. where the first fringe is completed in the form of a rectangle enclosing the central portion, while, in the other parts of the prism, the tint has not risen above the yellow of the first order.

Having thus ascertained the properties of the prism, when examined through its parallel faces, I proceeded to determine its structure at right angles to the axis, by observing the phenomena which the separate laminæ exhibited, in relation to the part of the prism from which they were extracted.

The plates near the summit of the crystals are exactly the same as the uppermost slice A, Fig. 2. of the Apophyllite already described. The subjacent plates are also similar, with this difference only, that the veined border increases in breadth, and is often beautifully divided into groups of veins, like the frame of a picture; and they retain nearly the same character till we reach the central figure. At this point the inflected lines *e h l*, &c. shewn in Fig. 1. appear within each of the four inner sides of the border; and when seen by polarised light, the slices of the central figure exhibit the tesselated structure shewn in Fig. 16., with some slight modifications. It is very remarkable, however, that when these same slices are examined with a microscope, the figure which they display is different from Fig. 16., and resembles the structure shewn in Fig. 15. In Fig. 16. some of the quadrilateral outlines which form the border, have the planes passing through the two axes at right angles to those of others; from which it follows, that some parts all round the border are luminous, and others dark, when the diagonal is in the plane of polarisation, and *vice versâ* when the diagonal is inclined 45° to this plane.

 There

There is another variety of Apophyllite from Greenland, of a very interesting kind. Sir Charles Giesecke', who kindly communicated to me several specimens of it, discovered it at Kudlisaet in Disco Island *, and describes it as of a cylindrical form, presenting the shape of a barrel, from being contracted at the extremities.

Upon examining some of the best specimens of this mineral, I find that each of the four curvilineal surfaces, by which the prism is contained, often consist of three planes, inclined to one another at very great angles. There is a distinct truncation, too, upon the angles at the summit, and its inclination is nearly the same as in the perfect crystals.

As all the transparent crystals which I have seen of this mineral, are intersected with diverging groups of capillary mesotype, or, more probably, capillary apophyllite, it is not unlikely, that the usual law of its crystallisation has been modified by its formation either at the extremity of one, or in the middle of several groups of these filamentous crystals †.

When the uppermost slice of this kind of Apophyllite is cut off, it has only one axis of double refraction, like the same slice of the regular quadrangular prisms, and displays no tesselated structure.

The second slice exhibits a tesselated appearance, which varies in different crystals, as represented in Figs. 18. and 19. In both these figures, the shaded part has only one axis of double refraction, while the five sectors have two axes, and the plane passing

* See this Volume, p. 270.

† There are many examples of Apophyllite having been deposited upon groups of Needlestone; but in these cases, the crystal is not penetrated by them, but merely rests upon their filaments.

passing through the resultant axes of the sectors A and C, is at right angles to the plane passing through the resultant axes of B and D. In Fig. 18. the tints gradually increase from the centre to the angles A, B, C, D, from the black, or *zero* of the scale, to the yellow of the first order. In Fig. 19. the tints are uniformly the white of the first order, which is immediately followed, upon inclining the plate, with the most brilliant gamboge yellow, and then green *.

Having thus described the remarkable structure of Apophyllite, I shall now direct the attention of the Society to the general optical properties of this mineral.

In the ingenious and elaborate memoir of Mr Herschel, on the action of crystallised bodies on homogeneous light, &c., read to the Royal Society of London on the 23d December 1819, he has investigated the origin and nature of the tints which compose the singular system of coloured rings, which I discovered in Apophyllite in 1816. By examining these rings, he found that they "indicated an action on polarised light very nearly the same for all the colours, being equal upon the red and indigo blue rays, a little greater for the yellow and the green, and a little less for the violet;" and hence he accounted for those unusual tints which characterised this mineral.

In a subsequent paper, read before the Cambridge Philosophical Society on the 1st May 1820 †, Mr Herschel confirmed and extended these observations. He found that the law of proportional action was so far subverted in a particular specimen of Apophyllite, that the periods performed by a red ray

 were

* The mechanical structure of the cleavage planes resembles the optical figure even after the planes are ground.

† Published in their *Transactions*, vol. i.; and in the *Edinburgh Philosophical Journal*, vol. iv. p. 334.; and vol. v. p. 334.

were shorter than those passed through by a violet one. The rings exhibited a complete inversion of the Newtonian scale, and the red rays were so much more energetically acted upon than the violet, that the whole prismatic spectrum was displayed in the first ring.

In a third memoir, read before the Cambridge Society on the 7th May 1821, but not yet published, Mr HERSCHEL has resumed the subject of these anomalous actions upon light. " Upon reconsidering his results, it appeared that these specimens (viz. of Apophyllite, which produced an inversion of the Newtonian scale) could not be referred exclusively either to the class of attractive or of repulsive doubly refracting crystals, nor to the intermediate class, which is devoid of the property of double refraction. They appeared to belong at once to all the three classes of media just mentioned, possessing the property of attractive crystals, when exposed to the rays forming one extreme of the spectrum, and of repulsive, in their action on the other extreme; while, for certain intermediate rays, they were altogether devoid of the property of double refraction. Mr HERSCHEL was led to this inference, by observing, that the curves whose ordinates represented the polarising energy, after approaching very rapidly to the axis, would again recede rapidly from it on the same side, except the ordinates were supposed to become negative, which appeared more probable. This induced him to examine the truth of his supposition, by measures taken in homogeneous light, and the result was a complete confirmation of the remarkable singularity above noticed *."

Although we cannot doubt the accuracy of these interesting results, yet it must be remembered, that the property which they

* Proceedings of the *Cambridge Philosophical Society*, in the *Edinburgh Philosophical Journal*, vol. v. p. 213.

they establish is not characteristic of any of the varieties of the mineral, but has been found only in a detached portion of a crystal. In order to ascertain how far it might be general, I have examined, with the greatest care, numerous specimens of all the varieties of Apophyllites, including those from Fassa, Utoë, Faroe, and Iceland; but having effected a distinct separation of the ordinary and extraordinary images, I have invariably found, that the *doubly refracting force was Positive or Attractive, like that of Quartz, whether the ray was Red, Blue, or Yellow.* We must, therefore, regard the property discovered by Mr HERSCHEL as an accidental anomaly, having its origin in some peculiar relation of the polarising forces of Apophyllite. What this relation is, we shall now proceed to consider.

In the *Biaxal* Apophyllite, one of the polarising axes *must be* in the plane of the laminæ, and in both the *Biaxal*, and the *Uniaxal* Apophyllite, there appears to be an axis perpendicular to the laminæ. As the form of the prism of Apophyllite is perfectly symmetrical in relation to the axis, it is probable that there are two equal and rectangular axes, of a *Positive* or *Attractive* character, in the plane of the laminæ, each axis being perpendicular to the parallel faces of the crystal, and we know that there is a *Positive* or *Attractive* axis at right angles to the laminæ, and coincident with the axis of the prism *. The two equal *Positive* axes, which we shall call the *Horizontal* axes, on the supposition that the prism is placed upon its base, will obviously produce a single *Negative* axis, coincident with the

* I must refer the reader to my paper "On the Laws of Polarisation and Double Refraction," in the *Phil. Trans. Lond.* for 1818, p. 231, and p. 245,—254. for the grounds upon which this resolution of axes is made. In the case of Apophyllite, there are reasons of a peculiar kind for supposing the existence of three axes.

the other *Positive* axis, or the *Vertical* one perpendicular to the laminæ, and the system of rings round the resultant of these two axes, will deviate more or less from NEWTON'S scale, according to the nature of the dispersive forces of the elementary axes *. Let us suppose that the resultant negative vertical axis has the same action upon the *Yellow* rays of the spectrum, as the real positive vertical axis; but that it acts much more energetically upon the *Red* extremity, and much less energetically upon the *Blue* extremity of the spectrum. The *yellow* rays being thus solicited by equal and opposite forces, the crystal will exercise over them no polarising energy. The *red* rays being subjected to a greater polarising energy from the *Negative* than from the *Positive* axis, will give rings corresponding to the difference of their opposite actions, and the characters of these rings will be *Negative.* The *blue* rays, on the contrary, being much less energetically acted upon by the *Negative* than by the *Positive* axis, will form rings proportional to the difference of their actions, and these rings will be *Positive*, from the predominating influence of the positive axis. In this way, a particular crystal of Apophyllite may exercise over the red rays of the polarised beam a negative influence; over the blue rays a positive influence; and over the yellow rays no influence at all †; while it is the general character of the mineral to exert an attractive doubly refracting force over all the rays of the

* For an illustration of these views, the reader is referred to my letter to Mr HERSCHEL, published at the end of his paper in the *Phil. Trans.* 1820, p. 94.; and to Mr HERSCHEL'S paper in the *Transactions of the Cambridge Philosophical Society*, vol. i.; or in the *Edin. Phil. Journal*, vol. iv. p. 335.; and vol. v. p. 340.

† This partial equilibrium of polarising forces is analogous to the paradoxical phenomena of a compound lens, which, as I have elsewhere shewn, may be constructed so as to *converge* the *Blue* rays, *diverge* the *Red* rays, and exercise *no action* at all upon the *Yellow* ones. That is, the same compound lens is a *Plane lens* in *yellow* light, a *convex* one in *blue* light, and a *concave* one in *red* light.

the spectrum. The ray of compensation, in place of being yellow, may have any position in the spectrum, and those on each side of it will afford positive or negative tints, according as the positive or the negative axis exercises over them a predominating influence.

This view of the polarising structure of Apophyllite, affords a complete explanation of the singular tints which surround its resultant axis. Each order of colours is as it were a residual spectrum *, arising from the opposite actions of the negative and the positive axis, and the tints of which these orders are composed, will consequently vary, according to the locality of the ray of compensation †.

Having thus described the structure and properties of the tesselated Apophyllite, it becomes interesting to inquire how far such a combination of structures is compatible with the admitted laws of crystallography. The growth of a crystal, in virtue of the aggregation of minute particles endowed with polarity, and possessing certain primitive forms, is easily comprehended, whether we suppose the particles to exist in a state of igneous fluidity or aqueous solution. But it is a necessary consequence of this process, that the same law presides at the formation of every part of it, and that the crystal is homogeneous throughout, possessing the same mechanical and physical properties in all parallel directions.

The

* Among the various residual spectra which I have examined in the course of my experiments "on the Action of Transparent Bodies upon the differently coloured Rays of Light," there are many among the polarised rings which have exactly the same tint; and there are some which resemble as nearly as possible those in Apophyllite. See *Edinburgh Transactions*, vol. viii. p. 1.

† The preceding explanation may be presented in a more brief form, by stating that the specimen of Apophyllite in question had three positive rectangular axes, which were in equilibrium only for the yellow rays of the spectrum. See *Phil. Trans.* 1818, p. 256.

The tesselated Apophyllite, however, could not have been formed by this process. It resembles more a work of art, in which the artist has varied, not only the materials, but the laws of their combination.

A foundation appears to be first laid by means of an uniform homogeneous plate, the primitive form of which is pyramidal. A central pillar, whose section is a rectangular lozenge, then rises perpendicularly from the base, and consists of similar particles. Round this pillar are placed new materials, in the form of four trapezoidal solids, the primitive form of whose particles is prismatic, and in these solids the lines of similar properties are at right angles to each other. The crystal is then made quadrangular by the application of four triangular prisms of unusual acuteness. These *nine solids*, arranged in this symmetrical manner, and joined by transparent veins, performing the functions of a cement, are then surrounded by a wall, composed of numerous films, deposited in succession, and the whole of this singular assemblage is finally roofed in by a plate exactly similar to that which formed its foundation.

The second variety of the Tesselated Apophyllite is still more complicated. Possessing the different combinations of the one which has just been described, it displays, in the direction of the length of the prism, an organisation of the most singular kind. Forms unknown in crystallography occupy its central portion, and on each side of it particles of similar properties take their place, at similar distances, now forming a zone of uniform polarising force, now another increasing to a maximum, and now a third, descending in the scale by regular gradations The boundaries of these corresponding, though distant zones, are marked with the greatest precision, and all their parts as nicely adjusted, as if some skilful workman had selected

selected the materials, measured the spaces they were to occupy, and, finally, combined them into the finest specimen of natural Mosaic.

Those irregularities of crystallisation which are known by the name of *Macle* or *Hemitrope* forms, and those compound groups which arise from the mutual penetration of crystals, are merely accidental deviations from particular laws, which govern the crystallisations in which they occur. The aberrations themselves testify the predominance of the laws to which they form exceptions, and they are susceptible of explanation by assuming certain polarities in the integrant molecules. The compound structure of the Apophyllite, however, cannot be referred to these capricious formations. It is itself the result of a general law, to which there are no exceptions, and when more deeply studied, and better understood, it must ultimately lead to the introduction of some new principle of organisation, of which crystallographers have at present no conception.

The difficulty of accounting for the formation of Apophyllite, is in no way diminished, by giving the utmost licence to speculation. We cannot even avail ourselves of the extravagant supposition of a crystalline embryo, which, like that of animal and vegetable life, gradually expands to maturity. The germ of plants and animals is nourished by a series of organs, of which, however recondite be the operation, we yet see the action, and witness the effects; but, in the architecture of Apophyllite, no subsidiary organs are seen. The crystal appears only in its state of perfection; and we are left to admire the skill which presided at its formation, and to profit by the instruction which is so impressively conveyed by such mysterious organisations.

DESCRIPTION OF THE PLATES.

Plate XX.

Fig. 1. Represents the tesselated structure of one of the internal plates of the Faroe Apophyllite, as developed in ordinary light by the microscope, or as seen by exposing it to a polarised ray.

Fig. 2. Represents a complete crystal of the same Apophyllite, with the upper and under slices lifted up, to shew the internal tesselated structure.

Fig. 3. Represents the tesselated structure of the pyramidal crystals of Apophyllite from Faroe and Iceland.

Figs. 4, 5, 6, 7, 8, 9. Shew the effects produced by successive slices, taken from one of the pyramids of Apophyllite.

Fig. 10. Is a diagram for explaining the double central lozenge seen in Fig. 7.

Fig. 11. Shews the variation in the curvature of the fringes, or isochromatic curves, their convexity, as seen through two opposite faces of the pyramid, and the veins with which they are sometimes traversed, with the slips in the isochromatic curves.

Fig. 12. Represents a more singular variation in the isochromatic curves, and their concavity towards the summit, as seen through two opposite faces of the pyramid.

Fig. 13. Represents a complete crystal of the Iceland Apophyllite, with the new facets *o*, *p*, &c. at the summit of the pyramid, and of the six curvilineal and unpolished planes *m*, *n*.

Fig. 14. Shews the form of the isochromatic curves, as seen through the diagonal of a quadrangular prism of a transparent variety of Apophyllite from Faroe, the structure, through its parallel faces, being shewn in Plate XXI. Fig. 1.

Fig. 15. Represents the structure, as detected by the microscope of one of the central laminæ or slices of the crystal, shewn in Plate XXI. Fig. 1.

Fig. 16. Shews the optical effect produced by the same lamina or slice.

Fig. 17. Shews the form of the first isochromatic curve in a very small crystal.

Fig. 18. Represents the figure produced in polarised light, by an internal slice of the Barrel or cylindrical Apophyllite from Greenland.

Fig. 19. Represents the figure produced by a similar slice from another specimen.

Plate XXI.

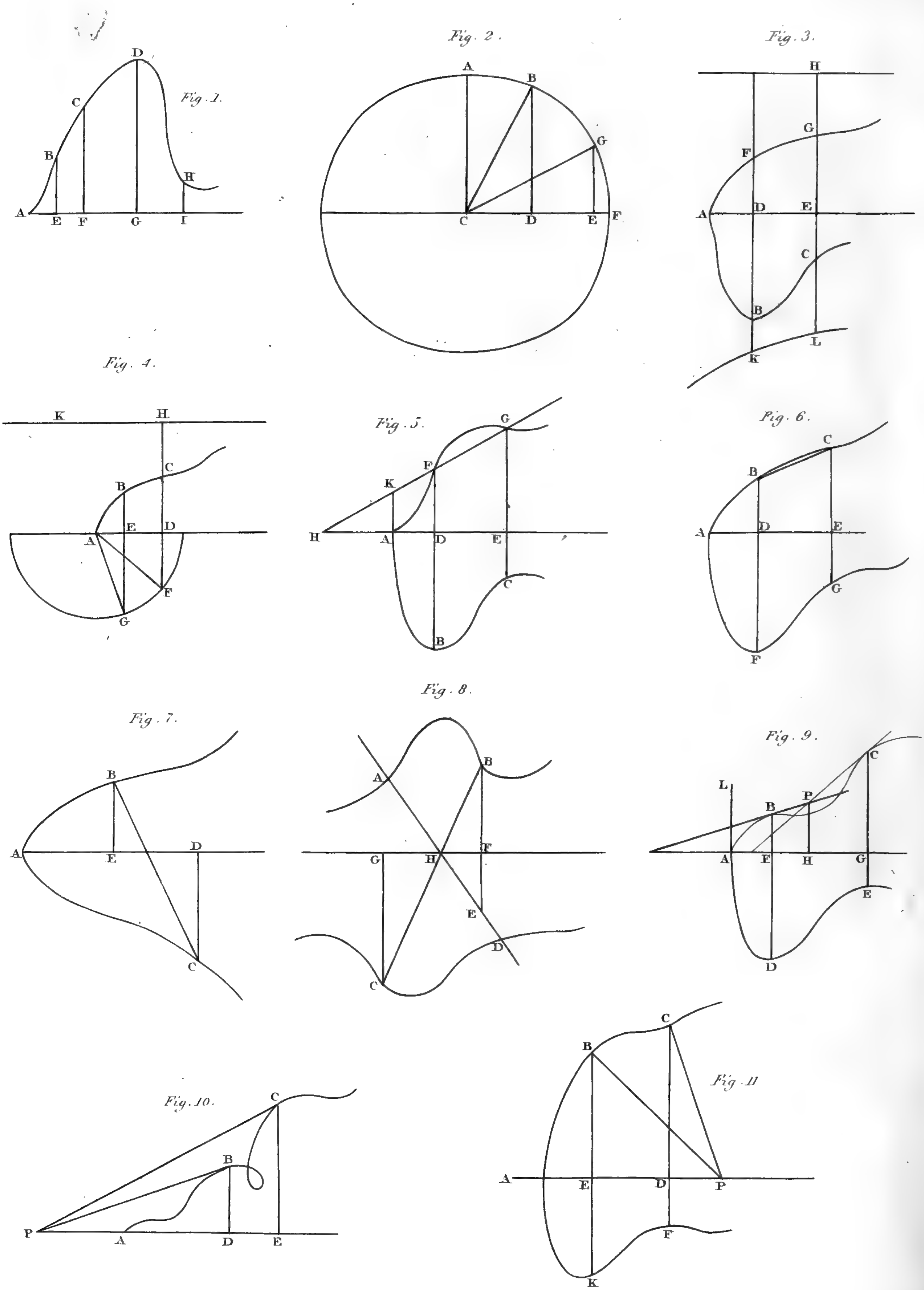
Fig. 1. Is a magnified representation of the Figure, and the Tints displayed by a complete crystal, of a particular variety of Faroe Apophyllite, when exposed to polarised light. The outlines of the figure are distinctly seen by the microscope alone, in ordinary light. The crystal is here magnified about 50 times.

Fig. 2. Shews the colours produced by one of the tesselated laminæ of Apophyllite, when crossed by a plate of sulphate of lime which gives one uniform blue tint.

Fig. 3. Represents the circular system of rings, with their anomalous tints, as seen round the axis of the *Apophyllite Surcomposée*.

PLATE XXII

Engraved for the Royal Soc. Trans. Vol. IX. page 337.



W H Lizars Sculpt.

XXIV. *On the Application of Analysis to the Discovery of Local Theorems and Porisms.* By CHARLES BABBAGE, ESQ. F. R. S. LOND. & EDIN.

(Read May 1, 1820.)

THOSE who have devoted much of their attention to mathematical inquiries, must have had frequent occasion to admire the unexpected and intimate connection which subsists between branches of their science apparently the most remote and unconnected with each other; and repeated observation will have convinced them, that no researches, however recondite or abstruse, should be neglected, because they appear to stand isolated and detached from the body of the science. These reflections appear to have been felt with strongest force, by those who have most contributed to its advancement, and were particularly insisted on by MACLAURIN, in the Preface to his *Geometria Organica.* The present Paper will add another example, to instances already numerous, of the latent affinity between departments of mathematics, usually regarded as the most opposite.

By those who have studied the writings of the illustrious restorers of the most valuable and interesting portion of the ancient geometry, the views which are here opened may probably be regarded with surprise, not unmixed with regret, that the increasing perfection of the language of symbols should gradually cause it to usurp the hitherto exclusive domains of the higher geometry. But whatever may be the discoveries to which the geometrical interpretation of language, at once the most comprehensive and condensed which human ingenuity has devised, shall give birth, the restorer of the Porisms of Euclid, and the author of the General Theorems, will retain an undiminished reputation, and their works continue to be studied, by all those who wish to acquire a correct taste for the geometry of the ancients. Those propositions which have received the appellation of Local Theorems and Porisms, may, in one point of view, be considered as differing from theorems and problems, by having something more general, or indeterminate, in their nature; by affirming that some property is possessed not merely by one individual, but by every one, of some class or species. It is on this circumstance that the algebraic investigation of porisms is founded: the arbitrary constants of an equation of two variables, are made to submit to certain conditions, which shall leave the variables themselves still indeterminate. By generalising this process, we take, instead of arbitrary constants, unknown functions of the variables themselves; and instead of the resulting algebraic equations, we find functional equations which determine the form of the functions we have assumed.

This process, which will be better understood by the subsequent inquiries, leads us at once to the highest pitch of generality, and puts us in possession of innumerable porisms, and local theorems, each comprehending whole classes of curves. By limiting and determining the form of the arbitrary functions involved in the solution, we gradually restrict the extent of of our results, and we frequently arrive at *loci* belonging to the conic sections. Sometimes, however, the simplification is still greater, and we are surprised by recognising, amongst extensive classes of curves, possessed of some peculiar property, some well known *locus* of the straight line or circle.

The inquiries which follow are given nearly in the order in which they occurred; a different arrangement might have appeared more systematic, but it would have had the great disadvantage of concealing the means by which the results were arrived at. Several of the more restricted porisms and local theorems, might have admitted of a geometrical dress; but this would have been inconsistent with the object I had proposed to myself in the present paper. The greater part are, I believe, beyond the powers of geometry; and this opinion, if allowed to be correct, will perhaps, by the admirers of the ancient geometry, be admitted as some excuse for the present attempt to add to its stores, by means so very foreign.

There exist numerous classes of curves possessed of the following property:

If we take any abscissa AE, Plate XXII. Fig, 1, and ordinate BE, and if we make AF = BE, and find the new ordinate CF, and repeat the same process n times, the nth ordinate HI shall equal the first abscissa AE. It is easy to perceive, that if $y = \psi x$ represent the equation of the curve, then the equation determining the form of ψ will be

$$\psi^n x = x$$

As the classes of curves here alluded to, will frequently occur in the following inquiries, I shall venture to bestow on them the name of *Periodic Curves*, which was suggested by the similar name assigned by Mr Herschel to the function which satisfies the equation just given. It will also be convenient to apply

ply some name to the series of ordinates thus found: I shall therefore call them *Corresponding Ordinates.* These curves may be divided into orders, according to the value of the index n; if $n=1$, the first order consists of only one curve, namely, $y=\psi x=x$, which is the equation of a right line, making an angle of 45° with the axis.

When $n=2$, and ψ is determined from $\psi^2 x=x$,

$$y=\psi x$$

represents all periodic curves of the second order, and so on.

The equation $\psi^n x=x$ has been solved by me in the *Philosophical Transactions* for 1816, and numerous examples are given in another paper, published in the following year. This solution has, however, been much improved by Mr Horner (see *Annals of Philosophy*, October 1817), who has shewn that the algebraic equation to which my method of solution leads in all cases, admits of a ready solution. The form which is thus assigned to the function ψ is

$$\psi x=\varphi^{-1}\left\{\frac{a+bx}{c-\dfrac{b^2-2bc\cos\frac{k\pi}{n}+c^2}{2\left(1+\cos\frac{k\pi}{n}\right)a}x}\right\}$$

Amongst those included in the second order of periodic curves, will be found the right-angled hyperbola referred to co-ordinates parallel to its assymptotes, and also circles of all orders, where equations are $x^n+y^n=a^n$; these curves possess many singular properties. All those in which n is even are re-entering curves, without any infinite branches, whose form is nearly that of the subjoined figure, Fig. 2. In this curve, if we take any abscissa, and ordinate CD and BD, and if we turn the triangle CBD, into such a position that B shall coincide with the axis CF, then the point C will coincide with G some point

point in the curve, and also the arc GF, together with the arc BF, will be equal to the quadrant AF of the curve.

Let ABC be any periodic curve of the second order, whose equation is $y = \alpha x$, and DB, EC any two corresponding ordinates, it is required to find another curve AFG, such that the sum of its two ordinates, at the points D and E, may be always a constant quantity.

From the nature of the curve ABC, we have $AD = x$, and $AE = DB = \alpha x$; also $\alpha^2 x = x$.

Let $y = \psi x$ be the equation of the curve AFG, then $FD = \psi x$, and $GE = \psi (AE) = \psi \alpha x$, and by the prescribed condition, we have for the equation determining ψ

$$\psi x + \psi \alpha x = c;$$

the general solution of which is,

$$\psi x = \frac{c \phi x}{\phi x + \phi \alpha x};$$

the function ϕ is perfectly arbitrary, and of the class of curves comprehended in the equation $y = \dfrac{c \phi x}{\phi x + \phi \alpha x}$, we may enunciate the following porisms.

Any of this family of curves being given, a periodic curve of the second order (ABC), *may always be found such, that if we take any two abscissæ in the curve given, respectively equal to any two corresponding ordinates of the curve found, and draw ordinates to the given curve, and if we prolong either of these ordinates* (EG) *above the curve, until the part above* (GH) *is equal to the first of the two ordinates, the extremity of the ordinate, thus increased, will always be situated in a right line given by position*, Fig. 3.

The line thus given by position is parallel to the abscissæ, and situated at the distance denoted by c.

If

If we prolong either of the two ordinates (GE) *below the abscissæ, by a quantity* (EL) *equal to the first ordinate, the extremity of the ordinate, thus prolonged, will always be situated in a curve, similar and equal to the given curve, which is also given by position.*

The position of the given curve is parallel to the original curve. The deduction of these porisms is so obvious, from the property of the class of curves, that I consider any farther explanation of them unnecessary. We shall, however, by assigning particular values to some of the functions, find some very simple results. Let us suppose $\alpha x = \sqrt{a^2 - x^2}$, then the family of curves will be contained in the equation,

$$y = \frac{c \varphi (x)}{\varphi x + \varphi (\sqrt{a^2 - x^2})}.$$

Of these curves, the following property may be stated:

Any curve of this family being given, a straight line (HK) *may be found through any point, of which, if a line* (HD) *be drawn at right angles to the axis of the abscissæ, it will cut off an abscissa* (AD), *and part of it will form the ordinate* (CD), *if an abscissa* (AE) *be found, whose ordinate* (BE) *is equal to that part of the line drawn, which is intercepted between the line found and the curve; and if both the two ordinates thus found, be prolonged below the axis, until the part of each below is equal to the abscissa belonging to the other ordinate, the two points to which these lines are prolonged, are situated in the circumference of a circle given by position.* See Fig. 4.

Let $\alpha x = -x$, then the curves included in the family $y = \frac{c \varphi x}{\varphi x + \varphi (-x)}$ possess the following property:

Any

Any curve of this kind being given, if we take two equal abscissæ, on opposite sides of the centre, and prolong the ordinates at both these points, until the parts of each produced be equal to the ordinate at the other point, then the locus *of the points thus found is a right line given by position.*

If we make $\varphi x = a + x$, the curve becomes a right line, whose equation is $y = \frac{c}{2} + \frac{c}{a} x$; and the line found is parallel to the axis, and the curve given, is a right line passing through a point in the axis of the ordinates, equally distant from each parallel.

Let ABC be any periodic curve, Fig. 5. and DB, EC, any two corresponding ordinates; draw the ordinates FD, GC, and draw the line HFG, passing through the points F and G, it is required to find the equation of this line.

w and v being the co-ordinates of any point in this line, its equation will be $v = A w + B$; the quantities A and B being determined by the condition, that it must pass through the points F and G, whose co-ordinates are respectively x and ψx, and αx, and $\psi \alpha x$, we have

$$v = \frac{\psi x - \psi \alpha x}{x - \alpha x} w + \frac{\alpha x . \psi x - x . \psi \alpha x}{x - \alpha x}.$$

Let us now determine the form of the curve AFG by this condition, that the line HG shall always be parallel to itself. It is well known, that the co-efficient of the abscissa w expresses the tangent of the angle of the inclination of the line to its axis; this must therefore be constant, and we have

$$\frac{\psi x - \psi \alpha x}{x - \alpha x} = c, \text{ or } \psi x - \psi \alpha x = c(x - \alpha x);$$

the solution of this equation is $\psi x = \frac{c(x - \alpha x) \varphi x}{\varphi x + \varphi \alpha x}$.

This suggests the following porisms :

 Any

Any of the family of curves contained in the equation $y = \frac{c(x - \alpha x)\,\varphi x}{\varphi x + \varphi \alpha x}$ *being given, a right line may be found, through any point of which, if a right line be drawn perpendicularly, cutting the curve in two points, and if the ordinate at each of these points is produced to a point below the axis, until the part below each is equal to the abscissa belonging to the other ordinate, the two points thus found will always be situated in a periodic curve, given in species and position.*

The line to which the other lines are drawn perpendicular, is at right angles to the line HFG in the figure.

If we make $\alpha x = \sqrt{a^2 - x^2}$, the curve which is the locus of these points is a circle, whose radius is equal to a, and if we also make $\varphi x = b$, the original curve is an ellipse.

If we make $\alpha x = \frac{a^2}{x}$, and also $\varphi x = b$, the equation of the given curve is $y = \frac{c}{2}\left(x - \frac{a^2}{x}\right)$, which is an hyperbola, and that of the curve found is $y = \frac{a^2}{x}$, a right-angle hyperbola.

If in the equation of the right line,

$$v = \frac{\psi x - \psi \alpha x}{x - \alpha x}\, w + \frac{\alpha x \,.\, \psi x - x \,.\, \psi \alpha x}{x - \alpha x},$$

we make $w = 0$, we have the distance of the point K from A; let us suppose this to remain constant, then

$$\frac{\alpha x \,.\, \psi x - x \,.\, \psi \alpha x}{x - a x} = c, \text{ or } \alpha x \,.\, \psi x - x \,.\, \psi \alpha x = c\,(x - \alpha x);$$

the solution of which is $\psi x = \frac{1}{\alpha x} \cdot \frac{c\,(x - \alpha x)\,\varphi x}{\varphi x + \varphi \alpha x}$.

The

The class of curves comprehended in the equation $\psi x = \frac{1}{\alpha x} \cdot \frac{c(x - \alpha x) \varphi x}{\varphi x + \varphi \alpha x}$, are possessed of the following property:

Any curve of the kind being given, a point (K) *may be found, through which, if a right line* (KG) *be drawn in any direction, cutting the curve in two points* (F *and* G), *if the ordinate at one of these points be prolonged to a point below the axis, until the part below is equal in length to the abscissa corresponding to the other point of intersection, then the point thus found is always situated in a periodic curve of the second order, given in species and position.* Fig. 5.

If in the equation of the line, we make $v = 0$, we have $w = \frac{\alpha x . \psi x - x . \psi \alpha x}{\psi x - \psi \alpha x}$, and if we suppose this to remain constant, we in fact fix the point K in the axis of the abscissæ. This gives the equation for determining ψ,

$$(\alpha x - c)\, \psi x = (x - c)\, \psi \alpha x;$$

whose solution is $\psi x = \frac{c \chi \{\bar{x}, \overline{\alpha x}\}}{\alpha x - x}$.

Let AFG be any periodic curve, Fig. 6., and AD, AE any two corresponding abscissæ. Required the equation of all curves, such that the line joining the summits of the two ordinates, raised at the points D and E, shall be constant.

The equation of the periodic curve being $y = \alpha x$, let that of the family of curves sought be $y = \psi x$, then we have $\mathrm{AD} = x$, $\mathrm{AE} = \alpha x$, $\mathrm{BD} = \psi x$, $\mathrm{CE} = \psi \alpha x$, and the equation determining the form of ψ is

$$(\psi \alpha x - \psi x)^2 + (\alpha x - x)^2 = c^2. \qquad (a)$$

 This

This equation is one of those which I noticed in a paper in the *Philosophical Transactions* for 1817, p. 211. I there stated, that it appeared impossible for any function to satisfy the equation, unless it contained a radicle, and unless different roots were taken in different parts of the equation. This explanation will perhaps be rendered more satisfactory by the application to geometry. The general solution of the equation in question, is

$$\psi x = \pm \frac{\varphi x . \sqrt{c^2 - (\alpha x - x)^2}}{\varphi x + \varphi \alpha x} = y,$$

where the upper sign must be used in one part of the equation, and the lower sign in another. From this equation we learn, that for every value of x there are two values of y, equal, but extending in opposite directions; or that the curve is symmetrical with regard to the axis of the x's: and since we must use different values of the radicle, it appears that the two points B and C cannot be in the same branch of the curve, and on the same side of the axis, but that one point being situated above the axis, the other must be placed in the corresponding branch, which exists below the axis. In fact, it seems to follow, from the very nature of the equation (a), that no curve possessing this property can have both the two points B and C situated in the same branch. These considerations render it necessary, in some measure, to limit the generality of the function φ; and it may be stated, that no form of φ is admissible, which takes away the double sign placed before the whole of the value of y.

Thus, if we take $\varphi x = \alpha x + \sqrt{c^2 - (\alpha x - x)^2}$, we have

$$y = \frac{\alpha x}{2} \pm \frac{1}{2} \sqrt{c^2 - (\alpha x - x)^2};$$

but

but this does not satisfy the condition of rendering the curve symmetrical relative to its axis.

Let $\alpha x = \sqrt{a^2 - x^2}$, then we have

$$y = \frac{\sqrt{c^2 - a^2 + 2x\sqrt{a^2 - x^2} \cdot \varphi x}}{\varphi x + \varphi\sqrt{a^2 - x^2}};$$

and the following property belongs to all the curves contained in this family:

Any curve BAC *of this species being given*, Fig. 7., *a right line* BC *given in length may be found such, that if it be any how placed, so that its extremities* B *and* C *coincide with any two points of similar branches, but on opposite sides of the axis; then the sum of the squares described on the abscissæ* AE, AD, *shall be equal to the square described on a right line which may be found.*

If we make $\alpha x = - x$, we have the family of curves expressed by the equation

$$y = \frac{\sqrt{c^2 - 4x^2} \cdot \varphi x}{\varphi x + \varphi(-x)};$$

which possess the following property:

Any one of this class of curves being given, a right line CB *may be found, which, if it be placed so that its extremities rest on two opposite branches of the curve* (*at* C *and* B), *and if the ordinate at one of these points be prolonged on the other side the axis, until the part produced* (FE) *be equal to the abscissa* (GH) *at the other point, the extremity of the line so produced* (E), *will be situated in a straight line given by position.*

If we make $\varphi x = b$, the equation becomes $y = \sqrt{\frac{c^2}{4} - x^2}$,

and the curve is a circle whose radius is $\frac{c}{2}$, the line to be

found

found is equal to twice the radius, and the line given by position passes through the centre, making an angle of $\frac{\pi}{4}$ with the axis.

ADE being any periodic curve of the second order, and AF, AG any two corresponding abscissæ, and ABC being any other curve, whose equation is $y = \psi\, x$, required the co-ordinates of the point of intersection of its two tangents, at the points B and C.

$$\text{Call AF} = x' \quad \text{AG} = x'_1$$
$$\text{BF} = y' \quad \text{CG} = y'_1 ;$$

and let x and y be the co-ordinates of any point in either of the tangents, then

$$y = x\,\frac{d\,y'}{d\,x'} - \frac{x'\,d\,y'}{d\,x'} + y'$$

$$y = x\,\frac{d\,y'_1}{d\,x'_1} - \frac{x'_1\,d\,y'_1}{d\,x'_1} + y'_1$$

are the equations of the tangents; and if we call v and w the co-ordinates of the point of intersection P, we have

$$v = \frac{y' - \frac{x'\,d\,y'}{d\,x'} - y'_1 + \frac{x'_1\,d\,y'_1}{d\,x'_1}}{\frac{d\,y'_1}{d\,x'_1} - \frac{d\,y'}{d\,x'}}$$

And

$$w = \frac{\frac{d\,y'_1}{d\,x'_1}\left(y' - \frac{x'\,d\,y'}{d\,x'}\right) - \frac{d\,y'}{d\,x'}\left(y'_1 - \frac{x'_1\,d\,y'_1}{d\,x'_1}\right)}{\frac{d\,y'_1}{d\,x'_1} - \frac{d\,y'}{d\,x'}}$$

Let

Let us now suppose that the point P is always situated in the right line AL, perpendicular to the axis; we have $v = 0$, and since the curve ADE is a periodic one, whose equation is $y = \alpha x$,

$$\psi x - \frac{x \alpha \psi x}{d x} - \psi \alpha x + \frac{\alpha x . d \psi \alpha x}{d \alpha x} = 0$$

Whence $$\psi x - \frac{x d \psi x}{d x} = \chi \{\bar{x}, \overline{\alpha x}\}$$

or $$\frac{x d \psi x - \psi x . d x}{x^2} = - \frac{d x}{x^2} \chi \{\bar{x}, \overline{\alpha x}\};$$

from which $$y = \psi x = - x \int \frac{d x}{x^2} \chi \{\bar{x}, \overline{\alpha x}\}.$$

Now, let $\alpha x = (a^4 - x^4)^{\frac{1}{4}}$, the family of curves are comprehended in the equation

$$y = - x \int \frac{d x}{x^2} \chi \{\bar{x}, \overline{(a^4 - x^4)^{\frac{1}{4}}}\};$$

and they possess the following property:

Any of this species of curve being given, if any two abscissæ are taken, the sum of whose fourth powers is equal to the fourth power of a line, which may be found, then the tangent drawn at the extremities of the ordinates corresponding to these abscissæ, will intersect each other in a line given in position. This line is perpendicular to the axis.

If we suppose the point P always to be situated in the axis of the abscissæ, we have $w = 0$, consequently,

$$\frac{d y_1'}{d x_1'} \left(y' - \frac{x' d y'}{d x'} \right) - \frac{d y'}{d x'} \left(y_1' - \frac{x_1' d y_1'}{d x_1'} \right) = 0,$$

or

or $\frac{d\psi\alpha x}{d\alpha x}\left(\psi x - \frac{x\,d\psi x}{dx}\right) = \frac{d\psi x}{dx}\left(\psi\alpha x - \frac{\alpha x\,.\,d\psi\alpha x}{d\alpha x}\right)$,

multiplying both sides by $\left(\frac{d\psi x}{dx} - \frac{d\psi\alpha x}{d\alpha x}\right)^{-1}$ we have

$$\psi x\left(\frac{d\psi x}{dx}\right)^{-1} - x = \psi\alpha x\left(\frac{d\psi\alpha x}{d\alpha x}\right)^{-1} - \alpha x;$$

and since both sides are symmetrical relative to x and αx, we have

$$\psi x\left(\frac{d\psi x}{dx}\right)^{-1} - x = \chi\left(\bar{x}, \overline{\alpha x}\right),$$

or $$y\frac{dx}{dy} = x + \chi\left(\bar{x}, \overline{\alpha x}\right);$$

hence, $$\frac{dy}{y} = \frac{dx}{x + \chi\left(\bar{x}, \overline{\alpha x}\right)}.$$

If we suppose $\alpha x = (a^n - x^n)^{\frac{1}{n}}$, the class of curves comprehended in the equation

$$\log y = \int\frac{dx}{x + \chi\left\{\bar{x}, \overline{(a^n - x^n)^{\frac{1}{n}}}\right\}}$$

possess the following property:

If we take any two abscissæ AD, AE, *the sum of whose nth powers is equal to a given nth power, then the tangents* BP, CP, *drawn to the curve at the extremity of the ordinates corresponding to those abscissæ, will always intersect each other on the axis of the abscissæ.* Fig. 10.

