XI. *An Account of Observations, made by Lord WEBB SEYMOUR and Professor PLAYFAIR, upon some Geological Appearances in Glen Tilt, and the adjacent Country. Drawn up by Lord WEBB SEYMOUR.*

(Read May 16. 1814.)

1. **T**HE river Tilt is a principal branch of the Tay, which rises on the borders of Aberdeenshire, and runs towards the south-west, through the north-eastern part of the county of Perth. A portion of the valley along its course, for about ten miles above Blair of Atholl, is called *Glen Tilt*.

2. The adjacent country presents the common character of the Highlands. It is mountainous and rugged, and the surface, except in the lower parts of the valleys, is chiefly covered with heath. Peat-moss frequently occurs. The rock beneath consists entirely of those substances, which belong either to the *Primitive Formation*, or the *Overlying Primitive Formation*, of WERNER, and of which the stratified part is by Dr HUTTON denominated *Primary*. This account is warranted by all the observations which have been made upon these mountains; and their general aspect furnishes a confident inference for the whole. To the north and north-east, the mountains about the head of the river Dee, two or three of which are little inferior

in height to Ben Nevis *, are said to be mostly of granite ; and, it is probable, that either granite, or substances akin to it, occur in many places between these mountains and Glen Tilt. From the south-east, round by the south, to west, there is little room to doubt that the rock is almost wholly stratified, and that its chief components are gneiss, mica-slate, granular limestone, and granular quartz, with their intermediate gradations. This opinion was supported by our own observations, at the Pass of Killicranky, a few miles to the south-east of Blair, where there is a fine transverse section of the strata, and by others upon the rocks in the channels of the Garry and the Bruar, to the west and north-west of Blair. Without dwelling upon these †, I shall enter upon a detailed description of what appears nearer Blair, and proceed with it up Glen Tilt ‡.

3. In

* Their height is about 4000 feet ; that of Cairngorm, one of the highest, is 4060.

† See Note A, at the end of the paper.

‡ The minute details, which continually occur in the following pages, must, to most readers, appear tedious and useless. It is necessary, therefore, to mention, that Glen Tilt was the first scene, in which Dr HUTTON met with what he considered as a confirmation of his views, respecting the relations that subsist between granite and the strata adjacent to it ; and, in the controversy that has since prevailed, between his followers and those of WERNER, the former have insisted much upon the phenomena in this Glen, while the latter have repelled their arguments by a very different account of the structure of the rocks, and of the substances that compose them. It became of importance, therefore, to ascertain the facts more precisely. With this intention, Mr PLAYFAIR and myself passed some days in examining Glen Tilt, in the autumn of 1807 ; and I returned again, for a short time, in 1808. In my description, I have endeavoured to avoid the language of theory as much as possible. When any thing has been noticed which is trivial, and does not immediately bear upon the main question, it
will

3. In the immediate neighbourhood of Blair, the river Tilt, and the small stream of the Banavie, which runs through the Duke of Atholl's pleasure-grounds, afford, each of them, a deep section of the rock, and shew that it is almost wholly formed of strata. The slight examination which we gave to these, led us to conclude, that they consist, for the most part, of granular quartz, mica-slate, hornblende-slate, and granular limestone. An observation made with an instrument for the purpose *, upon the strata by the side of the Tilt, not far above its junction with the Garry, determined the stretch to be about N. 60° E. ; and another upon the strata in the bed of the Banavie gave N. 58° E. This near coincidence must, however, be regarded as accidental ; for the position of these strata is varied by many inflexions of their planes, especially on the banks of the Tilt. The dip is every where southerly, at an angle which varies considerably, but is commonly small for
primary

will be remembered, I hope, that the occasion called for a statement of the *whole case* ; and, besides, while the mere outlines of theory are still under discussion, it seems expedient, in describing phenomena which strongly affect any single point of importance, to enter largely into the concomitant circumstances ; since it is impossible to foresee what may, or may not, become subservient to a more precise determination of the truth.

* This instrument was a *Clinometer*, in its earliest form, without the brass plate. Though it was by no means so accurate as the improved one, the observations may, in general, be considered as within a few degrees of the truth. Some error may occasionally have arisen, from the surface of the rock being rather uneven, or from its not being quite parallel to the plane of stratification. For a more convenient comparison of the various positions of the strata, the bearing of the line of stretch is, throughout, indicated by the number of degrees east of north. As the line of dip is always at right angles to that of the stretch, it was thought sufficient to mark on which side the depression lay, by mentioning that of the four, or of the eight, principal points of the compass, which was nearest to its bearing.

primary strata. Where observed by the side of the Tilt, it was between 20° and 30° ; in the bed of the Banavie, it was 32° .

4. On the western bank of the Tilt, between two and three miles above its junction with the Garry, we observed some sienite in a scar, by the side of a walk through the Duke's plantations; and in another, not far from it, some gneiss. The soil that covered the neighbouring ground, prevented us from ascertaining the geological relations of the sienite. The gneiss is singular for having its component substances so disposed, that the structure of the stone bears no marks of stratification; but its structure differs from that of granite, in being less perfectly granular, and less highly crystallised.

5. The strata in the bed of the Banavie, a little below a bridge, that crosses it about a mile above Blair, are cut by a vein, or dyke, of felspar-porphry. The felspar base is chiefly of a red colour, but partly also grey. The vein is vertical, and about ten feet broad*.

6. There is a good road carried up Glen Tilt, as far as Forest Lodge, one of the Duke of Atholl's hunting-boxes, nearly seven miles from Blair. This road, after crossing two or three small streams, in the beds of which there is mica-slate, descends, about the end of the second mile, to the side of the river. There is here a bridge, called Gilbert's Bridge, and about fifty yards below it, we found in the channel gneiss, interstratified with granular limestone. From the bridge the road follows the bottom of the valley, and being often carried along the bank of the river, affords good opportunities of examining
the

* Dr HUTTON mentions, (in a manuscript intended for his third volume, and never published) that he found several dykes, both of grey and red porphyry, in the course of this stream.

the rocks, which the violence of the stream has exposed in many parts of the channel. The substances of which they consisted, to a point rather more than a mile and a quarter below Forest Lodge, and marked by the letter A in the map* (Plate XXI.), and the plan of the river (Plate XVI.), were, as far as we observed them, gneiss, mica-slate, and granular limestone.

7. On the west side of the valley, between Gilbert's Bridge and the opening of Glen Merk, a great quantity of fragments, brought down by torrents from the steep bank of the mountain, consisted chiefly of mica-slate; though there were among them a few small ones of sienite. Mica-slate may, therefore, be inferred to be the prevailing rock on this side, and some strata of it, near the brow of the declivity, were distinguishable in the bed of a torrent, even from a distance. Strata of mica-slate occur also at the falls of the Merk, near its junction with the Tilt. Farther up, on the same side of the valley, where the road crosses the Criny, that stream flows over some beds of granular quartz.

8. On the eastern side of the valley, we often found granular limestone near the road, between Gilbert's Bridge, and another about two miles farther up, called Gow's Bridge; and a quarter of a mile beyond this, limestone is visible from a distance, in a scar on the same side, and three or four hundred feet above the bed of the river.

9. Through all this part of the Glen, the stretch and dip of the strata are tolerably uniform. In four observations † made between a point a little below Gilbert's Bridge, and Gow's Bridge,

* The outline of the map is copied from STOBIE's Map of Perthshire. An attempt has been made to give a better representation of the mountains near Glen Tilt; some names have been added, and others have been differently spelt, with a view of conveying the Gaelic pronunciation more distinctly.

† An observation at the falls of the Merk is included.

Bridge, the two extremes of the stretch were N. 38° E., and N. 51° E., and the angle of dip, which was southerly, varied from 26° to 38° . As far as the eye could judge, we had no reason to suppose that the irregularity any where exceeded these limits.

10. Fifty yards below Gow's Bridge, the strata, which are here of mica-slate, are cut by a vein of greenstone-porphyry. The imbedded crystals of felspar are few and small, and the base is very minutely crystallised, containing, in the place of hornblende, what seems to be common actinolite; but this distinction is, perhaps, of little consequence, since HAUY has been induced to unite these two substances under the same species, on account of their agreement, both in the structure of the crystal, and in chemical composition, as proved by the analyses of VAUQUELIN. The vein is about ten feet thick, and dips westward at a large angle.

11. At the point A, the rocks in the bed of the river undergo a material change, and for upwards of three miles, they consist in some places of sienite, and in others of primary strata; and sometimes they exhibit masses of gneiss, granular limestone, granular quartz, hornblende-slate, and other materials of primary strata, interspersed among unstratified masses of sienite. An idea of the irregular succession of the stratified and unstratified masses may be derived from the plan*, which includes the course of the river between this point and a bridge above Forest Lodge. Appearances of the same kind occur for a mile and a half farther up.

12. In

* This plan was laid down, by taking bearings with the compass along the bank of the river, according to its changes of direction and by pacing the distances. The length of a certain number of paces was determined by measurement.

12. In some of these rocks, the sienite is seen in contact with various materials of the primary strata, and it was our particular object, to examine the phenomena in such cases. But, before I enter upon a detailed account of them, it may be of use to give a general sketch of this part of the valley.

13. Glen Tilt, for about two miles below Forest Lodge, and for three miles above it, to the junction of the River Chlochan, runs nearly in a straight line, in the direction of N. from 46° to 48° E., and therefore not far from N. E. and S. W.

14. The elevation of this part of the valley is considerable. According to General Roy's measurement, the lawn at Blair is 425 feet above the level of the sea; and Mr PLAYFAIR's observations with the barometer, indicated the difference of level between Blair and Forest Lodge to be about 400 feet. At the time of these observations, the barometer was falling, and the result is consequently too great; but after allowing for any probable error in excess on this account, the height of Forest Lodge above the sea can hardly be estimated at less than 700 feet.

15. The bottom of the valley is narrow, rarely exceeding a furlong in breadth, and generally much less. The lowest banks of the mountains rise on either side with very steep declivities; on the south-east, to the height of from 600 to 800 feet above the river; on the north-west, to between 1000 and 1200 feet. They are not cut by any lateral valleys; except, that on the south-east side, two or three deep ravines, descending from the sides of Ben y Gloe, join Glen Tilt between Glen Chlochan and Forest Lodge; and on the north-west side, a mile and a half above the Lodge, a brook, called the Crochie*, has deeply indented the ridge of the mountain,

VOL. VII. P. II.

R r

tain,

* This stream is called in the country Auld Crochie. *Auld* signifies *brook* in Gaelic.

tain, though it has still to find its way by a succession of falls to the bottom of Glen Tilt. Towards the upper end of the valley, the breadth of it is contracted to that of the river, and the declivities are lower.

16. To the south-east of Forest Lodge, the lowest steep of the mountain is succeeded by a more gradual ascent to the top of Cairn Toorchie, which is from 1500 to 1800 feet above the valley. Beyond this, after a small intervening descent, an easy slope leads to the top of Cairn Kin Callum, one of the three broad summits of Ben y Gloe, the highest ridge in this neighbourhood. Cairn Gowar, the most lofty of the three, was ascertained by General ROY to be 3650 feet above the level of the sea, and Cairn Kin Callum cannot be much lower. The third summit is Cairn Leea, which lies at the south-west end of the ridge.