In the same manner, a class of curves may be found, and ordinates may be drawn, in such a manner, that the tangent at at those ordinates shall intersect each other in a line given in position.

In the curve ABC, taking any two ordinates, BE, CD, required its equation when the normals at these points intersect each other on the axis; let x, y, and x_1, y_1 be the ordinates, then we must have

$$AE + EP = AD + DP,$$

or

$$x + \frac{y\,d\,y}{d\,x} = x_1 + \frac{y_1\,d\,y_1}{d\,x_1}$$

if the two points E and D are so chosen, that $x_1 = \alpha\,x$, and if α is a periodic function of the second order, we have, supposing $y = \psi\,x$

$$x = \frac{\psi\,x\,.\,d\,\psi\,x}{d\,x} = \alpha\,x + \frac{\psi\,\alpha\,x\,.\,d\,\psi\,\alpha\,x}{d\,\alpha\,x},$$

or

$$x + \frac{\psi\,x\,.\,d\,\psi\,x}{d\,x} = \chi\,(\bar{x},\ \overline{\alpha\,x});$$

hence $y^2 = -x^2 + 2\int d\,x\,\chi\,(\bar{x},\ \overline{\alpha\,x})\cdot$

If we make $\chi\,(x,\ \alpha\,x) = x$, we have

$$y^2 = -\,x^2 + 2\,c\,x + c_1,$$

which is the equation to a circle, and it is well known, that this curve possesses the property, since all its normals intersect each other in the centre.

This furnishes us with the following local theorems. *Any curve of this family being given, if from any point* (P), *in the axis of the abscissæ, we draw two lines cutting the same branch of the curve perpendicularly* (*in* B *and* C), *and if we prolong the ordi-*

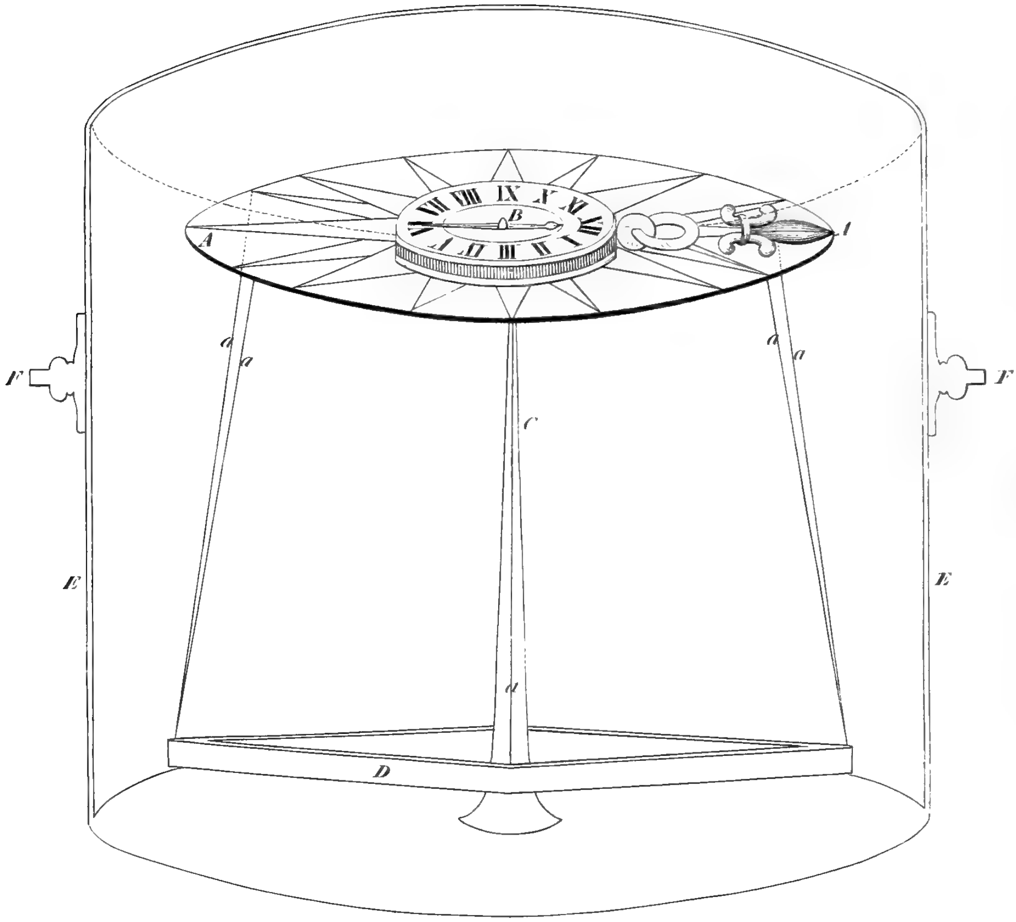
nate (CD) *at one of these points below the axis, until the part below* (DF) *is equal to the abscissa corresponding to the other point* (AE), *then the* locus *of the extremity of the ordinate* (F) *thus produced, is always a periodic curve of the second order.* Fig. 11.

The questions which we have now considered, appear to me sufficient to point out the nature of that connection between the theory of functions and that of curves, which it was my object to establish. The difference between the properties thus brought to light, and those which have been hitherto known, seems to consist chiefly in two points. The first is, that the families of curves to which they relate are larger: this arises from the arbitrary functions necessarily introduced into the solution of functional equations. The other difference is, that the properties discovered relate to many points of the same curve, only connected by some given law. In the first respect, they in some measure approach to the investigations of M. Monge, in his excellent work *L'Application de l'Analyse à la Geometrie;* whilst, in the second respect, they bear some analogy to the more general properties of curves, deduced from the theory of equations in the *Proprietates Curvarum* of Waring: these resemblances are, however, but superficial. The nature of the questions we have considered requires, by the usual methods of analysis, the application of mixed differences; and, in most of the few instances in which any such problems have been proposed, they have been attempted by that method.

Devonshire Street, Portland Place,
July 1. 1818.

XXV.

Engraved for the Royal Soc Trans Vol II page 353



Engd. by W.H. Lizars

XXV. *Observations on the Errors in the Sea-Rates of Chronometers, arising from the Magnetism of their Balances; with Suggestions for removing this source of Error. By* WILLIAM SCORESBY, ESQ. F. R. S. EDIN.

(*Read April* 15. 1822.)

THE value of the Chronometer for finding the Longitude at Sea, being, by the experience of many years trial, fully established, I am induced to offer to the Royal Society some remarks on the change of rate observed in this instrument, when on ship-board. This change of rate, that had usually been supposed to arise from the motion of the ship, has recently been attributed, by Mr FISHER, who accompanied Captain BUCHAN in his Voyage towards the North Pole in the year 1818, "to the magnetic action exerted by the iron in the ship upon "the inner rim of the Chronometer's balance, which is composed of steel." I apprehend, however, that it will be very easy to show, that although the alteration of rate may be, and most probably is, owing to magnetism, yet the magnetic action of the iron in the ship, excepting in cases where chronometers are placed in immediate contact with large masses of iron, can contribute but in a very small degree to the error in

question.

question. For, in the same proportion as the magnetism of the earth, or the directive force on the compass-needle, exceeds the magnetism of the ship, or the deviating force, the influence of terrestrial magnetism on the chronometer, must, I conceive, exceed that influence exerted by the iron in the ship on the chronometer. A modified action, indeed, takes place where the direction of the magnetic force of the earth differs from the direction of the " local attraction" of the " ship;" but yet the combined influences of the two forces, however modified by direction, should, I imagine, be similar on the balance of the chronometer, which vibrates in a horizontal position, to what it is on the compass-needle, which traverses in the same position.

Now, the medium effect of the attraction of the iron in vessels on the compass, in the parallels of Great Britain, does not appear to exceed five degrees of deviation on each side of the magnetic meridian ; it is probably a little less. The force producing the deviation, therefore, is represented by the sine of the angle of deviation, or 5° ; while the directive force is represented by the sine of 85°. The relation of these two is as 1 to 11.35; that is, the directive influence of the earth's magnetism on the compass is $11\frac{1}{3}$ times greater than the deviating influence of the local attraction. Hence, the proportion of error due to the local attraction of the ship, would appear not to exceed, in these latitudes, the eleventh or twelfth part of that resulting from the earth's magnetism ; while nearer the equator, this proportion of error must be still less. So long as the action of terrestrial magnetism, therefore, remains uncorrected, it will be of little service to compensate for the error arising from the local attraction. In the Polar Seas, indeed, the force of local attraction approaches the directive force much nearer than in the British Seas, and in some situations very near the

Magnetic

Magnetic Poles exceeds it; but still the local attraction operates without any increase of force, excepting what may arise from the little augmentation of the magnetic intensity of the earth in those regions; so that, in reality, the rate of a Chronometer in polar regions, where the earth's magnetism acts nearly at right angles to the plane of the balance, could the effect of temperature on the instrument be perfectly compensated, ought to be more equable than in any other region, where the direction of terrestrial magnetism is more nearly in the plane in which the balance vibrates.

In the important and truly scientific experiments of Mr Barlow, on the effects produced in the rates of Chronometers by the proximity of masses of iron, we have a corroboration of the preceding opinions; for Mr Barlow, though he observed that a variation of rate was occasioned by the influence of a mass of iron equivalent to the local attraction of a ship, found by no means so great effects as those observed by Mr Fisher. But the force of terrestrial magnetism acting upon a balance that is magnetic, is fully sufficient to account for every change of rate observed.

Mr S. Varley, in a paper in *Tilloch's Philosophical Magazine*, published in the year 1798, was the first, I believe, who showed that an irregularity observed in the rate of some time-pieces, was owing to the magnetic state of their balances. He was directed to the inquiry by a watch of excellent workmanship that he had in his possession, which performed the most irregularly of any watch he had ever seen. It occurred to him that the cause might be magnetism; and, on examining the balance, he found it so strongly magnetic, that when suspended horizontally without the spring, it directed itself like a compass-needle in a certain position, which it invariably returned to when it was disturbed. The pendulum spring being put on, and

and the balance replaced in the watch, Mr Varley laid the watch with the dial upward, and the north pole of the balance, as determined by the previous experiment, towards the north; —in this situation it *gained* 5′ 35″ in twenty-four hours. He then directed the north pole of the balance towards the south, every thing else being as before, and it now *lost* 6′ 48″ in twenty-four hours. Mr Varley afterwards took away the steel-balance, and substituted one made of gold; then having brought the watch to time, he carefully observed its rate, and found it as uniform as any watch of like construction. He subsequently examined many dozens of balances, out of which he could not select one that had not polarity.

The instance observed by Mr Varley is no doubt an extreme one; but yet the influence of magnetism in the balance most probably affects the rate, in some degree, of almost every watch and chronometer. I have attempted to ascertain how far this influence might be considered as general, by experiments both on detached balances, and on the rates of watches under magnetic influence. Similar experiments have been made by others; but there were some circumstances neglected in all, which I was anxious to examine, particularly the position of the watch or chronometer when its rate was determined. These experiments, owing to the arrival of the season for undertaking my usual voyage to the Polar Seas, I have been unable to complete; but this much was accomplished: In seven detached chronometer balances, very sensible magnetic properties, both attractive and repulsive, were found in all *; and in three watches subjected to the action of magnetism,

* In some of these balances, the magnetism was strong. One, with three arms, had a vigorous south pole at the extremity of each ray, and a common north pole at

tism, a change of rate took place, whenever a change was made in the relative position of the watch and the magnet. Had any of the balances been free from magnetism, its rate, in all horizontal positions, I expected, would have been uniform, whether under the action of terrestrial, or of moderate artificial magnetism. For although iron acquires polarity, by mere juxta-position with a magnetised body, and the balances of watches placed near magnets become magnetic; yet, were the magnetism of the balance only transient, the poles would change with every change of position in the watch, and its rate would be unaffected by any slight magnetic influence; but were any of the balances already permanently magnetic, there would be a repulsive action from the magnet in some positions, and an attractive in others, which affecting the vibrations of the balance in different ways, might be expected to produce a change in the rate of the watch. These effects, it was presumed, would be the same whether the watch were tried in different positions, under the influence only of terrestrial magnetism, or under the action (directed in a similar way) of artificial magnetism; the only difference being in the quantity.

One of the watches under experiment was remarkable for the beauty of the movement, and the uniformity of its rate. I shall confine my remarks, therefore, to the results obtained with this.

A bar magnet, 12 inches long, was laid in the magnetic meridian, and the watch placed in the same line, four inches distant from the magnet, with its XII o'clock mark towards the north.

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at the centre. The other balances had generally two poles only; but, in some, the poles of the rim were not exactly coincident with the poles of the rays.

north. Its previous rate was in mean time; and it was set by, and compared with, a chronometer, whose rate was very nearly the same. After an interval of 2 hours 18 minutes, it was found to have lost 13 seconds, being at the rate of 135 seconds *per* day; the XII o'clock mark being now turned towards the south, it gained 12 seconds in 2 hours 12 minutes, being at the rate of 131 seconds *per* day. The position being again reversed, it began to lose as in the first instance; but at a rate somewhat less; and on being once more turned round, with its XII o'clock mark towards the south, it gained 56 seconds in the course of the night, being at the rate of 156 seconds daily. This acceleration above its former rate was probably owing to the diminution of temperature. The regularity of a change of rate, from losing to gaining, with each reversion of position in the watch, every thing else being the same, was a sufficient proof that some part of the watch was magnetic, and that that part was acted upon by the influence of the magnet.

Three means have occurred to me, of either lessening, or altogether obviating, the anomalous action of the magnetism of the balance, viz.

1. To employ a substance in the construction of the balance without magnetical properties.
2. To free the balance of any magnetism accidentally acquired.
3. To prevent the unequal action of the magnetic influence, by giving to the chronometer a fixed position as regards the magnetic meridian.

The first method, should there be no practical objection, would go far towards the removal of all magnetic influence. The

The best material, in this case, to be substituted for steel, would probably be platina, or an alloy of platina. As the expansion of platina with heat appears to be less than that of almost any other metal, being nearly one-third less than that of steel, and less by above one-half than that of brass *, I should imagine that it would be better suited for effecting the compensation than steel.

For accomplishing the second object, I should recommend that the flat surface of the balance be the last part that is finished, and that it be ground and polished in the plane of the magnetic equator. From various experiments with different ferruginous substances, I found that no friction, however severe, produced magnetism in flat plates or slender bars, when the friction was endured in the plane of the magnetic equator; but that, on the contrary, such substances, especially iron and soft steel, when hammered, bent, twisted, scowered, filed, or polished in the plane of the magnetic equator, were deprived of any small quantity of magnetism that they might have previously acquired †; whereas by a treatment precisely similar, excepting as to position, ferruginous bodies were invariably rendered magnetic. I have made some experiments on chronometer balances, with the view of removing their polarities; but although a sensible diminution of their magnetism occurred after grinding them in the plane of the magnetic equator, or striking them in the same plane with a small smooth-faced hammer, while resting upon a hard, flat substance, yet I have not had leisure to accomplish their neutralisation so

 effectually

* Henry's *Chemistry*: Table of Expansion of Solids by Heat.

† See *Transactions of the Royal Society of Edinburgh* for 1821; "Description of a Magnetimeter," &c. Propositions 4, 5, 6, 10, &c.

effectually as could be desired. As the balances are now generally, I believe, wrought out of a solid piece of soft steel, encompassed by a rim of brass, it would conduce to the same end if they could be *turned* in the plane of the magnetic equator; and still further, when *blued* after polishing, if this process were completed while the balances maintained the same position.

But as a balance that has been freed from magnetism might again acquire polarity, the third method I have to suggest might probably prove the most efficacious, as regards steel-balances and balance-springs, and it has the advantage of being applicable to all small chronometers. As its employment, however, would be attended with some difficulties, I merely throw out the hint at present, but with the hope of being enabled hereafter to determine the efficacy of the plan by experiment.

A chronometer, even with a magnetic balance, may keep very accurate time when on shore, and yet perform very ill at sea. Because, while on shore, its position is usually preserved unchanged: it is perhaps kept on a shelf or a bench; in either case it is not liable to be turned from its position, since the lock of the box being commonly kept in front, naturally fixes it invariably in the same way. But when the same chronometer is taken to sea, its position is changed at the least every time the course of the ship is altered; and with every change of position there is probably an alteration of rate. Whenever the north pole of the balance is directed towards the north, the rate will (it is presumed from the experiments of Mr Varley) be accelerated; when towards the south, retarded. Could, however, any method be adopted for giving a uniform position to the chronometer, the errors arising from the above-mentioned cause would no doubt cease. Something might be done,

done, by placing the chronometer, when on board, in the same position that it occupied on shore, when its rate was taken, and turning it whenever the ship's course was changed. On board vessels navigating in trade-winds, and in all voyages where a steady course is preserved for a long time together, this would not be difficult to accomplish; but as a good deal of trouble would attend this management, in some voyages, it appears to me that it would not be impracticable to fix a pocket chronometer on the top of a thin plate of metal or wood, suspended on a needle-point as a centre, and moved by a magnetised bar. To diminish, as far as practicable, the influence of the magnetism of this bar over the chronometer, the plane for the support of the chronometer might be fixed a few inches above the needle; and to prevent error from agitation, the apparatus could be fixed on gimbles like a compass.

It may be objected, that the influence of the magnetic bar, connected with the apparatus for carrying the chronometer, would induce magnetism in the balance, notwithstanding it might be at some inches distance, and thus augment the source of error. I apprehend, however, that as the bar is proposed to be placed beneath the chronometer, so that its action would be almost vertical to the plane in which the balance vibrates, very little, if any effect, would be produced on the rate of the instrument. Besides, were the rate of the chronometer taken on shore when fixed in a certain position on this apparatus, there would be every chance of its maintaining its rate at sea, while the *dip* was nearly the same; for the action of terrestrial magnetism, combined with that of the local attraction of the ship, would produce a mean action on the bar carrying the chronometer, and a similar action on the chronometer. Under great changes, indeed, in the magnetic intensity or dip, a chronometer even thus situated might be liable to a small va-

 riation

riation in its rate; but were the rate of the chronometer taken in various positions in the apparatus, and the position where its rate was nearest a mean given to it for its permanent position, then, I imagine, its rate would be uniform under all magnetic dips, and under all ordinary changes of intensity.

APPEN-

APPENDIX.

Since forwarding my communication to the Royal Society, "On the Errors in the Sea-Rates of Chronometers, arising "from the Magnetism of their Balances," &c. I have constructed a temporary apparatus on the principle described in the *third* "suggestion for removing this source of error." I was at first doubtful whether a plate, however light, when loaded with the weight of a pocket chronometer, could be made to traverse by the polarity only of a compass-needle; and whether, within a moderate compass, the magnet intended for directing the plate could be so far removed from the chronometer as to prevent all fear of additional mischief from its proximity.

On trial, I was happy to find my apprehensions respecting the interference of both these apparent difficulties entirely removed. For, by means of a compass-needle, indifferently magnetised, the plate for the chronometer traversed, when loaded with a pound weight avoirdupois; and the magnetic influence of this needle, at five inches distance (the distance between the chronometer plate and the needle) was only equal to the directive force of the earth on a horizontal needle in Britain. Now, such a degree of influence would probably be an advantage to the chronometer's going rather than otherwise; because the denomination of magnetism in either end of the needle, operating on the part of the chronometer to which it was most contiguous, would be of the opposite kind to that of the earth operating on the same part of the chronometer; hence the tendency of the magnetism of the needle on the

the chronometer (being the opposite of that of the earth, and nearly equivalent in intensity), would be to neutralise the effect of the magnetism of the earth on the chronometer.

The apparatus I propose for giving uniformity of position to chronometers at sea, so as to obviate the varying action of the magnetism of the earth on magnetic balances in different positions, is represented in Plate XXIII., where

A, Is a compass-card (without a needle), having a light slip of brass across the under side, and an agate cap in the centre, for carrying the chronometer B.

C, A centre of brass pointed with steel, of a needle temper, upon which the card and chronometer traverse.

D, A magnetic rhomboidal compass-needle, on Captain KATER's construction, adopted in consequence of its great directive force. This needle is suspended from the card by 4 or 6 small wires (*a*, *a*), which serve to keep the card horizontal, and cause it to traverse.

EE, A cylinder of thin copper or brass, to the bottom of which is fixed the centre C, which passes through the opening in the middle of the rhomboidal needle.

FF, The centres by which the apparatus is attached to gimbles in the usual form.

The whole is enclosed in a square wooden box, with both a glass and a wooden lid.

The chronometer being placed in the centre of the card, and adjusted with its XII o'clock mark always in one direction, will evidently maintain the same position so long as the card continues to traverse.

XXVI.

XXVI.—*Report on a Communication from* Dr Dyce *of Aberdeen, to the Royal Society of Edinburgh, "On Uterine Irritation, and its Effects on the Female Constitution."* *By* H. Dewar, M. D. F. R. S. Edin.

(Read February 18. 1822.*)*

The communication received from Dr Dyce chiefly consists of a description of a singular affection of the nervous system, and mental powers, to which a girl of sixteen was subject immediately before puberty, and which disappeared when that state was fully established. It exemplifies the powerful influence of the state of the uterus on the mental faculties; but its chief value arises from some curious relations which it presents to the phenomena of mind, and which claim the attention of the practical metaphysician. The mental symptoms of this affection are among the number of those which are considered as uncommonly difficult of explanation. It is a case of mental disease, attended with some advantageous manifestations of the intellectual powers; and these manifestations disappearing in the same individual in the healthy state. It is an instance of a phenomenon which is sometimes called double consciousness, but is more properly a *divided consciousness*, or *double personality*; exhibiting in some measure two separate

parate and independent trains of thought, and two independent mental capabilities, in the same individual; each train of thought, and each capability, being wholly dissevered from the other, and the two states in which they respectively predominate subject to frequent interchanges and alternations.

The particulars will be most agreeably communicated, in the order of their occurrence which is followed by Dr Dyce,—part of the narrative being given in the words of Mrs L——, in whose house the patient lived as a servant, and the rest in the words of Dr Dyce himself, consisting of the facts which fell under his own observation.

The history of the complaint, while under the eye of this gentleman, extends from the 2d of March 1815, to the 11th of the following June, including a period of more than three months. But the symptoms had made their appearance in the end of the preceding December.

The first symptom was an uncommon propensity to fall asleep in the evenings, for which she was reproved by Mrs L——. This was followed by the habit of *talking* in her sleep on these occasions. She not only uttered such wild incoherent expressions as persons, under the affection of sleep-talking commonly do, but repeated the occurrences of the day. She also sang musical airs, both sacred and profane.

One evening, in the house of an acquaintance of Mrs L——, where she seems to have come for the purpose of seeing her mistress home, she fell asleep in this manner, imagined herself an Episcopal clergyman, went through the ceremony of baptizing three children, and gave an appropriate *extempore* prayer. Her mistress shook her by the shoulders, on which she awoke, and appeared inconscious of every thing except that she had fallen asleep, of which she shewed herself ashamed.

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Another evening, having fallen asleep surrounded by some of the inhabitants of the house, she imagined herself to be living with her aunt at Epsom, and going to the races; placed herself on one of the kitchen stools, and rode upon it into the room, with much spirit, and a clattering noise, but without being wakened. Being afterwards severely reprimanded for this exhibition, she continued free from the habit for a week. After that interval, however, it returned in a similar form, with this addition, that, when in this state, she answered questions which were put to her by others. The disease now increased, and came on her at different times of the evening and morning. She sometimes dressed herself and the children while in this state, or, as Mrs L—— calls it, "dead asleep," answered questions put to her in such a manner as to shew that she understood the question; but the answers were often, though not always, incongruous. One day, when she was in this state, her fellow-servant was desired to get the key of a closet from her, in order to do the duty which was generally hers, that of setting the breakfast-table. The girl, however, refused to give up the key, and set the breakfast herself with perfect correctness, with her eyes shut. She afterwards woke with the child on her knee, and wondered how she had got on her clothes. If seized in this manner in the house, she was sometimes restored to her senses by being taken out to the cold air, especially when the wind blew in her face. At other times she was seized with this affection while walking out with the children.

In the mean time, a still more singular and interesting symptom began to make its appearance. The circumstances which occurred during the paroxysm were completely forgotten by her when the paroxysm was over, but were perfectly remembered during subsequent paroxysms. Her mistress

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says, that, when in this stupor on subsequent occasions, she told her what was said to her on the evening on which she baptized the children. It was remarked that, while under the paroxysm, she knew a person better by looking at the shadow than at the body; that is, she perceived those objects best which were presented merely in outline, or were very dimly illuminated. The disease made progress in the interval between its first appearance in December and the beginning of March, though no dates of its different stages are given. From the 2d of March till its disappearance Dr DYCE's account is very circumstantial.

She was brought to him for medical advice by her mother. The mother called these affections *sleepy fits.* The girl herself called them *wanderings.* They sometimes continued for an hour. If they came on when she was in bed, she sometimes rose and tried to raise the sashes of the windows. The eyes were described as half-shut, the pupils dilated, and the cornea covered with a dimness or glaze, resembling those of a person in syncope. She answered many questions correctly, shewing at times scarcely any failure of her mental powers. It was remarked, that she always retained the impression last made on her previous to the fit.

With regard to the case as an object of medical attention, it is sufficient to mention that some foulness of tongue, and other symptoms of torpor or disorder in the alimentary canal, accompanied these mental phenomena, and were treated by Dr DYCE principally with emetics and laxatives, in proportion to their degree.

The symptoms of the paroxysm, as they fell under the Doctor's own eye for the first time, are thus described. " When she was brought to my room she appeared as if in a state of

stupor.

stupor. Her eyes were half-open; but, when desired, she could open them completely. At other times she closed them, as if inconscious of what she did. When desired to look at me, and tell who I was, she gave a vacant kind of stare, and named some other person. When desired to look round, and say where she was, she looked round with some apparent attention; but, though she had been in that room more than once before, she said she was in the New Inn. When desired to turn her eyes to the direct rays of the sun, she readily obeyed, but there was no perceptible contraction of the iris. She saw some objects perfectly, for she read quite distinctly a part of the dedication of a book which she could not have seen before, and corrected herself in the pronunciation of the word *conspicuous*, which she had called *conspicious*. Being asked to tell the hour by a watch which was shewn to her, she did not give the proper answer. Pulse 70; extremities rather cold. Being desired to stand up, she did it most readily, but required some time and a little effort to stand firmly, as she staggered at first like a person waked out of sleep. But soon after, she could stand, walk, or dance as well as other people. Being desired to sing, she sang a hymn delightfully; and from a comparison which I (Dr Dyce) had an opportunity of making, it appeared incomparably better sung than she could sing the same tune when well. The same appeared to be the case to persons whose skill in music was much superior to my own."

Her hands were immersed in cold water, in consequence of which she recovered her senses, exactly like a person waked out of a sound sleep, and with the same yawning and stretching. This mode of rousing her had often succeeded in the house where she lived, and was tried now at the suggestion of the person who accompanied her. She now knew the persons and things surrounding her.

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The account which she gave of her feelings as connected with her present situation was, that previously to an attack she felt drowsy, with a little pain in the head; then a cloudiness or mistiness came over her eyes; she heard a peculiar noise in her head resembling that of a carriage running, and had a feeling of motion as if she were seated in such a carriage. When this stage supervened, her conceptions of external objects were immediately altered.

Next day (March 5.) while under a fit, she performed in the most correct manner some of her accustomed duties relating to the pantry, and the dinner-table. Dr Dyce went to see her; she gave him a wrong name as formerly; when her mistress desired her to stand straight up, look round, and tell where she was, she recovered instantly; but it was only for a little; she very soon relapsed. When asked to read in an almanac held before her, she did not seem to see it, nor did she notice a stick which was held out to her. Being asked a second time to read, she repeated a portion of Scripture, and did not give a correct answer when asked where she was. Being desired to state what she felt, she put her hand to her forehead, and complained of her head; said "she saw the mice running through the room." Mrs L—— mentioned that she had said the same thing on many former occasions, even when her eyes were shut; that she also frequently imagined that she was accompanied by a little black dog, which she could not get rid of; did not, in general, express any particular uneasiness from that cause; at times, however, cried in consequence of it, and at other times laughed immoderately. In some of her repeated paroxysms, she insisted that she was going to church to preach. One day, while taking out two infants for an airing, she was seized with one of her fits on the quay, and without hesitation walked along a single plank placed between a ves-

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sel and the shore, and even danced on it with the children. Of this circumstance she afterwards, when well, denied all knowledge. This was invariably the case; but with equal regularity she acknowledged and asserted it when under the influence of a paroxysm.

On the following day she had a threatening, which went off without being followed by the usual degree of insensibility. She says she now knows for a quarter of an hour before the attack. This day some local bodily symptoms were added to her usual complaint, which it is unnecessary to particularise, but which were fully accounted for by a horrid transaction which on the following day (the 8th of March), her mother related to Dr Dyce. Another young woman, a depraved fellow-servant, understanding that she wholly forgot every transaction that occurred during the fit, clandestinely introduced a young man into the house, who treated her with the utmost rudeness, while her fellow-servant stopped her mouth with the bed-clothes, and otherwise overpowered a vigorous resistance which was made by her even during the influence of her complaint. Next day she had not the slightest recollection even of that transaction, nor did any person interested in her welfare know of it for several days, till she was in one of her paroxysms, when she related the whole facts to her mother. Some particulars are given by Dr Dyce clothed in the Latin language, and others were told him which he does not think it necessary at all to detail.

Next Sunday she was taken to church by her mistress, while the paroxysm was on her. She shed tears during the sermon, particularly during an account given of the execution of three young men at Edinburgh, who had described in their dying declarations the dangerous steps with which their career of vice and infamy took its commencement. When she returned home, she

she recovered in a quarter of an hour, was quite amazed at the questions put to her about the church and the sermon, and denied that she had been in any such place; but next night, on being taken ill, she mentioned that she had been at church, repeated the words of the text, and, in Dr Dyce's hearing, gave an accurate account of the tragical narrative of the three young men, by which her feelings had been so powerfully affected. On this occasion, though in Mrs L——'s house, she asserted that she was in her mother's.

Dr Dyce saw her on many subsequent occasions, when similarly affected, and from one fit she recovered in his presence. He said the eyes had now all the vivacity of youth and health. Previously they were like those of a person under amaurosis, or those of a person half-inebriated, and who had never been in that state before. The difference, he says, is not perfectly expressed by either or both of these comparisons, but was very striking to all who saw her.

Calling one day, an hour after recovering from a fit with which she had been seized in the morning, she was quite well, only complaining of a confused feeling in her head, accompanied now and then with ringing of the ears. The countenance was somewhat dejected, and there was a slight lividity under the eyes.

On one occasion, when the Doctor saw her in a fit, he says her stare was accompanied with something resembling a *squint* in the eye.

About the 26th of March she complained of a pain in her head, as if it had been cut in two. Formerly she had only complained of confusion.

On Sunday the 26th, while in a fit, she commenced preparations for going to church; but, while curling her hair, burned her brow with the hot curling-tongs, which roused her from the

the torpid state, and she immediately recollected that her mistress had given her orders to stay at home.

On Friday the 7th of April, Dr Dyce had an opportunity of seeing her under the influence of a fit, in her mistress's house. He found her running up and down the room, and arranging things which appeared to her to be in confusion. On being asked if she knew him, she said, "Oh yes, I know that stick and tassel; they are Dr Dyce's." Her eyelids appeared shut; but when he stooped, and looked to them from below, he found them not entirely closed. When he raised the upper eyelid a little, it seemed to give her pain, at least she would not allow it to be repeated. When he desired her to point to different parts of his body and dress, and name them, he found that she could not do it when the light of the candle or fire shone fully on him; but pointed out every part accurately, when it was placed in the shade. At this time, when he tried again to open the eyelids, he found the pupils greatly contracted, a state the reverse of that which made its appearance in all his previous examinations. This contrariety is not easily explained when we consider that the habitudes of the function of vision seemed in all other respects the same as on former occasions.

On examining her head all over, Dr Dyce now remarked particularly, that she shrunk much when he touched the upper part, the region of the fontanelle. The head was shaved, with a view to the application of a blister, and he found some degree of swelling in that situation. The soreness was entirely superficial, for a light touch gave the same pain as a ruder impulse, or a considerable pressure.

From Monday the 17th of April, till Friday the 2d of May, she was free from any paroxysm.

In consequence of the appearance of bloody stools, and other symptoms of a similar nature, Dr Dyce thought proper to to have her bled. An emetic was exhibited, and brought up from the stomach a black matter, appearing to consist partly of old and darkened blood.

On the 18th of June she felt a little fulness and uneasiness in her breasts.

On the evening of the 11th there was a slight appearance of the menstrual discharge, which disappeared next day.

On the 15th the same appearance occurred.

The menses appeared regularly on the 9th of July and the 5th of August.

Ever after the first appearance of this discharge she continued free from complaint, up to the time when Dr Dyce's account closes, when he had just seen his quondam patient more than a year after she had been perfectly well.

This case certainly gives an interesting illustration of the obliquities to which the physiology of the nerves, and the exercise of the mental powers are subject.

Somnambulism is in itself a very remarkable phenomenon, not so much from the partiality of the affection of the senses implied in it, for this is sufficiently exemplified in the act of dreaming, in which the imagination alone is active, and is not guided, and but very obscurely influenced, by any of the objects which solicit the external senses. It is well known, however, to those who have studied the history of dreams, that this is not always the case, and that in many instances the manner of dreaming is dictated not only by the scenes in which the individual has been engaged when awake, but by those objects which are at the time presented to his senses, especially to those of touch and hearing. The most remarkable circumstance

stance in somnambulism, is the unequalled accuracy with which a person in that state sometimes conducts his proceedings, an accuracy superior to that of which he is capable when fully awake. A somnambulist has gone out by a window, and walked along the roof of a house, with a degree of security which he never could have enjoyed in the same local situation in his waking hours. Such facts evince a strange mixture of accurate perception and self-management with the absence of general recollection and self-knowledge: and it is remarkable that the accurate perceptions which persons in this situation retain, and which may in some measure be the effect of habit on the faculties, are so completely dissevered from the immediate influence of general sensation, that when the individual is wakened by loud speaking, or by a shock from a by-stander, he sometimes becomes inexpressibly bewildered and unhappy, and does not know where he is. Instances are said to have occurred, in which a somnambulist abruptly wakened while walking out of doors, has, by the unhappy distraction attending the transition, been thrown into a state of permanent insanity.

The influence of association on all our thoughts, on the memory, on the imagination, and even on the freedom and facility of those mental movements which we call exertions of the active powers, is familiarly observed by every person who has paid the least attention to human nature, or to the proceedings of his own mind. We never wonder at our mental acts being varied in their degree of intensity or facility by this all-pervading principle. It is only a greater degree of the same dependence on particular associations that constitutes such anomalies as made their appearance in the history of this poor girl. In other cases, objects are recollected less easily and less vividly in some circumstances than in others. In this case one set of objects was not recollected at all, and could not be

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in the least degree recognised or brought to mind by any suggested associations, unless they occurred in that train, and while the mind was under that particular diseased habit under which they were generated; and in this case they occurred with readiness and fidelity.

This, indeed, was a case of disease, evidently depending on the state of the brain as connected with the habitudes of the sanguiferous system. In this particular it is to be ranked with the aberrations which constitute many cases of insanity; and it is both curious and humbling to think, that in insanity itself there is scarcely a mental irregularity admitting of description, but what may be shown to be only a greater degree of those mental aberrations, those follies, and those partialities to which the most vigorous and the most correct minds are continually liable *.

The strong contrast between the mental states of this person under her fit, and when it was off, is to be classed with a set of facts, of which some other examples have lately come to the public knowledge. One of them was in an apparently simple girl in the neighbourhood of Stirling, who, in her sleep, talked like a profound philosopher, solved geographical problems, and enlarged on the principles of astronomy, detailing the workings of ideas which had been suggested to her mind, by over-hearing the lessons which were given by a tutor to the children of the family in which she lived. The originality of the language which she used, shewed something more than a bare repetition of what she had heard. She explained the alternations of winter and summer, for instance, by saying, that "the earth was set a-gee."

Another

* Some views on this subject are given by the author of the present report in the article "Insanity," in the Edinburgh Encyclopædia.

Another case was mentioned in some of the newspapers, two or perhaps three years ago, of a more marked instance of double consciousness. The individual was liable to two states, each of which, if I rightly recollect, continued for two or more years. In the one state, when it first came on, there was an oblivion of all former education, but no deficiency of mental vigour as applied to ideas or pursuits subsequently presenting themselves. It was necessary for this woman to recommence the studies of reading and the art of writing. A separate set of notions, and separate accomplishments were now formed. In one of the states an exquisite talent for music, and some others which implied refinement, were displayed. When another mental revolution arrived, these utterly disappeared, and the individual was reduced to a level with the rest of mankind, displaying a sufficient portion of common sense, but nothing brilliant.

Differences more or less allied to these are produced by a variety of causes.

Sometimes external fortune has an influence of this kind. There are individuals who, in the hour of prosperity, and when under the influence of sober and uniform gratification, show an exquisite taste for music, but lose this as soon as a slight cloud appears on the horizon of life, and who then, though they evince such talents as are the result of persevering thought, and are capable of being exercised by deliberate study, lose all that satisfactory delight which gives birth to a brilliancy of mental manifestations; at least these only appear in the occasional occurrence of happy combinations, being never, for any length of time, animated by such a supported impulse as to generate a current of habitual felicities.

Sometimes the state of the brain, as influenced primarily by disease, determines the operation of these mental states.

External applications are well known to possess a similar agency. We all know the influence of opium, and still more familiarly that of inebriating liquors.

A more singular agent is the gas called the nitrous oxide, when inspired by the lungs, by the use of which the individual is elevated in half a minute to the third heavens, and when it is discontinued, is in an instant reduced again to the feelings of a common child of earth.

The girl who is the subject of Dr Dyce's communication made, in the mode of commencement of her paroxysm, an approach to what is frequently the effect of this curious agent. Some persons (perhaps the greater number) who breathe the gas first feel a little confusion, afterwards a tingling in the ears, then a sensation of great fulness and tension of the cranium, giving the idea of a bladder distended with air. This is accompanied with a feeling of alarm, but is instantly followed by a train of rapturous thoughts, accompanied by a feeling of mental power, during which thousands of ideas seem to pass through the mind in a small fraction of a minute, and the individual feels as if nothing in the universe could resist his energies. The commencement of this state has some resemblance to that of this girl, as above described; she said that she first felt a drowsiness, with a little pain in the head; then a cloud or mist came over her eyes, attended with a peculiar noise and motion in the head, resembling a carriage in which she was placed, moving along with great velocity. The resemblance is not perfect. It is only such as to shew some analogy between the effects of the nitrous oxide and the state induced by a paroxysm of disease arising from particular spontaneous circumstances of the constitution, and accompanied by a sufficient susceptibility to tender emotions, and the exhibition of more than her ordinary degree of musical taste and execution.

The

The preceding analogies are, I confess, somewhat loose. It would be interesting to have a copious collection of well authenticated facts, and an arrangement given to them fitted to shew the shades of transition by which different mental states graduate into one another.

H. Dewar.

XXVII.

Engd. for the Royal. Soc. Trans. Vol IX page 381

PLATE XXIV.

INDIAN IDOLS.

OF TALCACEOUS STONE

BUDA.

Fig. 4.

1 Foot 7 Inches

Part of the Inscription which is in the nimbus behind the head of Buda

CALI.

Fig. 1.

1 Foot 6 Inches

Fig. 3.

1 Foot 10 Inches

SURIA, THE SUN.

Fig. 2.

2 Foot 2 Inches

SURIA, THE SUN.