17. To the north-west of the Lodge, the bank that forms the valley, is immediately overtopped by another steep, of which the highest point is called the Griurnon. Mr PLAYFAIR determined the elevation of this above the valley, by means of a base measured in a flat close to the Lodge, and found it to be 1590 feet. From the Griurnon, a broad ridge extends, in a north-westerly direction, for nearly a mile and a half, and rises a few hundred feet to the pointed summit of Cairn y Chlannan. The height of this mountain above the sea is probably about 2800 feet.

18. The opposite sides of this part of Glen Tilt present a striking contrast in their surfaces. The south-eastern side is mostly covered with soil, bearing either good herbage, or heath, and shews but little of the rock, either fixed or loose. Along the north-western side, the mountain has in many places a craggy brow, the ruins of which lie thickly scattered over the declivity below, so as frequently to cover the ground. This is particularly

particularly the case between the Crochie, and a point more than three quarters of a mile below Forest Lodge, and opposite to M in the map, and the plan of the river.

19. Such a difference of aspect in the surface, gave reason to expect a difference in the nature of the rock beneath. Accordingly, on the south or south-east side, we found it to consist of strata, of which the chief materials were granular limestone, granular quartz, gneiss, and mica-slate. The general stretch of these strata coincides nearly with the direction of the valley, and their dip is towards the south-east, into the face of the mountain, at a large angle; though the stretch and dip are occasionally somewhat varied by inflexions. On the north or north-west side, the mountain is chiefly composed of grey sienite, or rather sienitic greenstone, which bears no marks of stratification. In the bottom of the Glen, therefore, is the line of junction between the strata on the south-eastern side, and the unstratified masses on the north-western; and it seems as if the course of the Tilt had here been very much determined by the position of the limestone strata, which occur frequently throughout the Glen, on the left bank of the river, and have been cut through by the stream. The facility with which limestone is worn away by water, in comparison with most of the other materials of a primary country, must have struck every mineralogist, who has met with it in that situation.

20. This general account of the rocks, that form the opposite sides of the valley, rests on the following observations.

21. We saw no sienite on the south side of the river, except immediately on its bank. The rock, where it appears, within a hundred feet above it, is stratified, and often of limestone. In order to ascertain its nature higher up, we ascended the mountain in two places, following, in each, a line almost at right

R r 2

angles

angles to the direction of the valley, and therefore also at right angles to the stretch of the strata.

22. One of these lines was in the course of a brook, which falls down the mountain within a quarter of a mile to the eastward of the point A, and has made a deep section of the rock, though not in the immediate vicinity of the river, where the declivity is gentle. After passing over this declivity, I found granular limestone and mica-slate, from where the rock first appears, to the height of about two hundred feet above the river. For the next two or three hundred feet, there followed a gneiss, resembling that which I have already mentioned as occurring near Blair, on the western side of the Tilt. It is rarely stratified in its texture, and its stratification can only be learned from the outgoings of its large beds. These, as well as the limestone and mica-slate below them, dip into the mountain to the south-east, at an angle sometimes considerably more than 45° , and sometimes a little less. To the gneiss succeeds mica-slate, conformably stratified; and to that, another gneiss, a good deal similar in its texture to the last. Its beds are crossed by numerous slaty fissures, at right angles to their planes, which give it the delusive appearance of a stratification dipping at right angles to that of the rocks below; while, in fact, the beds lie conformably. Above, are distinct strata of granular quartz, also conformable. This quartz was the highest rock that I examined, and might be about six hundred feet above the river. About a quarter of a mile farther to the eastward, the strata are intersected by another brook; and, as far as I could judge from a distant view, they correspond with those in the first, as to the limestone, and the lower beds of gneiss.

23. The other line, in which the rock was examined, on this side of the valley, sets off from the Tilt, at a bridge near half a mile

mile above Forest Lodge, a spot remarkable for its distinct exhibition of a junction between the strata and the sienite, in the bed of the river. The southern bank of the river is here the foot of a declivity, several hundred feet in height, and excessively steep, on which the rock appears only at intervals.

24. In the ascent of this declivity, Mr PLAYFAIR saw nothing but granular limestone, to the height of perhaps more than three hundred feet. The beds of the limestone dip southerly, into the face of the mountain. Over the limestone is a bed of porphyry, twelve or fifteen feet thick. The base of the porphyry is a grey compact felspar, and contains numerous small and imperfect crystals, of a reddish felspar, hornblende, and mica. At the foot of the declivity, and close to the bridge, there are lying many blocks of a porphyry, which has a base of grey compact felspar, and is singular for containing distinct crystals, not only of white felspar and quartz, but also of mica in thin hexagonal plates. From the sharp angles of the blocks, they must be supposed to have fallen from the declivity above; but whether they are a variety of the bed just mentioned, or from another rock, we found no opportunity to determine.

25. Above the porphyry is mica-slate, alternating with beds of granular limestone; and Mr PLAYFAIR observed granular limestone upon the brow of this steep face, where it changes to a more gentle slope. This is the highest point that is visible from the Glen below, and, by comparing its level with that of another on the same face, immediately above the Lodge, the height of which was afterwards determined by trigonometrical measurement, he computed it to be about eight hundred feet above the Tilt.

26. From hence the ascent is more gentle for a considerable distance, and the ground is covered with long heath. The rock is rarely seen; but what appears is mica-slate. The line in which Mr PLAYFAIR ascended, conducted him to a
ridge,

ridge, formed on one side by the slope he had passed over, and, on the other, by the declivity of a deep ravine, through which flows a stream that rises in the higher part of Ben y Gloe, and joins the Tilt about three quarters of a mile above the bridge, by a course almost due north, while that of the Tilt is to the south-west. On this ridge he found mica-slate, stretching N. 38° E., and dipping to the south-east at an angle of about 35° .

27. In the direction of south, and perhaps a little west, from this spot, and at the distance of about a quarter of a mile, is a conical eminence, of considerable height, forming the point of Cairn Toorchie. All the way to its summit, he observed the rock to be a granular quartz, in which there occur thin layers of felspar and mica; and thus the stone is a gradation into gneiss. The granular quartz lies above the mica-slate last mentioned, and, as far as he could judge, has the same stretch and dip. Another high and bare point, at the distance of about half a mile on the other side of the ravine, appeared pretty evidently to consist of a similar rock.

28. Mr PLAYFAIR descended towards the north, along the sloping edge of the ridge, by the side of the ravine, and, in the course of his walk, went more than once to the bottom of the ravine, in order to examine the rock. At first, he found mica-slate upon the ridge, and, in the bottom of the ravine, granular quartz. Lower down, there was granular limestone upon the ridge, of the same characters with that which he had seen in ascending the steep declivity above the bridge, and he had no doubt that it extended all the way to the side of the Tilt. The rock, on this part of the ridge, is indeed generally covered with a thick coat of earth; but, in the bottom of the ravine, for several hundred yards before it opens upon Glen Tilt, there is limestone, which many falls in the stream have worn down, and scooped out, into a variety of irregular forms.

We

—We were prevented from examining the higher parts of Ben y Gloe, by an unusually inclement season, which brought showers of snow, for several days together, before the middle of September.

29. On the northern side of Glen Tilt, there is not much of the fixed rock to be seen upon the lower parts of the declivities. At the foot of the lowest fall of the Crochie, and on the west side of it, there is grey sienite, approaching to sienitic greenstone. In the bed of the first torrent to the east of the bridge above Forest Lodge, there is, on the lower part of the mountain, granular quartz, stratified, and dipping at a large angle to the south-west, but irregular. Higher up the same stream, there is sienitic greenstone.

30. The rock was examined in the bed of another torrent, which joins the Tilt between the bridge and a fall a few hundred yards below it. On ascending the course of this stream, the first fall in it discovers hornblende-slate, obscurely stratified, but, as far as could be judged, conforming to the ordinary stretch of the strata on the south side of the valley. A little higher, there is sienitic greenstone, and this continues, as you proceed, to a considerable distance. The hornblende-slate seemed to lie over the sienitic greenstone. In a spot not far below the Lodge, and at the height of perhaps three or four hundred feet above the river, the rock is partly sienitic greenstone, and partly granular quartz.

31. We examined the fixed rock of the crags on the brow of the mountain in one or two places only, nearly opposite to the point M, and it was there a small-grained sienitic greenstone. But very satisfactory information, with respect to the nature of these crags, was afforded by the angular blocks, and loose fragments, strewed over the steep declivity below. We examined numbers of them through almost the whole length of the valley, and found them to consist chiefly of gradations
between

between grey sienite and sienitic greenstone, all bearing a strong resemblance to one another in their general character, as well as to those which have been already mentioned, as occurring in the fixed rocks on different parts of the mountain. In these aggregates, the felspar is commonly whitish, but has various shades of colour, and is sometimes tinged with red. The proportion of the hornblende to the felspar is generally large. The grains are in some instances large and distinct, and in others extremely minute. Quartz is seldom an ingredient, and mica still more rarely. I conceive the most appropriate name for all the varieties to be Sienitic Greenstone, as the majority of them approach more nearly to that substance, than to sienite.

32. Among the angular blocks of sienitic greenstone, there occur also a few of gneiss and granular quartz; and a little below the point marked B in the plan of the river, I saw, on the side of the mountain, some fragments of hornblende-slate and greenstone-porphyry.

33. Along the declivity, from a point over against M, to another a little above Forest Lodge, there are occasionally fragments of a sienite, similar to that which appears so often in the bed, and on the banks, of the river. This differs, in several respects, from that which approaches to sienitic greenstone. Its chief ingredient is felspar, sometimes grey, but most commonly red. It also contains less hornblende, and quartz in various proportions. Nearly opposite to the point B, I found a few fragments of it a little below the crags, and about seven hundred feet above the Tilt.

34. To these remarks on the northern bank of the valley, it may be added, that the Griurnon, a point several hundred feet above the crags of sienitic greenstone, consists of granular quartz, containing

containing specks of felspar, or small cavities, which may be supposed to have been once filled by it.

35. I return now to a farther consideration of the rocks along the bed of the river, which consist partly of strata, and partly of sienite. Our examination of these, and indeed of the whole Glen, was much facilitated by the kind hospitality of the Duke of Atholl, who allowed us to fix our residence at Forest Lodge for several days.

36. Among the substances that compose the strata, gneiss, hornblende-slate, granular quartz, and granular limestone, have already been mentioned. Mica-slate occurs more rarely. Besides these, there are many compounds of quartz, felspar, mica, hornblende, actinolite, compact dolomite*, chlorite, talc, steatite, and serpentine, which, in different rocks, are found intimately mixed in a great variety of combinations, and in different proportions. As examples of these compounds, I may mention that, among the specimens we collected, one is a compact dolomite, penetrated by chlorite and talc; a second, hornblende-slate, penetrated by carbonate of lime; a third consists of actinolite, felspar, mica, and carbonate of lime; a fourth, of felspar, with hornblende and carbonate of lime; a fifth, of quartz, compact dolomite, and brown felspar; a sixth, of quartz, penetrated with chlorite, talc, and carbonate of lime; and other varieties might be added. We found steatite and

VOL. VII. P. II.