Drawn & Engd. by W.H.Lizars

XXVII.—*Description of some Indian Idols in the Museum of the Society.* *By* W. A. Cadell, Esq. F. R. S. Lond. & Edin.

(Read March 6. 1820.*)*

THE figures, sculptured in full relief, and here represented by the four drawings in Plate XXIV., are idols brought from India in the year 1800, by Francis Simpson, Esq., which I had the honour of presenting to the Society at his request.

According to information with which I have been favoured by gentlemen conversant with the literature of India, these idols are Cali, Suria and Buda.

The first of the figures (Plate XXIV. fig. 1.) is the goddess Cali, a personification of all-devouring Time, like the Cronos τεκνοφαγος of the Greeks; and of the destroying principle, as Typhon was in the Egyptian mythology. The Egyptians, considering the continual recurrence of generation, growth and destruction in the universe, ascribed to the energy of Isis and Osiris all the regular phenomena and processes of Nature which are beneficial to mankind; Isis was therefore myri-onymos, she had a multitude of names, she was the fertilising water of the Nile, the Sun, the Earth,

Earth, Heaven; she was worshipped as the giver of all that is good and beautiful in nature. They imagined another deity, Typhon, the destroying power, the cause of miasma, of excessive heat, of storms, of every inordinate action of the elements, whether in excess or defect, and whatever is hurtful to mankind *. In like manner, amongst the Hindus, Vishnu, (that is the pervader), the preserver and giver of life, is a personification of the power of the Supreme Being, which is exerted in preserving the universe. Siva represents the Supreme Being, considered as the destroyer and changer of forms; and Bramah represents the creating power of the Supreme Being. The goddess Cali is the consort of Siva; she is represented in the figure before us as an emaciated old woman, with a hideous countenance, and pendulous breasts. The eye-balls appear like hemispheres in the sockets, by reason of the atrophy of the fat and muscle. The figure has many hands, holding weapons of different kinds; a sword, a sacrificing knife, a mace, a bell that announces the sacrifice, a rattle called damaru, shaped like an hour-glass, and a human head. The right hand in front holds a cup of the blood of sacrifices; a finger of the left is placed on the lips. The sole of the left foot is turned upwards, and a round body like a coin is placed on it. Human skulls are in the head-dress, which is surmounted by a bird like an owl; snakes hang down from the head, on each side, in place of hair. A cord on which human skulls are strung, called mund mala, (that is, chaplet of skulls), hangs down over the shoulders. The skulls represent the lapse of ages, by the extinction of successive generations. Cali is seated on the prostrate figure of a man, typical of the destruction of the world, and of secular time, which

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* Plutarchus de Iside et Osiride.

which is trodden under foot by Maha Cali or eternity*. A small figure of an antelope or kid standing, and looking up, is on the left side of the stone, near the head of the prostrate figure: this is not seen in the drawing, which represents only the front of the stone. Cali is painted black by the Hindu artists. Anciently human sacrifices were offered to Cali, according to the ritual of the Vedas; the sacrifices now offered are kids. The worship of Cali originated in India, with the Saiva's, that is, the sect of Siva, and caused a separation from the Vaishnava's or sect of Vishnu. The consort of Siva, like the other deities, is known by many different epithets, with some variation of character and attributes in each form and name; she is Cali, Parvati, Darga, Bhavani. The Cali age, or Kolei joog, in Hindu mythology, is the fourth age of the world, the age which now exists: the epoch of the commencement of this era is 4916 years ago.

In the possession of the Antiquarian Society of Edinburgh, there is an Indian idol of stone, representing a man standing, with four arms holding weapons, and a cord hanging down from the arms, like the figure of Cali at Fig. 1: but the expression is quite different, the figure is not emaciated, the face is placid, and there are no skulls on the cord. The god Cal, a god of the sect of Siva, is represented with similar emblems in the excavated temples of Elephanta. Vishnu is also represented with four arms, holding the flower of the nelumbo; the sancha, an emblem of his power to preserve; the mace, a type of his destroying power; the chacra, shewing his universal supremacy.

Another figure of this kind, with four arms, holding a mace and other weapons, and standing upon a lion, is in the Museum

* See Asiatic Researches, vol. viii. Dissertation 3.

seum of the University of Edinburgh: it is Cali in one of her characters called Darga, (that is, difficult of access), attended by Siva, in form of a lion; the figure is of talcaceous stone. The Hindu god Iswara, a name which Sir W. Jones supposes to be analogous to Osiris; the goddess Isani, who represents the powers of nature; Carticeya, the son of the goddess Parvati, (parvat signifies mountain); these three (Iswara, Isani, and Carticeya) are deities of the sect of Siva, like Cali, and are represented like Cali with many arms holding weapons. The god Quanwon, worshipped in Japan, is represented in the same manner *.

The next figure (Pl. XXIV. fig. 2.) is Suria, the Sun, the deity whose province is analogous to that of Apollo in the Greek mythology. The three great Hindu divisions of the power of the Supreme Being, are Vishnu the preserver and giver of life, who is also called Narayan, (that is, moving on the waters); Siva the destroyer, reproducer, and changer of forms, called also Mahadeva: and Brahma, the Creator. Suria is the image of a portion of the first of these powers. Etymologists have shewn the resemblance of the Sanscrit to the Persian, the Greek, Latin, and Gothic languages; so as to make it probable that the nations of Europe, the Persians and the Hindus, derive their language and birth from one and the same ancient nation which existed in Persia before the Assyrians, and before the times recorded in the histories now extant. An instance of this resemblance occurs in the Hindu word Suria, and the Greek Σειριος, which appear to originate from the same root, signifying in both languages a brilliant star and the Sun. Suidas and Hesychius mention that the words Σειρ and Σειριος, in the languages anciently spoken

* See a figure in Kaempfer's History of Japan.

spoken on the eastern shores of the Mediterranean, were applied to denote the Sun as well as the star Sirius, which is one of the most brilliant of the fixed stars visible in the climate of the Mediterranean. Crishna is another name given by the Hindus to the idol that they have formed as a personification of the Sun. Crishna, the shepherd god, is also considered to be an incarnation of Vishnu, and his life upon earth is related in Hindu books: in a celebrated temple in India, Crishna is worshipped under the name of Iagan-nath, that is, the lord of nature. The figure of Suria is here erect. The principal figure, and three of the attendants, are placed upon bases, formed like the flower of the nelumbo or water-lily, and flowers are represented on each side, indicating the power of the sun in promoting the vegetation of plants on the earth. The hands of the figure are broken off, but there remains an octopetalous flower, which was held in the left hand. By the side of the figure of Suria are three smaller figures, in the same dress as the principal figure, with the hands clasped in the attitude of adoration: they are called the gopis or shepherdesses; one of them has four arms. Four small figures, seated with the legs across, are in the upper part of the composition, and a figure seated with the legs across is in the head-dress of Suria. The head-dress is formed of several tiers of ornaments, somewhat in form of crescents, or like the two horns of a chamois. At the lower part of the composition, on the left, is a small figure bearing a club, the emblem of the strength of the divinity. A small figure on the right of the deity, and lower than the feet, has the head of an elephant, as the Indian god Gunees is usually represented: Etymologists have remarked the resemblance between the name of Gunees and the Janus of the

 ancient

ancient Romans. The sect of Hindus who pay particular adoration to Suria are called Sauras.

The third figure (Pl. XXIV. fig. 3.) represents Suria seated, and attended by the shepherdesses, two of them above, with each a wreath held out towards the head of the deity, two beneath, with their hands clasped in an attitude of adoration, and sitting on a flower. On the left of Suria, is a small figure holding a mace or club, representing the strength of the god. In the left hand this small figure holds the weapon which terminates in a ring. The sole of the left foot of Suria is turned upwards, and a round body, like a piece of money, is placed on it. In some Indian figures, the round body placed on the palm of the hand, or on the sole of the foot, resembles the half-expanded flower of the water-lilly. The left hand of the figure of Suria holds a stalk terminated by a hexapetalous flower; the erect figure of Suria before described also holds a flower. The string of beads passing over the left shoulder likewise occurs in both figures. A figure seated with the legs across is on the head-dress of Suria. The border of the whole composition is a canopy formed of two columns, with capitals, supporting a trifoliated arch. The talcaceous stone of which this figure is sculptured, is of a finer grain than the talcaceous stones of the other three figures.

In the valuable collection of Indian and Chinese works of art, at the library of the India House, there is a sculpture in black stone, 3 feet high, representing Suria holding flowers, and attended by 9 small figures, in many respects resembling the two figures of Suria here mentioned. But, in addition, the figure in the India House has a charioteer holding the reins of seven small horses; the horses are at the lower part of the composition in front, and a wheel is on each side, so that the whole composition is an image of the Sun in his chariot, and is called Suria Vahana, or Suria Ratha, the chariot of the Sun. The Vahana, or vehicle of some of the other Indian gods, is a bird

bird or quadruped upon which they ride. The charioteer of the Suria Ratha, at the India House, is Arjuna or the dawn. There is a figure discharging an arrow, which denotes the rays of the sun. A figure on each side with a fly-flap and a fan, are the common attendants on royalty in the East. Two male figures, one on each side, holding a baton, are giants, emblems of force. A small starving figure on each side, on the side of the stone, represents the effect produced by the absence of the sun's heat. The dress of this figure of Suria at the India House, differs from that of Figs. 2. and 3., which were probably sculptured in a more southern part of India. The figure in the India House is represented with Tartar half-boots, in form like the Hungarian. Tartar and Chinese sculptors are frequently employed to make the idols in India, and they form the dress, and other accessory parts of the composition, after the manner of their country. The seven horses in this composition, may allude to the seven planets, and the days of the week. The Hindus name the seven days of the week from the regent genii of the same planets, and in the same order as we do. It was from Egypt that the week, and the names of the days of the week, were introduced into Europe.

There is another sculpture of the chariot of the sun at the India House, in Coade's baked clay, copied from a sculpture which exists at Delhi.

Among the Indian sculptures at the British Museum, there is a figure of Suria, between three and four feet in height, with the usual attendant figures. This work is of a kind of schistus.

The last sculpture (Pl. XXIV. fig. 4.) is Buda, represented by the figure of a man seated, with the legs across, and the soles of the feet, and palm of the left hand, turned upwards. On each of the soles, and on the palm, is placed a round body like a coin. Buda, in his childhood,

was

was recognised by a round mark on the palm of the hand, which indicated his divine nature. The hair of the head is curled. The figure of Buda is seated on an expanded flower of the nelumbo or red-flowered water-lily, which grows in the waters of the Nile, of India, and of China, called by the Hindus the flower of the waters. This flower is held sacred in India, and occurs frequently as a plinth, on which figures rest in Indian sculptures; it is seen in the two figures of Suria above described, (Fig. 2. and 3.) Behind Buda are two quadrangular columns supporting an architrave, and surmounted by a canopy. On the base of the composition is the figure of a woman, with one knee on the ground, and the hands lifted up. On each side of the woman is a lion.

The three great sects in India are the sects of Brahma, Buda, and Iain. In a small bronze image from Ceylon, a figure in the usual attitude of Buda, is represented as seated on the coils of a serpent, whilst the serpent extends his hood over the head of the divine personage. Figures overshadowed in this way are usually ascribed to the sect of Iain. In an image of dark-coloured stone, about four feet high, at the India House, Iain-Deo is represented as a man, over whose head a snake is expanding his hood. The sect of Iain is not so widely extended as the others. Some authors are of opinion, that the religion of Buda is derived from that of Brahma; and some of the Brahmens consider Gautama Buda to be the ninth avatar, or incarnate appearance of their deity Vishnu. Other authors believe that the religion of Buda is quite distinct from the religion of Brahma It is supposed by some to have had its origin in the north of India, or Tibet.

Gautama Buda is a god who assumed the human form, and was born of Maha Maya, the consort of Sootah Dannah Rajah of Cailas. Cailas is a mountain in Tibet near the source of of the Ganges, covered with perpetual snow, which the Hindus suppose to be the favourite abode of Mahadeva, the chief deity of the sect of Siva. Gautama Buda became a priest, and having attained that perfection of virtue and supreme knowledge by which he was constituted Buda, he employed his time in converting men to religion and a virtuous life. The word Buda signifies wise. He died at the age of 85; and his death, which is the epoch from which the Siamese, and the natives of Ceylon, reckon their years, is stated to have happened 544 years before the Christian era *. The religion of Buda prevails amongst the inhabitants of a very considerable portion of the world; it is the religion of Ava, Siam, Ceylon, and other countries of the East, and it is one of the religions that prevails in the empires of China and Japan. In China, Buda is called Fo, Sasya, Siaka, Xaca; in Japan, Bud, Siaka, and Si Tsun, that is, the great saint: Gaudma in Ava: Gautama Buda in Ceylon: in Siam, Samono Gautama and Samonocodom. The religion of Buda was introduced into China and Japan in the year 65 of the Christian era. Fo, which is the Chinese pronunciation of Buda, belongs to a system which has no connection with Fo-hi in the remote and fabulous part of Chinese history, who invented the eight koa', trigrams, or ancient mystical characters, composed of horizontal and parallel straight lines, and taught the Chinese the arts and sciences, as Tot or Hermes did to the Egyptians. Clemens Alexandrinus, who flourished in the reign of Severus and Antoninus Caracalla, about the year 200, mentions the religion of Buda as prevailing in some parts of India †.

In

* See Laloubere royaume de Siam; and Dr Davy's Account of Ceylon.

† Εισι δε των Ινδων οἱ τοις Βυτ̓α πειθομενοι παραγγελμασιν· ὁν δι' ὑπερβολην σεμνοτητος εις Θεον τετιμηκασι. CLEMENS ALEXANDR. ςρωματεων, lib. I. sect XV. p. 305.

In the Museum of the University of Edinburgh, amongst several idols from Java, there is one of Buda, very much like that represented at Fig. 4., and of the same kind of talcaceous stone, so that they seem to be productions of the same school. Others of these Java sculptures are of a dark-coloured porous lava.

In the British Museum there is a stone image of Buda seated, with an attendant figure on each side; on the back of the stone is carved an ornamented pointed arch, of the form called Gothic, with internal projecting cusps.

Figures of Buda, in the same attitude as that before us, are described and engraved in Syme's Account of the kingdom of Ava, in the Museum Borgianum by Paulinus, in Kaempfer's Japan, and other works. All these images represent Buda in the state of perfect quiescence and impassibility, to the enjoyment of which he passed after he quitted his abode upon earth; this his followers consider to be the future state of maturity into which souls perfectly virtuous are elevated.

In Java there is a low hill of considerable extent, covered with a remarkable assemblage of large stone images of Buda, placed in lines which go round the hill, and are parallel to its base. A description of this monument is published in the accounts of Java by Sir Stamford Raffles, and by Crawford. Smaller figures of Buda, cast in bronze, are also met with in Java. Pallas, in the course of his travels in the north of Asia, collected some bronze figures of Buda, which are now in the possession of Charles Hatchett, Esq.

There are inscriptions in the Nagari letters and in the Sanscrit language, on the base of the upright figure of Suria, and within the horse-shoe formed curve which is placed as a nimbus, behind the head of the figure of Buda; there is also an inscription scratched on the plinth of the seated figure of Suria, composed of letters less carefully executed, the work of an inexperienced

inexperienced hand. The inscription round the head of Buda is not so much obliterated as the others are. According to the translation which a learned orientalist was so obliging as to give me, it relates to the "Author of Creation having contemplated for 1000 years, by reason of the existence of irreligion."

An ornamental border of a particular kind of foliage surrounds the upright figure of Suria, and a similar border surrounds the head of Buda. This kind of foliage is also seen in the small brass Javanese images of Buda.

All the figures have the lobes of the ears very long and hanging down.

The seated figure of Suria and the figure of Buda have a round mark on the forehead, between the eye-brows, like the mark which the Hindus paint between the eye-brows, to denote the cast. The erect figure of Suria has an oblong mark on the forehead.

The stone of which all the figures are carved, is a talcaceous stone, called by mineralogists Talcaceous Schistus, but of a different grain in each figure. The stone of which the seated figure of Suria is sculptured is of the finest grain. The others are more schistose and granular. It is uncertain in what part of India or of the eastern islands these figures were made. Talcaceous schistus, similar to that of which they are formed, occurs in different parts of the world; it is quarried at St Catherine's near Inverary, and in other parts of the Highlands of Scotland and Ireland. It is a magnesian stone, and is easily cut by the chissel and file, so as to exhibit any figure that the ability or genius of the sculptor can command. Crosses, and arabesque ornaments on tombs, at Icolmkill and Loch Awe, are carved out of talcaceous schistus; it is one of those

 kinds

kinds of stone that can be wrought into form on the turning lathe, as the Chinese do their image-stone, of which they sometimes make cups. In the Valtelline, a valley on the southern declivity of the Alps, kettles for boiling food, are formed of talcaceous schistus on the turning lathe, and sent to Milan, where they are sold on the streets. These turned stone-kettles of the Valtelline were used also in ancient times, as we learn from Pliny, who makes mention of them.

XXVIII.

XXVIII.—*Observations on the Formation of the Chalk Strata, and on the Structure of the Belemnite.* By Thomas Allan, Esq. F. R. S. Edin. &c.

(Read 2d April 1821.*)*

Of the various rocks of which the Earth's surface is composed, there are some which present very satisfactory indications of their origin; while others, when considered in that respect, seem to be placed almost beyond the reach of hypothesis. The Granite and Trap rocks, by extending their ramifications among their contiguous neighbours, distinctly avow, not only a subsequent formation, but, in many instances, they present the most unequivocal marks of an igneous origin. The Limestones and Sandstones, however, are equally constant in their indications of aquatic deposition, although, at the same time, the assistance of another agency may sometimes be inferred, when their consolidation and position are taken into the question. Of all the rocks with which I am acquainted, there is none whose formation seems to tax the ingenuity of theorists so severely, as the White Limestone or Chalk, in whatever respect we may think fit to consider it.

 This

This rock, while compared with others, is of rare occurrence; for although it be found in various parts of Europe, it does not, so far as we know, exist in any of the other quarters of the Globe. In the south-east of England it may be said to abound; and in the north-east angle of Ireland, the white limestone prevails to a great extent. Its connection with other rocks has of late years occupied the attention of Geologists, and it has been found to be a member of a considerable series, as uniform in position with respect to its members, as any of those which compose the great system of Werner; and although it be among the earliest of this series, yet in England it very generally occurs uncovered, while in Ireland it is almost always overlaid by the trap rocks. In both, it uniformly rests on the Green Sand or Mulatto-stone.

The extent and position of the white limestone in Ireland is somewhat remarkable. From Belfast it reaches all round the coast, extending to Rathlin, and, with some trivial intermissions, to Colerain; and in a line to the westward of this, it runs south through the middle of the county of Londonderry, to its verge in the low lands which border Lough Neagh. On the west and south of that lake it disappears; but it occurs again to the south-east, at Moira, in the county of Down, which connects itself with the range in the neighbourhood of Belfast. In all this extent, the limestone generally appears to dip inwards, so that within the area of the space I have described, I understand it is nowhere to be seen, although, from the position all round, there can be little doubt that it exists.

In England, it has also been observed, that there are two distinct varieties of chalk, one of which is much harder than the other; occurs in a lower position, and contains no flints, or at least very rarely. The stratification of this variety is marked by seams of a greyish-coloured chalk, containing probably an

admixture

admixture of clay along with shells. The upper chalk is distinguished by its inferior hardness, and the abundance of flint with which it is accompanied.

In Ireland, excepting when traversed by dikes, I have never observed but one kind; it is harder than any of the English chalks; it contains quantities of flints, and, as we shall shortly see, a tolerable abundance of organic remains. It is used for all the different purposes of limestone, including building.

The alteration produced by the occurrence of a whin-dike has been observed by every geologist who has visited this part of the country. In place of the dull earthy fracture of the chalk, it presents a crystalline disintegrated mass, very friable and phosphorescent, of a pale green colour, and maintaining these characters only in the immediate vicinity of the dike.

Geologists seem to have been very shy in treating of the formation of chalk; they have in general been contented with quoting the opinions of some predecessor, very little that can be considered original, being to be found in any of the geological works I have examined. Some ingenuity has, however, been displayed in ringing the changes on the same ideas; but in the progress of this investigation, we find very little added to the first projected opinions. Professor Jameson satisfies himself with placing the Chalk at the end of his great Limestone series, (*System*, p. 91. 1818), and considers that it agrees admirably with the preconceived ideas of the diminution of the waters, with which Werner inundated the surface of the Earth; and he adds, that its occurrence on the *sea-coast*, and its earthy aspect, point out the lateness of its formation, (176). Why the proximity of the sea-coast should afford any evidence of the period of its formation I cannot conjecture, as we know of no rock that is not washed by the waves of the ocean.

Mr

Mr Jameson avoids giving any opinion of his own on the formation of Flint, in any of his works on Mineralogy and Geology. He contents himself with stating, "That the beds of flint, and also the tuberose and other shaped masses found in chalk, appear to have been formed at the same time with the chalk." But he adds, "Werner is of opinion that the tuberose, and many other forms, have been formed by infiltration, and conjectures, that during the depositions of chalk, air was evolved, which, in endeavouring to escape, formed irregular cavities, which were afterwards filled up by infiltration with flint," *System*, vol. i. p. 235. 1820. This opinion was also embraced by Kirwan, which is a little remarkable; for although it be very probable that Werner never had an opportunity of studying the chalk strata, Kirwan must have seen them frequently, and the most simple inspection of the singular regularity with which the flints are disposed in parallel lines to each other, ought at once to have obliterated any such opinion; for supposing it possible, had air been evolved, to the extent of one single line of these flints, a vacuity, equal to the whole plane of the rock, or nearly so, must have been formed, and the superincumbent strata as it were suspended,—a position not likely to meet with support even from Werner himself, particularly when it must be conceded, that the vacuity so formed must be multiplied by the number of lines of flint that occur in the bed of chalk.

Besides, it is difficult to suppose that this discharge of air, from a stratum calculated to extend to the thickness of 600 feet, should have been confined to certain straight lines. Air, to have been evolved, must first have been generated, and, like the nuclei in amygdaloid, must have pervaded the mass irregularly and indiscriminately, throughout its whole extent. It must be observed too, that it was not till after the air was evolved that the

the infiltration took place, so that it is not only a vacuity, but a vacuum, that is required for the operation.

Another hypothesis, equally destitute of philosophic induction, has been proposed to account for the formation of flints; and because they present an outer crust, although perfectly siliceous, as white and as opake as the chalk they were lodged in, some speculators have not hesitated to urge the probability of a transmutation; and BAKEWELL, (*Introd.* p. 171. 1813.) gravely tells us, "that as it is a common belief among working miners, that lime and flint are changed into each other, we should not hastily reject the opinions of *practical men*, but examine whether their opinions be opposed to facts only, or to theories." As well might we listen to the fancies of the *practical men* at the diamond-mines of Mallevully, who insist that the precious gem is actually generated among the turned-over rubbish; an idea which, had it been entitled to more attention than the transmutation of the precious metal, must have been traced and determined long ere now.

On the subject of transmutation, however, PARKINSON, vol. i. p. 322, observes, "In the present advanced state of chemistry, it is unnecessary to dwell on the opinion which has been entertained by M. PATRIN, M. DE CAROSI and others, that chalk undergoes a conversion into flint, except for the sake of remarking, that all those apparent transmutations which have given rise to this opinion, are easily explained, by supposing a partial introduction of a siliceous fluid in various quantities, into porous calcareous earth." And after a good deal of argument on the subject of this formation, he arrives at the following supposition, vol. i. p. 328. "Whether it be believed that these several bodies owe their existence to fire or water, it will, I conceive, be equally admitted, that they have been formed

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in cavities previously existing in the matrix in which they are contained. I suppose, then, that one of these cavities becomes filled by some small aperture, with a liquid holding silex in solution; that siliceous crystals form all round the cavity, except at the aperture, where there is nothing to attach themselves to; and that an aperture in some other part, allows a regular escape of the fluid, by which a correspondent supply is demanded from the first mentioned aperture, until, after perhaps the lapse of ages, the crystals fill up from the bottom and sides to the aperture by which the fluid was admitted, and form a solid crystallised mass from which the water is excluded. Nor does it even appear necessary for the formation of a solid crystalline mass, that there should be more than one opening, that which admits the fluid into the cavity; since the calibre of the opening, bearing a proper proportion to the cavity to be filled, it will remain open until the mass of crystallization is completed; it being reasonable to suppose, that the fluid containing the silex would, in consequence of its superior gravity, be continually supplying the place of that which, having been deprived of its silex by crystallization, would of course tend upwards; and thus might the cavity become entirely filled by crystallization, to the total exclusion of the solvent."

The surprise that I have expressed at the conclusions of Werner and Kirwan, is perhaps more applicable to this celebrated fossilist; for his works bespeak the labour of a lifetime on the very soil we are now engaged in. He does not, indeed, suppose a vacuum to have existed in any part of the strata, but he supposes an infiltration percolating through hundreds of these ranges of flints, which, to do its work, must have first proceeded to the lowest, and gone on gradually towards the top; but,

but, in place of this, the highest range is the first that would arrest the loaded siliceous solution, and that formed, the flints being often so closely deposited, as even to become continuous, the connection must have been interrupted, and many of the lower cavities left vacant,—a circumstance unknown in the history of chalk-rocks. It may be remarked, however, that Mr PARKINSON's observations are meant to apply to the formation of pebbles as well as flints; but the formation of agate and calcedony lead to a totally different inquiry.

The essay read by Dr HUTTON on the 7th of March, and 4th of April 1785, *on the Theory of the Earth*, published in the Transactions of this Society, is well known to embrace, in all its plenitude, the igneous theory of that philosopher; and in it we find the opinion which he entertained respecting the formation of flint to be as follows. "The actual form in which those flinty masses are found, demonstrates, 1st, That they have been introduced among those strata in a fluid state, by injection from some other place. 2d, That they have been dispersed in a variety of ways among these strata, then deeply immersed at the bottom of the sea. And, lastly, That they have been there congealed from the state of fusion, and have remained in that situation, while those strata have been removed from the bottom of the ocean to the surface of the present land." *Trans.* vol. i. p. 232.

The elegant commentator of Dr HUTTON only seeks in the formation of flint for an illustration of the igneous origin of that substance. He observes, § 20. "The round nodules of flint that are found in chalk quite insulated, and separate from one another, afford an argument of the same kind (alluding to fluidity produced by fusion), since the flinty matter, if it had been carried into the chalk by any solvent, must have been deposited with a certain degree of uniformity, and would not now appear

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collected into separate masses, without any trace of its existence in the intermediate parts; on the other hand, if we conceive the melted flint to have been forcibly injected among the chalk, and to have penetrated it, somewhat as mercury may by pressure be made to penetrate through the pores of wood, it might, on cooling, exhibit the same appearances that the chalk beds of England do actually present us with."

In the splendid work of Sir H. Englefield, *On the Isle of Wight*, we find the following observations: "With respect to the formation of flint itself, it cannot be doubted that this separation of the siliceous matter from the calcareous took place after the formation of the strata, and that the flints were not, as it would appear at a first glance, deposited in alternate strata with the chalk. The extraneous fossils found in the chalk often afford singular proofs of this. Many echini are seen filled with flint, which has, after completely filling up the cavity of the shell, formed a large bulb at the orifice of it, as a viscid fluid would do;" and after some farther remarks, he proceeds to ask, "What agent has in this manner, at *two* different times, separated the siliceous from the calcareous matter? and, How could the flint, when separated, form itself into masses in the solid chalk?—for it cannot be supposed that the flint only ran into cavities before empty, as in that case some of these cavities ought to be found either totally or partially void; but no such have ever been discovered in chalk," p. 20.

The two different periods of separation of which Sir Henry talks, allude to the supposed subsequent filling of certain fissures, which traverse the chalk in a contrary direction to the lines of the strata, which he describes as being "seldom above two inches wide, and seem to have been formed from each side towards the centre, which often contains some loose calcareous powder, inclosed between the two siliceous plates," p. 20.

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These veins may perhaps be considered as veins of secretion, formed in the fissures which may have occurred in the strata, during the dependence of the operations which produced the tuberose arrangement of the flints.

We are indebted to the ingenuity of Professor BUCKLAND of Oxford for another idea respecting flint. It was observed, that a variety of the nodules which occurred in particular gravel pits, presented something of an uniform shape, which, when broken, were found to contain zoophytic remains, such as alcyonia, corals, and sponges of different kinds, sometimes so perfect, as to be extricable from the outer case, when fortunately and carefully broken; at other times, when the external contour of the nodule bespoke a similar internal appearance, the mass would be found perfectly solid throughout, and the shape only of the organic body traced on the internal fracture, in colours of a shade differing from the general mass of the flint, or slightly tinged of a delicate purple, when the texture passed into that of calcedony; and so uniformly were these appearances connected, that where the slightest symptom of any of them occurred, it was held as indicative of one and the same origin. The origin of flint itself was by this analogy attributed to organization, though perhaps on grounds not altogether thoroughly investigated.

We find little in the French works tending to illustrate this subject. BROCHANT, following WERNER, considers flint to owe its origin to infiltration. BROGNIART states, that some have supposed flint to be formed by infiltration, introduced into cavities formerly occupied by mollusca and zoophytes,—an hypothesis which, he says, though admitted by a number of geologists, is exposed to considerable difficulties; and he adds, that the observation of M. GILLET LAUMONT tends to support this supposition; he having remarked that a tail of silex often proceeds from the mouth of the fossil echinite found in chalk, as if the animal matter which had flowed from that orifice had been petrified and changed into silex. He hazards no opinion of his own. *Traité*, vol. i. p. 316. 1807.

The recent work of DAUBUISSON, which is one of the most elaborate and extensive that has been published for some years, goes a little deeper into this subject. Talking of the spherical masses of flint, § 119. found in the limestone of Bavaria, he observes, " that they very probably owe their origin to a reunion of siliceous particles, which were disseminated in the calcareous mass still soft or fluid; yielding to their attractive force, they had grouped themselves, and, as it were, formed themselves into balls, round a centre. If this arrangement had not been accomplished in so perfect a manner, or that the attractions had operated in several, or around different neighbouring centres, tuberose masses would have been the result, and not balls; such is probably the origin of the flints which occur in such abundance in the chalk and other calcareous beds."

Having thus described the mode of formation of flint, he adds, § 301. " that the particles of carbonate of lime, which have formed the secondary limestone, appear to have been frequently mixed, in the fluid from which they were precipitated, with particles of silex, which were deposited at the same time. If these had been in small quantity, and had rested disseminated in the mass, limestone, impregnated with silex, would have been the result, and if they had united, a few detached flints would have been produced; but if they had been abundant, either the *Silici-calce* of SAUSSURE would have been formed, or a great number of tuberose flints. I have sometimes seen them so abundant, that they touched, and the limestone only filled the interstices. At some moments, and in some points, the

the precipitation might have been entirely siliceous, and then beds, or parts of beds, entirely of flint, would have been formed. The particles of silex, in gathering themselves into balls, have occasionally drawn along with them some carbonate of lime. Hence those masses are composed of two substances, pure silex in the centre, and *Silici-calce* on the surface."

"These flints, after their formation, having remained some time in a state of softness, which permitted them to yield to the compression occasioned by the weight of the superior masses, seems to be indicated by their frequent flattened form, or perhaps that form indicates, that the force which has united the particles, assisted probably by this weight, has exerted its action more in a vertical than a horizontal direction; the siliceous particles disseminated in a bed, in a state of semi-fluidity, will have descended to the lower part of the bed, and there have united."

I confess it is difficult to follow the meaning of M. Daubuisson throughout this theoretical disquisition. I have endeavoured to render the quotations as intelligibly as possible, but still there is much obscurity in what he says, particularly respecting the descent of the siliceous particles, because exposed to pressure. Unless he could have shown that that pressure had acted more directly on the silex than on the carbonate of lime which contained it, it is not easy to conceive how it should have changed its position either up or down.

Although I have extended these extracts much beyond what may appear to have been necessary; yet the materials, on the whole, will be found meagre and unsatisfactory, and very inadequate to afford any conclusive deductions on the formation of either Chalk or Flint. Some of them must be altogether rejected; but from others a few scattered hints may be elicit-

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ed. We must therefore revert to an examination of the rocks themselves, to the circumstances in which they are found to exist, and to the fossil remains which are peculiar to the strata of chalk; and endeavour to ascertain how these circumstances can be brought to combine with the formation of the beds themselves.

In England, particularly in the Isle of Wight, and on the coast of Dorset, where the features of that rock have been so faithfully delineated by the inimitable pencil of Mr WEBSTER, several sudden and very remarkable elevations of the strata have been described. The limestone, after extending for a considerable distance, in a position varying little from perfect horizontality, is all at once thrown up, and stands upon edge, no alteration having taken place in the arrangement of its flints, which are now piled on the top of each other, and exposed to an influence, with respect to the superincumbent weight, the very reverse of that mentioned by DAUBUISSON. In the Isle of Wight at Freshwater and Culver cliffs, and Scratchell Bay, and on the Dorset coast at Worthbarrow Bay, Handfast Point, and Batts Corner, magnificent examples of this are afforded. In all, strings of flints are seen disposed throughout, in lines parallel to the strata, in every altered position. Where we find similar bendings in strata, that are usually horizontal, the proximity of a whin-dike, an invasion of granite, or some of the other crystalline rocks, afford the Huttonian some grounds of conjecture as to the cause; but the eccentricities of the English chalk are dependent on some other cause, —a cause which, from its effects, denotes itself to have been of the most powerful description, and one to which HUTTON alone has alluded, in his hypothesis of the elevation of the strata from the bottom of the sea. This force could not be supposed always to have acted with perfect uniformity. Hence those

those contortions and elevations so remarkable at the spots I have enumerated; and the probable demolition of a large proportion of these strata, the remains of which are spread over so great an extent of England, in deposition of loose alluvial gravel.

The nature of the fluid from which the chalk strata have been deposited, I conceive it an idle pursuit to inquire into; but that they were deposited from a fluid is admitted on all hands, and that they were deposited, not where they now are, but when deep under the surface of the ocean, is proved beyond a doubt, by the marine remains, and only marine remains, which are peculiar to these strata. No metallic substance has ever been found in chalk, except some iron-pyrites, and that to a very limited extent; but the organic bodies have been numerous, and some of them in the most beautiful state of preservation. Difficult and accidental as it must be to extricate such objects, I have sometimes seen a fossil resembling the *Echinus circinatus* of GUALTIERI (whose spines are two or three inches in length) very entire, which denotes that it must have been deposited at a moment when the most perfect quiescence prevailed. These appear to me to be legitimate and sound data, on which to ground opinions respecting the nature of the chalk strata, and a more close examination of the fossil remains will perhaps lead to some probable conjectures respecting the formation of the flints.

I conceive it quite unnecessary to enter upon any refutation of WERNER's idea, of cavities being left by the expulsion of air, not only from the impossibility of the limestone remaining suspended, as before remarked, but that these very flints sometimes contain organic remains entirely enveloped, which could not have been introduced by infiltration, and must have been in the open sea, when the two substances, the siliceous matter

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of the flint and the fossil, came in contact with each other. It is equally difficult to embrace the idea of HUTTON, that flint was introduced among these strata from some other place, as no forcible introduction of flint, in the state of fluidity, which he supposes, would produce the long and extensive lines of spherical and tuberose masses, drawn parallel to each other with a precision almost mathematical, which the chalk strata everywhere exhibit; and the force by which that introduction is supposed to have been accompanied, was calculated only to annihilate the very delicate texture observable among the fossils which are included in it. Operations much more quiescent in their progress were necessary to the original arrangement of these objects,—the parallelism of the flints, the delicacy of the fossils, equally demand this. When these were got together, secured, and hermetically sealed, in their position, they could no longer be deranged, they could no longer be injured by forcible agitation, or concussions of any kind; and it is necessary to presuppose some security of this sort, before we can speculate on the elevation of a single bed of chalk.

I was led to these conclusions by an examination of some fossils I lately obtained from the north of Ireland, which, when combined with the consideration of the highly inclined chalk strata on the coast of England, I conceived were capable of throwing some light on the formation, not only of the chalk, but also of the flints, which have hitherto presented so much difficulty to the theorist.

The fossils which principally occur in the Antrim limestone, are the Belemnite and Echinite. Of the latter there are different species, and they vary in bulk, from the size of a wren's egg to that of a turkey's. When enveloped in chalk, the echinus is entirely calcareous, having the shell converted into cristallised carbonate, while the interior is filled with the usual

usual white limestone. When inclosed in flint, the shell still remains in the same state, and, as LAUMONT has observed, the interior and exterior flint are connected at the vent of the animal, and when the carbonate is removed by means of acid, the flint appears to have penetrated all the minute pores, and presents sharp and prickly ridges along the different lobes or portions of which the shell of the echinite is formed.

The Belemnite is a very common fossil, yet, for the sake of perspicuity, it is necessary to describe it in a particular manner.

It occurs in great abundance in the south of England; and although PARKINSON and others describe several varieties, the belemnites of Antrim appear to me to be only of one kind, pretty much of a size, measuring in general about three or four inches in length, and from half an inch to three-fourths in thickness. The form is that of a cylinder, terminated at one end with a conical point, furnished with a slender process, of about a quarter of an inch in length; but it is only when the belemnite has been inclosed in flint that this delicate member has been preserved. At the other extremity, the fossil is always more or less broken, and provided with a cavity or alveolus, which is filled up with the material in which it has been imbedded. This cavity is conical, terminating with a sharp point, and occupies a situation a little to one side of the centre of the cylinder.

In composition, the belemnite, whether inclosed in limestone, flint, clay or sandstone, is uniformly formed of cristallised carbonate of lime, striated and radiating to the circumference, from a line which passes from the apex of the alveolus to that of the fossil.

In colour it varies. Those that are found in strata where clay abounds, are opake, and of a dark-brown; while those

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that occur in chalk and flint are translucent, and of an amber-yellow.

This curious fossil, of whose nature nothing but the most vague conjectures have hitherto been hazarded, seems to have been the appendage of some animal, handed down to us probably unchanged since its creation. It will be remarked, that its structure is quite different from that of other calcareous fossils, which are formed in general of the common rhomboidal carbonate, while it is composed of radiated striæ, diverging from a point, which appears to have been dependent on some internal organisation. These striæ are interrupted by concentric lines, which are not frequently visible, although they are rendered so by the action of acid, and sometimes are displayed in the longitudinal fracture. This arrangement seems to indicate the growth of the animal, and had the belemnite undergone a conversion like other petrified substances, must certainly have been obliterated.

On this account we may perhaps be allowed to consider the belemnite as unaltered; but to what species of animal it has belonged, no conjecture can be formed. The thick end of the fossil is always broken, as, in consequence of the conical form of the alveolus, it is reduced to a thin, delicate edge, and may have been attached by cartilaginous matter to the body of the animal it belonged to.

Although the alveolus be very frequently filled with the material in which the fossil is imbedded, it likewise happens, occasionally, to present an organic structure. When the Antrim fossils, which are formed in flint, have been reduced by acid, the siliceous cone is found to be impressed with rings, set at regular distances; but this is only superficial, as the flint itself breaks in its usual conchoidal form, without any interruption from the external appearance. It is different, however, in

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some of the calcareous specimens; for when the cone is broken across, it separates by these lines, leaving in the upper part a concavity, and on the lower a corresponding convexity, and exhibiting a spot occupied by a siphunculus or duct, like the nautilus and other shells, at the side of the concamerated cone which is nearest to that of the belemnite; the use of which, according to Parkinson, vol. iii. p. 129. "in all the multilocular shells, was to bring the animal to which they are appended, with its shell, to a degree of specific gravity, so near that of water, as to render it capable of being raised or sunk with facility, by the apparatus of its siphuncle." I conclude that this part of the belemnite must have existed in such a state, as, by its lightness, it must, like the closed chambers, have served as a float to the animal.

Whether this was the use for which the organization of the belemnite was destined, entirely depends upon the nature of the animal to which it was appended. Any conjectures on that head must therefore be wholly gratuitous. One thing is evident, however, and marks a conspicuous distinction between the *concameration*, if I may use that expression, of the belemnite and the nautilus: the chambers of the last are separated from each other by a firm compact shell, while nothing of the kind appears to have existed in the belemnite. Its organisation may have been composed of a soft membranous substance, easily removed on the animal being deprived of life.

This supposition is somewhat confirmed by the appearance of the belemnites found in the Antrim chalk, which must have been dead shells (as that expression is understood by naturalists) at the time they were inclosed in the strata; for, besides all appearances of the body to which they had belonged being totally obliterated, the fossil itself is not only fractured at the edge of the alveolus, but is frequently, though not always, found to have been perforated by serpulæ, and thus affords one of the most singularly beautiful phenomena that I have had occasion to observe, connected with the mineral kingdom. Some also appear to have been broken, before they were inclosed in the flint, which has faithfully retained the impression of the fracture as perfectly as the finest sealing-wax.

It is some years ago since I was first led to this observation. While examining a flint which contained a portion of a belemnite, I remarked on the calcareous radiated section of the fossil two or three circular specks of flint; and as they also made their appearance at the other end, it occurred to me to remove the calcareous matter by means of acid. On the accomplishment of this, I was surprised and much interested to find, that these specks were the extremities of cylindrical portions of flint, having exactly the form and appearance of arteries, and connected with each other, and with that portion of the cone which remained, by means of smaller fibres representing veins, and affording the most striking resemblance to an injected anatomical preparation. This discovery naturally raised my curiosity; I searched my cabinet, but in vain, to find specimens of the same kind. I endeavoured, but with similar success, to procure some from Ireland, and it was not till last autumn (1820,) when I was in that country, in company with Lord Compton, that I was enabled to procure the necessary supply. In the extensive lime-quarries of Mr Farrel of Larne, I pointed out to the labourers the belemnites imbedded in flint, which were quite familiar to them, and for a trifling gratuity, an abundant quantity was sent me in a day or two to Belfast. On submitting them to the acid, almost all have afforded something extremely interesting and curious, and have opened up a source of investigation which may probably lead to unexpected, results.

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Fig. 1.

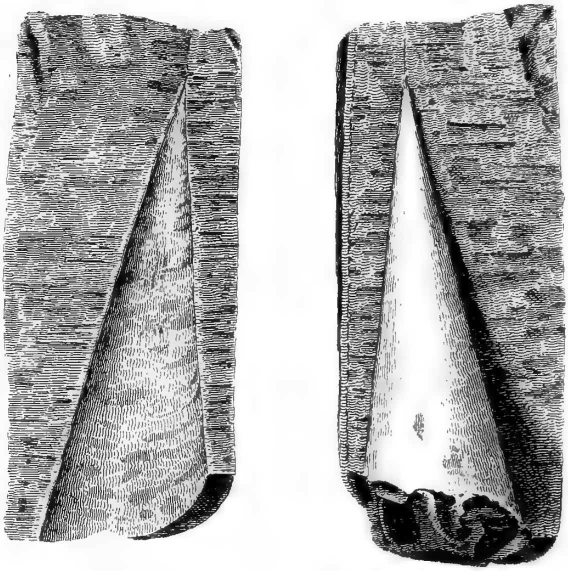


Fig. 2.

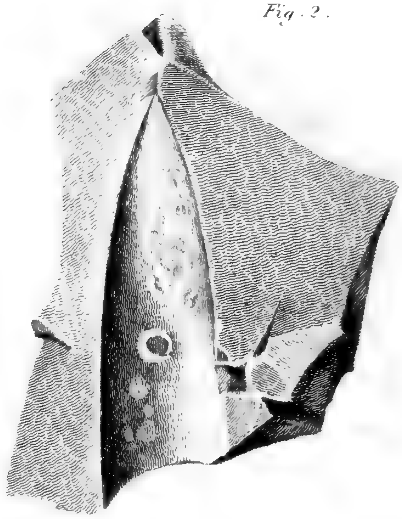


Fig. 3.

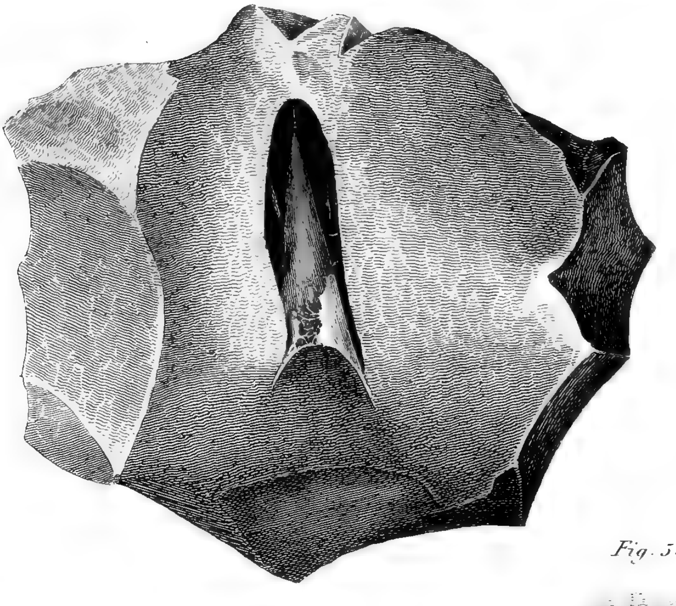


Fig. 4.

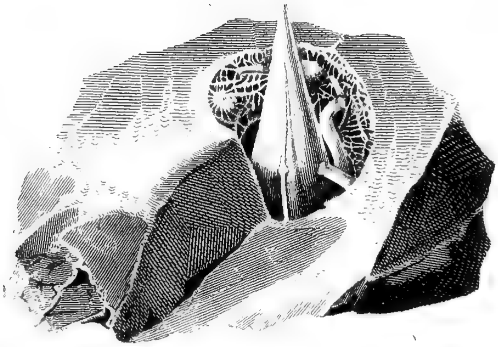
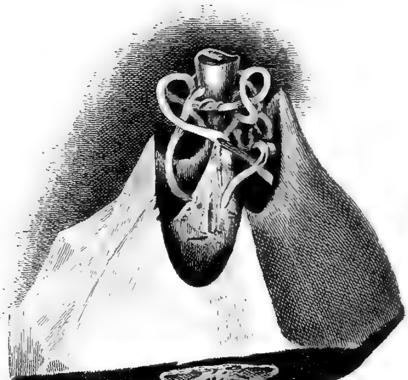


Fig. 5.



R. K. Greville delt.

W. H. Lizars Sculpt.

The means I employed was to dilute muriatic acid with four or five waters, and perhaps this was too rough an application for the very delicate and minute fibres which were often exposed to it, as I found in too many instances, that, after the specimens were dried, the flinty arborisations would sometimes fall to pieces. This extreme delicacy rendered an exhibition of these specimens impracticable, which is to be the less regretted, as I am indebted to the elegant and elaborate pencil of Mr Greville for the most faithful representations of them; and which I have now the honour of submitting to the Society.

No. 1. (Plate XXV.) the first drawing is a portion of a large belemnite, selected to shew the nature and situation of the alveolus, and the concamerated cone by which it is occupied. This specimen was sent me by Dr Fitton from Northampton.

No. 2. Is a flint from which the belemnite separated of its own accord, and is selected on account of the indication of a serpula, which seems to have been attached to the surface of the animal. In several of the specimens, the external surface seems to have been rough, and covered with minute protuberances, corresponding depressions being observable on the flint.

No. 3. In this specimen the cone fills up entirely the base of the belemnite; the trace of its circle being lost in the substance of the flint. At its apex there is a delicate capillary process appended. This is the process, which proceeds from the apex of the cone, to that of the belemnite. I have found it always extremely delicate, and it sometimes fell to pieces by its own weight. There are also some of the little branches of flint, which have occupied the pores or perforations alluded to.

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No. 4. This beautiful specimen resembles the first I obtained. Along side of the cone are those tubes and capillary vessels connected with the cone, and with the sides of the belemnite, and entangled in lace-like work, small, irregular, globular masses, all connected by the most slender fibres.

No. 5. In this specimen the fossil is inverted, the base of the cone being uppermost. In order to prevent it from falling to pieces, the dissolution of the carbonate was watched, and stopped, when the specimen was sufficiently displayed; it will be seen how much the vessels which have here existed, have the character of organization; they twist and range about, quite like the gut of an animal. Still, as we see so little resemblance between this and the other specimens, we cannot but hesitate to attribute it to an origin which bespeaks uniformity and regularity.

No. 6. Plate XXVI. This specimen is singular; it has evidently been broken off at each end; the cone, of which only a small portion remains, rests upon flint, which is impressed with the radiated structure of the fossil, and the upper part is broken off at right angles, showing not only that it must have been a fragment of the belemnite, when originally inclosed in the flint, but also that it was then possessed of the same radiated structure it now presents. Hence, if it be a petrifaction, in place of an original formation, as I have been led to consider it, it must have been transformed previous to its inclosure in the flint. Upon the surface small branches of arborescent flint may also be observed, as if the original had been covered with some delicate conferva, now converted into silex. There are also some of those cylindrical branches very short, as if they had occupied only the commencement of the perforation, which have proceeded from the surface inwards, without the appearance of fracture at the extremities,

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Fig. 6.

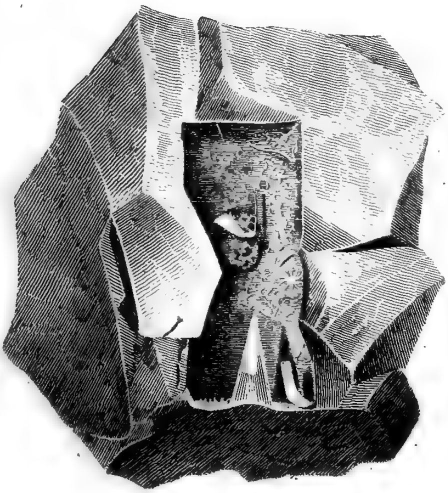


Fig. 7.

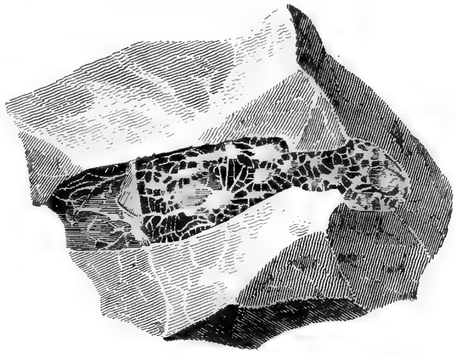


Fig. 8.

Fig. 10.

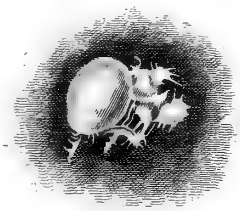
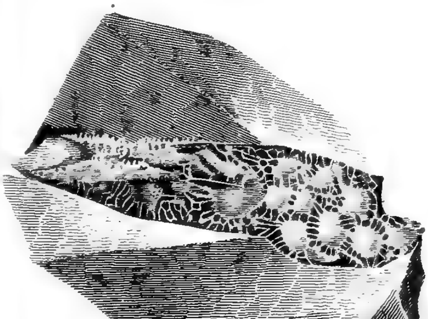


Fig. 11.

Fig. 9.



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ties, which are rounded off. These are very like the perforations of a worm, and have induced me to believe, that many of them are merely casts of flint, in cavities formed in that manner.

Nos. 7, 8, and 9. In these specimens the flint which has been displayed by the dissolution of the calcareous spar, presents a new appearance, which may perhaps be best compared to the ovarium of some animal. Small roundish masses are connected and entangled with each other by thin and very delicate threads.

No. 10. Is one of the globular masses * larger than usual, but also a little magnified in the drawing. I should observe, that the flint in most of these fossils approaches to calcedony, and is lighter in its colour than the general mass. It sometimes presents an opake chalky-looking aspect, which, I presume, arises from an admixture of calcareous matter, for I have found this variety very liable to crumble into dust, after the operation of the acid.

No. 11. Is the same fossil found in the limestone, and by being broken longitudinally, there appear in the section of it cavities filled with chalk, as they would have been filled with flint in the specimens I have described. I have a great many more of the same kind, particularly of the flints, and some of them presenting the most beautiful arborisations I ever saw, quite similar to the most delicate sea-weed, which had apparently been attached to the outer surface of the belemnite.

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* In specimens of this kind, I have noticed that the connection between these globular masses, is maintained, more particularly by *two* fibres, larger than the others, and more uniform in their position.

This curious arborescent, and most delicate arrangement of the siliceous matter, naturally gave rise to conjectures on the probable mode of its introduction into the fossil. From the specimen designed in Fig. 6. it is quite evident, that a fragment only was there inclosed, and the enveloping material being continuous with the cone as well as the little branches formed in the perforations, by which it had been penetrated, it is certain that these cavities must have been made in the calcareous mass of the belemnite. I am possessed of a specimen from Oxfordshire of a belemnite which is covered with serpulæ, and penetrated with numerous worm-holes; and supposing these to have been filled with flint, and laid open by the removal of the calcareous portion of the fossil, we might expect a preparation exactly similar to those I have been describing. The great dissimilarity among the specimens, seems to preclude the possibility of attributing their structure to organization, however strongly some of them may resemble it; and, after all, it may be, that this arrangement is due to more than one cause. One thing like uniformity in the interior structure, which may certainly be laid hold of, is the projection of the delicate fibre, from the apex of the concamerated cone, along the centre of the radiated cylinder, to the extreme point of the belemnite. This is partly distinguishable in the drawings, Nos. 3. and 9.; and, as I have observed it in many others, I think it may, with propriety, be attributed to an organic connection between the siphunculus and the apex of the fossil, which Parkinson says, vol. iii. p. 130., has already been described by Walch.

With respect to the singular arrangement displayed in Figs. 7. 8. and 9.; on a minute examination of these, and several other specimens, it is very difficult to come to any conclusion. The first idea that suggested itself, was the striking similarity to to the ovarium of an animal, as already stated; but this is a pursuit I must leave to the comparative anatomist. He may find in the threads by which these rounded masses are connected, more uniformity than could be attributed to the accidental perforations of a worm; nor do I think the elegant and delicate moss-like arrangement of the fibres with which they are surrounded, seem likely to have accrued from any such operation; and as an organised connection has been pointed out, extending from the siphunculus to the apex of the belemnite, perhaps more practised eyes may be able to trace it farther in these or other specimens *. But as these drawings shew, it is not the belemnites that are found in the flint only that present this curious internal structure, for those which occur in the chalk, when broken in the direction of their axes, also exhibit the same phenomena, having the cavities filled with white limestone, which, when contrasted with the amber-coloured radiated spar of the belemnite, is exhibited with perfect fidelity.

I have found several having these cavities filled partly with chalk and partly with flint; but this only when the belemnite, by extending beyond the mass of the flint, was partly surrounded by both.

Now, under what circumstances was it possible, for either the white limestone or the flint, to insinuate itself throughout the

* Naturalists, having any connection with Ireland, will have no difficulty in supplying themselves with specimens; for although Mr PARKINSON mentions the belemnite being found transfixed in flint as a circumstance of some rarity, the north of Ireland affords an unbounded resource; and it will be very interesting to me to learn, that this fossil, found under similar circumstances in other places, presents the same phenomena.

the delicate ramifications that are thus laid open to view? Certainly not with any degree of probability, by the deposition of the calcareous matter, or the infiltration of the siliceous, as suggested by Werner; nor is the forcible introduction of siliceous matter, as suggested by Dr Hutton, at all compatible with such delicate structures.

I am aware of the temerity of offering any thing like a new doctrine on the formation of the materials I have been now treating of, and perfectly sensible of the desire which, in spite of us, exists among us all, to find objections to any novelty of the kind, rather than to contribute our mite to its support, or to trouble ourselves about the investigation of the grounds on which it is established. Still, however, I cannot help stating, that after pondering upon this subject, and taking into account all that I am acquainted with respecting the strata of chalk-rocks, it appears to me that they must have been deposited in a very quiescent state; that the calcareous and siliceous matter had, by their respective attractions, separated, and that the latter was deposited in thin and multiplied continuous seams, in the manner conceived by Daubuisson; that the fossils were promiscuously intermingled throughout, when the specific gravity of each was equal, so that they occur in all parts of the stratum; that the whole was, according to Dr Hutton, exposed under pressure to a great degree of heat, which not only attenuated the substance of the carbonate of lime, and rendered it capable of being forced into the minutest cavities of the fossils; but also, by fusing the thin seams of siliceous matter, enabled that substance, by new and more powerful attractions, to collect itself in the spherical and tuberose groups it now exhibits, enveloping the fossils which were previously intermixed with it, and, from the pressure it maintained, forcing its way into all the cavities in the organic bodies, however minute, that happened to be among

among it. Then follow the other operations of HUTTON; the transference of the strata from the bottom of the sea to the surface of the dry land, which, we have already shown, is the only hypothesis at all reconcileable to the high inclination of the chalk strata. It may be asked, if this chalk had undergone a degree of heat capable of fusing it, what has become of the crystallisation that must have followed that operation? for, excepting in the cavities of the flint, where we sometimes discover some small crystallisations of quartz, and occasionally in the limestone, a few cotemporaneous veins of calcareous-spar, neither the flint, nor the limestone they rest in, present any trace of crystalline arrangement; the texture is homogeneous throughout, and, in general, extremely uniform. But we have many such anomalies in nature; the base of many of the trap-rocks presents as little the appearance of crystallisation as even the softest chalk, and yet it is now admitted, even by the pupils of the Freyberg School, to be of igneous formation; and the circumstance which Sir H. ENGLEFIELD mentions, of the flints being sometimes found maintaining externally their usual shape, but being, in reality, sometimes reduced to an absolute impalpable powder *in situ*, which he attributes to the severe concussion which altered the position of the chalk strata, we might adduce as an argument for this rapid cooling; for to what does his description of these crushed flints more nearly assimilate itself than to the state of unannealed glass?

Nor does this idea of fusion oppose itself to the theory of Professor BUCKLAND. I will still concede the possibility of an organic origin to flint; but I will suppose it to have been a marine organisation, and that the objects, like my fossils, had been embarrassed in the seam of siliceous deposition, and being probably charged with siliceous sand, the silex has formed round them, as nuclei, and, in the progress of assuming their

new

new shape, produced the alcyonic flints along with the tuberose masses we meet with. It may be observed, that these alcyonia occur only in certain districts, and generally among that immense mass of loose detritus * with which a large portion of our southern counties are covered,—the remains, no doubt, of chalk strata, which were probably demolished during the great exertion of raising them from the bottom of the ocean to the surface of dry land. These alcyonia, and other zoophytic remains, afford strong corroborative proof of the original site of the flint, and not a single observation we are acquainted with tends to subvert that fact. Nothing which could have existed on the surface of the earth has ever been found in chalk; and so perfect are the remains which are occasionally found in it, that there is reason to conclude, that, in many instances, they could not have been long deprived of life. In what state the ocean was at the time it contained in solution the strata we have now been treating of, it is not my intention to investigate; it is one of those hidden mysteries of the All-powerful Creator which we must be content to consider as beyond the reach of human investigation.

To contemplate and to admire the works of Nature, is a field open and patent to us all; and surely the order, the beauty, and the simplicity of every thing we meet with, are calculated to impress the thoughtful mind, with an humble and respectful admiration of the Almighty Power which is every where displayed, together with a true sense of our own ignorance and deficiency, in all that appertains to the undefinable wisdom we trace, throughout every department of the natural world.

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* I learnt from Mr Hodgkin, that they had recently been found *in situ* in the vicinity of Lewis.

XXIX.

XXIX.—*On a Submarine Forest in the Frith of Tay, with Observations on the formation of Submarine Forests in general.* By JOHN FLEMING, D. D. F. R. S. Edin.

(Read June 17. 1822.*)*

THE title which I have given to this paper, is, perhaps, faulty, and apt to lead the imagination to expect a description of the various forms of those sea-weeds which clothe the channel of the deep;—the arrangement of the species, as depending on the soil and depth of water, the food which they yield to the various creatures that browse upon them, and the protection they afford to such as take refuge among their leaves and branches. Very different, however, is the scene which I propose to describe,—a bed of peat-moss, covered by the sea at every full tide, but indicating, by the appearances which it exhibits, that its present low level is different from its original position. In other words, it is a geological phenomenon, occurring in the Frith of Tay, similar to the one observed on the Lincolnshire coast, which, in 1796, was examined by the late Sir JOSEPH BANKS and Dr JOSEPH CORREA DE SERRA, and described by the latter in the *Transactions of the Royal Society of London for* 1799, p. 145, under the title, " On a Sub-

Submarine Forest, on the East Coast of England." I venture to prefix the same title to this paper, which I now offer to the consideration of the Royal Society of Edinburgh, aware of its impropriety, but urged by the wish to connect similar phenomena by the common terms employed in their description.

The bed of peat to be described, and now dignified by the title of a *Submarine Forest*, occurs on the south bank of the Frith of Tay, and has been observed in detached portions on the west side of Flisk Beach, to the extent of nearly three miles, and on the east side, upwards of seven miles. At this particular place, to which the following observations chiefly apply, it rests upon a bed of clay of unknown depth. This clay is of a grey colour, much mixed with mica, and in some places with grains of quartz, and resembles the Carse ground on the opposite side of the Frith, or the contents of the sand-banks which obstruct its channel. The upper portion of this clay has been penetrated by numerous roots, which are now changed into peat, and some of them even into iron-pyrites. The surface of this bed is horizontal, and situate nearly on a level with low water-mark. In this respect, however, it varies a little in different places. The peat-bed occurs immediately above this clay. It consists of the remains of the leaves, stems and roots of various common plants, of the natural orders Equisetaceæ, Gramineæ and Cyperaceæ, mixed with roots, leaves, and branches of birch, hazel, and probably also alder. Hazel-nuts, destitute of kernel, are of frequent occurrence. All these vegetable remains are much depressed or flattened, where they occur in a horizontal position, but, where vertical, they retain their original rounded form. The peat can be easily separated into thin layers, the surface of each covered with leaves. The lowest portion of this peat is of a browner colour than the superior layers; the texture likewise is more

more compact, and the vegetable remains more obliterated. The peat contains a good deal of earthy matter.

The surface of this bed of peat is nowhere (that I have detected) covered by any alluvial stratum, nor does it occur at a higher level than four or five feet below high water-mark. Towards the shore it seems to be cut off by the old red alluvial clay, on which the newer grey, or carse clay also rests.

The only circumstance of much interest, in reference to this peat-bed, remains to be stated. Upon its surface may be perceived the stumps of trees, with the roots attached, and evidently occupying the position in which they formerly grew; as the roots are observed to spread, subdivide, and penetrate the bed in their usual natural manner. I have counted at one time, after a favourable tide had cleared away all silt and gravel from the surface, upwards of a score of these roots, situate at unequal distances from one another, but all, by the position and arrangement of their roots, demonstrating that such had been, while growing, their original situation. To prevent any suspicion from arising, that I may have been deceived on this subject, I may state, that the scene, situate but a few hundred yards from my dwelling, has been examined repeatedly, and under different circumstances, and several friends who have visited the spot, have appeared satisfied of the accuracy of my conclusions. I may mention the names of two of these, Mr Neill and Mr Bald, both members of this Society, and well qualified, by habits of observation, to form a correct opinion on the subject. Many of these trunks and roots occur from eight to ten feet below high-water mark.

If we assume, therefore, that the roots of these trees are in their natural position, with respect to the bed which now supports them, are we warranted to conclude that they grew on a surface ten feet lower than the high water-mark, but before that surface was exposed to the periodical inundations

tions of the tide? Every cavity, in this climate, situate at a lower level than that of the sea, is invariably filled with water, and in a condition hostile to the growth of trees, until its surface has been elevated, by the washing in of mud, or the growth of peat, to a position at least equal to the ordinary rise of the tide. Since these trees could not, therefore, have grown in an inland valley so far below the rise of the tide, even where the sea was excluded, we must draw the conclusion, that the surface on which these trees grew, was, at the period of their growth, at least ten feet higher, in relation to the sea, than at present; and to account for this remarkable change, we must adopt one of the following suppositions:—Either that the sea has risen ten feet, and overflowed that surface which was formerly beyond its reach; or, that the ground supporting these trees has sunk to the same extent.

The first of these suppositions, viz. A permanent rising of the sea, has not been resorted to by any of those writers whom we have had an opportunity of consulting. Indeed it is contrary to those known laws which regulate the movements of the ocean, and receives no support from any circumstances which have been observed on the maritime shores of this country.

If, then, we abandon the idea that the sea has gained an elevation of its level, and adopt the other supposition, viz. That the peat-bed has sunk, so as now to be ten feet lower than when the trees grew upon its surface, we advance a step nearer the object at which we aim. It still remains, however, to be determined, what those causes were, which operated in depressing the surface of this bed, and enabling the waves to pass over that soil which was formerly so much beyond their influence, as to be fit for the support of the hazel and the birch tree.

The

The first method of explaining the phenomenon likely to present itself, especially where the bed is limited in extent, is by supposing that the substratum, having lost its adhesion to the bed on which it rested, by the percolation of water, and the exposure of the side next the sea, moved down an inclined plane into deep water, carrying along with it the upper layer of vegetable matter, and the trees growing upon its surface. Such occurrences have taken place in several inland bogs, both in Scotland and Ireland, which have moved out of their positions to a lower level. The extent, however, of this bed, and the horizontality of its layers, prevent us from considering its present depressed position as having been produced by any sliding of this kind. Neither hath it arisen from the washing away of the soft matter on which the bed supporting the trees rested, for the clay still remains, and at the line of junction is much incorporated with the peat.

This washing away of the subsoil, however, has been resorted to by Mr Watt of Skail, to explain the conditions of a submarine forest on the west coast of Orkney. It occurred to him "that "this bed of moss and trees has arrived at its present level "(so as to be covered, during the flood-tide, to the depth of "at least fifteen feet of water), in consequence of the removal "of a bank of earth, at least eighteen feet deep, which has "been washed gradually away, by the water of the Loch of "Skaill oozing along the rocks upon which it rested, and "upon which the mass of leaves now rests, held together "by the fibres of the roots of the trees." See *Edinburgh Philosophical Journal*, vol. iii. p. 101. This explanation, however, is liable to very strong objections. It is not probable, that, on the stormy coast of the west side of Orkney, where the rocks themselves yield to the fury of the waves, and where the top of every cliff is a heap of ruins, a mass of earth,

 eighteen

eighteen feet in thickness, would be permitted to remain, until washed away by the slow force of percolating fresh water, or that a continuous bed of peat, of nearly an acre in extent, would be spared from destruction, and suffered to settle peacefully, in the Bay of Skaill, so as to be covered at flood-tide with fifteen feet of water.

If we have no reason to doubt that this Tay-bed was transported to its present situation, in what manner has it reached its present level? Two solutions of this curious question have been offered, as connected with similar occurrences, by eminent individuals, Dr Borlase, Dr J. Correa de Serra, and Professor Playfair.

Dr Borlase, who, in 1757, observed a submarine forest at Mount's Bay, Cornwall, covered at full tide with twelve feet of water, considered the depression of the bed, which supported the trees, and still contained their roots *in situ*, as having arisen from subsidence of the ground, produced by earthquakes, or, to state it in his own words, " that there has been " a subsidence of the sea-shore hereabouts, is hinted in my " letter to you, p. 92; and the different levels and tendencies " which we observed in the positions of the trees we found, " afford us some material inferences as to the degree and inequalities of such subsidences in general; as the age in which " this subsidence happened (near 1000 years since at least), " may convince us, that when earthquakes happen, it is well " for the country that they are attended with subsidences; " for then the ground settles, and the inflammable matter, " which occasioned the earthquake, has no longer room to " spread, unite and recruit its forces, so as to create frequent " and subsequent earthquakes; whereas, where there are " earthquakes without proportional subsidences, there the caverns and ducts under ground remaining open and unchoaked,

" ed, the same cause which occasioned the first has room to
" revive, and renew its struggles, and to repeat its desolations
" and terrors; which is most probably the case of Lisbon."
Phil. Trans. 1757, p. 52.

The views of Dr Borlase, in reference to this depression of the ground, in consequence of earthquakes, was evidently influenced by the curious observations which he had formerly made on the subsidence of some places at the Scilly Islands, as stated, *Phil. Trans.* vol. xlviii. p. 62; and other observers may be led to form the same opinion, especially if the singular sinking of the cliff at Folkstone, about forty feet, even in the absence of an earthquake, be taken in consideration. See *Phil. Trans.* 1786, p. 220.

Dr Correa de Serra also ascribes the depressed position of the submarine forest of Lincolnshire to the force of subsidence, aided by the sudden action of earthquakes. " There
" is a force of subsidence (he says), particularly in soft
" ground, which, being a natural consequence of gravity, slow-
" ly, though perpetually operating, has its action sometimes
" quickened and rendered sudden by extraneous causes, for
" instance, by earthquakes." " This force of subsidence, sud-
" denly acting by means of some earthquake, seems to me the
" most probable cause to which the actual submarine situa-
" tion of the forest we are speaking of may be ascribed. It
" affords a simple easy explanation of the matter; its proba-
" bility is supported by numberless instances of similar
" events." *Phil. Trans.* 1799.

Professor Playfair, when contemplating the phenomena of the Lincolnshire submarine forest, rejected the explanation offered by Dr Correa de Serra, and availed himself of some of the peculiar assumptions of the *Huttonian Theory of the Earth.* " The subsidence (he says) however, is not here "understood to arise from the mere yielding of some of the "strata immediately underneath, but is conceived to be a part "of that geological system of alternate depression and eleva-"tion of the surface, which probably extends to the whole mi-"neral kingdom. To reconcile all the different facts, I should "be tempted to think, that the forest which once covered "Lincolnshire, was immersed under the sea by the subsidence "of the land to a great depth, and at a period considerably "remote; that when so immersed, it was covered over with "the bed of clay which now lies upon it, by deposition from "the sea, and the washing down of earth from the land; that "it has emerged from this great depth till a part of it has be-"come dry land; but that it is now sinking again, if the tra-"dition of the country deserves any credit; that the part of "it in the sea is deeper under water at present than it was a "few years ago." *Illustrations of the Huttonian Theory*, p. 453.

A careful examination of these conjectures, which had been offered to account for the phenomena of submarine forests, soon convinced me that the subject was still imperfectly understood. Under this impression, I endeavoured to become possessed of all the conditions of the problem, and now venture to offer a solution. The opinion which I have been led to form has been entertained for some years, and stated to several friends, without an objection having presented itself.

If we suppose a lake situate near the sea-shore, and having its outlet elevated a few feet above the rise of the tide, we have the first condition requisite for the production of a submarine forest.

If we now suppose, that, by means of mud carried in by rivulets, and the growth of aquatic plants, this lake has become

come a marsh, and a stratum of vegetable matter formed on the surface, of sufficient density to support trees, we arrive at the second condition which is requisite. This state of a marsh, formerly a lake, is of common occurrence, more especially where the surrounding grounds are high, and covered with soil, for in this case the rain washes down earthy particles, and, by spreading them on the grassy surface, renders it a more suitable soil for the growth of trees.

In this second condition, all the strata below the outlet of the marsh are kept constantly wet, or in a semifluid state. The force of ordinary subsidence, aided by occasional earthquakes, may render the whole tolerably compact; yet the quantity of water necessarily present, will prevent any thing like the degree of condensation of ordinary alluvial land or soil from taking place.

Suppose a marsh in this condition to have the level of its outlet lowered, or rather, to have its seaward barrier removed (an occurrence which many circumstances induce us to believe to have happened frequently both on the east and west coasts of this country, where submarine forests are not of rare occurrence), what consequences would follow? The extremities of the strata now exposed to the sea, would at every ebb-tide be left dry, to a depth equal to the fall of the tide. Much water, formerly prevented from escaping by the altitude of the outlet, would now ooze out from the moist beds, and the subsiding force would act more powerfully in the absence of the water which filled every pore. All the strata above low water-mark would thus collapse, and the surface of the marsh, instead of remaining at its original height, would sink below the level of the sea. But the escape of the water from the strata would not, in such circumstances, be confined to the beds situate above the low water-line. Even those occupying a position considerably

considerably lower, would be influenced by the change; for the water even in such would be squeezed out, in consequence of the pressure of all the matter of the strata above the low water-mark, exerted during every ebb, in the expulsion of the water at the lowest level, thus permitting the subsidence of the strata to take place even to the lowest beds of the morass.

In consequence of this drainage, produced by the ebbing of the tide on those marshes, the original barriers of which have been destroyed, there is no difficulty in accounting for the depression of the surface of a marsh many feet lower than its original level, nor in explaining the fact that Neptune now triumphs where Sylvanus reigned, and that the sprightly Nereids now occupy the dwellings of their sister Naids.

The same explanation, now offered to account for the submarine forest of the Tay, seems equally applicable to those of Mount's Bay, Lincolnshire, and Orkney. It is warranted by the effects which we have observed to have taken place in different districts of Scotland, from the artificial drainage of marshes which had formerly been lakes, and which were in a condition of surface fit for the growth both of willows and alders. In some cases, where the outlet of the marsh has been lowered perhaps ten feet, and a ditch at this new level opened through the middle of the ground, an expectation has been formed that the original surface would be drained of all its moisture, and brought into an arable condition. A season, however, has scarcely elapsed, before this deep ditch has become shallow, not by the silting up of the bottom, but by the subsidence of the neighbouring matter, in consequence of the abstraction of the water; and the ground which was expected to become fit for yielding crops of grain, has returned to a condition better suited to the growth of of rushes. No provision in these cases had been made for the effect of subsidence.

Before concluding this paper, I may take notice of a few facts which seem to have some interest in a geological point of view.

1. One effect of the subsidence to which I have here alluded, is the complanation of all the vegetable remains which occur in a horizontal position, or parallel with the surface of the bed of peat; while those situate vertically retain their cylindrical shape. The vegetable remains, so common in the strata accompanying coal in this country, exhibit the same appearances in similar circumstances, and lead to the conclusion, that the matter of the strata, at the period of deposition, was in such a condition as to admit of the mechanical effects of subsidence taking place.

2. In the examination of the vegetable remains in this bed of peat, and of others which have been investigated, I have been led to conclude (contrary to the commonly received opinion*), that many of the supposed *stems* of reeds which occur in a petrified state, are in fact *roots*. These roots, or rather subterranean stems, such as the Arundo colorata and phragmites, Menyanthes trifoliata, and many other marsh plants exhibit, frequently occur in beds of peat, in a dead state, and exhibit their peculiar characters, when but few traces of the stems to which they belonged can be detected.

3. Several

* See Parkinson's *Organic Remains*, vol. i. p. 455.

3. Several changes of a chemical kind have already taken place in this stratum of peat. The fibrous structure of much of the vegetable matter is obliterated, small portions of the reeds, and even of the wood, are so changed as to resemble wood-coal;—changes these, which plainly intimate, that a process is going on, by which, in time, that which is now peat may become coal. In the crevices of some portions of the wood I have detected thin crusts of the *blue phosphat of iron.* It is rather singular to have found some of the roots in the soft clay changed into *iron-pyrites.* This change has chiefly taken place in the bark, and in such cases the wood and pith are wanting. In one example, however, the pith remained, and had likewise been converted into pyrites. In many cases the clay is full of tubular cavities, the remains of the spaces which the roots or stems of plants once occupied. The walls of these cavities are usually of a darker colour, and firmer texture, than the surrounding matter, and have evidently undergone some change, in consequence of the decomposition of the vegetable matter. In some cases, the epidermis of the plant remains in contact with the surrounding clay, while the matter of the interior has disappeared. Into these cavities the clayey matter enters slowly, and fills the mould which the decomposition of the plant has prepared. This may be regarded as a process similar to the one which has taken place in those vegetable petrifactions so common in the argillaceous and arenaceous beds of the coal-formation, in which slate-clay, clay-ironstone and sandstone, are exhibited under the external forms of plants.

Should these observations appear interesting or satisfactory, I shall feel disposed to transmit, at no distant period, the result

sult of some observations "On the present level of the Carse of Gowrie, in reference to the Frith of Tay;" and likewise some remarks on "the Truncated Sand-hills and Deep Basins, which occur between Leuchars and Wormit Bay in Fifeshire."

MANSE OF FLISK,
15th June 1822.

XXX.

XXX.—*Description of a Monochromatic Lamp for Microscopical purposes, &c. with Remarks on the Absorption of the Prismatic Rays by coloured Media.* By DAVID BREWSTER, LL. D. F. R. S. LOND. & SEC. R. S. EDIN.

(Read April 15. 1822.*)*

IN a Paper on Vision through coloured Glasses, which I had lately the honour of submitting to the Society *, I pointed out the advantages of coloured media in Microscopical and Telescopical observations. Having experienced the great utility of *Green* and *Red* lenses, in developing vegetable structures that required to be examined with high powers, I was anxious to derive from this new principle all the advantages which it appeared to possess. In attempting to do this, it became necessary to ascertain the power of giving distinct vision, which belonged to each separate colour of the spectrum, and though I had stated in my former paper, " that it was difficult to discover " any reason why one coloured medium should be preferred " to another, provided each of them transmits equal quantities " of homogeneous light;" yet it was desirable to put this theoretical opinion to the test of direct experiment. Sir WILLIAM HERSCHEL † had long ago investigated this point in reference to the use of coloured media for solar observations, and had concluded *that every colour of the spectrum possessed the*

 same

* See the *Edinburgh Philosophical Journal*, vol. vi. p. 102.

† *Philosophical Transactions*, 1800.

same power of giving distinct vision; but his method of observation, which consisted in viewing through a microscope a Nail illuminated in succession with each of the colours of the prism, was by no means calculated to give definite results, and therefore left the question in all its uncertainty.

In order to obtain precise indications, which were not capable of being misinterpreted, when applied to practical purposes, I formed a spectrum from a luminous disc, by means of a prism of a highly dispersing substance, and with a large refracting angle. I then examined this spectrum through a great variety of coloured media, both solid and fluid, and marked the size and shape of the image into which it was converted. The perfection of this image, or its narrowness in the direction of the length of the spectrum, became a precise and unequivocal test of the fitness for distinct vision which belonged to the light out of which it was formed.

By this method of observation, I found that a distinct image of the luminous disc could not be obtained either by producing a Blue or a Green image, and that it was only in the Red portion of the spectrum that such an effect was likely to be obtained. In the use of purple glasses, I observed that the middle portion of the Red space was absorbed before the two extreme portions, so that instead of one Red image there were two, quite separate, and tolerably distinct. By increasing, however, the thickness of the plate, the most refrangible red image was absorbed, and the least refrangible one left in a state of the most perfect distinctness. Although I had now determined the part of the spectrum that was best fitted for giving perfect vision, yet the quantity of light extinguished before the insulation of the extreme red ray was affected, was so great as to render the determination of little practical utility, excepting in cases where the outline of an object was to be observed. Had it been possible to insulate the *most luminous rays of the spectrum* as perfectly as the extreme Red ones, the advantage

advantage would have been of very considerable amount; but I have found this quite impracticable, and I venture to say, that the separation of homogeneous green or homogeneous yellow light, of any considerable intensity, cannot be effected by any coloured media with which we are at present acquainted.

Abandoning, therefore, all hopes of obtaining from coloured media any farther improvement upon the microscope than what I had formerly announced, it occurred to me, that the object which I had in view might be obtained, if I could procure, from the combustion of inflammable substances, *a homogeneous flame for illuminating microscopic objects.*

It had long been known, that a great quantity of homogeneous yellow light was created by placing salt or nitre in the white flame of a candle, or in the blue and white flame of burning alcohol *. A light, however, generated in this manner, was more fitted for a casual experiment, than for a permanent source of illumination; and as insalubrious vapours are disengaged during the combustion of these salts, I did not avail myself of this method of obtaining yellow light.

After numerous experiments, attended with much trouble and disappointment, I found *that almost all bodies in which the combustion was imperfect, such as paper, linen, cotton, &c. gave a light in which the homogeneous yellow rays predominated;*—that the quantity of yellow light increased with the humidity of these bodies;—and that a great proportion of the same light was generated, when various flames were urged mechanically by a blowpipe or a pair of bellows.