S s

serpentine

* By Compact Dolomite, I mean a magnesian limestone, differing from common dolomite, in having its structure compact, and such as to render the fracture not granular, as in common dolomite, but splintery, and passing to the even. The fracture is thus well described by Mr JAMESON, in his account of the dolomite of I-columb-kill, in his *Mineralogy of the Scottish Isles*; and the name of Compact Dolomite has been used by the Comte de BOURNON, in describing some specimens from that island, in the collection of Mr ALLAN. Compact dolomite is found also in GlenElg, and in Kintail, on the coast opposite to the island of Skye.

serpentine in one or two places only. Almost all these compounds effervesce, more or less, with muriatic acid ; and of course carbonate of lime, or carbonate of magnesia, perhaps both, are among their ingredients. Small specks of iron pyrites are frequent in them. One of the most common of them consists of quartz and compact dolomite. The quartz is in a large proportion ; but the dolomite renders the mass extremely tough under the hammer, and imparts a little of its characters to the fracture, which sometimes approaches to that of compact felspar. It effervesces with muriatic acid, though often feebly. Its colour is whitish-brown, where it is not decomposed. By decomposition, it assumes a rusty-brown colour near the surface, indicating perhaps that manganese is an ingredient. Specimens from different spots present many varieties in these general characters. In some of the rocks consisting of the compounds above mentioned, neither the form of a bed, nor a stratified structure, is discernible ; but we were led to consider them as parts of the strata, from the imperfect crystallisation of their ingredients, and their analogy to others that are distinctly stratified.

37. The rocks of sienite do not indicate stratification, either by the form of a bed, or by the structure of the stone. Of the sienite there are two varieties, one grey, and the other red ; the colour of each depending on that of the felspar, which in both is the principal ingredient. Both contain quartz, and agree in most other circumstances. We paid little attention to the grey, as we no where found it in contact with the strata ; but the characters, which distinguish it from the grey sienite graduating into sienitic greenstone, on the northern side of the valley, have already been mentioned. In the red sienite, the felspar presents different shades of red, graduating into grey ; the hornblende varies much in its proportion, and in the size of its grains,

grains ; and so likewise does the quartz *. Minute crystals of iron pyrites are sometimes interspersed ; and our specimens effervesce slightly with muriatic acid. At a point marked C in the plan of the river, there is a variety of sienite, or rather sienitic greenstone, which I shall have occasion to describe hereafter.

38. In the bed of the river there are four spots, that draw peculiar attention by affording a good exhibition of the rock, and three of them contain the most distinct phenomena of the junctions of the strata with the sienite. They are marked in the plan of the river by the letters A, B, C, and D, and I shall employ these as names in describing them.

39. The spot marked A is the first place where the sienite is met with, in ascending the course of the Tilt. It may be readily found by a singularity in the channel of the river. Some large irregular masses of rock project on either side from the banks, and through them the water has cut a deep and narrow chasm. Above these rocks, the river holds a course nearly coinciding with that of the valley ; on meeting with them, it makes a sharp turn to the southward, and, after falling a few feet, in its passage through the chasm, expands into a pool at the outlet, and resumes its former direction. The direction of the channel through the chasm is nearly N. and S.

S s 2

40. At

* This red sienite bears a close resemblance to that of the Malvern Hills in Worcestershire. I do not remember to have seen one like it any where else.

40. At the lower end of the chasm, the rock is a large bed of granular quartz, stretching across the river in the direction of about N. 56° E. Its stretch is indicated in the plan* of A (Plate XVII.) by a line expressing the water-line upon its southerly face, and referred to by the figure 1. Its dip is to the south-east, at an angle of about 45° . Its structure is not stratified.

41. Immediately below this, (at 2 in the plan) there appears a rock consisting of quartz, penetrated by compact dolomite. Little of it is visible on the southern bank, but what there is, agrees in its general character with the larger masses on the northern, and there is probably a bed of it, conformable to that of granular quartz. The masses of it on the northern bank, are intermixed with others of granular quartz, but we could not pronounce them to be in alternating beds.

42. The rock on the north side is then concealed by the soil for a considerable distance down the river, except that, about forty yards below the quartz rock, (at 3 in the plan), there may be seen in the channel some small masses of gneiss, interstratified with, and graduating into, mica-slate. The stretch of these strata is N. 63° E., and their dip to the south-east, at an angle of about 45° . Some of the gneiss is so highly crystallised, as to have entirely lost its stratified structure, and is here and there in the form of veins, one or two inches in breadth, and cutting the strata of mica-slate at a very small angle. Figure I, in Plate XIX, is a sketch of a horizontal section of a forked vein of this kind.

43. On the southern bank, the strata are much covered by soil for a short distance below the quartz rock, but granular
limestone

* In this plan the rocks were merely sketched in by the eye. So likewise in the plan of D.

limestone begins to appear about ten yards from it. Soon after, the bank of the river turns to the westward, and exhibits the outgoings of the limestone strata for about a hundred yards. Their average stretch may be considered as about N. 30° E., within 20° of the direction of the bank, and their dip is to the south-east., at an angle varying from 26° to 56°. On a close examination, some rapid inflexions may be observed, and among them, a small one is remarkable for setting the planes of the strata at right angles to one another. This is in the slope of the bank, near to where the limestone is first seen below the quartz rock.

44. Returning now to the large bed of quartz, we find next to it, on the eastward, a rock composed of quartz and brown felspar; and this is succeeded by an aggregate of quartz, brown felspar, and hornblende. The granular quartz is not bounded on this side by any tabular face, or strata-seam; and we had reason to think, that the granular quartz passes into the quartz and felspar, and that again into the compound of quartz, felspar, and hornblende. Though the constituent parts of this last rock are those of a sienite, the mass differs from sienite in having them less perfectly crystallised, especially the hornblende. It may be considered as bearing the same relation to sienite, which the gneiss, already described as having an unstratified structure, does to granite, and perhaps may with propriety be called Sienitic Gneiss. Some specimens of it effervesce with muriatic acid.

45. In the rock of quartz and felspar, and in that of quartz, felspar, and hornblende, there are no marks of a stratified structure, nor are there any of a formation in beds; except that, on the south side of the stream, the sienitic gneiss lies very distinctly over, and conformable to, some strata that follow to the eastward of it, and dip to the south. This circumstance, as well

as the oryctognostic characters of these rocks, and the appearances of gradation from the granular quartz, induce me to regard them as parts of the primary strata. Yet, if they are so, they have been subjected to some peculiar cause of irregularity; for the stretch of the face of the granular quartz, which forms their western boundary, is about N. 56° E., and that of the strata, which bound them on the eastward, is at least 80° E. of N., while the distance between these different lines of stretch, measured along the middle of the channel, is less than thirty yards.

46. The strata to the eastward are a few feet in thickness, and consist, partly of hornblende-slate, and partly of granular limestone, varying to a compact dolomite penetrated with quartz. They appear on both sides of the river. Owing to some disorder in them, and a good deal of inflexion in one place, their position could not be well determined; but their average stretch was judged to lie between 80° and 90° E. of N., and their dip is southerly about 40° . It must be remarked, that these strata stretch from 17° to 27° more to the eastward than the gneiss and mica-slate lower down, and from 50° to 60° more to the eastward than the granular limestone on the southern bank.

47. Above this, the channel of the river opens into a broad and straight reach for a hundred and forty yards. On either side the bank is high, and exhibits the bare rock along its foot.

48. Beneath the northern bank, the strata last mentioned are succeeded by the red sienite, which may be seen on that side with few interruptions, through the whole of the reach, and for between forty and fifty yards beyond it. Low rocks of this substance often project into the water.

49. On the southern bank, nothing worth notice appears for near twenty yards, and then (at 4 in the plan) we meet with
strata

strata lying over the red sienite, of which a large mass follows to the eastward. The strata have somewhat of the characters of compact dolomite, and probably consist of this substance intimately blended with a large proportion of others. Their stretch is about N. 75° E., and their dip southerly at a considerable angle. Near the junction there are portions of the strata included in the sienite, so as to produce some resemblance to an interstratification of the two substances.

50. From hence rocks of the sienite appear on this side also, near the water and beneath it, through the rest of the reach, and forty or fifty yards farther. For about sixty yards, and to a point marked 5 in the plan, a junction of the strata and the sienite may be accurately traced in the bank; beyond that, the whole rock is of sienite. The strata, at the junction, lie over the sienite, dipping into the bank at an angle of from 30° to 50° . In some places they are bent. No veins of the sienite are here seen passing into the strata, and in the body of the strata I observed only one small obscure vein of sienite, or perhaps red felspar.

51. But in some of the rocks along the northern bank, there are junctions of strata and the sienite, attended with different circumstances. We found there no continuous strata of great extent, but various detached masses, consisting of granular limestone, gneiss, mica-slate, and hornblende-slate. These masses lie very irregularly; some of them are imbedded in the sienite, and others intersected by veins of it. Two instances deserve to be more particularly described.

52. One occurs in some strata of mica-slate, near the edge of the water, in a spot referred to by the figure 6. In stretch and dip, these were judged to agree nearly with the strata lying under the sienitic gneiss lower down; and this makes their stretch to be N. from 80° to 90° E., and their dip southerly
about

about 40° . These strata rest on the main rock of sienite; and from it small veins of the sienite proceed upwards into the strata, and intersect them, running sometimes parallel, and sometimes transverse, to their planes. I think that the veins do not any where exceed an inch in breadth, and that they cannot be traced for more than a foot, owing to a covering of soil; but, though the fact is exhibited on so small a scale, it is very distinct.

53. The other instance is in a mass of gneiss and mica-slate, which stands detached, at a little distance from the bank, and close to the water, at 7 in the plan. Its form is somewhat pyramidal, and its greatest dimensions may be about twelve or fourteen feet long, six or eight broad, and between four and five high. The stratification is very distinct. This mass is cut by veins of the sienite, from half an inch to fourteen inches in thickness, which branch in various directions, and run in some places parallel, in others transverse, to the planes of the strata. The veins may be traced all round the mass, and, on the south-east side, to their connexion with the main body of sienite below. Figure II, in Plate XIX, is a sketch of this rock taken from the south-east, on the opposite bank of the river. There is no attempt at perspective in it, and it must be understood to represent an orthographic projection of the surface of the rock upon an inclined plane, dipping towards the spectator; but care has been taken to convey a faithful idea of the relative position of the strata and the sienite, as actually exhibited upon the surface. The strata on the west side, which rise to the top of the rock, have their stretch N. 168° E., and their dip westerly 51° . At the foot of the rock on the east side, the strata dip nearly at right angles to those on the western. The lines of junction between the strata and the sienite are marked with great precision. Near the top of the rock, the strata that dip to the west, where in contact with the sienite, are a gneiss containing

containing red felspar, but this extends only a few inches, and graduates rapidly into mica-slate.

54. Farther to the eastward, within about twenty yards of the end of this reach of the river, and at 8 in the plan, a cut lately made in carrying the road along the top of the bank, displays a junction of the sienite with some strata of hornblende-slate. The strata lie to the eastward of the sienite, and are visible for about seventeen yards. The cut into the rock is of small depth, and, where the substances are in contact, there is not much to be learnt. But the strata stretch about N. 130° E., and dip to the north-east at an angle of about 60° , thus indicating a position very different from that of most of the strata already described. In these strata there are some veins of sienite.

55. Beyond this, we observed nothing remarkable on either bank of the river for a considerable distance.

56. The spot marked B lies about eight hundred yards, in a straight line, above A. Here we found considerable masses of rock, consisting of gneiss, granular quartz, hornblende-slate, granular limestone, and some of the compound substances already described, in strata variously interposed. Some of the limestone is a fine white marble. Rocks of the red sienite also appear in many parts of the bed of the river, and the face of the southern bank affords a clear view of a body of strata lying over the sienite.