As the *yellow* rays seemed to be the product of an imperfect combustion, I conceived that alcohol diluted with water would

* *Edinburgh Physical and Literary Essays*, vol. ii. p. 34.; and Dr Thomas Young's *Nat. Phil.* vol. i. p. 438. Mr Herschel informs me, that sulphur in a certain stage of its combustion produces a homogeneous yellow light.

would produce them in greater abundance than when it was in a state of purity, and upon making the experiment, I found it to succeed beyond my most sanguine expectations. The whole of the flame, with the exception of a small portion of blue light, was a fine homogeneous *yellow*, which, when analysed by the prism, exhibited faint traces of green and blue, but not a single ray of red or orange light. The green and blue rays which accompanied the yellow flame, had comparatively so little intensity, that they disappeared in the processes of illuminating and magnifying the object under examination; and, even if they had existed in greater abundance, it was quite easy to absorb them at once by the intervention of a plate of the palest yellow glass, and thus render the lamp perfectly monochromatic.

From many experiments on the combustion of diluted alcohol, I found that the discharge of yellow light depended greatly on the nature of the wick, and on the rapidity with which the fluid was converted into vapour. A piece of sponge, with a number of projecting points, answered the purpose of a wick better than any other substance, and the extrication of the yellow light became more copious, by placing a common spirit-lamp below the burner of the other. In order to obtain a very strong light for occasional purposes, I connected with the top of the burner a frame of wire-gauze, which, by moving vertically round a hinge, or by a motion to one side, could be placed in a horizontal position about half an inch above the wick. As soon as it had become red-hot, it was made to descend into contact with the sponge, when it converted the alcohol rapidly into vapour, and produced an abundant discharge of yellow light. See Plate XXVII. Fig. 1.

If a permanently strong light is required, I find it preferable to dispense entirely with the use of the wick, and to allow the diluted alcohol to descend slowly from the rim into the bot-

tom

tom of a concave dish of platinum, kept very hot by a spirit-lamp placed beneath it. The bottom of the dish is made with a number of projecting eminences, in order that the film of fluid which rests upon it may be exposed at many points to the action of the heated surface. See Fig. 2. After the lamp has burned for some time, a portion of unevaporated water, mixed with a small quantity of alcohol, will remain at the bottom of the dish, in a state unfit for combustion. This water may be taken up by a sponge, or it might be prevented from accumulating, by having a fountain of pure alcohol, from which the exhausted strength of the diluted fluid could be renewed.

The *Monochromatic Lamp* being thus completed, I lost no time in applying it to the illumination of Microscopic objects. The effect which it produced far exceeded my expectations. The images of the most minute vegetable structures were precise and distinct, and the vision in every respect more perfect than it could have been, had all the lenses of the microscope been made completely achromatic by the most skilful artist. The errors which arise from the different refrangibility of light, being removed from microscopical observations, I was enabled to enlarge considerably the aperture of the object-glass, till the image became sensibly affected by the errors of spherical aberration. In order to diminish these as much as possible, the object-glass should consist of an annular portion of the lens that gives a minimum spherical aberration, and while its surfaces are nicely centered, their common axis should be adjusted so as to coincide accurately with that of the other lenses. The optician, however, will probably be induced to exert his ingenuity in the formation of elliptical and hyperbolical lenses, which, since the days of DESCARTES and HUYGENS, have existed only in optical theories, and thus remove the only imperfection which still attaches to the microscope.

Independent

Independent of its use in microscopical observations, the *Monochromatic Lamp* will find an extensive application in various branches of the arts and sciences. In certain cases of imperfect vision, where a number of coloured images are formed by the separation of the fibres of the crystalline lens, a homogeneous light will improve the vision, by removing the prismatic tints, which obliterate the principal image. In illuminating the wires of Transit Instruments and Micrometers;—in graduating the limbs of divided Instruments, which is generally done by candle-light;—in reading off the same divisions in fixed observatories;—in forming signals in Trigonometrical Surveys;—in obtaining correct and uniform measures of Refractive Powers;—in measuring the separation of the two pencils in Doubly-refracting Crystals;—in determining the focal lengths of lenses;—in observing various optical phenomena, where the light is decomposed;—in these, and, in general, in all delicate works, where correct vision is essential, the employment of a homogeneous flame will be found to confer the most signal benefits.

Having thus described the construction and application of the Monochromatic Lamp, I shall now proceed to give a short account of the experiments which I was led to make, during this enquiry, on the modification of the prismatic spectrum by the action of differently coloured media.

These experiments relate to three different points:

1*st*, To the manner in which coloured media absorb the different portions of the prismatic spectrum.

2*d*, To the influence of heat in modifying this absorbent power; and,

3*d*, To the determination of the question, whether or not yellow light has a separate and independent existence in the solar rays.

1. Dr

1. Dr YOUNG (*Phil. Trans.* 1803) has long ago remarked, that the light transmitted by a specimen of *Blue* glass exhibited two red spaces when analysed by a prism ; but he does not mention their relative intensities. Among the various kinds of blue glass which I have examined, I have found one, which, like Dr YOUNG's, leaves two red spaces, or rather an *orange-red* and a *red* space, the rays which belonged to the intermediate portion having been entirely absorbed, and the least refrangible of the red spaces being more luminous than the other. In another specimen, the interior orange-red image was absorbed along with the middle one, and in a third specimen, the exterior red image and the middle one were alone absorbed. In all these glasses the absorbent power attacks also the green rays adjacent to the red, and leaves a greenish-yellow image, separated by a dark interval from the most refrangible green. When light is reflected from the blue oxidated surface of steel, the middle red space is completely absorbed, and there remains only of the inner orange-red space, a few of the red rays that border upon the green light. From these experiments it follows, that blue glass attacks the spectrum in several points at the same time, and after absorbing all the middle rays, it leaves only the extreme red, and the portions of the blue and violet spaces which are contiguous. By increasing the thickness of the glass, however, the violet is at last overpowered, and the red alone remains. The very same phenomena are obtained by fluid media of a blue colour. With some Blue glasses, however, the red is overpowered before the violet. See Fig. 4., Nos. 2, 3, 4, 5.

In making a series of analogous experiments with *Green media*, I have found that they attack the spectrum at both extremities, but the blue end with more force than the red end. By increasing the thickness of the glass, the blue and red light gradually diminish, but it is extremely difficult to free the

green

green image from these adhering tints. The *sulphate of copper*, even in thin laminæ, exerts a very powerful action over the *red* and *violet* extremities of the spectrum. See Fig. 4. Nos. 6, 7, 8.

In examining the spectrum with *Yellow* glasses, the *Violet*, *Blue*, and *Green* rays are absorbed in succession, and the red and yellowish-green remain untouched. By means of a very thin plate of native *yellow orpiment*, the violet, and almost all the Blue rays are absorbed, while the Red, and all the Green are left.

Red glasses, like those which are Blue, do not attack the opposite extremity of the spectrum. They first absorb the blue rays, then the violet, then the green and yellow; and by increasing their thickness, the red itself finally disappears. A red glass, with a slight tinge of yellow, absorbed with great avidity the blue and green that are adjacent to one another, leaving the violet in full force, and also the green adjacent to the red.

2. In attempting to ascertain the influence of heat upon the absorbing power of coloured media, I was surprised to observe that it produced opposite effects upon different glasses, *diminishing* the absorbent power in one case, and *increasing* it in another.

Having brought to a red heat a piece of purple glass that absorbed the greater part of the *Green*, the *Yellow* and the interior, or most refrangible *Red*, I held it before a strong light, and when its red heat had disappeared, I observed that the transparency of the glass was increased, and that it transmitted freely the *Green*, the *Yellow*, and the *interior Red*, all of which it had formerly in a great measure absorbed. This effect, however, gradually disappeared, and it recovered its former absorbent power when completely cold.

When a *yellowish-green Glass* was heated in a similar manner, it lost its transparency almost entirely. In recovering its green

green colour, it passed through various shades of olive-green; but its tint, when cold, continued less green than it did before the experiment. A part of the glass had received in cooling a polarising structure, and this part could be easily distinguished from the other part by a difference of tint.

A plate of deep-red glass, which gave a homogeneous red image of the candle, became very opaque when heated, and scarcely transmitted the light of the candle after its red heat had subsided. It recovered, however, its transparency to a certain degree, but when cold, it was more opaque than the piece from which it was broken.

3. As it has been concluded from Dr Wollaston's experiments on the prismatic spectrum, that it consists only of four colours, *Red*, *Green*, *Blue* and *Violet*, that pure white light does not contain any *yellow* rays;—and that when yellow does appear at the boundary of a large white space seen through the prism, it is a compound light, consisting of *Green* and *Red* rays *, it occurred to me that the accuracy of these opinions might be examined by means of the absorbing media already mentioned.

I therefore formed a very brilliant spectrum, from a narrow aperture placed between my eye and the sun, and by varying the distance of the prism from the aperture, I obtained a spectrum exactly similar to that described by Dr Wollaston and Dr Young, who has adopted and illustrated the opinions of his friend respecting the composition of white light.

Upon viewing this spectrum through a glass, which absorbed the *Red* next the *Green*, and also through a glass which absorbed the *Green* next the *Red*, I was entitled to expect that these portions of the spectrum would vanish; but instead of this taking place, the space from which these colours were absorbed was in both cases occupied by *Yellow* light, which was

 not

* Dr Thomas Young's *Lectures on Natural Philosophy*, vol. i. p. 138.

not only bright, but well defined in its boundaries. This distinct exhibition of the yellow space, established beyond a doubt its existence in the spectrum, and may be considered as proving, in a very convincing manner, that the Red and Green spaces, at the place where they come in contact, consist of Red and Green rays, respectively mixed with yellow rays of the same refrangibility. The *Yellow* light, therefore, of the solar rays, instead of occupying a separate place in the spectrum, has its *most* refrangible rays mixed with *green* light of equal refrangibility, and its *least* refrangible rays mixed with *red* light of equal refrangibility.

In order to ascertain whether or not the yellow homogeneous light produced by imperfect combustion, occupied the same place in the spectrum with the yellow light, which remains after the absorption of part of the red and green spaces, I formed a spectrum like Dr Wollaston's, from the flame of a candle, as shewn at AE, Plate XXVII. Fig. 3. I then put some salt into the wick, for the purpose of producing a considerable portion of yellow light, which affected principally the margin of the upper and lower part of the flame, and I again observed the spectrum, when I found that the yellow light occupied the position at B *b*, so as to cover a part both of the green and the red space; the part of the green space occupied by the yellow light, being to that of the red spaces occupied by it nearly as 3 to 1. From these experiments, we are entitled to conclude, not only that *yellow light has an independent existence in the spectrum*, when formed from any kind of white light; but *that the prism is incapable of decomposing that part of the spectrum which it occupies.*

EXPLA-

EXPLANATION OF PLATE XXVII.

Fig. 1. Represents one form of the Monochromatic Lamp, where A is the reservoir containing the diluted alcohol, which descends by the channel ABCD to the broad wick E, which is generally made of sponge. A frame of wire-gauze F moves round a hinge H, so that it can be brought over the flame, and made to descend, when hot, upon the surface of the wick. Excellent wicks may be made with concentric cylinders of thin mica, or of platinum foil.

Fig. 2. Is another form of the Lamp, *without a wick*, in which the diluted alcohol is burned in a flat platinum or metallic dish MN, which may be made to have a slight spontaneous oscillatory motion, for the purpose of bringing the fluid over the heated projections of the platinum. A common spirit lamp OP, inclosed in a case, is placed below the platinum dish MN, in order to produce sufficient heat for throwing off the vapour from the diluted alcohol.

A chimney, or a cylinder, of pale yellow glass may be placed round the flame, if it should be thought of any consequence to absorb the small portion of blue light which accompanies the yellow flame.

Fig. 3. Represents the method of finding the position of the *Yellow* space in the spectrum.

Fig. 4. Represents the various ways in which the prismatic spectrum is attacked by the absorbent action of differently coloured glasses, as described in the paper.

No. 1. Represents the prismatic spectrum as described by Dr Wollaston.

No. 2. Represents the effect produced by viewing the spectrum through a blue glass, like that used by Dr Young. The spectrum is attacked at *a*, *b*, *c*; a portion of the middle of the *Red* space being destroyed at *a*, a portion of the *Red* and *Green*, disclosing the *Yellow* at *b*, and a portion of the *Violet* being destroyed at *c*.

No. 3. Shews the effect of a different kind of blue glass, which destroys the inner portion of the *Red* space at *a*, a less portion of the *Violet* at *c*, and a greater portion of the *Green* at *b*; the disclosed *Yellow* being now of a different hue.

No. 4. Shews the effect produced by the *Blue* glasses of No. 2. and No. 3. combined. The spectrum is now attacked at a fourth point, viz. the commencement of the *Blue* space at *c*, and the *Yellow* is rendered less brilliant. By increasing the thickness of these plates of blue glass, the *dingy Yellow* part vanishes, then the *Green*, as in No. 5., then the

Blue,

Blue, and, last of all, the *Indigo*; so that the combinations of Blue glasses have now the effect of Red glasses.

No. 5. Shews the effect of increasing the *Blue* glasses in No. 4. to a certain thickness.

No. 6. Shews the effect of a *Sky-blue* paste, which reflects most copiously the Blue light. The whole spectrum is destroyed excepting the extreme Red.

No. 7. Represents the effect produced by a great thickness of Green glass.

No. 8. Sulphate of copper, which is bluish-green, both in the solid state and in the state of a solution, leaves unabsorbed a great quantity of Yellow light, which may be rendered tolerably homogeneous by means of a pale Yellow glass. The figure shews its effect in attacking the Red and Violet ends of the spectrum, a portion of *blue* and *red* being left.

No. 9. Shews the effect of a greater thickness of Sulphate of copper, in absorbing all the *Red*, and leaving a *Greenish-yellow*, with an adhering margin of *blue* light.

No. 10. Shews the influence of a thick plate of *Yellowish-red* glass, in absorbing all the *blue*, and part of the *green*, leaving the *violet* slightly affected.

No. 11. Represents the singular effect produced by a solution of *Lake*. There are here *two greens*, and an effect is produced at the boundary of the *red* and *green* space.

No. 12. Represents the effect of a thick piece of fine *Red glass*, coloured with gold, and also of a piece of stained glass, which I found in the Abbey of Konigsfelden, in the canton of Berne. The same effect is produced by common red ink, and by a solution of beet-root in vinegar.

No. 13. Shews the action of an opaline milky-white glass upon the most refrangible half of the spectrum.

No. 14. Shews the effect of a certain thickness of *native yellow orpiment*.

No. 15. Shews the effect of a red glass combined with yellowish-green and bluish-green glasses. The yellow is much more copious and brilliant when the red glass is combined with a certain thickness of sulphate of copper, but it is then fringed with a narrow margin of Red on one side, and of Green on the other.

No. 16. By combining with the same red glass a thicker plate of sulphate of copper, the *yellow* becomes *green*; and by a thicker plate still, the colour becomes *blue*, as in the figure.

XXXI.

Fig. 3.

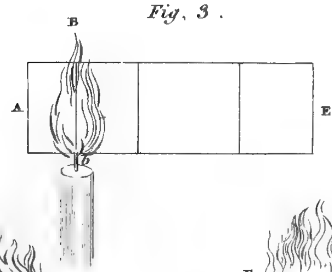


Fig. 2.

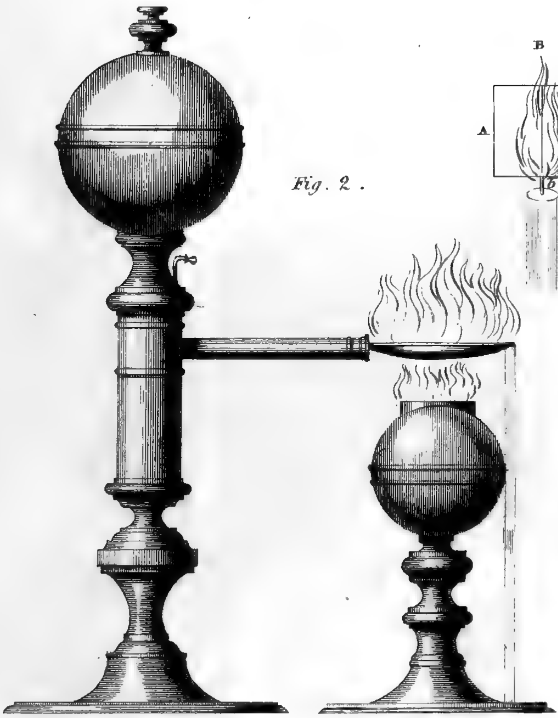


Fig. 1.

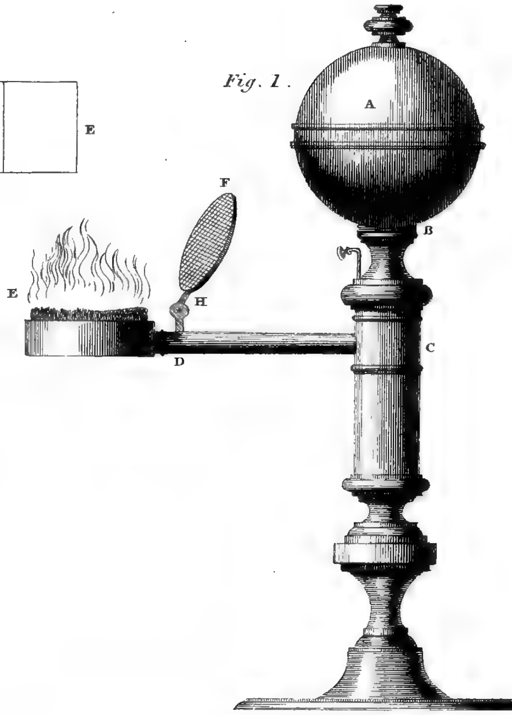
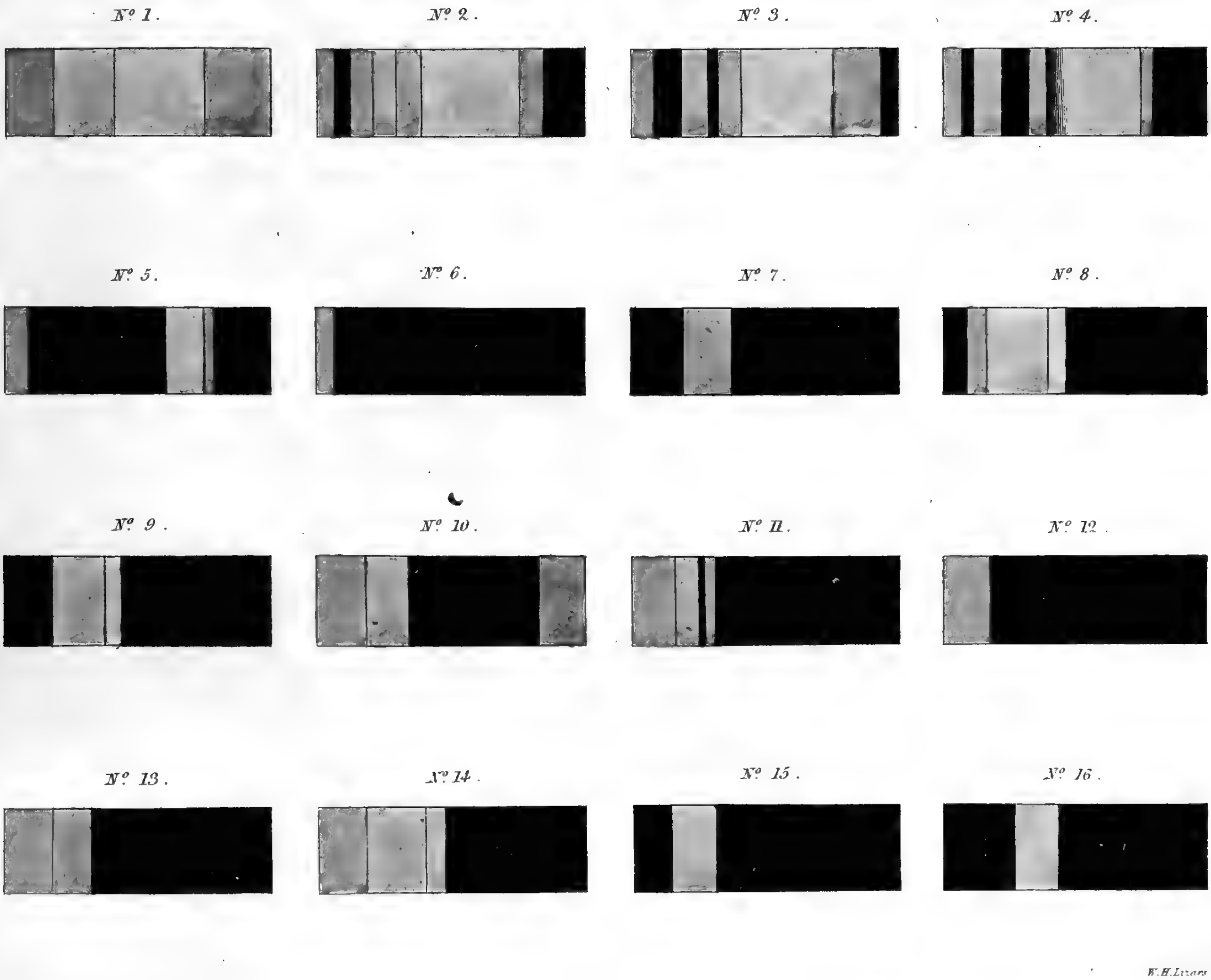


Fig. 4.



W. H. Lizars Sculp.

XXXI.—*On the Absorption of Light by Coloured Media, and on the Colours of the Prismatic Spectrum exhibited by certain Flames; with an Account of a ready Mode of determining the absolute dispersive Power of any Medium, by direct experiment.* By J. F. W. HERSCHEL, Esq. F. R. S. Lond. & Edin. In a Letter to Dr BREWSTER.

(*Read November* 18. 1822.)

MY DEAR SIR,

1. AS I see by a notice in your Journal, No. 13., which has just reached my hands, that your attention has been occupied by the phenomena of Coloured Flames, and the Absorption of Coloured Light by Diaphanous Bodies; and that you have been successful in the very valuable discovery of a *manageable flame*, discharging a homogeneous yellow light of an invariable character, I shall perhaps be excused, while the contents of your paper are unknown to me more particularly, for stating some phenomena which I have myself observed, relative to this highly interesting department of physical optics.

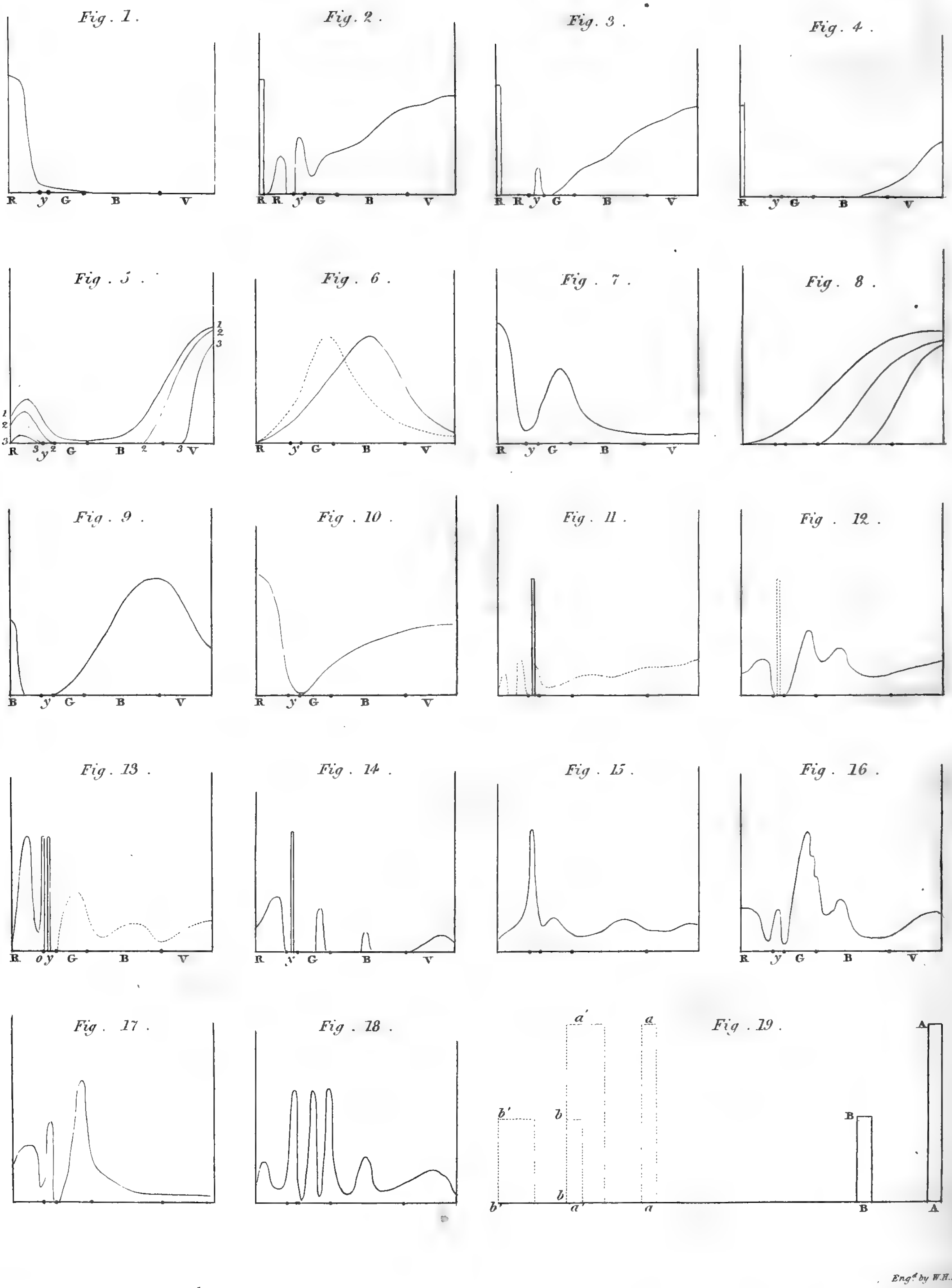
2. In the course of my experiments in 1819, on the scale of tints developed by different crystals in polarised light, having frequent occasion to measure the diameter of the rings of different

different homogeneous colours, I naturally had recourse to the prismatic spectrum; but soon finding the extreme difficulty of procuring a tolerably homogeneous ray by this means, owing to the sun's diameter, the irradiation of the sky, and the imperfections of prisms, not to speak of the mobility of the spectrum, being then unprovided with a heliostat, I began to study the resources afforded by transparent coloured media, in hopes that I might discover some, whose limits of transmission, either singly or combined, might be such as to allow the passage of rays only within very narrow limits of refrangibility. In this examination I immediately encountered the singular phenomena, noticed, I believe, first by Dr Young, of an almost total obliteration of some of the colours by certain glasses, while others intermediate between, or sharply bordering on those obliterated, appeared to be transmitted in all their brilliancy, thus producing an image (when a narrow luminous line is examined with a prism, and such a coloured glass), not consisting of a broad band of gradually varying colour, but an assemblage of more or less sharply defined coloured streaks of different breadths and colours, separated by intervals, in some cases absolutely black,—in others only feebly illuminated. This singularity gave me strong hopes of success in the object of my inquiries, and I was not wholly disappointed.

3. Among the first specimens of glass which occurred to me, were a disc of bright ruby-red glass, from an ancient window, and a quantity of deep-blue glass, with a sensible tinge of purple, which is manufactured in large quantities for sugar-basins, finger-glasses, &c., and is one of the most common of the coloured glasses. The former permitted to pass almost the whole red, and a considerable portion of the orange; while, in

PLATE XXVIII.

Engd for the Royal Soc Tran, Vol IX page 447.



Engd by W.H.Lizars.

in strong lights, a sensible quantity of yellow, and even a feeble trace of green, might be perceived. If we conceive the abscissa RV, Plate XXVIII. Fig. 1. to represent the prismatic spectrum, and erect an ordinate at every point, proportional to the number of rays, out of any given quantity, of the corresponding refrangibility the medium is capable of transmitting, its extremity will have for its *locus* a curve of the form $r\,o\,y\,g$, which, for brevity's sake, I will call the *type* of this medium; the type of a colourless medium being the straight line MN, parallel to the abscissa.

4. Let t be the thickness of any homogeneous medium, or the number of colorific molecules, of equal absorbent powers, traversed by a ray in its passage through it; and let C represent the intensity of a ray of any given refrangibility, at its first intromission, y being the ratio of its intensity, after traversing a thickness equal to unity, to its original intensity C. Then will

$$C + C' + C'' + \&c., \text{ or } S\left\{C\right\}$$

from one end of the spectrum to the other, represent the tint and intensity of the ray at its intromission, while its character, after traversing the thickness t, will be

$$C y^t + C' y'^t + C'' y''^t + \&c., = S\left\{C y^t\right\}.$$

It would appear, at first sight, that the effect of doubling or tripling the thickness of any coloured medium, would simply be to increase the depth and intensity of the tint, but not to alter its character. If a white object appear blue through a blue glass, we should expect it to appear still bluer through two, and yet more so through three such glasses. The above formula shews, however, that this is so far from being the case,

 that

that the tint of the emergent pencil is essentially dependent on the thickness of the medium, and that it is only from a knowledge of the relative values of y, y', &c. in the various parts of the spectrum, that we can say, *a priori*, whether the tint of a thick glass will retain any similarity to that of a thin one of the same kind. It is evident that, y being necessarily a fraction less than unity, the values of y^t, y'^t, &c. will all diminish, with an increase in that of t. Those terms, however, in which y is smallest, will decrease most rapidly, and, however trifling may be the difference in this respect, it is always possible to render its effect sensible on the tint, by taking t sufficiently large. Thus the water of the Lake of Geneva is indigo-blue, that of the Lake of Como emerald-green, when viewed through a considerable thickness, though colourless in small quantities. If (as is very common) the value of y should have two unequal *maxima*, in different parts of the spectrum, and if, at the same time, the greater of these should happen to correspond to a ray of feebler illuminating power than the less, the tint, in small thicknesses of the medium, will (generally speaking) be that of the lesser *maximum*, the greater vividness of these rays giving them a predominance over the others, though more numerous; but as this inequality of number increases with the increase of thickness, the feebler rays will at length begin to influence the tint, and finally obtain the predominance; thus producing, in several cases, a complete change of colour, not a little surprising to those who are ignorant of its cause. Dr THOMSON's muriated liquor (chloride of sulphur), which is yellowish-green in very small thicknesses, and bright red in considerable ones, is a case in point. A solution of sap-green presents the same phenomenon yet more strikingly. If inclosed between glass-plates slightly inclined, so as to form a thin wedge, its colour towards the edge will appear emerald-

emerald-green, and towards the back blood-red, passing in the intermediate thicknesses through a kind of livid neutral tint.

5. The blue glass above mentioned exhibits this change of tint in a very marked manner. When a piece of the thickness 0.042 inch was employed, it separated the red portion of the spectrum into two; the least refracted being a well-defined band of perfectly homogeneous and purely red light, and separated from the other red by a band of considerable breadth, and totally black. This latter red was nearly homogeneous; its tint, however, differing in no respect from the former, and being free from the slightest tinge of orange. Its place in the spectrum is such, that its most refracted limit exactly comes up to that remarkable black line which Dr WOLLASTON observed separating the red from the yellow in the solar spectrum. A small sharp black line separated this red from the yellow, which was a pretty-well defined band of great brilliancy and purity of colour, of a breadth exceeding that of the first red, and bounded on the green side by a dark, but not quite black interval. The green itself was dull, and ill defined; but the blue and violet seemed to be transmitted with very little loss. The type of this glass is as in Fig. 2.

A double thickness (0.084 in.) obliterated the second red, but left the first unimpaired. The yellow was greatly enfeebled, and somewhat reduced in breadth, and terminated on the side of the green by a black band, equal in breadth to itself. The green also was extremely diminished, but the blue less so, and the violet remained nearly as before. The curve, Fig. 3., exhibits the type of this thickness of the glass. Lastly, When a great many thicknesses of it were laid together, the extreme red and the violet only were transmitted, and the type assumed the character of Fig. 4.

The facility with which the extreme red ray is transmitted by this glass, in comparison with the rays of intermediate refrangibility, produces a change in the general hue of the glass corresponding to its thickness. In small thicknesses it appears purely blue; but as its thickness is increased, a purple tinge comes on, which becomes more and more ruddy, and, finally, passes to deep-red, a great thickness being, however, required to produce this effect.

6. On the other hand, a glass of a rich ruddy purple was found to have its type, as in Fig. 5. The curve 1 corresponding to a thickness 0.065 in.; 2 to a thickness 0.086; and 3, in which the least refrangible rays are almost entirely obliterated, to their sum. In consequence of this, the tint of the glass loses its ruddy hue, by an increase of thickness, and passes to a fine violet.

7. The extreme red light, transmitted with such facility by the glass described in Art. 6., is copiously absorbed by this. The species of light alluded to is remarkable, *first*, for its perfect homogeneity; and, *secondly*, for its position in the spectrum. When the solar spectrum received on a white paper in a darkened room, is viewed through a moderate thickness (0.08) of that glass (of Art 6.) cemented to any red glass of a tolerably pure colour, it will be seen reduced to a perfectly circular and well-defined image, of a deep-red colour. If a pin be now stuck in the *centre* of the red circle, it will be found, on removing the glass from the eye, to have been fixed in what an ordinary observer would call the *very farthest termination* of the red rays, and a mark similarly made at its circumference will appear to lie wholly without the spectrum among the dispersed light which usually hangs about its edges. In other

other words the red, thus insulated, is of too feeble an illuminating power to affect the sight in the immediate vicinity of the other more brilliant rays, and only becomes visible when they are extinguished, or greatly enfeebled. To an eye defended by such a glass, vision, through a prism with the largest refracting angle, is as sharp, and the outlines of minute objects as free from nebulosity and indistinctness, as if the rays had suffered no refraction. These characters,—the absolute homogeneity of the rays,—their situation precisely at the least refracted limit of the spectrum, and the facility with which they may be insulated, render them of peculiar importance as standards of comparison in optical experiments. I shall in future always be understood to speak of these, when I use the expression *extreme* red rays.

8. Almost analogous in its type to that of Figures 2, 3, and 4., but differing from it in a higher degree of insulation of the yellow rays, is a species common enough in ancient windows. Its tint is a blue, much less vivid than the blue glass above mentioned, and bordering rather on grey or slate colour. A thickness 0.184 in. of this glass, is sufficient to produce a very sharp termination of the yellow band on the least refrangible side, and almost to obliterate the green. The yellow portion of the spectrum is thus placed in the clearest evidence. It is of great brightness, and by no means that almost infinitesimal line which Dr Young seems to have regarded it; its breadth being nearly $\frac{1}{4}$th of the interval between the red and blue parts of the spectrum. By the aid of this glass, I have succeeded in insulating a yellow ray of considerable strength, cutting off the more refrangible end of the spectrum by a yellow or light-brown glass, and the less by a bluish-green one, and, though not quite homogeneous, having still an adhering

hering fringe of green. It is quite sufficient for experiments of ordinary delicacy.

9. It is needless to detail the numerous experiments I have made with glasses of different shades; but it may not be amiss to mention in a general way, the effect of prismatic analysis on the tints of most usual occurrence in coloured media. Red, scarlet, orange, and brown coloured media, with all the shades of yellow, such as glasses of the above-mentioned hues, Port wine, infusion of saffron, vegetable blues turned red by acids, brandy, India soy, permuriate of iron, muriate of gold, &c. &c. act by extinguishing the violet end of the spectrum with peculiar energy, and their type has the general character of Fig. 1. In consequence, they all become red by increase of thickness, and some of them (as Port wine of a good colour), may be used to insulate the extreme red in a high degree of purity and abundance.

10. Among green media, we may distinguish those in which the type has a *maximum* ordinate corresponding to some part of the green rays (as in Fig. 6.), and whose hue, in consequence, becomes more purely green by an increase of thickness. Of this kind are most green glasses, green solutions of copper, nickel, &c. These absorb both the extremities of the spectrum; the red, with greater energy, if the tint verges to blue, but the violet if to a yellow. Besides these, however, are to be remarked media in which the type has two *maxima*, one corresponding to the red, and one to the green rays, as in Fig. 7. In most of these the green *maximum* is less than the red, and in consequence the tint, on an increase of thickness, passes from green, through a dirty neutral brown, to red. Among these spurious greens, the aqueous solution of sap-green

green has already been noticed. The tincture extracted from the petals of the common red peony (*Pæonia officinalis*), by a weak solution of carbonate of potash, is a yet more striking example of the same phenomenon, to which we may add the dark-coloured liquid formed by impregnating a solution of sulphat of iron with nitrous gas, and various mixtures of red and blue, or green media. In a green solution of manganesiate of potash (*Chameleon mineral*), the maxima correspond likewise to the extreme red, and the green; but the absorbing power on these two rays being nearly equal, the change of tint does not take place. In an aqueous infusion of logwood, the type has, in like manner, two maxima, corresponding to the red and green; but the former is always predominant, and the only change of colour it undergoes by a change of thickness, is from a ruddy purple to a deep-red.

11. Among blue media we may in like manner distinguish, such as absorb the spectrum with an energy regularly increasing, from the more to the less refrangible extremity (whose type in consequence is as in Fig. 8.), and those whose types have other maxima, as in Fig. 2. Blue solutions of copper are in the former case; and the best example, perhaps, is the beautiful blue liquid produced by dissolving carbonate of copper in carbonate of ammonia, or supersaturating any cupreous salt with the ammoniacal carbonate. The extreme violet ray seems capable of penetrating through almost any thickness of this medium; and this property, joined to the unalterable nature of the solution, and the facility of its preparation, render it a valuable resource in optical experiments; and a tube of some inches in length, closed at the ends with glass-plates, and filled with this solution, is the instrument I always employ in experiments

riments on the violet end of the spectrum. I have met with no coloured glass possessing a similar character.

A solution of oxalate of nickel (free from cobalt) in ammonia, may at first sight be mistaken for the ammonio-carbonate of copper just mentioned. When set side by side with it, however, it is characterised by the greater purity of its blue, which amounts to an indigo tint, while the cupreous solution, owing to the excess of the violet rays, has a strong blush of violet. Examined with a prism, the solution of nickel is found to absorb the most refrangible red, the yellow, green, and extreme violet rays, with peculiar energy; but, what is remarkable, the extreme red rays are transmitted by it with facility, and with their usual definite character. Their illuminating power is too feeble, however, to affect the tint of the liquid, and in very great thicknesses they are absorbed, leaving only an image on the confines of the blue and violet. The type of this medium is as in Fig. 9.

12. The yellow rays are absorbed with peculiar energy by most purple media, but by none more decidedly than by a solution of archil. This liquid, in small thicknesses, is of a neutral purple hue, but becomes more ruddy by an increase of thickness, and soon passes to the deepest red. (See Fig. 10.) On the other hand, the various shades of purple, which pass on one side into rose-colour, peach-blossom, and crimson, and on the other into plum-colour and violet, arise from a *minimum* of the spectrum in the space occupied by the green rays. The various shades of purple glasses, the acid and alkaline solutions of cobalt, &c. afford examples of this *minimum*.

13. Hitherto I have supposed the illumination employed to be that of solar light, or ordinary day-light, and the above results

results are of course influenced by the peculiar character of this light, as those rays which the sun does not emit, or emits but sparingly (as in the confines of the red and yellow), cannot be found in the transmitted beam, however well disposed the medium may be to give them passage. These rays, however, may exist in light from other sources, as star-light, electrical or phosphorescent light, or that of flames, which differ extremely in their types when examined with the prism, and that in a manner the most capricious imaginable. I shall here set down a few examples of remarkable flames which I have observed.

Sulphur, when burning with its usual feeble flame, emits all the rays, but principally the violet and blue. When the inflammation is violent, however (as when a piece of sulphur is thrown into a white-hot crucible), the light emitted is perfectly homogeneous, being a pure, brilliant yellow, and of a refrangibility so strictly definite, that all the minute flickerings of its flame, seen through a prism of the largest refracting angle, appear as sharply defined, and free from nebulosity, as when viewed with the naked eye. As the violence of the inflammation abates, a faint train of green and momentary red spectra appears.

To insure a regular and violent inflammation of the sulphur, I attempted to burn it with nitre, but the definite character of the flame was now lost, other colours coming in, and, in particular, two red spectra, sharply separated from the yellow and each other, as in Fig. 11., in which the dotted curves represent the additional portions of the type arising from the nitre.

14. The flame of alcohol (a common spirit-lamp), consists of two portions,—a cone of yellow flame, inclosed in a shell or envelope of blue, but projecting above it, like an acorn from its

its cup, or, rather, like a rose-bud from its enveloping calyx. The yellow cone extends only about two-thirds of the way down; and the bottom, or purely blue portion of the flame, emits no yellow rays; its type, when examined with the prism, being as in Fig. 12., consisting of an ill-defined train of red, a bright but undefined green, with masses of blue and violet light varying in their character. The middle portion of the flame, whose light emanates at once from the blue envelope and the yellow cone, has the same type, with the addition of a bright yellow spectrum, as marked by the dotted line in Fig. 12., while the upper portion of the flame consists of light perfectly homogeneous, and corresponding to the less refrangible portion of the yellow, as denoted by the dotted line alone. Its tint is visibly more inclining to orange than that of the yellow in the solar beam, and it is extremely enfeebled by the interposition of the glass described in Art. 8., which transmits the latter so readily.

If the flame of a spirit-lamp be viewed through a glass consisting of a pale-orange and a pale-green one, cemented together, the light transmitted is homogeneous, and if inclosed in a lanthorn of such combined glass, may be used as a monochromatic lamp.

15. The tinges given to the flame of alcohol by different saline combinations are well known, but have never been described with any exactness, though some of them present remarkable peculiarities.

If muriate of strontia be the salt held in solution, the flame assumes a beautiful carmine-red colour. When viewed through a prism, with the usual precautions to diminish the angular breadth of the incident pencil, a broad, but well-defined red, and a narrow yellow image, are perceived separated

rated from each other, by a very obscure, but not wholly black space, almost equal in breadth to the red. This red, however, consists entirely of the more refrangible portion, and is extinguished by a standard glass, which transmits only the extreme red rays. The yellow image is remarkable. Narrow as it is, it is evidently bifid, being divided by a black line into two images, of tints very visibly different. The most refracted is a pure pale yellow, without any ruddy or green tinge. The least is a decided orange, equally contrasted with the yellow on the one side, and the red on the other. What is yet more remarkable is, that when this bifid image was viewed through the bright-red glass, described in Art. 3., it was rendered single, the yellow being entirely absorbed, while the orange was very little affected. At the point of the flame, the yellow image (which seems strictly homogeneous, and is quite sharply defined on both sides), terminates the spectrum; but in the lower part a faint green image is visible, and some traces of the blue and violet, becoming stronger as we approach the bottom. (See Fig. 13.)

Muriate of lime dissolved in spirits gives no such orange image. The type of this flame is as in Fig. 14. Neither does muriate of baryta or corrosive sublimate, the type of whose flames, which are very similar, is represented in Fig. 15.

The solution of muriate of copper in alcohol is of an emerald-green colour; that of the nitrate is blue. The colours of their respective flames are the reverse; the former giving a blue, and the latter a fine green flame, the types of which are given in Figures 16. and 17.

Boracic acid has often been remarked for its efficacy in communicating a green tinge to the flame of alcohol. Examined with the prism, the spectrum of this flame is seen divided into six, a feeble red, a bright yellow, two greens of the same tint,

one

one extremely faint bluish-green, and one almost evanescent violet; its type being in consequence as in Fig. 18.

It is needless to insist on the advantage that may be taken of these and similar properties of coloured flames and media, in optical researches. The power they afford of insulating rays of several species, of a refrangibility perfectly definite, and capable of being identified at all times, offers every facility for a more exact examination than has hitherto been undertaken, of the dispersive action of media on the intermediate rays, as well as for the direct determination of the dispersions of the extreme ones. A method which I have sometimes practised with success for the latter purpose, is as follows: Let two parallel slits AA, BB, the one half the length of the other, and each about two-tenths of an inch in breadth, be made in a screen, and being placed horizontally in a window, examined with a prism of known refracting angle, having its edge horizontal. The eye being defended by a thickness of blue glass (such as is described in Articles 3. and 5.), sufficient to stop the green, yellow, and most refrangible red; two images *a a*, *a′ a′*, and *b b*, *b′ b′*, of each slit are seen a red and a violet of each; the red being perfectly sharp and well defined; the violet also pretty well defined at its most refracted edge. The eye and prism being now gradually withdrawn, the violet image *a′* of the longer slit will approach the red *b* of the shorter one, and at length be seen projected upon it, (the apparent angle between the slits diminishing, while the angle of dispersion remains invariable). When arrived at such a point that (the prism being placed in a position of *minimum* deviation) the corresponding edges *a′ a′* and *b b* form one straight line, which may be hit with very considerable exactness; it must be stopped, and its distance from the slit measured. In this situation, the difference of deviation of the extreme rays, is equal to to the angle subtended by the interval between the corresponding edges AB of the slits; and this being known, the dispersive power is easily calculated. In fact, if i be the interval between the corresponding edges of the slits observed, and d their distance from the prism, A the angle of the prism, D the deviation of the extreme red rays, μ the refractive index for those rays, and p the dispersive power, we have

$$p = \frac{\partial \mu}{\mu - 1} \text{ where } \partial \mu = \frac{\frac{1}{2} i}{d} \cdot \frac{\cos\left(\frac{A + D}{2}\right)}{\sin \frac{D}{2}}$$

For example, to determine the dispersions of 8 specimens of glass, I found by this method as follows:

$\frac{1}{2} i = 0.535$						
Number, &c. of Glass.	A =	D =	μ =	d =	$\partial \mu$ =	p =
1. Flint,	39° 40′	26° 8′	1.6010	34.40	0.03849	0.06404
2. Do.	30 36	18 36	1.5780	49.76	0.03705	0.06409
3. Do.	25 5	15 10½	1.5847	61.95	0.03734	0.06386
4. Do. "Heavy,"	24 0	14 56	1.6028	61.40	0.03951	0.06555
5. Flint,	24 15	14 38	1.5847	64.08	0.03747	0.06409
6. Crown,	40 6	23 1	1.5265	58.60	0.02139	0.04063
7. Do. a different kind,	24 40	13 29½	1.5301	94.90	0.02494	0.04704
8. Plate,	24 45	13 5½	1.5133	102.30	0.02616	0.05096

These results will doubtless appear extraordinary, after all that has been written on the subject of dispersive powers. The highest value of p, for flint-glass, given in Dr BREWSTER's Table, is only 0.052, which is $\frac{1}{6}$th lower than any of these results; yet I have no doubt of the correctness of my observations. The agreement of the dispersions of the three first specimens of flint, within a 260th part of their whole quantity, while the refractive indices differ so considerably, is not a little remarkable. The prisms used were made at once, by the same artist,

artist, for another purpose, and were probably taken from the same melting pot. Meanwhile, it ought not to excite surprise, that the dispersions deduced by this method should considerably exceed all former estimates. It will be recollected, that they are founded on observations of rays situated rigorously at the extremities of the spectrum. These rays elude all ordinary observation in the solar spectrum, and are too feeble to exert any sensible influence on the colours of the edges of objects, in the usual mode of compensation. This latter, indeed, being merely comparative, assuming as known the dispersion of a standard prism, its results must be affected by all the uncertainties attending the determination of this element, which, if obtained by actual measurement of the solar spectrum, must, as I have before observed, necessarily err considerably in defect: add to which, the method of compensation, owing to the "irrationality of the coloured spaces," can only give results corresponding to the union of the two brightest and most strongly contrasted colours, which may differ considerably from those corresponding to extreme rays. The values of p for the crown and plate glass, Nos. 7. and 8., may possibly be somewhat incorrect, from the smallness of the refracting angles of the prisms used.—I have the honour to remain, dear Sir, with sincere regard, yours,

JOHN F. W. HERSCHEL.

Slough, July 24. 1822.

XXXII.

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Fig. 1.

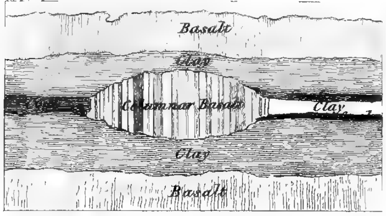


Fig. 6.

Appearance near Rideviig

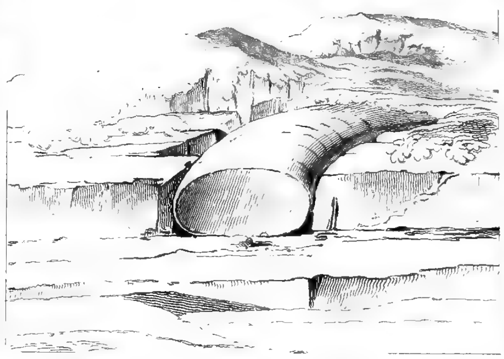
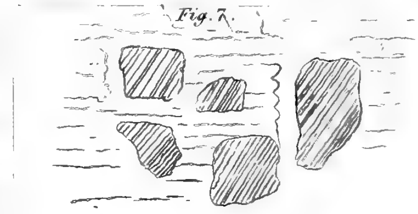
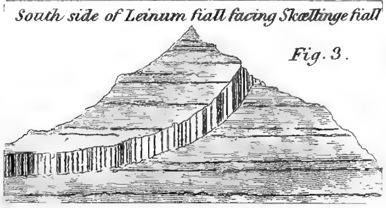


Fig. 7.



South side of Leinum fiall facing Skællinge fiall

Fig. 3.



South side of Negwa

Fig. 4.

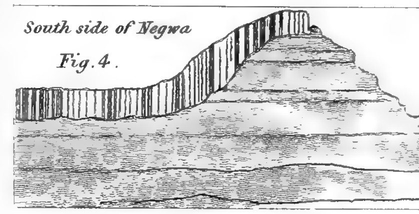


Fig. 2.

Section from North to South extending about 6 miles

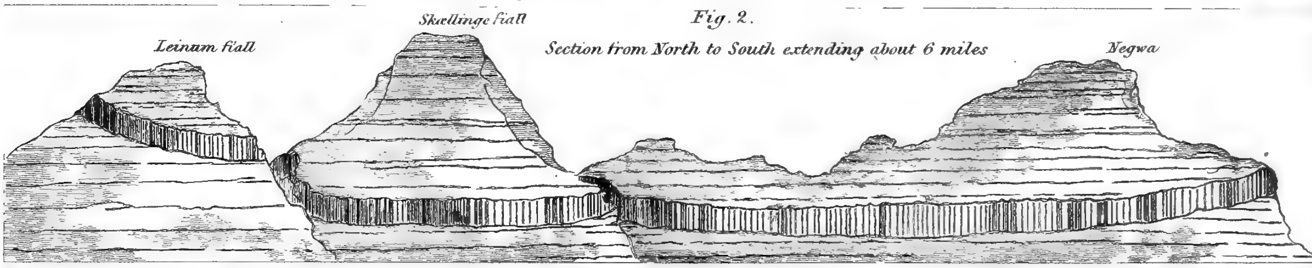


Fig. 5.

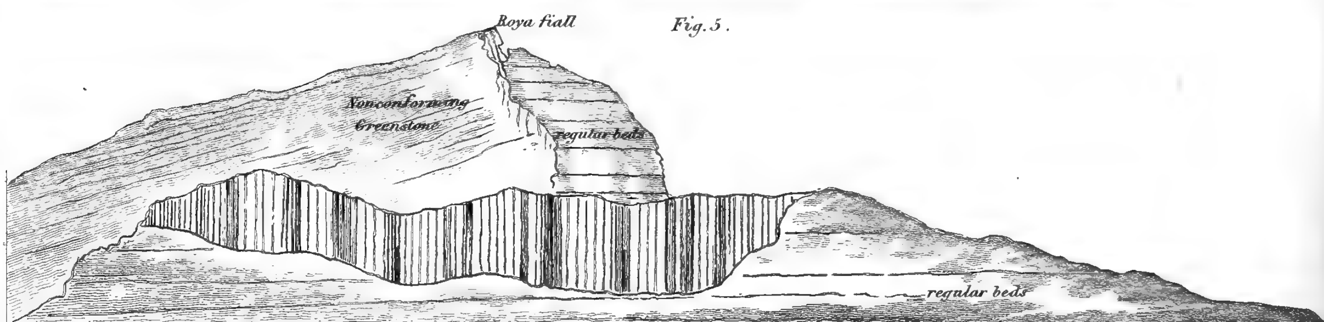


Fig. 8.

Engd. by W.H. Lizars

XXXII.—*On the Mineralogy of the Faroe Islands.* *By* W. C. Trevelyan, Esq. F. R. S. E.

(Read Nov. 18. 1822.)

My dear Sir, *Wallington, July* 22. 1822.

In compliance with your request, I send you a few notes of some of the principal geological facts I observed in Faroe, which may serve as a supplement to Sir George Mackenzie's and Mr Allan's accounts of these islands, which, as far as they extend, I found perfectly correct.

The Coal in Suderoe, which was not visited by them, is situated between two thick beds of hard clay, resembling the Clunch-clay of this country; to which succeed beds of trap. In some parts, pieces of petrified wood are very abundant in the superincumbent clay, and also nodules of ironstone; and in the coal, pieces of wood resembling charcoal. The coal has the same degree of inclination as the other beds, dipping towards the south-east, at an angle of about 4° or 5°; being the same as the dip in the other islands, excepting in part of Myggenæas, where it is much greater, being near 45°. The thickness of the coal varies from a few inches to 5 or 6 feet, and in quality much

much resembles the Scotch coal generally consumed in Edinburgh. It is but little worked, owing to the want of time, and peat being abundant, and more easily obtained. Scarcely any is taken to the other islands, as they have no vessels of sufficient size for that purpose. A few cargoes were carried some years since to Copenhagen, but not being found to answer, the exportations were discontinued.

In the map of Suderoe, Plate XXIX. Fig. 8. copied from Captain Born's chart, the spots where coal has been observed are marked with a double line, and where it is worked, with a broad black line. The section below the map shews the situation of the coal from the level of the sea to the summit of a hill south of Famoye, where it is stated to occur, though we could not perceive it, which might perhaps be owing to the superincumbent rubbish.

The coal on Myggenæas appears to be in the same position, but not of sufficient thickness to be worked. On Tindholm are also appearances of it and the clay, apparently enclosed in the trap.

At Tiodnenæs, near Qualboe, a mass of columnar Basalt is intruded into the place of the coal, which disappears near it, as shewn in Fig. 1.

The best instance of columnar basalt which we saw, is near Frodboe in Suderoe; it is well described in Landt's History of Faroe.

The marks of fusion, mentioned by Sir George Mackenzie, are very frequent, and also another appearance which may perhaps be connected with it. The upper part of many of the beds (more particularly of the amygdaloidal), is filled with small insular perpendicular cavities, as if caused by the escape of a gaseous fluid, when the rock was in a soft state. They are sometimes empty, but frequently contain zeolite.

One

One of the most remarkable beds we observed, is the Greenstone mentioned by Mr Allan (p. 255. vol. vii. *Royal Society Transactions*), which does not conform with the general position of the trap. The annexed sections, Figs. 2, 3, 4. will give a better idea of its position than can be done in words.

Another bed of the same nature appears in Osteroe, near Zellatræ, part of which is represented in the sketch Fig. 5. Royafiall is a mountain above 2000 feet high, nearly equidistant from Ore and Zellatræ. This bed, at the outcrop, is broken into columns; but, a few yards from it, the surface seems quite compact.

Near Rideviig is a curious mass or vein of basalt, Fig. 6. reposing on an amygdaloidal rock, which gave me the idea of a stream of lava. It may be traced for about 30 yards, when it is concealed by rubbish and earth. Its breadth is three yards and one-half, and thickness one yard.

Figure 7. represents a basalt lying on an amygdaloid, (the shaded part), which also appears to be intersected by numerous veins of the former, as if a number of fissures in it had been filled up by the basalt flowing over it, when in a fused state; or perhaps it is a conglomerate, or trap-tuff. I am sorry I neglected examining it more particularly.

Near Leinum Lake we obtained specimens of noble, fire and pearl Opal, in a bed of felspar-porphyry, through which they are disseminated in small nodules. They were discovered by Mr Holm of Quivig since Sir George Mackenzie's visit.

Native Copper is very frequent, though not abundant. It occurs generally in amygdaloidal rocks. In Suderoe, near Famarasund, we found it in thin plates in a bed of claystone. Some of it contains gold, also (but rarely) found separate.

I may remark, that we found compact zeolite in a stalactitic form, evidently of recent formation, and deposited from water, in the same way as stalactites of lime.

We observed some hair zeolite, which, when pressed, gave out a milky fluid.

Believe me, dear Sir, very truly yours,

W. C. TREVELYAN.

To Dr Brewster.

XXXIII.

XXXIII.—*Electro-Magnetic Experiments and Observations.* By THOMAS STEWART TRAILL, M. D. F. R. S. EDIN. & WILLIAM SCORESBY, *jun.*, Esq. F. R. S. LOND. & EDIN.

(Read May 6. 1822.)

THE interesting discoveries of OERSTED, and the subsequent researches of AMPERE, ARAGO, DAVY, and VON BUCH, which promise to throw a clearer light on the mysterious nature of Galvanism and Magnetism, induced us to undertake, and pursue conjunctly, a series of Electro-magnetic experiments. In prosecuting our inquiries in this new branch of scientific investigation, we have observed various interesting facts, some of which appeared to us new, while others did not seem to have been detailed so fully as their importance merited.

Some of our earliest experiments on this subject were performed in November 1821, with a cup of platina and slip of rolled zinc, in the manner proposed by M. M. VON BUCH *. In order to ascertain the effect produced on the needle, by both sides of the lower portion of the zinc, the whole apparatus was placed on a piece of plate-glass. With this small apparatus the electro-magnetic effect was slight, and its intensity irregular, when the proportion of the acid amounted only to $\frac{1}{30}$th or even $\frac{1}{20}$th of the liquid employed; but the needle was

very

* *Annals of Philosophy*, vol. ii. p. 282.

very sensibly affected, whenever the strength of the acid liquor in the cup was sufficient to cause such an effervescence with the zinc as to render the liquid turbid.

The most striking phenomena of this galvanic arrangement are, the different effects produced on the magnetic needle by the relative positions of the platina and zinc, in regard to the magnetic meridian, and the opposite influence of the outer and inner sides of the slip of zinc, as will be seen in the tabular results below.

1. Cup North.

1. Compass at	O.	See Pl. XXX. Fig. 1.	deflected to the			E *.
2. -	I	-	-	-		W.
3. -	*i*	-	-	-		W.
4. -	*o*	-	-	-		E.

2. Cup South.

1. Compass at	O,	deflected to	W.
2. -	I,	-	E.
3. -	*i*,	-	E.
4. -	*o*,	-	W.

3. Cup West.

1. Compass at	O,	not sensibly deflected.
2. -	I,	inversion of Poles.
3. -	*i*,	inversion of Poles.
4. -	*o*,	not sensibly deflected.

4. Cup East.

1. Compass at	O,	inversion of Poles.
2. -	I,	not sensibly deflected.
3. -	*i*,	not sensibly deflected.
4. -	*o*,	inversion of Poles.

In

* In this paper, where it is not otherwise specially indicated, the deflection, to either hand, means the deflection of the *North Pole* of the needle.

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Fig. 1.

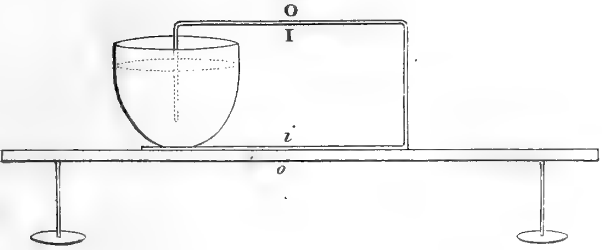


Fig. 2.

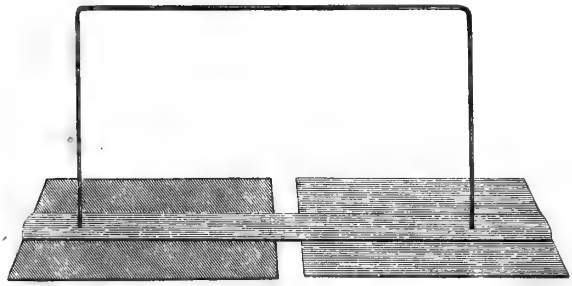


Fig. 3.

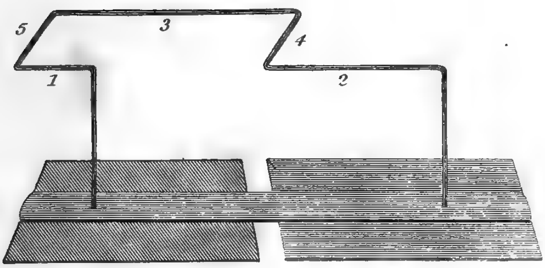


Fig. 4.

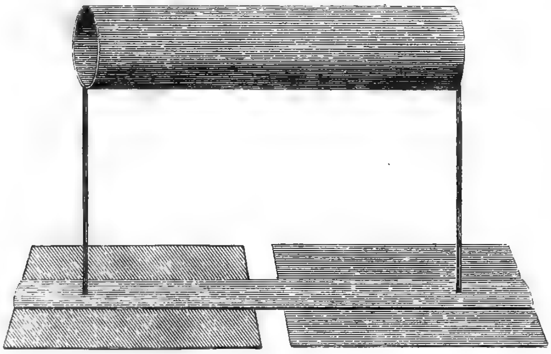


Fig. 5.

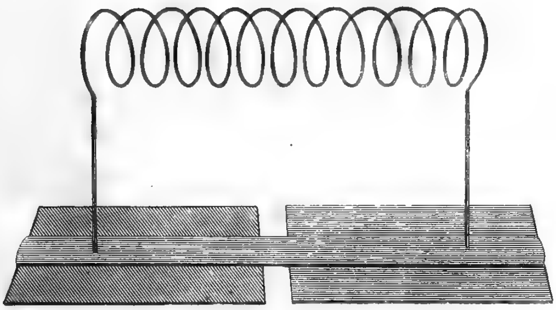


Fig. 6.

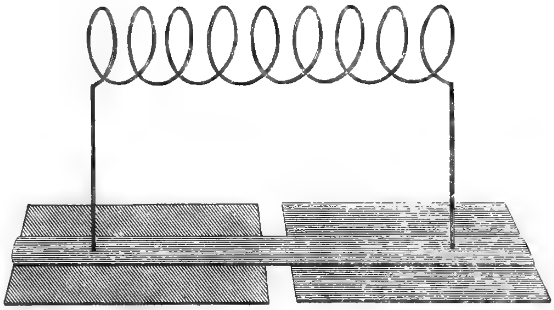


Fig. 7.

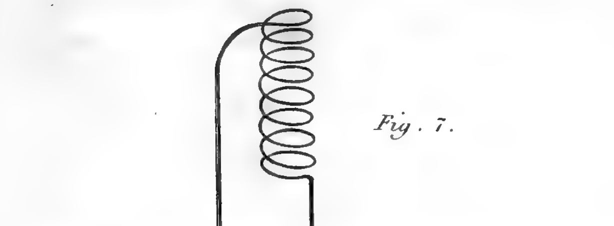
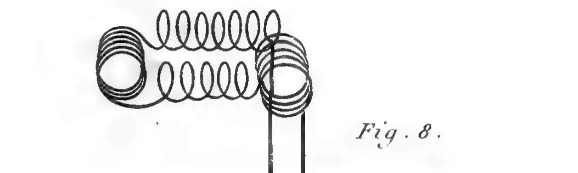


Fig. 8.



In using this apparatus, we found it necessary to change the acid frequently, otherwise the results were not so complete as stated in the 3d and 4th series, and the action on the needle appeared to be subject to capricious and sudden movements, probably produced by the unequal action of the zinc and acid. We therefore constructed another apparatus, which combines simplicity with cheapness.

It consists of two single plates of zinc and copper, 4 inches square, retained about $\frac{3}{4}$th inch apart by a slip of mahogany rivetted to them, as in Fig. 2. This, while it preserves the due position of the plates, affords a convenient support to the connecting wires or helices, which can be instantaneously changed without displacing the plates; for the ends of the wires are merely inserted into holes which perforate the wood. When experiments were to be made, the plates, thus connected, were placed in a shallow earthen-ware dish, containing the acid liquor *.

Our first experiments with this apparatus were made on 15th November, and have been many times since repeated with the same results.

Experiments with the simple connecting-wire, Fig. 2.

1. Zinc North.

1. Needle placed below the wire, deflected to the W.
2. - above - - E.

2. Zinc

* The liquid which we found most convenient, is 1 part of nitric acid with 30 parts of water, and $\frac{1}{2}$ a part of sulphuric acid. The zinc plates were made according to Messrs Silvesters' and Robson's patent, now in the hands of Messrs Philips, George and Co., about $\frac{1}{25}$ inch in thickness; the connecting wires and helices were of copper, or of brass wire, from $\frac{1}{30}$ to $\frac{1}{15}$ inch in thickness; the helices most used had a diameter of about 2 inches; and the needle employed was either a small pocket compass, with an agate cap, or a naked needle, supported on a fine point fixed at right angles on a glass rod.

2. Zinc South.

1. Needle placed below the wire, deflected to the E.
2. - above - - W.

3. Zinc West.

No sensible effect either above or below the wire.

4. Zinc East.

No sensible effect either above or below the wire.

In these experiments, there appears to be a maximum of deflection when the connecting wire is in the magnetic meridian; but when it is at right angles to that meridian, the effect is imperceptible. This, however, is evidently owing to the small portion of the connecting medium, which, in this position, can act on the needle; for when a broad piece of metal was substituted for the connecting wire, the needle was powerfully acted on, as was evident by its short oscillations; and the same thing was observed with Von Buch's apparatus above described.

In order to ascertain how far the influence of the connecting wire depended on the supposed direction of a galvanic current or currents, passing from one metal to the other, a connecting wire was bent several times at right angles, as is shewn in perspective in Fig. 3., and the following effects were observed on applying a needle to different parts of the wire, in different positions of the plates.

1. Zinc North.

When the needle was presented to those portions of the wire in the magnetic meridian 1, 2, 3, the deflection was as follows:

1. Above the wire, deflection - to W.
2. Below - - to E.

but in other parts of the wire there was no deflection.

2. Zinc

2. Zinc South.

When the needle was presented to the portions of the wire in the magnetic meridian 1, 2, 3.

1. Above the wire, deflection - to E.
2. Below - - to W.

but in other parts of the wire no sensible deflection.

3. Zinc West.

In this position there are two parts of the wire in the magnetic meridian 4, 5, which present reversed results.

1. Above that portion, number 4, deflection to E.
2. Below - - 4, - to W.

but 3. Above - - 5, - to W.

4. Below - - 5, - to E.

4. Zinc East.

In this position the influence of the portions 4 and 5 were exactly as in the last position of the zinc. At first sight the results of former experiments ought to have led us to expect a difference; but a little reflection will shew, that if these effects are produced by a current passing from the zinc to the copper, by the connecting wire, when the zinc is west, the current must pass northward through 5, and southward through 4; and in the opposite directions through both, when the zinc plate is placed to the east of the copper. This circumstance counteracts the effect of turning the plates, and the appearances agree with the result of our previous experiments, no less than with those that follow.

The phenomena of electro-magnetism appear to favour the idea of currents capable of affecting the needle differently, passing in opposite directions, and on opposite sides of the connecting wire, from the two metals forming the galvanic arrangement; and the results which we obtained with the bent wire, prove that the influence of the relative position of the zinc

zinc and copper plates, depends rather on the direction which is thus communicated to the electro-motive currents, than on the point of the compass from which they begin to flow.

Helices were substituted for the connecting wires already described. These were usually formed by bending copper-wire 10 or 12 times round a wooden cylinder. We did not find any difference in effect, whatever might be the metal of which they were made, or whether they were $\frac{1}{2}$, 1, 2, 3, or 4 inches in diameter; but we found those of two inches most convenient in our experiments. They were either *right* or *left* helices; and for one experiment we employed a helix, one-half of which was a right, and the other a left helix *.

In the following experiments, the needle was generally introduced iu the centre of the helix; but it did not alter the results, when moved about in it, provided the needle had free space to turn round.

Experiments with a Right Helix. Fig. 5.

1. Zinc North.
   Needle introduced in the axes had its poles inverted.
2. Zinc South.
   No deflection of the needle.
3. Zinc West.
   Needle deflected to the E.
4. Zinc East.
   Needle deflected to the W.

Experiments

* Those unaccustomed to such operations, find some difficulty in distinguishing between a right and a left helix; but if it be placed on one end, the spires of a *right* helix rise in the direction of the sun's diurnal course; those of a left helix in the opposite direction.

Experiments with a Left Helix. Fig. 6.

1. Zinc North.
   Needle not deflected.
2. Zinc South.
   Needle had its poles inverted.
3. Zinc West.
   Needle deflected to W.
4. Zinc East.
   Needle deflected to E.

Experiments with a Double Helix.

This helix is 6 inches in length, and 2 in diameter; it consists of 16 spires, 8 of which are in a right, and 8 in a left direction.

The needle, when placed in either end, was deflected, as in the order of the simple helices, to which it belonged. When placed in the centre of this helix, the needle only obeyed terrestrial magnetism; but the slightest deviation to either extremity produced a deflection.

Instead of the helices, we employed a thin tube of brass, Fig. 4.; but with the small apparatus no certain effects were produced. In subsequent experiments, however, with a larger galvanic arrangement, we remarked singular irregular motions of the needle in its axis, which were not easily reducible to any general law.

To increase the power of our electro-motive apparatus, without rendering it complicated, seemed desirable, as we thought that we perceived a law, respecting the action of helices, which we hoped to develope more clearly by an increase of power.

We procured a copper tray, 14 inches long by 10 inches wide, and 1 deep, AA, Fig. 7. BB is a plate of zinc, 13 inches

inches long by 9 wide, which has a short pipe of the same metal soldered to its centre, for supporting one end of the connecting wires, while the other is inserted in a similar pipe soldered to the copper-tray, as represented at C. When this apparatus was used, nothing more was necessary than to separate the zinc and copper by a few slips of window-glass, or by thick paper, and then pour the acid into the tray. The effect of changing the relative positions of the metallic plates, as in the former experiments, could be instantly produced, by moving one end of the connecting wire to either side of the copper-tray. On this account, it is the most convenient form of the apparatus, and is sufficiently powerful to give sparks, and to magnetise small sewing needles, if previously softened by heat.

With this apparatus all our former experiments were repeated, and the following are the general results which were obtained.

The effect of the simple and conducting bent wires differed only in energy from what was before observed. The deflections, when the acid was fresh, was $= 90°$ to either hand; and in those positions where there was no deflection, there was evidently very strong electro-magnetic action.

When helices were employed, we found that the needle introduced invariably arranged itself parallel to the axis of the helix, whatever might be its direction. This law was strikingly illustrated by the combination represented in Fig. 8. Here a very long left helix was employed, portions of which were bent toward the four cardinal points; and on successively introducing the needle into each, it assumed the direction of the axis of that portion of the helix; but in such a manner, that the *north* pole of the needle is always directed, so as to meet the

the supposed current, passing from the zinc toward the copper by the helices.

With right helices, the needle as invariably arranges itself in the direction of the axis of the helix; but, in this case, the *south* pole of the needle is always directed, so as to meet the current, which we have supposed to proceed from the zinc to the copper by the connecting wires.

This general statement will supersede the necessity of detailing the numerous experiments which we made to determine these laws. It is evident that the deflections of the needle, when the helices were arranged either in an east or a west direction, could never be less than 90° ; and in certain directions must have amounted to complete inversion of the poles.

The foregoing experiments were made with horizontal helices; and we conceived that it was important to ascertain the effect which an inclined, or a vertical position of the helices might produce on the needle.

With a vertical helix, as in Fig. 7., a needle, poised on a centre, dipped so much as to have its free motion destroyed: we therefore introduced a magnetic needle, suspended by a fine thread, or a fibre of raw silk. This uniformly assumed the direction of the axis of the helix, whether truly vertical, or inclined to the horizon.

In a Right Vertical Helix.

1. When the end of the helix connected with the zinc is uppermost, the N. pole is *depressed.*
2. When the end of the helix connected with the zinc is lowermost, the N. pole is *elevated.*

That is, the *south pole*, as in a horizontal right helix, is turned, to meet the supposed current proceeding from the zinc.

 In

In a Left Vertical Helix.

1. When the end of the helix connected with the zinc is uppermost, the N. pole of the needle is *elevated.*
2. When the end of the helix connected with the zinc is lowermost, the N. pole of the needle is *depressed.*

That is, the *north pole*, as in a left horizontal helix, is turned, to meet the current proceeding from the zinc.

Similar experiments were made on helices inclined at angles of 70° and 20°. The needles assumed the direction of tne axis of those helices; and the other phenomena were similar to what are above stated.

We may then reduce the influence of the interior of the helices on electro-magnetic arrangements, into two general laws.

1*st*, When a magnetic needle is introduced into such a helix, it has a tendency to assume a direction parallel to the axis of the helix.

2*d*, When the helix is a *right helix*, the *South* pole of the needle is deflected toward that part of it in connection with the zinc; and when it is a *left helix*, the *North* pole of the needle is deflected toward that part of it in immediate contact with the zinc.

In prosecuting our experiments, we had occasion to observe, that the upright wires supporting the helices, were not without their influence on the needle. When the needle approached the vertical portion of the connecting wires, there were marks of strong electro-magnetic action; but the deflections of the needle differed at each side of the wire. There is some difficulty in ascertaining the precise effects of each side of the wire, and we therefore substituted, first, a rectangular tube of copper, of the same form as the connecting wire in Fig. 2., the sides of which were about $\frac{5}{8}$ths of an inch in breadth; and afterwards a solid piece of lead, cast of the same size and shape as the

the tube. With both of these, as a connecting piece, the deflections of the needle were found to be precisely similar.

These deflections will be easiest represented by references to horizontal sections of the limbs of the connecting piece, as below.

I. Zinc North.

1. Needle applied to *s* S, deflected 90° E.
2. - - *n* S, - 90° W.
3. - - *w* S, inversion of poles.
4. - - *e* S, no deflection, but vigorous action.
5. - - *s* N, deflection 90° W.
6. - - *n* N, - 90° E.
7. - - *w* N, no deflection, but vigorous action.
8. - - *e* N, inversion of poles.

II. Zinc South.

1. Needle applied to *s* S, deflected 90° W.
2. - - *n* S, - 90° E.
3. - - *w* S, no deflection, but vigorous action.
4. - - *e* S, inversion of poles.
5. - - *s* N, deflected 90° E.
6. - - *n* N, - 90° W.
7. - - *w* N, inversion of poles.
8. - - *e* N, no deflection, but vigorous action.

Similar

Similar experiments were repeatedly made with the zinc west and east; but in both those cases, the effects of the vertical portions of the limbs were perfectly similar to those here given under II., or *Zinc South;* so that the same table will represent the action of the four sides of the vertical limbs in three positions of the zinc. When the compass is carried round one of these vertical limbs of the connecting piece, the needle makes one revolution on its centre.

We next examined the effect of the horizontal part of the rectangular connecting piece on the magnetic needle.

I. Zinc North.

1.	Needle above the horizontal part deflected	90° E.
2.	- below - -	90° W.

II. Zinc South.

1.	Needle above the horizontal part deflected	90° W.
2.	- below - -	90° E.

III. Zinc West.

1. Needle above shewed no deflection, but vigorous action.
2. - below had its poles inverted.

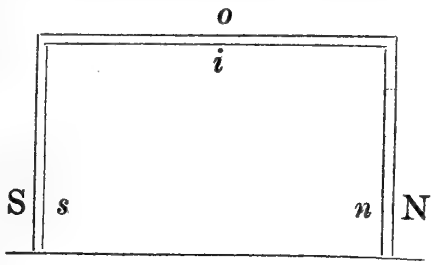
IV. Zinc East.

1. Needle above had its poles inverted.
2. - below shewed no deflection, but vigorous action.

When the needle was applied to the two perpendicular surfaces of the horizontal part, there was a difference of deflection, as it approached either the upper, or the lower surface, partaking of the effect of that surface to which the compass was approximated. The action of the upper and under surfaces of the rectangular conducting piece, when the zinc was north or south, did not differ from that of the simple connecting wire in Fig. 2.; but the breadth of these surfaces developed

veloped an effect on the needle when the zinc was west, or east, which could not be detected by using a small connecting wire.

On comparing the results obtained by using different kinds of connecting pieces, it appears, that if the needle be applied along their exterior surface, as in the direction S, *o*, N, the deflection will be the same, while the relative position of the zinc and copper are unchanged, or while the electro-motive current flows in one direction ; and if the needle be carried along the interior surfaces of the connecting piece, as in the direction *s*, *i*, *n*, the deflection will be uniformly in the opposite direction.



The thin brass cylinder Fig. 4. was then applied to the tray and plate apparatus, Fig. 7.

I. Zinc North.

1. Needle in its axis, deflected E.
2. - at its upper surface E.
3. - at its lower surface W.

II. Zinc South.

1. Needle in its axis, not at all deflected.
2. - above, deflected W.
3. - below - E.

III. Zinc West.

1. Needle in its axis not deflected, but vigorously acted on.
2. - above, not visibly acted on.
3. - below, had its poles inverted.

Zinc

IV. Zinc East.

1. Needle in its axis, deflected 90° E.
2. - above, deflected E.
3. - below, not deflected, but strongly acted on.

The sides of this cylindric tube shewed no action, except when the needle was moved toward the upper, or under part of the tube, when it partook more or less of the action peculiar to that surface.

The electro-magnetic effects of the outside of the cylindrical tube, appear to differ in no respect from those of rectangular connecting pieces, or common connecting wires. When a needle is introduced in its axis, and is deflected at all, that deflection partakes, more or less, of the direction it assumes, when applied to the upper surface of either; but the degree of deflection appears to be subject to sudden variations and irregularities, of which the cause was not always apparent. If we may be allowed the expression, it seemed as if the electro-magnetic current moved through the tube with difficulty.

Finding the outside of the tube giving such decided electro-magnetic indications, we examined the action of the outside of the helices.

Experiments with Right Helix.

I. Zinc North.

1.	Needle applied above, deflected	90°	E.
2.	- below, -	90°	W.

II. Zinc South.

1.	Needle applied above, deflected	90°	W.
2.	- below, -	90°	E.

III. Zinc

III. Zinc West.

1. Needle applied above, deflected 90° W.
2. - below, inversion of poles.

IV. Zinc East.

1. Needle applied above, deflected 90° E.
2. - below, deflected to E.; but varying a little in degree, as moved along the helix.

Experiments with Left Helix.

I. Zinc North.

1. Needle applied above, deflected 90° E.
2. - below, - 90° W.

II. Zinc South.

1. Needle applied above, deflected 90° W.
2. - below, - 90° E.

III. Zinc West.

1. Needle applied above, deflected 90° E.
2. - below, inversion of poles.

IV. Zinc East.

1. Needle applied above, deflected 90° W.
2. - below, deflected to W.; but varying a little in degree, when moved toward either end of the helix.

These experiments shew, that the reversed action of right and left helices is chiefly confined to their interior; for when the zinc is south or north, the outsides of left and right helices act similarly on the needle; when, however, the zine is west or east, the deflections of the needle are reversed in each sort of helix. The analogy also between the outsides of helices, and

and the surfaces of the horizontal part of the rectangular pieces is very close; the upper surfaces of helices, when the zinc is west or east, affording the only differences of action between helices and other connecting pieces, while a complete inversion of poles takes place at the lower sides of *all*, when the zinc is to the westward of the copper.