57. To shew the irregularity that prevails among the strata at this place, and how much their positions differ from that of the great body of strata along the south side of the valley, I shall mention the stretch and dip of several masses, within

small distances of each other. It must be recollected, that the ordinary stretch through the valley is between 30° and 60° E. of N., while the dip is uniformly to the south-east. Near the southern bank, a little below the face of rock in which the strata are seen lying over the sienite, are some strata standing up in the river, which stretch N. 97° E., and are almost vertical. Within twenty feet of these, there is, on the north side of the stream, a large mass of strata of gneiss and limestone, which stretch N. 78° E., and dip to the north at an angle of 40° . Not thirty yards from thence, the road, which runs along the edge of the northern bank, has been cut into some strata, composed of actinolite, felspar, mica, and a little carbonate of lime; and these stretch N. 165° E., with an easterly dip of 24° . Within a hundred yards, on the southern bank, and farther up the stream, are some strata, which stretch N. from 78° to 83° E., and dip to the north at a large angle.

58. Where the strata in the southern bank lie over the main rock of sienite, we did not observe that they were cut by any veins of sienite. But such veins abound in most of the neighbouring masses of strata, of which the irregularities have been just described, and they traverse them in every direction. Many of the veins contain little besides red felspar, but the felspar resembles that of the sienite; and I remarked, where the main rock of sienite was in contact with some strata of compact dolomite, penetrated by other minerals, that the substance of the rock was sometimes merely felspar for two or three inches from the line of junction.

59. In the pure white granular limestone, there are veins consisting of reddish felspar, minutely mixed with quartz. The limestone has yielded more readily to the action of the water, and left the veins very distinctly exhibited in their projections on the surface; but the fracture of the rock shews the substance of the vein to be intimately blended with
the

the limestone on its sides. The outlines of these veins are often extremely irregular, and their breadth is rapidly varied.

60. The strata on the northern bank, described above as consisting of actinolite, felspar, mica, and carbonate of lime, are cut by small veins, partly of red felspar, and partly of the red sienite. The outlines of these veins are very regular and distinct.

61. To the eastward of these strata is a greenstone porphyry, similar to that of the dyke below Gow's Bridge. I conceive it to lie here in a bed conformable to the strata.

62. In many of the veins at B, shifts, or slips, are very conspicuous, and they occur even in veins of large dimensions.

63. Within a hundred yards above B, the strata appear in the bed of the river in several places, and are much intersected by veins of sienite, or sometimes perhaps felspar.

64. The spot pointed out by the letter C lies about 260 yards above Forest Lodge. There is here a fall in the river, and large masses of rock appear on both sides of it, but they do not afford much information to the geologist.

65. Those on the southern bank are strata, which seem to consist either of granular quartz, or of compound quartzose substances, similar to those at A. There is a mass of granular quartz standing up in the middle of the stream.

66. On the northern bank, the rocks are an aggregate of red and grey felspar, intermixed with black or greenish hornblende. The hornblende is in a large proportion, and the stone may be considered as one of those gradations between sienite and sienitic greenstone, which have been already described. The

rocks of this substance have not a stratified structure, nor do they appear to form a bed.

67. From the nature of the place, the junction of the sienitic greenstone with the adjoining strata cannot easily be traced, and the rocks of either kind present few remarkable circumstances. We found, however, some pieces of granular quartz and gneiss imbedded in the sienitic greenstone, and there is an appearance of veins of sienite cutting the large mass of granular quartz in the middle of the river.

68. At the foot of the fall, there is a vein of granular limestone approaching to compact dolomite, which cuts the rock of sienitic greenstone for three or four feet, and varies in thickness from an inch to less than half an inch. Its fracture is splintery, but passing to the foliated. Its hardness is considerable; and from this, as well as from the appearance of its decomposed surface, it is evidently penetrated by some siliceous substance. Its colour is a dark greenish-grey; its greenish hue being probably derived from chlorite. It does not graduate into the sienitic greenstone that forms its walls, and there are small pieces of the sienitic greenstone imbedded in it. Its termination could not be seen in either direction.

69. The bridge over the Tilt, rather more than half a mile above Forest Lodge, stands at the place referred to by D. Twenty yards above the bridge, there is a fall of the river, and the arch is thrown between two of the nearest points of the precipices, which extend for a short distance on both sides of the deep pool below the fall. This is by far the most interesting scene in the whole valley for its geological phenomena. For a plan of it, see Plate XVIII.

70. On the southern bank, seventy or eighty yards below the bridge, is the eastern extremity of a high scar, extending
from

from this point for about a hundred yards down the river, and forming at once the bank of the river and the foot of the mountain, which rises about eight hundred feet above it, with more than usual steepness. The rocks, that appear in this scar, are strata, consisting for the most part, either of mica-slate, or, more frequently, of granular limestone penetrated with mica. On a close view, they were found to be much bent: however, their general stretch may be estimated at about N. 33° E., and is nearly parallel to the course of the channel at this place. Their dip is to the south-east, commonly at an angle of from 30° to 40° , but in one place they are almost vertical.

71. Over against a point fifty yards below the east end of the scar, (at 1 in the plan) the rock begins to shew itself under the northern bank. The substance of it has here a base of grey compact dolomite, which serves as a cement to angular pieces of quartz, sometimes so numerous as to constitute the largest portion of the stone. The pieces vary in size, from that of a nut to the smallest grains. This stone lies in a bed stretching about N. 48° E.; and nearly in that direction from hence, there is on the other side (at 1) a rock of a similar character, near the east end of the scar, close to the water's edge; so that the bed probably extends across the river*. The dip of the bed we could not determine.

72. On the northern bank, a little farther up the stream, (at 2 in the plan) the rocks present characters that are various and complex. From near the same spot, I have one specimen consisting of quartz, penetrated with talc, chlorite, and carbonate

* In the plan, the bearings of the corresponding substances on the southern bank have in every instance been laid down more to the east of north, than is stated in the description. Perhaps, in sketching the channel of the river, it was made too broad, which would account for the error.

nate of lime or magnesia, and another composed of red felspar, hornblende, and carbonate of lime. The latter is very similar to the red sienite; but the substances are not so highly crystallised, as is commonly the case in the sienite. Within twenty yards, these are succeeded (at 3) by a compound of brown felspar, quartz, and a small proportion of compact dolomite. The decomposed state of these rocks, and their complex characters, make it difficult to ascertain their ingredients with much precision. The rock last described bears some slight marks of stratification, but the stretch indicated by them is in a direction nearly at right angles to that of the strata on the opposite side of the river, for it is nearly at right angles to the course of the channel: it must be observed, however, that the planes of these strata, if such they are, are much bent. Farther up, on the southern bank, (at 3 in the plan) and in the direction of between 43° and 53° E. of N. from this point, there are rocks of substances similar in character to some of those hereabouts; and these are in distinct strata, dipping south-east, conformably with the neighbouring strata of limestone.

73. About the place where these strata appear on the northern bank, the line of the bank turns to the northward; and from hence to the bridge, a distance of near a hundred yards, there is a straight reach of the river. On both sides of it, the banks are high and steep, and the margin of the water is indented by many projections of the rock.

74. In proceeding towards the bridge about twenty yards along the foot of the northern bank, the rock is found to vary considerably. It is often a mixture of compact felspar and quartz, and sometimes a pure granular quartz, but the felspar is generally the predominant substance; sometimes also it approaches to a gneiss. Specks of pyrites occur among these substances. Their structure is not stratified, and, if they
are

are in beds, the small quantity of the rock, that appears, would hardly discover them to be so.

75. These compound substances are succeeded (at 4 in the plan) by a red sienite, very similar to that at A. Owing to a covering of lichens, which makes every thing obscure, and a reddish tinge, which pervades the rocks last described as well as the sienite, the one appeared on a first view to pass into the other; but, on a closer examination, the lines of junction between the sienite and the granular quartz, even where the latter approaches to a gneiss, were distinctly traced, and veins of the sienite observed to run through the granular quartz. The sienite first shews itself on the southern bank a little farther up, (at 4 in the plan) in the direction of N. between 48° and 53° E. from where it first occurs on the northern.

76. From these points, to the fall above the bridge, a distance of about sixty yards on the southern bank, and between eighty and ninety on the northern, the prevailing rock is the red sienite; but it is interspersed, especially on the north side of the river, with masses of gneiss, granular limestone, hornblende-slate, and granular quartz, from the size of a hazelnut, to that of several feet in every dimension. The stratification of these masses is for the most part distinct. Many of them are imbedded in the sienite; and others are intersected by veins of it, varying in their breadth from a small fraction of an inch to more than a foot.

77. The appearances throughout these rocks are closely analogous; but it may be more satisfactory to give a separate description of the most remarkable of them, subjoining at the same time, that in such spots as are not particularly dwelt upon, we observed no facts materially different from what I have to state. Every thing that I have to notice below the bridge is on the north side of the river.

78. The

78. Fifty yards below the bridge, measuring along the northern bank, there is a large rock, (at 5) which projects farther into the water than any in its neighbourhood. A little to the west of this, is another rock, containing a mass of limestone imbedded in the sienite. The junction of the two substances takes place without any gradation, or, if there is any, it is a very rapid one.

79. The most prominent part of the large projecting rock has its base formed by the main body of the sienite, and its top by several considerable masses of strata, consisting chiefly of hornblende-slate, with some interstratified felspar. These masses appear to rest entirely on the sienite, as the sienite can be traced below all round them. Some of them dip to the north-east, and others at large angles to the south-west. They are intersected by veins of the sienite, several of which were observed to be continuous with the main body of sienite below. One of these, which, though small, was very distinctly traced, is near the top of the rock, on the side towards the bank. Three others may be discovered by a close inspection in the steep face of the rock towards the river. The mass of strata intersected by them consists of hornblende, felspar, and quartz, and may perhaps with propriety be called Sienitic Gneiss. One of the veins is from six to eight inches broad, another about four inches, and the third about an inch and a half. The substance of the two larger veins has precisely the same characters with the sienite of the continuous main rock beneath them. Where the small vein joins the main body of the sienite, the substance of the main body, along the edge of the stratified mass, is chiefly felspar, and so is that of the vein for three or four inches; but above this, the vein is of a sienite similar to the common sienite of the rock below. The stratified masses separated by the larger veins exhibit no remarkable

remarkable correspondence in their outlines on the opposite sides of these veins; but there is a distinct correspondence in those divided by the small vein.

80. Adjoining to this projecting rock, but nearer to the bank, are several masses of gneiss. Along the lines of junction between the gneiss and the sienite, there is sometimes an appearance of gradation, owing to a large proportion of felspar in the gneiss, and an irregular structure in its stratification. We believe there are instances, in which they may be justly said to graduate into each other, but more commonly the line of junction is pretty well defined.

81. Among the rocks immediately to the eastward, we observed an imbedded mass, which, from its general aspect, might be considered as a granular limestone, but exhibited in some parts a singular siliceous character, especially near its junction with the sienite, though the line of junction is precisely marked. This character consists in a fracture that is rather splintery than foliated, a hardness so considerable as to yield with difficulty to the knife, and a greasy lustre. Yet its decomposed surface shows that it contains carbonate of lime, and it effervesces when pulverised. Its colour is a light greenish-grey.

82. Not far from this, there is a vein of limestone, less than an inch in thickness, running between two masses of sienite, and connected with an imbedded mass of limestone. The imbedded mass and the vein have similar oryctognostic characters. The fracture approaches more to the foliated, than that of the substance last described, and the hardness is less. The lustre is greasy, and the stone appears to contain a good deal of magnesia, but not a large proportion of silex.

83. A part of these rocks (near 6 in the plan) is formed by some large masses of granular quartz, containing numerous

specks of a reddish felspar, which give their tinge to the whole substance. The coincidence of colour, and that want of a stratified structure which is common in granular quartz, made it easily mistaken, on a superficial view, for a gradation from the sienite; but a more minute examination proved the line of junction to be well defined.

84. Nearer to the bridge, and from fifteen to twenty yards below it, the northern bank is formed by a rock, that rises almost perpendicularly from the edge of the water. This rock consists principally of the red sienite; but, near the level of the water, there appears in the face of it (at 7 in the plan) a mass of granular quartz, interstratified with hornblende-slate, about ten feet long, and four thick. The stretch of these strata is nearly the same as that of the strata of limestone in the scar lower down on the other side of the river, about N. 33° E. But their dip is at an angle of 47° to the north-west, and therefore in a direction opposite to that of those strata, and opposite to the common dip of the strata on the south side of the valley. They dip immediately into the face of the rock, and, as the sienite may be traced completely round them, they are evidently imbedded in it. These strata are traversed by two veins, composed of quartz and red felspar, in large grains, and not intimately mixed. The veins run almost vertically. They are visible for some feet in the sienite beneath the strata, and under the surface of the water, and one of them is continued in the sienite above the strata. There is a shift in one of these veins.

85. At the bridge the breadth of the river is much contracted, and the rocks on both sides rise many feet above it, with precipitous and irregular faces. Those immediately under the bridge, and to the east of it, are free from lichens, and their surfaces either retain that coarse polish, which they received,
when

when formerly cut through and rounded off by the stream, or have had it occasionally refreshed by the action of the water in time of floods. They are thus well prepared to show the contrasted colours of the red sienite, and the blackish hornblende-slate, and to render the phenomena attending the junction of these substances extremely distinct.

86. From the east side of the bridge, there may be seen lying under the road that leads to it from the northern bank, a large body of granular limestone, mixed with felspar, and penetrated by chlorite, and often approaching in its characters to a serpentine. The position of the mass, with respect to its stratification, cannot, I think, be well determined; but I was inclined to consider its stretch as parallel to that of some strata, which rise, a few feet to the eastward of it, on the other side of an intervening chasm, and the stretch of these is N. 115° E. Veins of the sienite appear in the limestone. A part of the main body of sienite also lies over it, and the plane of their junction dips towards the southern bank.

87. The rock, in which the sienite thus lies over the limestone from the south, terminates towards the river (at 8) in a bold projection, affording a distinct section on its top, and on the three sides of its perpendicular face. Its substance is a part of the main body of the sienite, but it contains many imbedded masses, of various sizes, particularly about its summit. Two of them are of granular quartz, and the lines of junction between these and the sienite are perfectly distinct. In the rest we observed nothing but hornblende-slate, consisting entirely of pure black hornblende, except that it is here and there interstratified with a small quantity of red felspar. The angles of the imbedded masses are always quite sharp, even when the mass does not exceed half an inch in its largest dimension. In these masses there are numerous veins, of which the sub-

stance is often quite the same with that of the main body of the sienite, but they also exhibit a variety of gradations from it. The crystallised grains are often larger in the veins; in some of them there is a little mica; and sometimes, though rarely, they contain white felspar mixed with the red. There are small veins of red felspar and hornblende, running parallel to the stratification of the hornblende-slate, and veins of the same sort occasionally traverse the strata. The lines of junction between the veins and the hornblende-slate are generally well defined, and often extremely so; sometimes, however, the substances are blended. I imagine that, by a nice selection of small specimens, a series of gradations might be made out between the hornblende-slate and the sienite; but in the general aspect of the two substances, even where in close contact, there is a marked distinction of character. The veins are sometimes reticulated, and display the greatest irregularity in their outlines and direction. I believe that those parts of the veins, which are near the main body of the sienite, may in almost every instance be traced to be continuous with it.

88. The southern abutment of the bridge rests on a rock, which projects considerably under the arch. The larger part of it is formed of the main body of the sienite, but it contains many masses of hornblende-slate, in which felspar is sometimes interstratified. A large one, on the east side of the rock, contains much felspar, and is penetrated with carbonate of lime. Of the larger masses, some cannot be traced to rest entirely upon the sienite; but others can, and some of the smaller, which dip into the face of the rock, are manifestly imbedded in the sienite. There are adjacent masses, in which a correspondence of form argues that they were once connected. The position of the masses, with regard to their stratification, is very irregular; and as instances of it I may mention, that on
the

the top of the rock, in an area of about ten feet by eight there is one having its stretch N. 143° E., and its dip south-west at an angle of 40° ; a second having its stretch N. 36° E., and its dip north-west at an angle of 55° ; a third, which appears to have been once united to the last, stretching N. 13° E., and dipping west at an angle of 58° ; and a fourth, stretching N. 108° E., and dipping north at an angle of 55° . The observations were taken in an order from the west to the east side of the rock. Of the four masses, the first and last extend to an unknown depth into the rock below; but the second and third rest entirely upon the sienite. Veins of sienite and felspar, and of gradations between them, are frequent in most of the larger masses, and many of them may be traced to be continuous with the main rock of sienite below. In the small veins there is generally white felspar intermixed with the red. As in the rock last described, there are small veins of felspar mixed with hornblende, running sometimes parallel, and sometimes transverse, to the planes of the strata. The veins also resemble those in the rock at 8 in their reticulation, in the great irregularities of their direction and outlines, and in having their lines of junction commonly distinct. There is here too the same marked difference in the general aspect of the substances of the sienite and the hornblende-slate. Sometimes perhaps the parts in contact are blended, but this is rare. They are usually bounded by lines that are well defined, and some of the imbedded pieces are remarkable for the sharpness of the angles, which they exhibit in the common section of them and the sienite, afforded by the surface of the rock.

89. At the bridge, the channel of the river makes a sharp turn to the eastward. The rocks about the bridge are chiefly formed of the main body of the sienite; but, near the fall, this is succeeded

succeeded by a body of strata, stretching obliquely across the stream, which is cutting its passage through them. They extend about twenty yards along the northern bank, and twenty-five along the southern, and consist for the most part of gneiss, hornblende-slate, and granular limestone. Some of the hornblende-slate on the north side of the river, is a pure schistose hornblende, similar to that which forms the pieces imbedded in the rock at 8. The average stretch of these strata is about N. 115° E., and their dip to the south-west at an angle so large as 64° ; but there are some irregularities from shifts and bendings. In the strata of limestone there are many small undulations, which are clearly marked on the horizontal surface, by parallel curved ridges of interstratified hornblende and felspar: these harder substances have been left projecting, while the softer limestone has been worn away by the water. Fig. III, in Plate XIX, shews the curved line of one of these undulations on the north side of the river. I think that the breadth from x to y may be about a foot.

90. The strata along the northern bank are not much intersected by veins of the sienite; but those along the southern are so in the most striking manner, especially in the neighbourhood of the main rock of sienite. A blast in the rock on the southern bank procured us specimens of these veins, where they run through some strata of a dark colour, consisting of hornblende, intimately mixed with talc and carbonate of lime, and shewed us that a section of this part of the rock, in any direction, would exhibit a complete net-work of them. The spot, where the blast was made, is near 9 in the plan. From hence I traced the veins in an oblique direction towards the bridge, irregularly branching, and again uniting, among the separated masses of the strata, to their junction with the main
body

body of the sienite, which forms the lower part of the perpendicular face of rock over the river, a few yards below the fall. In tracing the veins, an interruption, even of a few inches, in their actual substance, was scarcely any where passed over; and where any interruption was passed over, it was owing to a fissure, or some other circumstance in the surface of the rock, of such a nature as to cause no doubt of a perfect continuity of the substance of the vein in its original structure. I believe that the various and complex ramifications of the veins, between the spot in which the blast was made, and the main body of the sienite, would allow the connexion to be traced in more lines than one. As the veins approach the main body of the sienite, they grow larger, but contain many masses of the strata imbedded in them. Some of the imbedded masses are of granular limestone. One of these stands nearly vertical, and has its stretch about north-east; while the stretch of another, which is within a foot of it, and also nearly vertical, is at right angles to this.

91. The main body of the sienite appears on the horizontal surface of the rock for some yards to the east of the bridge; and it has been already mentioned that, where the adjoining part of the rock exhibits, on its upper surface, strata intersected by veins of the sienite, the main body of the sienite is to be seen in the lower part of its perpendicular face over the river. These strata, where thus intersected, appear therefore to rest upon the main body of the sienite.

92. The substance of the veins varies much in our specimens. Sometimes it is a sienite consisting of felspar, hornblende, and a considerable proportion of quartz, and precisely similar to some specimens of the main body of sienite, taken from a rock only eight yards nearer to the bridge. This forms the larger veins; but some of the smaller contain only felspar and quartz; and felspar occurs here and there alone in the smallest.

smallest. There is an evident gradation in these aggregates.

93. In the spot where the blast was made, the veins are so numerous, as to destroy in a great measure the character of stratification in the rock, and in our specimens some of the pieces cut by the veins do not exhibit a stratified structure; but, about six yards farther to the eastward, there are some distinct, and almost undivided, strata, from which we obtained specimens precisely similar, in their oryctognostic characters, to many of the pieces in our specimens of the veins. Among the pieces of strata intersected by these veins, we found also some specimens of serpentine.

94. The lines of junction between the veins and the strata are in general clearly defined, even in some veins of which the breadth does not exceed the sixteenth of an inch, and the angles of the pieces of strata are often sharp. However, there are partial instances of gradation, by an intermixture of substances, along the sides of some of the veins; and, in the smallest of them, the felspar of the vein occasionally assumes the appearance of a streak of red spots, upon the dark ground of the stratified mass. The connexion of such streaks with the compact veins was traced in a number of cases, without any exception.

95. On the south side of the river, the limestone among the more entire strata is intersected by veins of felspar, which are sometimes interrupted, so that pieces of the felspar appear insulated in the surface of the rock. Both the veins and pieces of felspar are very irregular in their form and outlines. These appearances of the felspar resemble those of the veins in the limestone strata at B.

96. The strata of gneiss, on the same side, are in some places traversed by thin veins of white calcareous spar. One of these,
about

about half an inch broad, at length meets a thick stratum of grey limestone, in which, after penetrating for an inch or two, it branches out into small tapering veins, and is lost altogether.

97. On the northern bank (at 10) a large vein of white felspar crosses a part of the strata. Its thickness varies, but is in some places between one and two feet.

98. In the veins of sienite, or its gradations, throughout the rocks I have been describing, shifts are not uncommon.

99. Beyond the body of strata last described, the rock on the southern bank is lost beneath the soil for a considerable distance, and on the northern it appears only in some small portions of strata, in which we did not observe any thing of importance.