We beg leave to lay before the Society these details of our experiments, rather as contributions toward the materials of a theory of electro-magnetic action, than with the idea of deducing from them any speculations on the nature of this mysterious agent; yet we cannot avoid remarking, that, while the substances connecting the poles of a galvanic arrangement become real magnets, the opposite effects of their upper and under surfaces appear to favour the doctrine of two electro-magnetic currents, moving in opposite directions; and that the *Boreal Magnetism* of the interior of *Right* Helices, and the *Austral Magnetism* observed in *Left* Helices, combined with the superior energy of helices over simple wires, seem to give probability to the supposition, that the two currents have a natural tendency to pursue a course in the direction of those spirals.

XXXIV.

XXXIV.—*Conjectures on the Analogy observed in the Formation of some of the Tenses of the Greek Verb.* *By* JOHN HUNTER, LL. D. Professor of Humanity in the University of St Andrew's. Communicated by the Rev. Dr LEE, F. R. S. Ed.

(Read Jan. 20. 1823.)

THE following conjectures concerning the Analogy observed in the formation of some of the Tenses of the Greek Verb seem worthy of farther inquiry; for, if well founded, they may be useful towards establishing juster rules for the formation of the Tenses in some instances; and, particularly, they will account for certain forms of the Verb in HOMER and HESIOD, which, being apparent violations of the usual analogy, have perplexed the grammarians, and reduced them to the necessity of assuming imaginary new Presents, without authority, and for no other reason, but to account for such anomalous forms.

1. The Perfect Middle has not a middle signification; see KUSTER *de Voce Media*, sect. I. Its form, too, is active; and therefore it probably belongs to the Active Voice, which, on this supposition, becomes more regular and uniform, having

a double Preterite, as well as a double Future and Aorist. Thus,

τυπτω	τυψω	ἐτυψα	τετυφα	1. Pret.
	τυπω	ετυπον	τετυπα	2. Pret.

It is no objection to this account, that the second Preterite may sometimes be found in a middle signification; for active verbs in all languages are sometimes used as middle, the reciprocal pronoun being *conceived*, though not *expressed*. Thus μεταβαλλω in Greek, *accingo* in Latin, *prepare* in English: omnes accingunt operi,—they all prepare (themselves) for the work.

2. ο in the second Preterite, or Preterite middle, uniformly arises from ε in the Present, and from nothing else.

λεγω, λελογα—βλεπω, βεβλοπα·
λειπω, λελοιπα—πειθω, πεποιθα·

That φθειρω, μειρω, ἀγειρω, and other such verbs having a liquid before ω, make ἐφθορα, μεμορα, ἠγορα, and not μεμοιρα, ἐφθοιρα, ἠγοιρα, &c. is no exception from the rule. For all such verbs probably had of old not ει, but ε only, in the penult. Thus φθειρω seems to have been of old φθεῤῥω, whence the old or Æolic Future φθερσω. So μειρω was μεῤῥω, whence μερος pars; and the old or Æolic form ἀγεῤῥω is still to be found. In like manner, βεβολα seems, as Dr Moor has observed, to be formed, not from βαλλω, but from the old verb βελλω, whence βελος *jaculum*.

3. Although the 1st Preterite, or Perfect active, generally follows the analogy of the 1st Future, yet it sometimes, too, observes that of the 2d. Thus,

Στελλω

Στελλω makes { not ἐστελκα from στελῶ 1. Fut. / but ἐσταλκα from σταλῶ 2. Fut. }

In the same manner, τεινω, κτεινω, κειρω, σπειρω, &c. &c.

4. On the other hand, although the 2d Preterite, or Perfect middle, generally follows the analogy of the 2d Future, yet it sometimes, too, observes that of the 1st. Thus,

Στελλω makes { not ἐστηλα from σταλῶ 2. Fut. / but ἐστολὰ from στελῶ 1. Fut. }

In the same manner, τεινω, κτεινω, κειρω, σπειρω, &c.

Nay, from ε in the penult, there often arises ο in the 1st Preterite, or Perfect active. Thus, πεπομφα, λελοχα, κεκλοφα, δεδοικα, from πεμπω, λεγω, κλεπτω, δειδω, &c. And this seems of old to have been still more frequent, and to have extended also to the Passive voice. Thus, μεμορθαι, πεπορθαι, in the old or Æolic dialect from μεῤῥω (*i. e.* μειρω) and περθω.

5. In the same manner, although the 1st Aorist generally follows the analogy of the 1st Future, yet it also seems, particularly in the more early periods of the language, to have sometimes followed that of the 2d Future. Thus, χεω, ἐχεα— so εἱπα, ἠνεγκα or ἠνεικα, ἀλευαμενος, ἐκηα, &c.

Since, then, there are in the Greek Verb two Futures, and two Preterites, each of which Preterites follows the analogy of either Future; and, since there are two Aorists, and that the 1st Aorist also follows the analogy of either Future,—query,—Would it not, from these facts, be rather probable than otherwise, that the 2d Aorist should also follow the analogy of either Future; that, as from τυπῶ there is formed ἐτυπον, so from τυψω there should be formed ἐτυψον? and, if this were admitted,

admitted, would it not account for such words as *καταβησεο, ἐδυσετο, λεξεο, ὀρσεο, οἰσε, οἰσετω, ἀξε—τω*, &c., which have so much perplexed the celebrated Dr Clarke, (see Notes on Iliad, B. 35. E. 109.; I. 613.) in a manner more satisfactory than is done by the arbitrary method of imagining new Presents in —*σω*, from which these forms may be deduced: For it is only to account for such anomalous forms that these new Presents have been imagined; and the grammarians would no doubt have assumed imaginary new Presents also, to account for such 1st Aorists, as *ἐχεα, ἐκηα*, if, by so doing, these aorists could have been reduced to the usual analogy.

Now this supposition, namely, that the *2d Aorist*, as well as the 1st, follows the analogy of either Future, which is thus rendered in some degree probable, has actually taken place, at least in some instances. Thus the compounds of *τεμνω*,

ἀποτεμνω { from the 1st Future *ἀποτεμῶ* has in
the 2d Aor. Part. *ἀποτεμὼν*, as well
as from the 2d Fut. *ἀποταμῶ, ἀποταμών*.

So *ἱξον*, they came, *Il.* 23. v. 38.; *κατεβησετο, Il.* 24. v. 191., both of which follow the analogy of the first Futures, viz. *ἱξω* (from *ἱκω venio*) and *καταβησομαι*. And every person acquainted with the elements of Greek is aware, that, as *μενω* is the primary form, whence, by the common reduplication, arises, first, *μιμενω*, and then, dropping the short *ε*, by what the grammarians call *syncope*, *μιμνω*, and as *γενω* is the primary form, from whence, in like manner, is derived *γιγνω* (Latin *gigno*) and *γιγνομαι*: so *πετω* is the primary form, which, by like reduplication and syncope, gave birth to *πιπτω, cado*, from which primary form *πετω*, making in the first Future *πεσῶ*, there is formed the second Aor. *ἐπεσον* in common use; which, in so far, both illustrates and confirms the foregoing hypothesis.

The

The foregoing paper was written about thirty years ago, before either Villoison's or Heyne's editions of the Iliad were published. It may not be improper, however, to subjoin some facts contained in these two celebrated editions, together with a few observations, suggested by these facts, and tending to confirm the opinion which I had been previously led to form, of those anomalous flexions of the Greek Verb.

From the ancient Scholia, quoted by Heyne in his observations on the various readings of the Iliad, and from the large volume of Scholia published by Villoison, (as well as from those contained in Barnes's edition of the Poems of Homer, published in 1711), it seems to be clearly established, that, in the days of the Ptolemys, this form of the 2d Aorist, following the analogy of the 1st Future, was more frequent in the writings of Homer, than that of the 1st Aorist, formed upon the analogy of the same Future; and that it was the reading received and approved by the most eminent of the Alexandrian grammarians, by Zenodotus, the keeper of the Alexandrian Library, and by Aristarchus himself.

While, however, the Greek scholiasts have recorded these as the ancient and genuine forms used by Homer, they have, I suspect, greatly erred in their manner of accounting for them. After the lapse of so many centuries, these Homeric forms had, in a great measure, become obsolete *, and the other form, that of the 1st Aorist, had come into general use; and those grammarians could devise no other method of accounting

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* One instance, however, of this ancient *Homeric 2d Aorist* occurs in Theocritus, and another in Callimachus; and, perhaps, by an attentive observer, more might be found.

counting for these old and now obsolete forms, but by imagining *new Presents* in —*σω*, of which they supposed these forms to be the regular Imperfects. This manner of solving the difficulty has been implicitly followed by Eustathius, in his Greek Commentary on the Poems of Homer, and (I am sorry to be obliged to add) by my late invaluable friend Lord Monboddo; of whom, and of the *dies Attici*, now long gone by, in which I enjoyed his learned and elegant society, I never can think but with an indescribable feeling of satisfaction and regret.

If, however, we acquiesce in this solution of the difficulty, we must be content to abate somewhat of our admiration of the Greek language, which has been heretofore held to express, with the utmost clearness and precision, all the various and diversified conceptions of the human mind, even to their minutest shades of difference. Indeed, that the Greeks, or any enlightened people, should employ those forms of their Verbs as *Presents*, which were familiar to every ear as appropriate expressions of the *Future*, or, as Eustathius often expresses it, should *draw back* the *Future* to express the *Present*, is, when duly considered, a supposition in itself so unreasonable, not to say absurd, that it would require better and more conclusive evidence to support it, than has yet been produced. Besides, where was the necessity of such an innovation? what advantage was to be gained by it? The original Presents remained in common use. Why then employ the *Futures*, *δυσομαι* and *ἵξομαι*, E. G. as *Presents*, when *δυω* and *δυομαι*, and *ἱκω* and *ἱκομαι*, present forms in common use, would answer the same purpose?

There is still another consideration, to which due weight ought to be given. There is no evidence whatever, that those

Present-

Present-Futures, or *future-Presents*, in —σω and —σομαι, ever existed. They are not to be found in the Poems of Homer or Hesiod. They are not to be found in the Greek authors posterior to Homer and Hesiod; and of Greek authors prior to the age of Homer and Hesiod we know absolutely nothing.

From these considerations it seems to be evident, that the existence of these *Future-Presents* is merely a gratuitous assumption of grammarians, to account for the Homeric forms βησετο, δυσετο, &c. which they could in no other way reduce to any known analogy of formation.

This, however, the learned Dr Clarke had too much acuteness and good sense to admit; and, accordingly, we find him regarding these Presents as altogether *fictitious*. His words on the passage Ὡς αρα φωνησας, απεβησατο——*Iliad*, II. 35. are these: "Editi plurimi habent απεβησετο, a verbo *ficto* αποβησο-"μαι." And, to obviate the difficulty, he changes απεβησετο here into απεβησατο; and, when βησετο, or any of its compounds, occurs, his general practice is to substitute the form of the 1st Aorist, βησατο. But, even if it would remove the difficulty, this change is unauthorised. The other form in —ετο is attested as genuine by the Alexandrian grammarians, is supported by the Greek scholiasts, by the ancient MSS. of the highest authority, and by the early editions. In Villoison's edition of the Iliad, which bears to be an exact transcript of a MS. of the tenth century, in the Library of St Mark at Venice, the form is uniformly —ετο, except in a single instance, and in that one instance, I suspect —ατο to be an error of the press.

Dr Clarke, however, soon finds that this change of —ετο into —ατο, violent and unauthorised as it is, will not remove the

the difficulty. In the address of DIOMEDE to STHENELUS, he meets with the Imperative, καταβησεο,

Ὀρσο, πεπον, Καπανηιαδη, καταβησεο διφρε. *Iliad.* v. 109.

which he attempts to account for in this manner: "Videtur "mihi *Imperativus ex futuro deductus*, licet id non agnoscant "Grammatici; errareque eos, qui verbum hic in præsenti fin-"gunt καταβησομαι. Quanquam, analogiâ haud dissimili, per-"sæpe usurpare visus est HOMERUS verbum δυσομαι, δυσεο, "ἐδυσετο," &c. Nothing can show more strongly the difficulty which Dr CLARKE must have felt in accounting for these forms, than that he is here obliged to have recourse to another gratuitous assumption of an Imperative of the Future, a thing unheard of before; and almost to admit δυσομαι as a Present, from which to deduce ἐδυσετο as an imperfect. The fact is, that he found the authorities in favour of δυσετο and ἐδυσετο, to be so numerous, and of such weight, that he did not venture, in these examples, to change —ετο into —ατο.

Afterwards, however, he found himself obliged to abandon this hypothesis of an Imperative of the Future, as well as his original position, that these new Presents in —σω and —σομαι are imaginary; and he appears at last (he or his son, it is uncertain which) to adopt, in its full extent, the explanation given by EUSTATHIUS. That commentator, whose remarks would have been invaluable, had his taste and judgment been equal to his means of information, if I rightly understand him, has this observation on v. 154. of the 20th Book of the Odyssey: "Ὀισετε is sanctioned by a poetic rule of formation "(ποιητικῶς κανονιζεται) as the *imperfect* of the verb ὀισω, the "*Future* having *retrograded* into a *Present*. For of ὀισω the "Imperfect is ὀισον, the 3d person ὀισε, the Imperative the "same in sound, also ὀισε, of which the plural is ὀισετε."

Dr

Dr Clarke or his son adds in continuation: " Atque analogiâ " quidem haud dissimili sæpe usurpare videtur poeta verba " δυσομαι, βησομαι, βησετο, &c. Vide autem ad *Il.* ε. 109.;" (where, however, he reprobates the hypothesis of these new Presents in —σομαι.) " Occurrit eadem vox (viz. οισετε) *Il.* " γ'. 103. ό. 718. et apud Theocritum, *Idyll.* xxiv. 48. Porro " fuerunt, teste Barnesio, qui οισατε ubique legendum statue- " runt, sed nullo profectu. Nam, uti ipse annotat, occurrit " apud Homerum οισε in Imperativo, numero singulari, ubi isti " emendationi locus nullus est, &c. et apud Callimachum, " —— φερε ϛαχυν, οισε θεριϛμον. *Hymn. in Cer.* v. 137."

All the attempts, however, to account for these forms in particular Verbs are partial and unsatisfactory. As the facts to be accounted for are all similar, the true solution must be *general*, and such as will embrace them all. Whether the method which I have ventured to suggest be of this description, does not belong to me to determine. It possesses at least this indispensable requisite, that it accounts for all the phenomena in question.

It would be tedious and tiresome to enter on a particular examination of every individual verb of the kind which we are considering. It may not be improper, however, to select one example for the purpose of illustration.

There are not many verbs of more frequent occurrence in Homer than ἱκω *venio* in one or other of its parts. It is found in the present:

> Ενθεν (e Cypro) δη νυν δευρο τοδ' ΙΚΩ πηματα πασχων.
> *Od.* ρ'. 444.

and the Future ἱξομαι occurs once in Hesiod, and ten or twelve times in Homer; and, in not one of these instances, can it by any sophistry be tortured into a *present*, or forced

into

into an expression of *present time*, in the sense in which present time is generally understood. I shall note the places of occurrence, that any person may, if he chuses, examine them, and judge for himself. They are these: *Hesiod. Op. et Dies*, *v.* 477.; *Il. α.* 240.; *ζ.* 363, 502.; λ. 182.; *ο.* 505.; *ψ.* 47.; *ω.* 728. *Od. δ.* 515.; *θ.* 198.; *κ.* 276.

Ἴξομαι, the Future of ἵκω, then, must be decidedly excluded from the catalogue of new Presnts, devised by the Greek Scholiasts to account for the supposed Imperfects, so frequent in Homer. And yet a new Present ἵξω, is equally necessary in this, as in any other verb of the kind, to account for ἷξον, *they came*, the past tense, formed upon the analogy of the first Future; which, though not noticed either by Dr Clarke, or by Heyne', is no less frequent in Homer than the Future itself. Thus,

> Ἀλλ᾽ ὅτε δὴ Τροίην ΙΞΟΝ, ποταμὼ τε ῥέοντε. *Il. ε.* 773.
> *At quando jam Trojam* VENERUNT, *fluviosque labentes.*

See also, *Il. κ.* 470.; *ξ.* 433.; *φ.* 1.; *ω.* 692. *Od. γ.* 5, 31, 495.; *δ.* 1.; *ε.* 194. Hymn. in Apoll. 411. 438. 230. 278.

Nor is there a single unequivocal example of the 1st Aorist of this verb to be found in the poems either of Homer or of Hesiod, except one, viz. ἷξας, which occurs in the Hymn to Apollo, *v.* 223. In that same Hymn, however, there are no fewer than four examples of the form in -ον (ἷξον), and another still in the Hymn to Mercury, *v.* 398.

This instance of ἷξον, so frequent in Homer, may therefore be fairly admitted to be, in the language of the celebrated Bacon, an *instantia crucis*, clearly pointing out the true method of accounting for all the other Homeric Forms of the same description. If so, there will be no longer any necessity for the

gratuitous

gratuitous assumption of new Presents in -σω and -σομαι, to account for these forms, nor for supposing, with Dr Clarke, that καταβησεο is an imperative of the *Future;* nor for changing, as he has generally done, the 2d Aorists βησετο, καταβησετο, &c. into regular first Aorists in -ατο. We ought rather to restore the Homeric 2d Aorists in -ετο, recognised as the genuine readings by the Grammarians of Alexandria, and the Greek Scholiasts, and confirmed by the ancient MSS. of highest authority, and the early editions.

If the view which I have ventured to give of these Homeric Forms in -ετο be well founded, it will hardly be necessary to notice the canon of criticism attempted to be establishen by the learned Heyne, in his voluminous edition of the Iliad, as to -ετο and -ατο, and the reasons for preferring the one to the other in particular passages. See his 4th vol. p. 506. Of the futility of that attempt, every classical scholar, who will read with sufficient attention the last seventeen verses of the 3d book of the Odyssey, will be fully convinced. The learned German has adopted, without scruple or hesitation, the explanation of these Homeric Forms given by the Greek scholiasts; and, in allusion, I presume, to the difficulty felt by Dr Clarke, in admitting the existence of new Presents in -σω and -σομαι, he states his opinion, and the grounds of it, with decisive confidence, in the following words: "Esse "autem talem formam præsentis βησομαι *dubitari nequit; nam* "est v. c. Θ. 105. Αλλ' αγ' εμων οχεων επιβησΕΟ," p. 506. v. 4. And on B. v. 35. he makes the following remark, not quite consistent with itself: "Quid hoc loco intersit, non video; "nisi quod απεβησετο *antiquioris vocis* speciem habet: *nova forma* subnata, ut δυσομαι, εδυσομην, et alia." How the *nova forma* should have *antiquioris vocis speciem*, I do not clearly comprehend. But a gleam of truth will sometimes burst through the darkness of inveterate prejudice.

HISTORY OF THE SOCIETY.

LAWS

OF THE

ROYAL SOCIETY OF EDINBURGH,

ENACTED 23D MAY 1811, 26TH FEBRUARY 1820,

AND 24TH JANUARY 1823.

I.

THE ROYAL SOCIETY OF EDINBURGH shall consist of Ordinary, Foreign, and Honorary Members.

II.

Every Ordinary Member, within three months after his election, shall pay as fees of admission Three Guineas, and shall further be bound to pay annually the sum of Two Guineas, into the hands of the Treasurer.

III.

Members shall be at liberty to compound for their annual subscription, each paying according to the value of an annuity on his life, determined as in the ordinary insurance on lives.

The power of raising the admission fee and the annual subscription shall remain with the Society.

IV.

Ordinary Members, not residing in Edinburgh, and not compounding for annual subscription, shall appoint some person residing in Edinburgh, by whom the payment of the said subscription is to be made, and shall signify the same to the Treasurer.

V.

Members failing to pay their subscription for three successive years, due application having been made to them by the Treasurer, shall cease to be Members of the Society, and the legal means for recovering such arrears shall be employed.

VI.

None but Ordinary Members are to bear any office in the Society, or to vote in the choice of Members or Office-bearers, or to interfere in the patrimonial interests of the Society.

VII.

The number of Ordinary Members shall be unlimited.

VIII.

The *Ordinary* Members, upon producing an order from the TREASURER, shall hereafter be entitled to receive from the publisher, *gratis*, the Parts of the Society's Transactions which shall be published subsequent to their admission.

IX.

The Society having formerly admitted as Non-resident Members, gentlemen residing at such a distance from Edinburgh as to be unable regularly to attend the Meetings of the Society, with power to such Non-resident Members, when occasionally in Edinburgh, to be present at the Society's Meetings, and to take a part in all their inquiries and proceedings, without being subjected to any contribution for defraying the expences of the Society; it is hereby provided, that the privileges of such Non-resident Members already elected shall remain as before; but no Ordinary Members shall be chosen in future under the title

and

and with the privileges of Non-resident Members. The Members at present called Non-resident shall have an option of becoming Ordinary Members; if they decline this, they shall continue Non-resident as formerly.

X.

The *Foreign* Members shall not be subject to the Annual Contributions, nor to any Fee on admission. They shall be limited to the number of Thirty-six, and shall consist of Foreigners distinguished in Science and Literature.

XI.

The *Honorary* Members shall not be subject to the Annual Contribution, nor to any Fee on admission. They shall be limited to the number of Twenty-one, and shall consist of Gentlemen eminently distinguished in Science and Literature.

XII.

The Election of Members shall take place on the 1st Mondays of every month during the Session, at the ordinary meetings of the Society, which shall be considered as General Meetings for the Election of Members. The Election shall be by Ballot, and shall be determined by a majority of votes, provided Twenty-four Members are present, and vote.

XIII.

No person shall be proposed as an Ordinary Member, without a recommendation subscribed by *One* Ordinary Member, to the purport below*. This recommendation shall be delivered to the Secretary, and

* " A. B. a gentleman well skilled in several branches of Science (or Polite Literature, as the case may be) being to my knowledge desirous of becoming a Member of the Royal Society of Edinburgh, I hereby recommend him as deserving of that honour, and as likely to prove an useful and valuable Member.

and by him laid before the Council, and shall afterwards be read at each of three ordinary meetings of the Society, previous to the day of the election, and shall lie upon the table during that time.

XIV.

Any *Three* Members may transmit, through the Secretary to the Council, recommendations of Foreign and Honorary Members. Foreign and Honorary Members may also be proposed by the Council, and they shall be elected in the same manner as the Ordinary Members.

XV.

The Classes shall meet alternately on the first and third Mondays of every month, from November to June inclusive. It shall be competent, however, to bring matters of a Physical or Literary kind, before either Class of the Society indiscriminately. To facilitate this, one Minute-book shall be kept for both Classes; the Secretaries of the respective Classes either doing the duty alternately, or according to such agreement as they may find it convenient to make.

XVI.

The Society shall from time to time make a publication of its Transactions and Proceedings. For this purpose the Council shall select and arrange the papers which they shall deem worthy of publication in the *Transactions* of the Society, and shall superintend the printing of the same.

The Transactions shall be published in Parts or *Fasciculi*, and the expence shall be defrayed by the Society.

XVII.

There shall be elected annually for conducting the publications and regulating the private business of the Society, a Council, consisting of a President; Four Vice-Presidents, two of whom shall be resident;

a

a President for each Class of the Society; Six Counsellors for each Class; one Secretary for each; a Treasurer; a General Secretary; and a Curator of the Museum and Library.

XVIII.

The election of the Office-bearers shall be on the fourth Monday of November.

XIX.

Four Counsellors, Two from each Class, shall go out annually. They are to be taken according to the order in which they at present stand on the list of the Council.

XX.

The Treasurer shall receive and disburse the money belonging to the Society, granting the necessary receipts, and collecting the money when due.

He shall keep regular accounts of all the cash received and expended, which shall be made up and balanced annually; and at a General Meeting, to be held on the last Monday of January, he shall present the accounts for the preceding year, duly audited. At this Meeting the Treasurer shall also lay before the Society a list of all arrears due above twelve months, and the Society shall thereupon give such directions as they may find necessary for recovery thereof.

XXI.

At the General Meeting in November, a Committee of Three Members shall be chosen to audite the Treasurer's accounts, and give the necessary discharge of his intromissions.

The

The report of the examination and discharge shall be laid before the Society at the General Meeting in January, and inserted in the records.

XXII.

The General Secretary shall take down minutes of the proceedings of the General Meetings of the Society and of the Council, and shall enter them in two separate books. He shall keep a list of the Donations made to the Society, and take care that an account of such Donations be published in the Transactions of the Society. He shall, as directed by the Council, and with the assistance of the other Secretaries, superintend the publications of the Society.

XXIII.

A Register shall be kept by the Secretary, in which copies shall be inserted of all the Papers read in the Society, or abstracts of those Papers, as the Authors shall prefer; no abstract or paper, however, to be published without the consent of the Author. It shall be understood, nevertheless, that a person choosing to read a paper, but not wishing to put it into the hands of the Secretary, shall be at liberty to withdraw it, if he has beforehand signified his intention of doing so.

For the above purpose, the Secretary shall be empowered to employ a Clerk, to be paid by the Society.

XXIV.

Another register shall be kept, in which the names of the Members shall be enrolled at their admission, with the date.

XXV.

A Seal shall be prepared and used, as the Seal of the Society.

XXVI.

The Curator of the Museum and Library shall have the custody and charge of all the Books, Manuscripts, objects of Natural History, Scientific Productions, and other articles of a similar description belonging to the Society; he shall take an account of these when received, and keep a regular catalogue of the whole, which shall lie in the Hall, for the inspection of the Members.

XXVII.

All articles of the above description shall be open to the inspection of the Members, at the Hall of the Society, at such times, and under such regulations, as the Council from time to time shall appoint.

LISTS

[illegible]

XXVI

[illegible] objects [illegible]
[illegible] of a [illegible]
[illegible] an account of the [illegible]
[illegible] which shall [illegible]

XXVII

[illegible] shall be [illegible]
[illegible] at such times, [illegible]
[illegible] from time to time shall [illegible]

[illegible]

LIST

Of the OFFICE-BEARERS and MEMBERS elected since the 26th January 1818.

November 30. 1818.

OFFICE-BEARERS.

Sir JAMES HALL, Baronet, President.

Right Honourable Lord GRAY, } Vice-Presidents.
Honourable Lord GLENLEE, }

Professor PLAYFAIR, General Secretary.

JAMES BONAR, Esq. Treasurer.

THOMAS ALLAN, Esq. Keeper of the Museum and Library.

PHYSICAL CLASS.

Sir GEORGE S. MACKENZIE, Baronet, President.

Dr HOPE, Secretary.

Counsellors.

Lieutenant-Colonel IMRIE.
Professor JAMESON.
Dr BREWSTER.
JAMES JARDINE, Esq.
Hon. Captain NAPIER, R. N.
Dr A. DUNCAN *jun.*

 Literary

LITERARY CLASS.

HENRY MACKENZIE, Esq. President.

THOMAS THOMSON, Esq. Secretary.

Counsellors.

Professor DUNBAR.
Rev. Mr ALISON.
Rev. Dr JAMIESON.
Lord RESTON.
Rev. JOHN THOMSON.
Rev. Dr BRUNTON.

January 25. 1819.

MEMBERS ELECTED.

HONORARY.

The Chevalier JOSEPH HAMMER.

ORDINARY.

Right Hon. Lord JOHN CAMPBELL.
Sir JOHN HAY, Baronet.
Dr SHOOLBRED.
PATRICK FRASER TYTLER, Esq.
Colonel DAVID STEWART of Garth.
PATRICK MURRAY, Esq. of Simprim.
Dr JAMES MUTTLEBURY, Bath.
Dr THOMAS STEWART TRAILL, Liverpool.
Dr ALEXANDER KENNEDY, Edinburgh.
Mr ALEXANDER ADIE, Optician, Edinburgh.
Dr WILLIAM COUPER, Glasgow.
Dr JOHN HENNEN.
Dr JOHN VEITCH.

ANDREW

ANDREW WADDEL, Esq.
GEORGE RANKEN, Esq.
Dr MARSHALL HALL.
JOHN BORTHWICK, Esq. Advocate.
RICHARD PHILLIPS, Esq.
WILLIAM SCORESBY, Esq. *jun.*
GEORGE FORBES, Esq.

November 29. 1819.

OFFICE-BEARERS.

Sir JAMES HALL, Baronet, President.

Right Honourable Lord GRAY, }
Honourable Lord GLENLEE, } Vice-Presidents.

Dr BREWSTER, General Secretary.

JAMES BONAR, Esq. Treasurer.

THOMAS ALLAN, Esq. Curator of the Museum and Library.

PHYSICAL CLASS.

Sir G. S. MACKENZIE, Baronet, President.

ALEXANDER IRVING, Esq. Secretary.

Counsellors from the Physical Class.

JAMES JARDINE, Esq.
Hon. Captain NAPIER, R. N.
Dr A. DUNCAN, *jun.*
GILBERT LAING MEASON, Esq.
Professor RUSSELL.
Dr HOPE.

LITERARY CLASS.

HENRY MACKENZIE, Esq. President.

THOMAS THOMSON, Esq. Secretary.

Counsellors from the Literary Class.

Reverend Dr Jamieson.
Reverend John Thomson.
Reverend Dr Brunton.
Sir John Hay, Baronet,
Professor Christison.
Hon. Baron Clerk Rattray.

January 24. 1820.

MEMBERS ELECTED.

Honorary.

His Royal Highness Prince Leopold.
His Imperial Highness the Archduke John.
His Royal Highness the Archduke Maximilian.
M. le Chevalier Delambre, Perpetual Secretary of the Academy of Sciences.

Ordinary.

JamesHunter, Esq. of Thurston.
Right Honourable David Boyle, Lord Justice-Clerk.
James Keith, Esq.
Right Honourable Sir Samuel Shepherd, Bart. Lord Chief-Baron.
James Nairne, Esq.
John Colquhoun, Esq.
Henry Raeburn, Esq.
Lieutenant-Colonel M. Stewart.
Charles Babbage, Esq. F. R. S.
Thomas Guthrie Wright, Esq.

John

John F. W. Herschel, Esq. F. R. S.
Adam Anderson, Esq. A. M. Perth.
John Shank More, Esq. Advocate.
William Hall, Esq. A. M.
Dr George Augustus Borthwick, Edinburgh.
Robert Dundas, Esq. of Arniston.
Dr Samuel Hibbert.
James Robinson Scott, Esq.
Dr Robert Haldane, Professor of Mathematics, St Andrew's.

May 1. 1820.

MEMBERS ELECTED.

Honorary Members.

Count Itterburg.

Ordinary Members.

Sir John Meade, M. D.
Thomas Kinnear, Esq. Banker.
Dr William Macdonald of Ballashore.

June 1. 1820.

MEMBERS ELECTED.

Honorary Members.

Count Berthollet.

Foreign

FOREIGN MEMBERS.

M. VAUQUELIN.
M. Le Chevalier LEGENDRE.
M. BROCHANT.
Baron VON BUCH.
M. BERZELIUS.
Baron KRUSENSTERN.
M. SISMONDI.
M. POISSON.
M. PRONY.
M. GAUSS.
M. BLUMENBACH.
Count VOLTA.
M. KAUSSLER.
M. DEGERANDO.

ORDINARY MEMBERS.

JOHN HAY, Esq. younger of Hayston.
Captain ROBERT HAY, R. N.
Dr BALLINGALL.

November 27. 1820.

OFFICE-BEARERS.

Sir WALTER SCOTT, Baronet, President.

Right Honourable Lord GRAY, } Vice-Presidents.
Honourable Lord GLENLEE,

Dr BREWSTER, General Secretary.

JAMES BONAR, Esq. Treasurer.

JAMES SKENE, Esq. Curator of the Museum and Library.

PHYSICAL CLASS.

Sir GEORGE MACKENZIE, Baronet, President.

ALEXANDER IRVING, Esq. Secretary.

Counsellors

Counsellors from the Physical Class.

Dr A. DUNCAN *junior*.
GILBERT LAING MEASON, Esq.
Professor RUSSELL.
Dr HOPE.
Professor WALLACE.
HENRY JARDINE, Esq.

LITERARY CLASS.

HENRY MACKENZIE, Esq. President.
Sir WILLIAM HAMILTON, Baronet, Secretary.

Counsellors from the Literary Class.

Reverend Dr BRUNTON.
Rev. Dr DAVID RITCHIE.
Sir JOHN HAY, Baronet.
Hon. Baron CLERK RATTRAY.
Right Hon. Lord CHIEF BARON.
Reverend Mr ALISON.

AT this meeting the following resolution, moved by Dr HOPE, and seconded by Sir GEORGE MACKENZIE, Baronet, was unanimously adopted, and ordered to be transmitted to Sir JAMES HALL, Baronet.

" The Royal Society having, in compliance with the wish of Sir JAMES HALL, Baronet, refrained from again placing him at their head, beg to avail themselves of this opportunity to offer him their best thanks, both for his long and zealous services as their President, and for the numerous valuable communications with which he has enriched their Transactions, and contributed materially to maintain the reputation of the Society."

January

January 8. 1821.

MEMBERS ELECTED.

Alexander Oswald, Esq.

James Wedderburn, Esq. his Majesty's Solicitor-General.

Lieutenant-Colonel Straton, C. B., &c. &c.

Dr Graham, Professor of Botany.

February 5.

MEMBERS ELECTED.

Foreign Member.

Sir Henry Bernstein.

Ordinary Members.

A. N. Macleod, Esq. of Harris.

Sir James M. Riddell, Baronet.

Archibald Bell, Esq. Advocate.

John Clerk Maxwell, Esq.

March 5. 1821.

MEMBERS ELECTED.

Foreign Member.

J. C. Oersted, Secretary to the Royal Society of Copenhagen.

Ordinary Members.

The Right Honourable the Earl of Hopetoun, G. C. B.

John H. Wishart, Esq. President of the Royal College of Surgeons.

John

JOHN LIZARS, Esq. Surgeon, Edinburgh.

EDWARD EARL, Esq. Chairman of the Board of Customs.

JOHN CAY, Esq. Advocate.

April 2. 1821.

MEMBERS ELECTED.

ORDINARY MEMBERS.

Sir CHARLES GIESECKE.

R. K. GREVILLE, Esq.

ROBERT HAMILTON, M. D. Edinburgh.

June 4. 1821.

MEMBERS ELECTED.

ORDINARY.

ROBERT ALLAN, Esq. Surgeon.

Honourable Lord SUCCOTH.

Sir DAVID MILNE, Bart.

Colonel MAIR.

A. N. CARSON, Esq.

Dr JAMES BUCHAN.

November 26. 1821.

OFFICE-BEARERS.

Sir WALTER SCOTT, Baronet, President.

Right Honourable Lord GRAY, } Vice-Presidents.
Honourable Lord GLENLEE, }

Dr BREWSTER, General Secretary.

THOMAS ALLAN, Esq. Treasurer.

JAMES SKENE, Esq. Curator of the Museum.

PHYSICAL CLASS.

Sir GEORGE S. MACKENZIE, Baronet, President.

ALEXANDER IRVING, Esq. Secretary.

 Counsellors

Counsellors from the Physical Class.

Professor RUSSELL.
Dr HOPE.
Professor WALLACE.
HENRY JARDINE, Esq.
Sir JAMES HALL, Bart.
Dr KENNEDY.

LITERARY CLASS.

HENRY MACKENZIE, Esq. President.

Sir WILLIAM HAMILTON, Bart. Secretary.

Counsellors from the Literary Class.

Sir JOHN HAY, Bart.
Reverend Dr D. RITCHIE.
Right Hon. Lord CHIEF-BARON.
Reverend Mr ALISON.
THOMAS THOMSON, Esq.
GEORGE FORBES, Esq.

December 1. 1821.

MEMBERS ELECTED.

ORDINARY MEMBERS.

JAMES TYTLER, Esq. of Woodhouselee, W. S.

January 7. 1822.

MEMBERS ELECTED.

FOREIGN MEMBERS.

M. AMPERE, Paris.

M. VAN SWINDEN, Professor of Natural Philosophy, Amsterdam.

M. SHUMACHER, Professor of Astronomy, Copenhagen.

ORDINARY MEMBERS.

FRANCIS CHANTRY, Esq. F. R. S. Lond. &c.

EDWARD TROUGHTON, Esq. F. R. S. Lond.

JAMES SMITH, Esq. of Jordanhill.

WILLIAM BONAR, Esq.

COLIN

COLIN MACKENZIE, Esq.
Rev. H. PARR HAMILTON.

February 4. 1822.
MEMBERS ELECTED.
ORDINARY MEMBERS.

Captain J. D. BOSWALL, R. N.
Dr JOHN AITKIN, Edinburgh.
JAMES GRAHAM, Esq. Advocate.
GEORGE WALKER ARNOTT, Esq.

March 4. 1822.
MEMBERS ELECTED.
FOREIGN.
Professor MOHS of Freyberg.
ORDINARY.

Rev. JOHN LEE, M. D. Edinburgh.
JOHN AYTON, Esq. of Inchdarnie.
RICHARD SAUMAREZ, Esq.

JUNE 3. 1822.
MEMBERS ELECTED.
FOREIGN.
Baron LARREY.
ORDINARY.

JAMES SOUTH, Esq. F. R. S. London.
Lieutenant-Colonel MARTIN WHYTE.
W. F. CAMPBELL, Esq. of Shawfield, M. P.
GEORGE JOSEPH BELL, Esq. Professor of Scots Law.
Dr WILLIAM DYCE, Aberdeen.
W. C. TREVELYAN, Esq.

November 25. 1822.

OFFICE-BEARERS.

Sir Walter Scott, Baronet, President.

Right Honourable Lord Gray,
Honourable Lord Glenlee. } Vice-Presidents.

Dr Brewster, General Secretary.

Thomas Allan, Esq. Treasurer.

James Skene, Esq. Curator of the Museum.

PHYSICAL CLASS.

Sir George S. Mackenzie, Baronet, President.

Alexander Irving, Esq. Secretary.

Counsellors from the Physical Class.

Henry Jardine, Esq.
Professor Wallace.
Sir James Hall, Bart.
Dr Kennedy.
Reverend Dr Macknight.
Robert Stevenson, Esq.

LITERARY CLASS.

Henry Mackenzie, Esq. President.

Sir William Hamilton, Baronet, Secretary.

Counsellors from the Literary Class.

Right Hon. Lord Chief-Baron.
Reverend Dr David Ritchie.
Thomas Thomson, Esq.
George Forbes, Esq
Hon. Lord Meadowbank.
Professor Wilson.

December 2. 1822.

MEMBERS ELECTED.

Ordinary.

Robert Abercromby, Esq. younger of Birkenbog.
Dr Shortt, Edinburgh.
Dr Wallich, Calcutta.

February 3. 1823.

MEMBERS ELECTED.

HONORARY.

M. GOETHE.

FOREIGN MEMBERS.

M. DE CANDOLLE, Geneva.
Dr OLBERS, Bremen.
The Bishop of ZEALAND.
M. ORIANI, Milan.
M. DUPIN, Paris.
M. BRONGNIART, Paris.
The Chevalier BURG, Vienna.
M. BREISLAK, Milan.
M. BESSEL, Konigsberg.

ORDINARY MEMBERS.

Sir GEORGE WARRENDER, Baronet.
JOHN RUSSELL, Esq. W. S. Edinburgh.
JOHN SHAW STEWART, Esq.
Dr ALEXANDER HAMILTON, Edinburgh.
Dr THOMAS HARLAND, Scarborough.
JOHN DEWAR, Esq. Advocate, Edinburgh.
Right Hon. Sir WILLIAM RAE, Baronet.
Sir ROBERT DUNDAS, Baronet.
WILLIAM CADELL, Esq. of Cockenzie.
Sir WILLIAM KNEIGHTON, Baronet.
Sir EDWARD FFRENCH BROMHEAD, Bart, A. M. F. R. S.

THE

The Law of the Society, No. xvii., having been altered, in terms of the Charter, so as to authorise the election of two Resident Vice-Presidents, these two offices were filled up on the 3d February 1823, as follows:

Dr Thomas Charles Hope,	Resident
Professor Russell,	Vice-Presidents.