100. It will be seen, from the plan of the river, that both the strata and the sienite occur frequently in the intervals between the spots upon which I have dwelt so long; but there is no other considerable section of the rock, nor are the strata and the sienite often seen in contact. In every other rock, in which we observed a junction of them, the appearances are quite analogous to those that have been described.

101. Above the bridge also, for about a mile and a half, and considerably beyond the junction of the Crochie, the rock, where it appears in the bed of the river, consists either of sienite, or of granular quartz, gneiss, and other stratified substances, of the same characters with those already mentioned. The strata are occasionally intersected by veins of the red sienite.

102. The preceding details afford grounds for the following general statement of some of the most important facts.

103. The mountain along the southern side of Glen Tilt consists almost wholly of primary strata; that on the northern is formed chiefly of sienitic greenstone, with gradations into sienite. Through the bottom of the valley the rocks consist partly of stratified substances, and partly of crystallised aggregates, which are commonly sienite, but in one or two places sienitic greenstone. (Paragraphs, 11 to 34, 66.)

104. The great body of strata on the southern side of the valley, forming the base of Ben y Gloe, dips towards the south-east; and some stratified rocks on the southern bank of the river, which, from their situation and general conformity, appear to be connected with this great body, have main rocks of the sienite lying under them. (Parag. 49, 50, 56.) The sienite may therefore be considered as occupying a position lower than that of these strata*.

105. The lines of junction between these stratified rocks and the sienite are in most places distinct. (Parag. 49, 50, 56, 58.)

106. The strata, which occur, with scarcely any visible interruption, through the lower part of the Glen towards Blair,
and

* It must be observed, that the fact of the sienite lying under these primary, or primitive, strata, is inconsistent with the geognosy of WERNER, who assigns to sienite a place in his *Overlying Primitive Formation*, that is, in a class of strata, which, according to him, always rest on the primitive strata, when those of the two classes are found in contact.

along the slope of the mountain on the south side of the valley, preserve a considerable degree of uniformity in their stretch and dip, and vary their position slowly by large undulations; on the other hand, some stratified rocks on the southern bank of the river, which appear to be connected with this great body of strata, but are adjacent to the main rocks of sienite, exhibit great varieties of position within a small distance, and rapid changes in the curvature of their planes. (Parag. 9, and from 19 to 27, compared with 43, 45, 46, 50, 70, 89.)

107. Adjacent to some spots, where the main rocks of sienite, and the great body of strata, appear either in contact, or near to each other, there are numerous masses composed of substances which are stratified, and closely resemble those that form the great body. These masses do not touch each other at the present surface, and sections of the rocks in every direction prove that many of them must be completely separate. The smallest of these masses are not larger than a hazel-nut; the larger would measure several feet every way. From the numerous sections of these masses, afforded by the indented and water-worn surfaces of the rocks, we farther learn, that the concealed surfaces of the masses are rough; that their shapes are irregular, and that they often terminate in sharp angles. In position, as to stretch and dip, they often differ extremely from the great body of strata, as well as from each other; and this difference prevails even among such as lie nearest together. (Parag. from 51 to 53, 76, from 78 to 81, 84, 87, 88, 90.)

108. Some of these masses rest upon the main rocks of sienite. (Parag. 52, 53, 79, 87, 88, 91.)

109. The intervals between such of these masses as appear adjacent on the present surface, vary in breadth, from the small

X x 2

fraction

fraction of an inch, to many feet. The intervals exhibit great diversity and irregularity in their forms; but an approach to parallelism between the surfaces of the masses, that lie nearest together, often gives to the interval the form of a vein. In all the various sections of the rock formed by the present surface, the intervals, whether above, below, or on the sides of the masses, appear, with few exceptions, to be completely filled, either with a sienite similar to that of the main rocks, or with felspar, either pure, or mixed with other substances, so as to present evident gradations from that sienite. (Parag. from 51 to 54, from 58 to 60, 76, from 78 to 81, 84, 87, 88, 90, 92.)

110. This appearance of separate masses of strata, with the intervals filled with sienite, was observed only where the great body of strata, and the main rocks of sienite, were each of them at no great distance. (Parag. 3, 6, 7, 21, 22, from 24 to 28.) One or two exceptions, however, occurred farther up the Glen*.

111. In several instances, the sienite and its gradations, which appear, in the form of veins, among the stratified masses resting upon the main rocks of sienite, were observed to join to the main rocks of sienite, without any abrupt change of character between the substance of the vein, and that of the main rock below. (Parag. 52, 53, 79, 87, 88, 90.)

112. The lines of junction between the stratified masses, and the sienite, or its gradations, are in most cases definitely marked. (Parag. 50, 53, 59, 60, 75, from 78 to 81, 83, 87, 88, 90,

* See the latter part of parag. 135, and note D at the end of the paper.

90, 94.) The principal exceptions are, where the strata are of gneiss, or of granular limestone *.

113. Shifts occur in the veins of sienite, and its gradations. (Parag. 62, 84, 98.)

114. These appearances afford grounds for some inferences respecting what took place in the formation of these rocks.

115. A crystalline character in a rock is generally admitted to prove, that it was once in a state to a certain degree fluid. An opposite notion has indeed been advanced by DOLOMIEU, and Mr. GREGORY WATT; but, both the mineralogical appearances, which suggested this opinion to DOLOMIEU, and the experimental results, which led Mr. WATT to it, admit of an easy explanation, from what Sir JAMES HALL ascertained by experiment, with regard to the varieties of structure produced by cooling under different circumstances; and no sound argument against the common opinion can be drawn from what either of them has described. We may therefore infer, that the main rocks of sienite have been in a state to a certain degree fluid; whether by aqueous solution, or igneous fusion, I do not now consider. We may make a similar inference for the sienite, and the gradations from it, which now occupy the intervals between the separate masses of the strata, often assuming the form of veins. I would farther infer, that the fluid from which the main rocks of sienite crystallised, and the fluid from which the veins of sienite, or its gradations, crystallised, were one and the same;

* The least real gradation may in appearance be a considerable one, where the surface of the rock cuts the plane of the junction at a small angle. This is a source of deception to be guarded against in observation.

same ; and that so far the main rocks and the veins are of the same formation, or have a common origin. This inference will probably be disputed by some, and I shall therefore offer a few remarks in support of it.

116. All would admit, that every part of one of the main rocks of sienite in the bed of the Tilt was of the same formation. As in any other case of a rock of a crystallised aggregate, such as granite, greenstone, &c. the continuity of the mass, and its uniform, or gently varied, characters, are the grounds for the inference. It is the most simple hypothesis, and the rule that "No more causes are to be admitted than " are sufficient to account for the phenomena," authorises us to conclude in favour of one productive process, where no reasons can be shown for inferring more than one. We have seen, however, that among the veins there are some consisting of a sienite precisely similar in its characters to that of the main rocks ; and that some such veins are connected with the main rocks, without any abrupt transition. Now, where both these circumstances occur in the vein, the vein and the main rock are parts of one continuous and homogeneous mass ; and every reason for admitting that any two parts of the main rock are of one formation, goes equally to prove that the main rock and the vein are of one formation, except in what regards the difference of form in the vein. But this difference affords no just ground of distinction. In several places, especially about the bridge, there are separate masses of the strata imbedded in the sienite. When such masses lie far asunder, the sienite between them is regarded as a part of the main rock : if we look out for such as have still smaller and smaller intervals between them, we shall by and by find the intervening sienite to obtain the form, and the name of a vein ; and the sooner, according as we select larger masses

masses of the strata, and such as have their adjacent sides more nearly parallel. The gradation thus pointed out removes any objection from the extreme case of difference in the form of the vein, where the vein is in substance precisely similar to the main rock, and visibly continuous without any abrupt transition.

117. In the next place, we have the evidence of close analogy, for extending the inference of a common origin to those veins in the neighbourhood of the main rocks, which consist of a sienite similar to that of the main rocks, but between which and the main rocks no connection can be traced on the present surface. These veins are in substance similar to the former, and they intersect similar strata in a similar manner. Their proximity to the main rocks therefore argues that they either are, or have been, connected with the main rocks, though that connection does not now appear.

118. With respect to all the veins which consist of a sienite similar to that in the main rocks, an argument may be derived from stating the question in a dilemma, between a common origin and a different one; and the probability of the former must be proportionate to the improbability of the latter. Now a sienite of these precise characters is by no means common, either among minerals in general, or among those of the adjacent district; and it must appear highly improbable, that two separate processes should have agreed in producing it, with such perfect similarity of substance, in these contiguous spots, and there only.

119. Among the hypotheses, by which a separate formation has been ascribed to veins analogous in character, and situation, to those in Glen Tilt, is that of a contemporaneous formation by secretion from the strata, while yet in a soft state. Should this hypothesis be applied to those veins of sienite in Glen Tilt, which are of a substance precisely similar to that of
the

the main rocks, it may be opposed with peculiar force by the last argument. The formation of the main rocks of sienite cannot be explained by secretion; and the improbability that two separate processes should have agreed in producing in contiguous spots a substance so rare elsewhere, as this sienite, is materially increased, when those two processes are supposed to have differed *in kind*.

120. From the veins, which consist of a sienite similar to that of the main rocks, it is easy to extend the argument to almost all those veins, which consist of various aggregates of felspar and quartz, or felspar and hornblende, with a little mica in one or two places, and those which contain felspar only. These present a great diversity in their ingredients, and in the size of the grains; but their continuity with the veins of sienite, and the gradation of the substances composing them into the sienite, were traced in many instances, even where the veins were most minute and obscure, and their ramifications most complex. These circumstances furnish sufficient grounds for referring their origin to the same fluid mass. Above the bridge, where the specimens were procured by a blast, we found many of the most minute and complex veins of this kind to graduate into veins of sienite, which again were joined to the main rock of sienite, and grew larger as they approached it; while we observed that in a stratified rock, of precisely similar characters, a little farther to the eastward, there were no such veins, or scarcely any. (Parag. 90, 93.) This, while it seems to exclude every explanation of those veins from circumstances attending the formation of the strata, points strongly to the once fluid substance of the main rock of sienite for their undoubted origin*.

121. W₂

* See note B at the end of the paper.

121. We may likewise recur to the argument, that veins of these substances appear rarely in the strata of the adjacent country, where no main rock of a crystallised aggregate is near.

122. It may farther be remarked, that the substance of the main rocks of sienite is not quite uniform in its characters, for in them the proportion of hornblende and quartz varies a good deal, and is in some places small. A main rock at B was mentioned, (parag. 58.) which, where in contact with strata of compact dolomite with other ingredients, consists sometimes of felspar only, for two or three inches from the line of junction. A similar fact occurs at D. (Parag. 79.) While, however, we admit, that the substances thus graduating into one another were formed by crystallisation from the same fluid, the similarity in the other circumstances of these veins forces us to conclude, that some very trifling difference of cause was sufficient to determine, whether hornblende and quartz should enter into the composition of the vein, and in what proportions.

123. It must at the same time be allowed, that there are certain veins of similar substances among these strata, of which it may be doubted if they have been formed from the same fluid mass with the main rocks of sienite; such especially are the large vein of white felspar on the east side of the bridge, and the veins of red felspar with quartz, intersecting a rock of sienite, and an imbedded mass of strata, at the foot of the northern bank, below the bridge.

124. The similarity of the stratified substances, lying in separate masses among the sienite, to those which compose the base of Ben y Gloe, and occupy a wide district to the south and west, leaves no room for doubting that both are of the same formation. But if this be admitted, and likewise the common origin of the sienite in the main rocks, and in the

veins, the intermixture of the stratified masses with the sienite remains to be accounted for, and the case seems to admit of only two hypotheses. One is, That after the sienite had assumed its present form, the stratified substances were deposited in the cavities of its surface. But the forms of these supposed cavities,—the absence of crystals on their sides, as now exhibited in the lines of junction,—the structure also of the veins, dividing upon the sharp angles of the interjacent masses, branching with every variety of size and direction, and crossing each other among the stratified masses,—all these circumstances make it difficult to imagine, that the sienite would have received its present appearance, if at perfect liberty to assume that which crystallisation tended to give; and the diversities in position among the stratified masses, relatively both to the sienite and to one another, furnish the strongest objections to the idea that these positions were original. This hypothesis therefore, though it has been adopted by some to explain analogous appearances elsewhere, may be rejected without hesitation. The hypothesis which remains, is, That the masses of gneiss, limestone, &c. are portions of strata once continuous, and lying conformably with those which form the base of Ben y Gloe; that these strata were bent and broken by some violent shock; and that the fluid, from which the sienite crystallised, was introduced among the fragments.

125. Admitting this as the most probable, the nature of that fluid comes immediately into question. It may be supposed to have been some unknown aqueous fluid, which held the substance of the sienite in solution, and deposited it by crystallisation. To account for the various positions of the fragments, and the height at which they are now found resting upon the main rocks of sienite, it may be supposed, that the fragments fell at various times from the sides of a chasm, in which the deposition

tion of the sienite was going on. But an objection to any idea of a crystalline deposition from an aqueous fluid, arises from the compactness of the rocks consisting of stratified masses intersected by the sienite. This circumstance has been urged by Mr PLAYFAIR, as an objection to the aqueous origin of granite rocks * ; and the argument may be applied with greater force to the veins of sienite in Glen Tilt. Had an aqueous solvent deposited this substance among fragments, in some places so confusedly heaped, in others so closely fitted, together, we might have expected to have found occasionally what so frequently occurs in a calc-tuf, a porous structure, and cavities, perhaps lined with crystals. On the contrary, in all these veins, however complex and minute, scarcely a single interstice appears unfilled.

126. It is to heat then that we may with more probability ascribe the fluidity of the sienite. This hypothesis is farther supported by the affinity of sienite to trap, or whinstone ; and, in proportion to that affinity, we may extend to sienite the inference of an igneous origin, which, with respect to trap, seems established by so many convincing arguments. The crystallised aggregates of Glen Tilt afford excellent examples of gradations between these substances, and the first steps of the series from trap may be traced in the sienitic greenstones of the northern side of the valley ; some of which very nearly resemble the most highly crystallised specimens of common greenstone from Salisbury Craigs. The sienite in the bed of the river may be considered again as a step in a continuation of the series to granite †. But, though these

Y y 2

gradations

* See *Huttonian Theory*, art. 81.

† This series of gradations, in composition as well as structure, between trap and granite, does not appear to have been duly noticed ; and I would particularly recommend it to the attention of those geologists, who, while they admit the

gradations afford a presumption in favour of the igneous origin of all granitic substances, that presumption must always diminish, as the affinity of the substance grows more remote; and we have yet to wait for proofs, as strong as those which the valuable experiments of Sir JAMES HALL have furnished for trap, to be drawn from direct experiments, in the same way, upon sienite and granite.

127. Even admitting the sienite to have been introduced in a state of fluidity from heat, it is still difficult to account for its having completely filled up every interstice among the fragments; and it seems necessary to infer, that it flowed with a strong impulse, while at the same time a pressure of superincumbent matter, confining the adjacent bodies, opposed its introduction. Indeed, if the sienite be inferred to have been fluid from heat, compression must be admitted to have modified the action of that heat, since the carbonate of lime in the sienite appears to have suffered no decomposition. If we ascribe the fracture of the strata, the disorder in which the fragments now lie among the sienite, and the wide separation of some of them, to the force of the impelled fluid, we shall adopt a simple, and connected, explanation of the phenomena. In favour of this it may be further urged, that the fracture and dislocation of the strata are confined to the neighbourhood of the sienite, while those at a distance are comparatively undisturbed.

128. Even close to the junctions, the large masses of strata on the southern bank, similar in their component substances
to

the igneous origin of trap, cannot bear the idea of violating by any such hypothesis the dignity of a rock, which has been so long venerated as the first foundation of the earth. The specimens, required to exhibit the whole series, would not be numerous, though the shades of difference, in every step, were slight. Perhaps our island does not afford a better field for illustrating the subject than Glen Tilt, and the mountains to the north-west of it.

to those among the sienite, but more nearly conforming in their position to that of the stratified base of Ben y Gloe, do not contain veins of sienite, or its gradations; (parag. 40, 43, 50, 56, 70.) and this fact, while it goes to exclude the idea of secretion, or any other tranquil process, attending the formation of the strata, as the source of the veins, argues that the force, which disturbed the strata, was one which impelled the fluid against, and among, them.

129. Some of the main rocks of sienite were observed to lie underneath large masses of strata, which are comparatively undisturbed, exhibit no veins of sienite, and are probably connected with the great body to the south. This circumstance favours the inference, that the direction of the impelled fluid was either lateral, or from below.—That the direction of the impulse was in some degree from below, may be inferred from another circumstance. On the top of some of the rocks of sienite, near the bridge, there are imbedded masses of hornblende-slate. Among these rocks, that referred to in the plan by the figure 8 is one which exhibits such masses with peculiar distinctness; and, in its perpendicular face, the sienite of the main rock is seen to the depth of several feet below them. The sienite of this rock was found to have its specific gravity 2.67; and of two masses of hornblende-slate resting upon it, one has the specific gravity of 3.00, the other that of 3.01. Hence it appears, that the specific gravity of the hornblende-slate is to that of the sienite, as 100 to 89. Now the specific gravity of the sienite, when fluid, whatever may have been the cause of its fluidity, was probably less than it is at present, and supposing it to have been somewhat greater, it must have been considerably less than that of the hornblende-slate: it can hardly therefore be imagined, that, if the fluid sienite came from above among the fragments, it would have
buoyed

buoyed them up, and raised them to their actual position *. Nor can this be explained even by supposing, that these masses of hornblende-slate were attached to others of gneiss, and limestone; for, while the heaviest specimen of sienite has the specific gravity of 2.67, the lightest of two specimens of gneiss was found to have that of 2.68, and the lightest of three specimens of limestone that of 2.70. A fluid impelled from below, though of a less specific gravity, might raise them; and that they should have remained suspended till the sienite crystallised round them, may be accounted for by the supposition, that the sienite was in that state of viscid fluidity, which earthy bodies, when melted, are known to assume at a temperature not far above their point of crystallisation; joined to the consideration, that the difference of specific gravity could not be great.

130. Any theory ascribing the origin of the sienite to an introduced fluid, of whatsoever kind, would lead us to account for the gradations, which in some places appear upon the lines of junction, by supposing that the stratified masses were acted upon by the fluid, so as to admit of their being penetrated by it, or at least by some of its ingredients. After having ascribed the fluidity of the sienite to heat, it is obvious to refer the mutual action of the substances to the same agent, and to suppose that it softened the strata, so as to enable certain ingredients of the fluid to penetrate them to a small depth. Some instances of gradation, where carbonate of lime is one of the substances,

* The large projecting rock below the bridge furnishes a similar argument. The specific gravity of one specimen of hornblende-slate, from the top of this rock, was found to be 2.95, that of another 2.97: the specific gravity of its sienite was not tried, but the mean specific gravity of two specimens of sienite from D is 2.66.

substances, agree very well with an igneous theory. Sir JAMES HALL found carbonate of lime, when fused under compression, to be a powerful solvent of silex. This offers an explanation of the gradation on the sides of the veins of felspar in the strata of limestone at B, and of some similar appearances at D, (parag. 95.); also of the siliceous character in the mass of limestone adjacent to the sienite at D, below the bridge, (Parag. 81.). In these cases, it may be supposed that the carbonate of lime, when fused by heat, derived a portion of silex from the felspar in contact. The siliceous character of the vein of granular limestone, or compact dolomite, at C, may be accounted for in the same manner. On the other hand, it may be supposed that the sienite of the main rocks derived its small portion of carbonate of lime by solution from the adjacent strata. But, whether we adopt an igneous theory, or any other, there are facts that it will appear difficult to explain; for we have seen that there are masses of hornblende-slate, and other substances, which, though penetrated by the felspar of the sienite, have still preserved a stratified texture, and the sharpness of their angles; and it is not easy to conceive a state of aggregation soft, or porous, enough for the former circumstance, and at the same time firm enough for the latter, or what agent could have produced it*.

Sir

* A remarkable example of fragments of a rock penetrated by an extraneous substance is mentioned by M. DAUBUISSON, as having fallen under his own observation. In a note to § 72. of his translation of WERNER's *Theory of Veins*, he tells us, that near Freyberg a metalliferous vein was found divided into several small veins, containing between them fragments of gneiss, through which galena was disseminated in so large a quantity, that the quintal of gneiss contained thirty pounds of lead. He adds, as something more remarkable, that it was only the gneiss of the vein, which contained galena; for the gneiss of the rock, even where adjacent to the vein, contained none at all.

Sir JAMES HALL mention the aggregation of curd and jelly, as an analogy to obviate similar difficulties. Perhaps the penetration of a fragment still retaining its shape may in some cases have been effected, by one more soluble component having been withdrawn by the action of a fluid in contact, and having thus left the pores it occupied to be filled with a new substance, derived from the fluid. It is clear, however, that where there is gradation on the lines of junction, it has been owing in some cases to a trifling difference of circumstance; for, among the specimens procured by a blast at D, the lines of junction are precisely marked in some, while in others the red felspar appears disseminated through the same blackish stratified compound for an inch, or more, from the side of the vein.

131. An igneous theory for the sienite might lead us also to ascribe the high state of crystallisation, in some of the stratified masses, to a slow reconsolidation after having been softened by the heat. Sir JAMES HALL's experiments upon the fusion of carbonate of lime under compression, make it more easy to admit this hypothesis with respect to the limestone, than in the case of the gneiss, and some other substances. The important information respecting the properties of carbonate of lime, which we have derived from Sir JAMES HALL's experiments, may assist us in explaining some other appearances in these rocks. Thus we may conceive that the vein of limestone proceeding from an imbedded mass, (par. 82.) was produced from a part of the mass which had been completely melted, and remained so, after the sienite had grown so hard as to admit of a crevice being formed. A similar origin may be ascribed to the vein of hard granular limestone at C, (par. 60.). The veins of calcareous spar, cutting strata of gneiss, (par. 96.) may have been formed, either from fused portions

tions of the adjacent limestone, introduced into crevices in the gneiss, or by secretion from the strata themselves, in which carbonate of lime is frequently an ingredient, and limestone an interstratified substance. Sir JAMES HALL observed that carbonate of lime, when fused under compression, is a viscid substance. In some limestone strata not far from the sienite, on the eastern side of the bridge, (par. 89.) there are rapid incurvations, without fracture, which strongly suggest the idea of a viscid state in the rock, at the time of their formation.