March 3. 1823.

MEMBERS ELECTED.

Ordinary.

Sir James Stuart of Allanbank, Baronet.

Sir Andrew Halliday, Knight, Physician to his Royal Highness the Duke of Clarence.

John Bonar, Esq. younger of Kimmerghame.

Alexander Waddell, Esq.

LIST

LIST of the Present ORDINARY MEMBERS of the ROYAL SOCIETY of EDINBURGH, in the Order of their Election.

His Majesty THE KING
Patron.

Andrew Duncan *senior*, M. D. *Professor of the Theory of Physic.*
Dr James Hamilton *senior, Physician, Edinburgh.*
Sir William Miller, Baronet, Lord Glenlee.
James Russell, Esq. *Professor of Clinical Surgery.*
Charles Stuart, M. D. *Physician, Edinburgh.*
Dugald Stewart, Esq.
The above Gentlemen were Members of the Edinburgh Philosophical Society.

1783. Sir Ilay Campbell, Bart.
Honourable Lord Hermand.
Honourable Baron Hume.
Henry Mackenzie, Esq.
Honourable Lord Bannatyne.
Reverend William Trail, LL.D. *Chancellor of St Saviour's, Connor.*
The above Gentlemen were associated with the Members of the Philosophical Society at the Institution of the Royal Society in 1783. *The Members which follow were regularly elected.*

1784. Sir James Hall, Baronet, F. R. S. Lond.
Reverend Archibald Alison, LL.B.
1785. James Hare, M. D. *late of Calcutta.*
1786. Robert Blair, M. D. *Professor of Practical Astronomy.*
1787. James Home, M. D. *Professor of the Practice of Physic.*
1788. Thomas Charles Hope, M. D. F. R. S. Lond. *Professor of Chemistry.*
Right Honourable Charles Hope, *Lord President of the Court of Session.*
1790. William Farquharson, M. D. *Surgeon, Edinburgh.*
1792. Andrew Coventry, M. D. *Professor of Agriculture.*
1793. Sir Alexander Muir Mackenzie, Bart. *of Delvin.*

1795. The very Reverend Dr George Husband Baird, *Principal of the University.*
Robert Hamilton, Esq. *Professor of Public Law.*
1796. General Dirom of Mount Annan, F. R. S., Lond.
Reverend Sir Henry Moncreiff Wellwood, Bart.
The Honourable Baron Sir Patrick Murray, Baronet.
Andrew Berry, M. D. *Edinburgh.*
1797. Andrew Duncan *junior*, M. D. *Professor of Materia Medica.*
1798. Alexander Monro, M. D. *Professor of Anatomy, &c.*
Right Honourable Sir John Sinclair, Bart.
1799. Reverend Thomas Macknight, D. D.
Honourable Lord Robertson.
Sir George Mackenzie, Baronet, F. R. S. Lond.
Robert Jameson, Esq. *Professor of Natural History.*
1800. Sir William Arbuthnot, Bart.
Gilbert Innes, Esq. *of Stow.*
Sir Walter Scott, Baronet, *of Abbotsford.*
Reverend Andrew Bell.
Colonel W. Robertson Macdonald,
1803. Reverend John Jamieson, D. D.
Thomas Telford, Esq. *Civil Engineer.*
James Bryce, Esq. *Surgeon, Edinburgh.*
Reverend Dr Andrew Brown, *Professor of Rhetoric.*
1804. William Wallace, Esq. *Professor of Mathematics.*
General Vyse.
Sir William Forbes, Bart. *of Pitsligo.*
Alexander Irving, Esq. *Professor of Civil Law.*
1805. Thomas Allan, Esq. F. R. S. Lond.
Thomas Thomson, M. D. F. R. S. Lond. *Professor of Chemistry, Glasgow.*
1806. Robert Ferguson, Esq. *of Raith*, F. R. S. Lond.
George Bell, Esq. *Surgeon, Edinburgh.*
George Dunbar, Esq. *Professor of Greek.*
1807. Sir James Montgomery, Baronet, *of Stanhope*, M. P.
John Barclay, M. D. *Lecturer on Anatomy, &c.*
John Leslie, Esq. *Professor of Natural Philosophy.*
John Campbell, Esq. *of Carbrook.*
Thomas Thomson, Esq. *Advocate.*
William Fraser Tytler, Esq. *Advocate.*
1808. James Wardrop, Esq. *Surgeon Extraordinary to his Majesty.*
David Brewster, LL.D. F.R.S. Lond.
1810. Reverend Dr William Ritchie, *Professor of Divinity.*
1811. Charles Bell, Esq. *Surgeon, London.*
Alexander Nimmo, Esq. *Civil Engineer.*

1811. Reverend Andrew Stewart, M.D. *Blantyre.*
Reverend David Ritchie, D.D. *Professor of Logic.*
His Excellency Sir Thomas Brisbane, K. C. B. *Governor of New South Wales.*
1812. Right Honourable Lord Gray, F.R.S. Lond.
General Dyce.
John Thomson, M. D. *Physician, Edinburgh.*
James Jardine, Esq. *Civil Engineer.*
Captain Basil Hall, R. N. F. R. S. Lond.
J. G. Children, Esq. F. R. S. Lond.
Alexander Gillespie, Esq. *Surgeon, Edinburgh.*
W. A. Cadell, Esq. F. R. S. Lond.
Macvey Napier, Esq. F. R. S. Lond.
James Millar, Esq. *Professor of Humanity.*
Sir George Clerk, Bart. M. P. and F. R. S. Lond.
Daniel Ellis, Esq.
1813. William Sommerville, M. D. F. R. S. Lond.
James Hare, *jun.* M. D. *late of Calcutta.*
Henry Davidson, M. D. *Physician in Edinburgh.*
1814. Henry Jardine, Esq. *King's Remembrancer in Exchequer.*
Patrick Neill, Esq. *Secretary to the Wernerian and Horticultural Societies.*
Right Honourable Lord Viscount Arbuthnot.
Reverend John Thomson, *Duddingston.*
Reverend John Fleming, D. D. *Flisk.*
John Cheyne, M. D. *Physician, Dublin.*
Sir James Mackintosh, Knight, M. P.
Lieut.-Colonel Tytler.
Reverend Alexander Brunton, D. D. *Professor of Oriental Languages.*
Professor George Glennie, *Marischall College, Aberdeen.*
1815. Gilbert Laing Meason, Esq. *of Lindertis.*
Robert Stevenson, Esq. *Civil Engineer.*
Sir Thomas Dick Lauder, Bart. *of Fountainhall.*
John Yule, M. D. *Physician in Edinburgh.*
Henry Home Drummond, Esq. *of Blair-Drummond,* M. P.
Charles Granville Stewart Menteath, Esq. *of Closeburn.*
William Thomas Brande, Esq. F. R. S. Lond. and *Professor of Chemistry in the Royal Institution.*
1816. Major Thomas Colby, *Royal Engineers.*
Leonard Horner, Esq. F. R. S. Lond.
Henry Colebrooke, Esq.
Reverend George Cook, D. D. *Laurencekirk.*

Right Honourable William Adam, *Lord Chief Commissioner.*
John Fullerton, Esq. *Advocate.*
Thomas Jackson, LL.D. *Professor of Natural Philosophy, St Andrew's.*
John Robison, Esq.
Hugh Murray, Esq.
1817. The Honourable Baron Clerk Rattray.
Right Honourable the Earl of Wemyss and March.
Francis Hamilton, M. D. F. R. S. and F. A. S. Lond.
John Wilson, Esq. *Professor of Moral Philosophy.*
Honourable Lord Meadowbank.
John Fleming, M. D. *late of Calcutta.*
James Hamilton Dickson, M. D. *Clifton.*
William P. Alison, M. D. *Professor of the Theory of Physic.*
James Skene, Esq. *of Rubislaw.*
John Howel, M. D.
Reverend Robert Morehead, *Edinburgh.*
Robert Bald, Esq. *Civil Engineer.*
Thomas Sivright, Esq. *of Meggetland.*
1818. William Richardson, M. D. *Physician, Harrowgate.*
Honourable Captain William Napier *of Merchiston, R. N.*
Harry William Carter, M. B. *Oxford.*
Patrick Miller, M. D. *Exeter.*
John Craig, Esq. *Edinburgh.*
John Watson, M. D.
Captain Thomas Brown, F. L. S.
John Hope, Esq. *His Majesty's Solicitor-General.*
Major James Alston *of Auchenard.*
William Ferguson, M. D. *Windsor.*
Sir William Hamilton, Bart. *Professor of Civil History.*
1819. Right Honourable Lord John Campbell, F. R. S. Lond. and M. R. I.
Sir John Hay, Bart. *of Smithfield and Hayston.*
Dr Shoolbred, *Calcutta.*
Patrick Fraser Tytler, Esq. *Advocate.*
Colonel David Stewart *of Garth.*
Patrick Murray, Esq. *of Simprim.*
James Muttlebury, M. D. *Bath.*
Thomas Stewart Traill, M. D. *Liverpool.*
Alexander Kennedy, M. D. *Physician, Edinburgh.*
Mr Alexander Adie, *Optician, Edinburgh.*
William Couper, M. D. *Glasgow.*

John Hennen, M. D.
John Veitch, M. D.
Andrew Waddel, Esq. *Hermitage Hill.*
Marshall Hall, M. D. *Nottingham,*
John Borthwick, Esq. *Advocate.*
Richard Phillips, Esq. *London.*
William Scoresby, Esq. *jun. Liverpool.*
George Forbes, Esq. *Edinburgh.*
1820. James Hunter, Esq. *of Thurston.*
Right Honourable David Boyle, *Lord Justice-Clerk.*
James Keith, Esq. *Surgeon, Edinburgh.*
Right Honourable Sir Samuel Shepherd, *Lord Chief-Baron.*
James Nairne, Esq. W. S. *Edinburgh.*
John Colquhoun, Esq. *Advocate.*
Sir Henry Raeburn, Knight.
Lieutenant-Colonel M. Stewart.
Charles Babbage, Esq. F. R. S. Lond.
Thomas Guthrie Wright, Esq. *Auditor of the Court of Session.*
John F. W. Herschel, Esq. F. R. S. Lond.
Adam Anderson, Esq. A. M. *Rector of the Academy, Perth.*
John Shank More, Esq. *Advocate.*
William Hall, Esq. A. M.
Dr George Augustus Borthwick, *Surgeon, Edinburgh.*
Robert Dundas, Esq. *of Arniston.*
Samuel Hibbert, M. D. *Edinburgh.*
Rev. Robert Haldane, D. D. *Principal of St Mary's College, St Andrew's.*
Sir John Meade, M. D. *Weymouth.*
Thomas Kinnear, Esq. *Edinburgh.*
Dr William Macdonald *of Ballyshear.*
John Hay, Esq. *younger of Smithfield and Hayston.*
Captain Robert Hay, R. N.
George Ballingall, M. D. *Professor of Military Surgery.*
1821. Lieutenant-Colonel Straton, C. B., &c. &c.
Robert Graham, M. D. *Professor of Botany.*
A. N. Macleod, Esq. *of Harris.*
Sir James M. Riddell, Bart. *of Ardnamurchan.*
Archibald Bell, Esq. *Advocate.*
John Clerk Maxwell, Esq. *Advocate.*
The Right Honourable the Earl of Hopetoun, G. C. B.
John H. Wishart, Esq. *Surgeon, Edinburgh.*
John Lizars, Esq. *Surgeon, Edinburgh.*

Edward Earl, Esq. *Chairman of the Board of Customs.*
John Cay, Esq. *Advocate.*
Sir Charles Giesèçké, *Professor of Mineralogy to the Dublin Society.*
Robert Kaye Greville, Esq. *Edinburgh.*
Robert Hamilton, M. D. *Edinburgh.*
Robert Allan, Esq. *Surgeon, Edinburgh.*
Honourable Lord Succoth.
Sir David Milne, Bart.
Colonel Mair, *Deputy-Governor of Fort George.*
A. N. Carson, Esq. *Rector of the High School.*
James Buchan, M. D. *Physician, Edinburgh.*
James Tytler, Esq. *of Woodhouselee, W. S.*
1822. Francis Chantry, Esq. F. R. S. Lond. &c.
Edward Troughton, Esq. F. R. S. London, &c.
James Smith, Esq. *of Jordanhill.*
William Bonar, Esq. *Edinburgh.*
Colin Mackenzie, Esq. *Deputy Keeper of the Signet.*
Rev. H. Parr Hamilton, *Cambridge.*
Captain J. D. Boswall, R. N. *of Wardie.*
Dr John Aitkin, *Physician, Edinburgh.*
James Graham, Esq. *Advocate.*
George A. Walker Arnott, Esq. *Advocate.*
Rev. John Lee, M. D. *Edinburgh.*
John Ayton, Esq. *of Inchdarnie.*
Richard Saumarez, Esq.
James South, Esq. F. R. S. Lond.
Lieutenant-Colonel Martin Whyte, *Edinburgh.*
Walter Frederick Campbell, Esq. *of Shawfield,* M. P.
George Joseph Bell, Esq. *Professor of Scots Law.*
Dr William Dyce, *Aberdeen.*
W. C. Trevelyan, Esq. *Wallington.*
Robert Abercromby, Esq. *younger of Birkenbog.*
Dr Shortt, *Edinburgh.*
Dr Wallich, *Calcutta.*
1823. The Right Honourable Sir George Warrender, Bart. *of Lochend.*
John Russell, Esq. W. S. *Edinburgh.*
John Shaw Stewart, Esq. *Advocate.*
Alexander Hamilton, M. D. *Physician, Edinburgh.*
Thomas Harland, M. D. *Physician, Scarborough.*
John Dewar, Esq. *Advocate, Edinburgh.*
Right Honourable Sir William Rae, Bart. *of St Catharine's, Lord Advocate.*
Sir Robert Dundas, Bart.

William Cadell, Esq. *of Cockenzie.*
Sir William Knighton, Bart.
Sir Edward French Bromhead, Bart. A. M. F. R. S. Lond., *Thurlsby Hall.*
Sir James Stuart, Bart. *of Allanbank.*
Sir Andrew Halliday, Knight, *Physician to His Royal Highness the Duke of Clarence.*
John Bonar, Esq. *younger of Kimmerghame.*
Alexander Waddell, Esq.

LIST

LIST of NON-RESIDENT and FOREIGN MEMBERS, elected under the Old Laws.

Sir Gilbert Blane, M. D. F. R. S. London.
John Hunter, LL. D. *Professor of Humanity, St Andrew's.*
George Jardine, A. M. *Professor of Logic, Glasgow.*
John Rogerson, M. D. *of Wamphray.*
Right Honourable the Earl of Morton, K. E.
Right Honourable the Earl of Dundonald.
Right Honourable Sir Robert Liston, Bart.
The Most Noble the Marquis of Lothian, K. T.
Mr Jefferson.
M. Le Chevalier, *Paris.*
Dr S. L. Mitchill, *New York.*
Right Honourable Thomas Wallace, Esq. *of Carlton Hall.*
Reverend Thomas Somerville, D. D. *Jedburgh.*
John Gillies, LL.D. *Historiographer to his Majesty.*
Robert Freer, M. D. *Professor of the Theory and Practice of Physic, Glasgow.*
M. A. Pictet, *Geneva.*
M. P. Prevost, *Geneva.*
Rev. Walter Fisher, *Cranston.*
Reverend Bishop Gleig, *Stirling.*
Charles Hatchett, Esq. F. R. S. Lond.
Major Rennel, F. R. S. Lond.
Sir Henry Stuart, Bart. *of Allanton.*
Matthew Baillie, M. D. *London.*
Sir William Blizzard, M. D. F. R. S. London.
Thomas Blizzard, Esq.
Sir William Ousely, Bart.
The Right Honourable the Earl of Traquair.
Sir William Drummond, Bart. *of Logie-Almond.*
Sir John Macgregor, M.D.
Richard Chenevix, Esq. F. R. S. Lond.
Right Honourable Lord Glenbervie.
Richard Griffiths, Esq. *Civil Engineer.*

LIST of HONORARY and FOREIGN MEMBERS, *elected under the New Laws.*

HONORARY.

The Marquis Laplace, *Member of the Institute of France.*
Baron Cuvier, *Secretary to the Institute of France.*
M. Humboldt, *Member of the Institute of France.*
Sir Humphry Davy, Bart. P. R. S. Lond.
M. Gay Lussac, *Member of the Institute of France.*
M. Biot, *Member* of *the Institute of France.*
M. Arago, *Member of the Institute of France.*
His Royal Highness Prince Leopold.
His Royal Highness the Archduke Maximilian.
Count Itterburg.

The above Members were elected before the new class of Foreign Members was established.

His Imperial Highness the Archduke John.
M. Le Chevalier Joseph Hammer.
M. Goethé.

FOREIGN.

M. Le Chevalier Legendre, *Member of the Institute of France.*
M. Poisson, *Member of the Institute of France.*
M. Vauquelin, *Member of the Institute of France.*
M. Prony, *Member of the Institute of France.*
M. Brochant, *Member of the Institute of France.*
Baron Leopold Von Buch, *Berlin.*
M. Gauss, *Professor of Mathematics, Göttingen.*
M. Blumenbach, *Professor of Natural History, Göttingen.*
Jacob Berzelius, M. D. F. R. S. Lond. *Professor of Chemistry, Stockholm.*
Count Volta, *Como.*
M. J. C. L. Simonde de Sismondi.
Baron Degerando.

Baron Krusenstern, *Member of the Academy of Sciences at St Petersburg.*
M. Oersted, *Secretary to the Royal Society of Copenhagen.*
M. Ampere, *Member of the Institute of France.*
M. Van Swinden, *Professor of Natural Philosophy, Amsterdam.*
M. Shumacher, *Professor of Astronomy at Copenhagen.*
M. Mohs, *Professor of Mineralogy at Freyberg.*
M. Kaussler, *St Petersburg.*
David Hosack, M. D. F. R. S. *New York.*
Nathaniel Bowditch, Esq. *Salem, Massachusets.*
Baron Larrey, *Member of the Institute of France.*
Sir Henry Bernstein, *Professor of Oriental Literature in the University of Berlin.*
M. De Candolle, *Geneva.*
Dr Olbers, *Bremen.*
The Bishop of Zealand, *Copenhagen.*
M. Oriani, *Milan.*
M. Dupin, *Member of the Institute of France.*
M. Brongniart, *Member of the Institute of France.*
The Chevalier Burg, *Vienna.*
M. Breislak, *Milan.*
M. Bessel, *Konigsberg.*

LIST

LIST *of Deceased Members from* 1799 *to March* 1. 1823,—*Continued from Vol. IV. p.* 37. *

1799.

Nov. 15. Rev. Dr Thomas Robertson, Dalmeny.
26. Dr Joseph Black.
Commissioner Edgar.

1800.

Nov. 5. Mr Jesse Ramsden.
10. Baron Gordon.
Dec. 27. Dr Hugh Blair.
Jan. 7. William Tait, Esq.
William Hall, Esq.
Alex. John Alexander, Esq.

1801.

Andrew Lumsden, Esq.
Dr Richard Pulteney.
June 19. Lord Stonefield.

1803.

Jan. 6. John Macgowan, Esq.
Mar. 13. General Fletcher.
Apr. 2. Sir James Montgomery, Bart. Lord Chief-Baron.
6. Sir William Hamilton, Bart.
19. John Grieve, Esq.
May 15. Robert Kennedy, M. D.
Aug. 18. Dr Beattie.
Mr J. Lindsay, Jamaica.
Nov. 5. Robert Arbuthnot, Esq.
J. Robertson, Register-Office.
Dec. 28. Professor Baron, St Andrew's.
31. Rev. Dr Walker.

1805.

Jan. 30. Professor John Robison, LL.D.
Aug. 28. Rev. Dr Carlyle.
Dec. 7. Professor John Hill, LL.D.

1806.

April 4. Benjamin Bell, Esq.
Nov. 10. Sir William Forbes, Bart.
Dec. 8. Professor Andrew Dalzell.

1807.

Mar. 22. John Morthland, Esq.
May 25. Professor Nicolas Vilant.
Aug. 30. Mathew Guthrie, M. D. St Petersburg.

1808.

Jan. 28. Dr James Finlayson, Professor of Logic.
Aug. 23. Rev. Dr Alex. Small, Dundee.
Sept. 4. John Home, Esq.
Oct. 15. Dr James Anderson.

1809.

Feb. 17. Dr John Hunter.
Mar. 5. Right Hon. The Earl of Dunmore.
Apr. 22. Rev. Dr Andrew Hunter, Professor of Divinity.
May 8. Dr Alexander Hunter.
22. Dr Hugh Macleod.
Aug. 3. Dr Andrew Mackay.
17. Matthew Boulton, Esq.

* This List is very imperfect, in consequence of no record of Deceased Members having been kept; but it contains the names of most of those Members who contributed to the prosperity of the Society.

Aug. 29. General Robert Melville.
Jan. 25. Caleb Whiteford, Esq.

1810.

Aug. 6. Dr James Anderson.
Oct. 28. Honourable Lord Cullen.
Bartholomew Parr, M.D. Exeter.
Dec. 15. James Flint, M.D. St Andrew's.
18. Sir James Grant, Bart.

1811.

Feb. 3. Dr John Rutherford.
9. Rev. Dr Maskelyne.
Mar. 23. Sir William Nairne, (Lord Dunsinnan).
May 10. Dr Anderson, St Vincent's.
20. Lord President Blair.
29. Right Hon. Lord Viscount Melville.
Sept. 8. P. Simon Pallas, M. D.
Dec. 7. John Burnet, Esq.

1812.

Mar. 1. Dr Maxwell Garthshore.
May 10. John Clerk, Esq. of Eldin.
June 1. Richard Kirwan, Esq.
11. Rev. Dr William Moodie, Professor of Oriental Languages.

1813.

Jan. 5. The Hon. Alexander Fraser Tytler, Lord Woodhouselee.
April 10. M. Le Comte Lagrange.
15. Rev. Alex. Murray, D. D.
July 8. Honourable Lord Craig.

1814.

Right Hon. The Earl of Minto.
Aug. 6. Rev. Walter Young, D. D.
Aug. Count Rumford.

1815.

Jan. 11. Right Hon. Lord Seaforth.
Jan. 14. William Creech, Esq.
Feb. 19. Dr William Roxburgh.

1816.

Feb. 22. Dr Adam Ferguson.
May 29. Right Hon. James Earl of Hopetoun.
June 14. Honourable Alan Maconochie, Lord Meadowbank.

1817.

May 30. Dr William Saunders.
June 30. James Glenie, Esq. F. R. S. Lond.
June 30. Professor Werner of Freyberg.
Sep. 3. James Byres, Esq.
Sept. 18. Dr Wells.
Oct. 2. Dr Alexander Monro.

1818.

Jan. 24. Robert Beatson, LL.D.
June 14. Dr John Gordon.
June 19. Patrick Brydone, Esq.
Aug. 30. Robert Wilson, Esq.
Dec. 12. Sir John Henderson, Bart.

1819.

Feb. 14. Professor William Ogilvie.
17. George Ranken, Esq.
26. Alexander Keith, Esq.
April 19. Right Hon. Lord Webb Seymour.
May 26. Rev. Principal Playfair.
June 17. Lord Chief-Baron Dundas.
24. Sir George Buchan-Hepburn, Bart.
July 20. Professor Playfair.
Aug. 18. Adam Rolland, Esq.
25. James Watt, Esq.

Sept. 19. Dr William Wright.
Dec. 15. Dr Daniel Rutherford.
Dec. 19. Rev. Principal Hill.

1820.

April 1. Right Hon. the Earl of Selkirk.
April 2. Dr Thomas Brown.
June 19. Honourable Baron Norton.
20. Sir Joseph Banks, Bart.
June 22. Dr John Murray.
25. Professor Christison.
Nov. 13. Lieutenant-Colonel Imrie.
18. Professor John Young.

1821.

Mar. 25. James Bonar, Esq.
April 2. Dr James Gregory.
12. Alexander Oswald, Esq.
July 9. William Douglas, Esq.
Aug. 29. James Robinson Scott, F. L. S.
June 18. Professor Cleghorn.
Oct. 4. John Rennie, Esq.

1822.

Mar. 27. Sir Alexander Boswell, Bart.
The Abbé Haüy.
Aug. 19. M. Le Chevalier Delambre.
Sept. 30. Hay Donaldson, Esq. W. S.
Oct. 19. Tho. Mackenzie, Esq. of Applecross, M. P.
Nov. 7. James Wedderburn, Esq. His Majesty's Solicitor-General.
Nov. 10. Dr Patrick Copland.

1823.

Jan. 19. Dr Henry Dewar.
Feb. 10. Charles Hutton, LL.D., F. R. S.

PRESENTS received by the ROYAL SOCIETY of EDINBURGH since 1811.

1812.	PRESENTS.	DONORS.
Mar. 2.	American Mineralogical Journal, Nos. 1st, 2d, and 3d. Edited by Dr Bruce.	Dr Bruce.
	Inquisitionum ad Capellam Domini Regis Retornatarum, &c. Abbreviatio, in 3 volumes folio.	The Commissioners of Public Records.
1813.		
Jan. 18.	Memoirs of the Wernerian Natural History Society of Edinburgh, vol. 1st.	The Wernerian Natural History Society.
	On the Mineralogy of the Vicinity of Dublin, London, 1812, by W. Fitton, M. D.	Dr Fitton.
	Reports on the General Management of Arable Lands, by Robert Kerr, M. D.	Dr Robert Kerr.
	Agricultural Report of Berwickshire, by Robert Kerr, M. D.	Dr Robert Kerr.
Apr. 5.	Report respecting the supply of Water to the City of Edinburgh.	Thomas Allan, Esq.
	Du Calorique Rayonnante, par M. P. Prevost.	M. P. Prevost.
Apr. 19.	A Collection of specimens of Flints.	Thomas Allan, Esq.
May 3.	On Scottish Gardens and Orchards, by Patrick Neill, Esq.	Patrick Neill, Esq.
17.	Memoirs of the Literary and Philosophical Society of Manchester, vol. 2d of the 2d series.	The Literary and Philosophical Society of Manchester.
	Agricultural Report of Berwickshire, and Sketch of a general Report respecting the Agriculture of Scotland, by Mr Kerr.	The Author.
31.	The Head and Horns of a large Animal of the Ox kind, found in a moss near Dunse.	Mr Watson of Dunse.
Nov. 1.	Transactions of the Royal Society of London, part 2d for 1811, vol. for 1812, and part 1st for 1813.	The Royal Society of London.
	Transactions of the Philosophical Society of Manchester, vol 2d of the new series.	The Philosophical Society of Manchester.
	Journal des Mines, from July 1811 to June 1812.	Thomas Allan, Esq.

	PRESENTS.	DONORS.
1814.		
Apr. 4.	Translation of Daubuisson's account of the Basalts of Saxony, by Mr Neill.	Patrick Neill, Esq.
18.	Treatise on New Philosophical Instruments, by Dr Brewster.	Dr Brewster.
	Werner's Nomenclature of Colours, with additions, by Mr Patrick Syme, Edinburgh, 1821.	Mr Blackwood.
Nov. 7.	Mémoires de l'Academie Imperiale des Sciences de St Petersburg, vols. 1st, 2d, and 3d.	The Royal Academy of Sciences of St Petersburgh.
	Memoirs of the Wernerian Natural History Society, vol. 2d. part 1st.	The Wernerian Natural History Society.
	Account of the Life and Writings of Dr Robert Simson, by the Rev. Dr Trail.	Rev. Dr Trail.
20.	The Transactions of the Royal Danish Society, from 1781 to 1808, 5 vols. 4to.	Sir George S. Mackenzie, Baronet.
	Transactions of the Royal Society of Copenhagen, vols. 2d, 3d, 4th, and 5th, 4to. from 1783 to 1799.	Sir George S. Mackenzie, Baronet.
	The Transactions of the Geological Society of London, vols. 1st and 2d.	The Geological Society of London.
Dec. 19.	A Drawing and Description of a remarkable Petrifaction found near Ardrossan.	The Earl of Eglinton.
	Treatise on the Diuretic Properties of the Pyrola umbellata, by Dr Somerville.	Dr Somerville.
1815.		
Feb. 20.	List of Mineralogical Synonimes and Analyses, by Thomas Allan, Esq.	Thomas Allan, Esq.
	Notitia Collectionis Vermium.	From the Museum of Natural History at Vienna.
Mar. 20.	Mémoires de l'Academie Imperiale des Sciences de St Petersburg, vol. 4th.	The Royal Academy of Sciences of St Petersburgh.
Nov. 6.	A Collection of Minerals.	Captain Basil Hall.
	An Account of a Stone which fell from the Atmosphere near Bombay, translated from the Persian.	Captain Basil Hall.
	The Acts of the Parliament of Scotland, vols. 2d and 3d.	Commissioners of the Public Records.
	Registrum Magni Sigilli Scotiæ.	Commissioners of the Publi Records.
	Reports of the Pestilential Disorder in Andalusia, by Sir James Fellowes, M. D. Lond. 1815.	Sir James Fellowes, M. D.
Dec. 4.	The Materia Medica of Hindostan, 1 vol. 4to. Madras, 1813.	Dr Ainslie.
	The Hunterian Oration, by Sir William Blizzard, Knight.	Sir William Blizzard.
18.	The Transactions of the Literary and Philosophical Society of New York, vol. 1st. 4to.	The Literary and Philosophical Society of New York.

	PRESENTS.	DONORS
	Elegiorum Sepulchralium Edinensium delectus.	Dr Duncan *sen.*
	Wood's General Conchology, 1 vol. 8vo, London, 1815.	Mr Wood.
1816.		
Jan. 8.	The American Medical and Philosophical Register, 3 volumes.	Drs Hosack and Francis, the Editors.
	Recherches sur l'Acide Prussique, par M. Gay Lussac, Paris, 1815.	M. Gay Lussac.
Apr. 15.	A Treatise on Universal Grammar, drawn up for the Edinburgh Encyclopædia, by Dr Henry Dewar.	Dr Henry Dewar.
May 20.	The Koran in Arabic.	General Macleod of Macleod.
27.	Treatise on Dew, by Dr Wells, second edition.	Dr Wells.
Nov. 17.	The Transactions of the Geological Society of London, vol. 3d.	The Geological Society of London.
	The Map of Cornwall, Devonshire, and Isle of Wight, published by the Board of Ordnance.	Captain Colby.
	Asiatic Researches, vol. 12th.	The Asiatic Society of Calcutta.
1817.		
Jan. 20.	The Transactions of the Geological Society of London, part 1st of vol. 4th.	The Geological Society of London.
	The Acts of the Parliaments of Scotland, vol. 4th.	The Commissioners of Public Records.
Feb. 3.	Developement de Geometrie, with the report of the Institute upon it.	M. Dupin.
	Examen des Operations et des Travaux de Cæsar.	M. Dupin.
17.	Two gold coins, one of King James the First, and the other of King James the Second.	The Barons of Exchequer.
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	On the Vital Functions and Internal Diseases, 1 vol. 8vo. Lond. 1817, by A. P. Wilson Philip, M. D.	Dr Wilson Philip.
	Transactions of the Linnean Society, vol 11th.	The Linnean Society.
1818.		
Jan. 12.	The Philosophical Transactions for 1817, part 2d.	The Royal Society of London.

1818.	PRESENTS.	DONORS.
Jan. 19.	A Report of a Committee of the Linnean Society of New England, relative to a large marine animal.	The Linnean Society of Boston.
Feb. 2.	The Ordnance Map, No. 7.	Captain Colby.
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Mar. 2.	Observations Entomologiques.	M. Bonelli of Turin.
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Dec. 7.	Histoire du Passage des Alpes, par De Luc.	M. P. Prevost.
21.	Deux Traités de Physique Mecanique, par M. Pierre Prevost.	M. P. Prevost.
	Histoire du Passage des Alpes par Annibal, by J. A. Deluc.	M. J. A. Deluc.
	Several Mathematical Tracts, by Mr Nathaniel Bowditch.	Mr Bowditch.
1819.		
Feb. 15.	Memoirs of the American Academy of Arts and Sciences at Boston, part 1st of vol. 4th.	The American Academy of Arts and Sciences at Boston.
Mar. 15.	Essay on the external application of Vapour to the human frame, by Professor Aldini.	Professor Aldini.
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	A sketch of the Economy of Man, by Dr Nicholl of Ludlow, 1 vol. 8vo.	Dr Nicholl.
	Flora Batava, No. 53, 54, 55.	His Majesty the King of the Netherlands.
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	Specimens of Native Hydrate of Magnesia, found in Shetland, and described in the Transactions, vol. 9th, p. 239.	Dr Samuel Hibbert.
	Sculptures of Indian Idols, described in the Transactions, vol. 9th, p. 381.	Francis Simpson, Esq.
	Essai Historique sur les Services et les Travaux scientifiques de Gaspard Monge.	M. Dupin.
	Silliman's American Journal of Science, Nos. 1st, 2d and 3d.	Thomas Allan, Esq.
20.	Transactions of the Linnean Society, vol. 12th.	The Linnean Society.
1820.		
Jan. 17.	The Acts of the Scottish Parliament, vol. 6th.	The Commissioners of the Public Resords.
Feb. 7.	A Treatise on Physical Astronomy, by Mr Robert Kerr of Douglas, Isle of Man.	Mr Robert Kerr.
Apr. 3.	Histoire Naturelle et Medicale de Casses, par L. Theod. Fred. Colladon, 4to, Montpellier, 1816.	Dr Colladon.
June 5.	A specimen of Sandstone from Craigleith Quarry, near Edinburgh, exhibiting a vegetable impression of the Palm tribe, with rudiments of buds or flowers.	Thomas Allan, Esq.
	The Acts of the Parliaments of Scotland, vol. 7th.	The Commissioners of the Public Records.
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	Memoirs of the Royal Academy of Sciences at Turin, 20 vols.	The Royal Academy of Sciences at Turin.
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	Voyages dans la Grande Bretagne, 2 vols. 4to., par M. Dupin.	M. Dupin.
	Progrès des Sciences et des Artes de la Marine Française, depuis la paix, par M. Dupin. Paris, 1820.	M. Dupin.
	Essai Geologique sur l'Ecosse, par Dr A. Boué.	Dr A. Boué.
	Visiteur des Pauvres, et Programme de cours de Droit Publique, par M. Degerando.	M. Degerando.
	Mémoire sur la combinaison de l'oxigène avec l'eau, par M. Thenard.	M. Thenard.
20.	Flora Batava, No. 56.	His Majesty the King of the Netherlands.
Nov. 20.	Characters of the classes, orders, genera and species of Minerals, by M. Frederick Mohs.	M. Frederick Mohs.
	The Acts of the Parliament of Scotland, vol. 8th.	Commissioners of the Public Records.
1821.		
Jan. 8.	An Essay on subjects connected with Taste, by Sir G. S. Mackenzie, Bart.	Sir G. S. Mackenzie, Bart.
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	Flora Batava, No. 58.	His Majesty the King of the Netherlands.
June 4.	Transactions of the Cambridge Philosophical Society, part 1st of vol. 1st.	The Cambridge Philosophical Society.
	Astronomische Hulfstaflen, for 1821, by Professor Schumacher of Copenhagen.	Professor Schumacher.
	Transactions of the Historical and Literary Committee of the American Philosophical Society.	The American Philosophical Society.
	Heckewelder's Narrative of the Missions of the United Brethren among the Delaware and Mohegan Indians.	The American Philosophical Society.
Nov. 5.	Memoirs of the Institute of France since 1810, 13 vols.	The Institute of France.
	Flora Batava, No. 59.	His Majesty the King of the Netherlands.
	Acta Literaria Societatis Rheno-Trajectinæ, 4 vols. Utrecht, 1793,—1803.	The Literary and Scientific Society of Utrecht.
	Essays and Tracts printed by the Society of Sciences of Utrecht, 9 parts.	The Literary and Scientific Society of Utrecht.
	Transactions of the Literary and Scientific Society of Utrecht, in Dutch, 9 vols. 1781–1803.	The Literary and Scientific Society of Utrecht.
	Disquisitio de Decompositione Acidi Carbonici in Vegetatione, Richardi Van Rees, præmio ornata, Utrecht 1818.	M. Van Rees.
	Oratio de vitanda, in Astronomiæ studio, fingendi temeritate, et Cœli Observatione quam diligentissime instituenda, Gerardi Moll.	Prof. Moll of Utrecht.
	Histoire de l'Astronomie Ancienne, 2 vols. par M. Delambre.	M. le Chevalier Delambre.
	Histoire de l'Astronomie du Moyen Age, 1 vol. par M. Delambre.	M. le Chevalier Delambre.
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	Asiatic Researches, vol. 13th.	The Asiatic Society.
	A Sanscrit Manuscript.	James Macpherson, Esq. of Belleville.
1822. Jan. 21.	Transactions of the Society of Arts, 35 vols.	The Society of Arts.
	Description of the Shetland Islands, by Dr Hibbert.	Dr Hibbert.

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Register of the Thermometer and of Springs, for 1821, kept at Thurston, East Lothian.	James Hunter, Esq. of Thurston.

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	Register of the Barometer, Thermometer, and of Springs, for 1821, kept at Inchbonny, Roxburghshire.	Mr James Veitch, Inchbonny.
Feb. 18.	Transactions of the Society of Arts, vol. 39th.	The Society of Arts.
May 6.	Specimens of Osseous Breccia, found near Rosia, in Gibraltar.	Lieutenant Macniven, 26th Regiment.
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	Tracts on Vaults and Bridges, by Mr Samuel Ware, London, 1822.	Mr Samuel Ware.
	Berzelius on the Blowpipe, translated by J. G. Children, Esq.	J. G. Children, Esq.
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	Transactions of the Horticultural Society of London, vols. 1st, 2d, 3d, and 4th.	The Horticultural Society of London.
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	Sur l'Origine de Cremation, (a translation of Dr Jamieson's paper in the *Edinburgh Transactions*, vol. 8th.)	Rev. Dr Jamieson.
	Introductory Discourse delivered to the Leeds Philosophical and Literary Society, by C. T. Turner Thackrah, Esq.	The Leeds Philosophical and Literary Society.
Nov. 18.	Journal of the Barometer, Thermometer, and Weather, kept at Faroe, from June 1. 1781 to September 6. 1782, translated from the original manuscript of Svaboe's Account of Faroe, vol. 3d, in the Royal Library of Copenhagen, by W. C. Trevelyan, Esq. F. R. S. E.	W. C. Trevelyan, Esq.
	Register of the Barometer and Weather, copied from a Journal kept at Thorshaven, in Faroe, chiefly by Captain Katen, Commandant in Faroe, during the years 1795, 6, 7, 8, 9.	W. C. Trevelyan, Esq.
	Journal of the Barometer, Sympiesometer, and Thermometer, kept at Faroe, from June 7. to October 18. 1821, by W. C. Trevelyan, Esq.	W. C. Trevelyan, Esq.
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	Series of Specimens of Flints from Warwickshire.	Edward Grimes, Esq. R. N.
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	Treatise on Optics in the Edinburgh Encyclopædia.	Dr Brewster.

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	Meteorological Journal, kept at Abbotsford, Roxburghshire, for 1822.	Sir Walter Scott, Bart.
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	Memoirs of the Wernerian Natural History Society, vol. 3d.	The Wernerian Natural History Society.
	Lettre adressée à la Societé Asiatique de Paris, par M. Louis De L'or, Paris 1823.	The Author.
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	Register of the Thermometer and Springs for 1822, kept at Hermitage Hill, Leith.	Alexander Waddel, Esq.
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	Register of the Thermometer, with the Temperature of Springs, and of the Tweed, for 1822, kept at Tweedsmuir in Peeblesshire.	Mr William Fairlie.
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	Asiatic Researches, vol. 14th Calcutta, 1822.	From the Asiatic Society of Calcutta.
	Register of the Thermometer for 1822, kept at Thirlestane, Selkirkshire.	Hon. Capt. Napier, R. N.
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