132. It has been mentioned, that there are shifts in some of the veins *. Whatever theory be adopted respecting the manner in which the sienite, and the stratified masses, assumed their present relative position; the shifts prove that, after they had done so, there was a dislocation among these rocks, in which the stratified masses, and the sienite between them, were moved together. But the fact that these rocks are now compact, and without cavities, can hardly be reconciled with the idea of such dislocation; unless by admitting that, when it took place, a certain degree of softness pervaded their whole substance, both the strata, and the sienite. It accords with an igneous theory to explain these circumstances by supposing, that the dislocation occurred not long after the introduction of the sienite, while the heat continued sufficient to maintain a softness through the whole. But the difficulty of conceiving such a soft-

VOL. VII. P. II.

. Z z

ness

* In a rock near the bridge, there was noticed (par. 84.) a shift in one of two veins, which are apparently of posterior formation to the sienite. It may be worth while to observe, that these veins dividing both the sienite, and the imbedded mass of strata, can hardly be ascribed to secretion; for it is highly improbable, that the strata, which are of granular quartz and hornblende-slate, should have agreed with the sienite in secreting the same substance; nor is it likely, that a secretion from the one, should have filled that part of the crevice, which had been formed in the other.

ness in all these substances recurs upon us ; and the advocates of an igneous theory cannot pretend to furnish a satisfactory explanation of these, as well as many other more common phenomena of a primary country, till they have acquired a farther knowledge of the properties of bodies composed of felspar, quartz, hornblende, carbonate of lime, mica, &c. when subjected to high temperatures, and regulated cooling,—with compression also, where there is any volatile ingredient. It is to an igneous theory, however, that we may look with the most confident hope, and it seems in vain to expect assistance from any hypothesis of aqueous solution and deposition.

133. The various inferences, for which I have been contending, have been separately considered, both for the sake of keeping the argument distinct, and because I conceive the evidence to be much stronger in favour of some, than of others. The whole hypothesis may be briefly expressed thus : That the sienite, in a state of igneous fusion, was impelled from below, by a violent force, against the strata ; that it bent them, broke them, dispersed them, and filled up the intervals, which it now occupies ; that the fragments of the strata were in some degree softened by the heated sienite, so as to admit of a mutual action ; that, while the whole intermixed mass was still soft, some farther dislocation took place in it, and that all this occurred under a great confining pressure of incumbent matter. This hypothesis coincides, in the main, with that by which Dr HUTTON explained the phenomena in Glen Tilt, in a paper read before this Society in the year 1790, and published in its Transactions. If it differs widely from the speculative views concerning these phenomena, which have been more recently given by Professor JAMESON and Dr MACKNIGHT, I must leave it to the candid inquirer to decide between us ; but, if I have differed

differed also in my description of the facts, Professor JAMESON's extensive experience, and acuteness in the discrimination of minerals, might seem to claim submission on my part; did I not consider that his observations must have been liable to a certain degree of bias from a favourite theory,—a bias, from which I can scarcely flatter myself that my own were kept entirely free*.

134. I proceed now to describe the rocks in the bed of the Tilt, as far as the junction of the Tarff, and shall subjoin some observations on the mountains to the north-west of the Glen.

135. For about a mile below the junction of the Chlochan, the channel of the Tilt is perfectly straight, and the bottom of the Glen is contracted to its breadth. The channel is here formed on both sides by rocks of a singular aggregate, approaching in its characters to sienitic greenstone. The colour of the mass is a dark greenish-grey, but varying according to the proportion of its ingredients, which are intimately mixed, and seem to be hornblende, felspar, sometimes compact, and sometimes crystallised, steatite or chlorite, and a good deal of carbonate of lime, or magnesia, perhaps both. The presence of these last ingredients is inferred from its effervescing briskly with muriatic acid. It may not be improper to consider the mass as a compound of hornblende, felspar, and compact dolomite, with a little chlorite, or steatite. Its hardness is not great, but it is very tough under the hammer. It is neither

Z z 2

stratified,

* See note C.

stratified, nor in beds. Sometimes it presents an appearance of veins, a few inches in breadth, and consisting of a brownish-red compact felspar, hornblende in large distinct grains, with a curved foliated fracture, and a little quartz. These veins, if they deserve that name, differ from those of the red sienite already described, in the irregularity of their outlines, and in a slow gradation on their sides into the contiguous mass. In the bed of the Tilt, not far from where it receives the Crochie, there is a rock of a similar character as to its constituents, which is in some places cut by veins of the red sienite, and the lines of junction are there precisely marked.

136. On the east side of the foot of the fall of the Crochie, and nearly on a level with the grey sienite, or sienitic greenstone on the opposite bank, (par. 29.) the rock is of a character similar to that last described, though its structure approaches to slaty. It effervesces slightly with muriatic acid, and seems to be a compact dolomite, penetrated by talc and chlorite. It is probable that a great part of the base of the mountain, between the Crochie and the head of the Glen, consists of similar aggregates; for a cut made by a brook farther up, shewed the rocks, to the height of two or three hundred feet, to have a strong resemblance to those that form the channel of the Tilt*. I consider all these congenerous rocks as belonging to the primary strata. In their constituents they resemble some of the compounds that I enumerated in the general sketch of the strata through the valley; and one of them, which has been mentioned as occurring in the bed of the Tilt, not far from the
junction

* Some of these substances bear a considerable resemblance to those which appear on the Malvern Hills, in the cut made by the road to Ledbury. The latter are in a state of decomposition, which makes it difficult to discern their ingredients.

junction of the Crochie, and as cut by veins of the red sienite, has in some parts a stratified structure. Their imperfect crystallisation, the small proportion of the felspar, and their brisker effervescence with acids, are the characters which distinguish them from the sienitic greenstones, that form so considerable a part of the northern bank of the valley. Along the foot of this bank, between the Crochie and the junction of the Clochan, angular blocks of sienitic greenstone, with similar varieties, still occur at intervals in great numbers, and shew that the higher parts of the ridge contain a large quantity of this substance.

137. On the south side of the long straight reach of the river, granular limestone appears in two or three places. Near the lower end, there are some beds of it extending about sixty yards close upon the edge of the water, in a face of rock that is nearly vertical, and a few feet in height. The lines, that mark the stratification of the beds, run horizontally in the face of the rock; but at each end the beds are curved upwards in a remarkable manner, so that at the eastern, the lines of stratification make an angle of between 30° and 40° with the horizon, and at the western, an angle of from 40° to 50° . At the west end, the rock immediately in contact with the limestone is concealed, but the dark-grey aggregate appears within a few yards of it on the brink of the river. At the east end, this aggregate lies immediately under the curved extremities of the beds of limestone. See Fig. iv, in Plate XIX.

138. On the same side, not a hundred and fifty yards below the junction of the Chlochan, and within fifty feet above the river, there are beds of limestone, dipping, as usual, into the face of the declivity, but perhaps rather more to the eastward.

139. At

139. At the junction of the Chlochan, the channel of the Tilt turns at a large angle to the northward, and preserves nearly the same direction to the junction of the Tarff, a distance of about half a mile. The Tarff flows from the west, and, immediately before it joins the Tilt, issues from a deep chasm formed by precipices on either side of the channel, which, near the outlet, is broken by two considerable falls. This spot is called Pull Tarff. Between the junction of the Chlochan and Pull Tarff, there appear at intervals various stratified rocks, consisting of granular limestone, mica-slate, the dark-grey aggregate, and granular quartz. Out of five positions observed with the clinometer, if we omit one that appeared to be owing to a convolution, the rest argue that these strata lie round, and lean against, the base of the mountain, which separates the valleys of the Tarff and the Tilt. Four observations gave successively N. 150° E., 128° E., 133° E., and 101° E.; while the dip was getting round by the east to the north *. Our observations in this quarter terminated at Pull Tarff. Dr HUTTON mentions †, that to the eastward of this, near Falar, he found both granite and primary strata between Glen More and Glen Beg. In following up the course of the Tarff to the westward, he observed that the strata disclosed by that river, while they stretched about east and west, dipped to the northward. In Glen Tarff he met with many tumbled stones, which he describes as "composed of broken schistus, including white granite," by which he of course means fragments of primary strata, intersected by veins of white granite. He also ascended to the summit of the ridge that separates the Tarff from the Tilt, where he found almost every thing to be granite, and but little of the primary strata.

140. The

* See note D.

† In the manuscript, of which some account is given in note C.

140. The extent of the granite, and other crystallised aggregates on this side of Glen Tilt, was farther confirmed by our observations on the mountains more to the south, about Glen Criny and Glen Merk. These mountains do not shew much of the fixed rock, and we were therefore left in most cases to infer the materials of which they consist, from the loose blocks that are scattered on their sides, and along the higher parts of the courses of the streams. In order to make the account as faithful as possible, I shall enumerate the substances that we met with, in the different lines of our walks, beginning with what lies nearest to Forest Lodge.

141. For a considerable distance from the Griurnon towards Cairn y Chlannan, along the broad ridge that joins them, I found fragments of granular quartz, and a few of granite. The summit of Cairn y Chlannan is granular quartz. To the southwest of it, the ground falls into the head of Glen Criny, which opens into Glen Tilt.

142. In ascending from the lower part of Glen Criny towards the Griurnon, but winding to the north, so as to gain the ridge that joins it to Cairn y Chlannan, I saw loose blocks of granular quartz, and sienitic greenstone graduating into grey sienite. This sienitic greenstone, and its gradations, resemble those so abundant on the northern side of Glen Tilt, and in the following pages the terms always denote similar substances. Through the lower part of Glen Criny, the stream runs with a very rapid fall, for between one and two miles, over red granite; which, as far as I could judge from where the observation was made, extends to a point within two or three hundred feet in perpendicular height, and perhaps a furlong in horizontal distance, from the granular quartz that appears at the bridge over the Criny in Glen Tilt. We regret that we had no opportunity of examining the junction of the strata and the granite, in the channel

channel of the Criny. Dr HUTTON relates, that he with some difficulty climbed up the precipitous bed of a rivulet, which comes from the mountain on the north side of Glen Tilt, and which, from his description, I can only conceive to have been the Criny. He there obtained a view of a section of the rock. "We first," he says, "found the alpine schistus inclined as on the south side, and heading, or rising up, to this north hill; immediately after which, we found the granite under the alpine schistus, seemingly bedded in like manner, and running parallel to the alpine strata." It did not strike me that the granite in Glen Criny was in parallel beds; though I own that my examination was hasty, and I had only a distant view of the lowest part of the Glen.

143. In following up the course of the Criny, many blocks of grey sienite, or rather sienitic greenstone, are seen, and many also of granular quartz. The granular quartz on Cairn y Chlannan and in Glen Criny, contains almost always either specks of felspar, or minute cavities similar to those already mentioned in the granular quartz of the Griurnon. Round the head of the Glen, the blocks of sienitic greenstone lie in great numbers, both on the side of Cairn y Chlannan to the east, and on that of Cairn Vardenoch to the west.

144. I ascended Cairn Vardenoch from the lower part of Glen Criny, and kept along the broad ridge of it, winding round to the westward, till I nearly reached that part which overlooks Glen Merk; and returning by a different track, on the west side of the same ridge, crossed over it, and came down into Glen Criny at a point higher up. In the whole of this walk, except on that part of the ridge which lies towards Glen Merk, I met with scarcely any thing but a small-grained granite, having its felspar red. It appears in loose blocks, and
the

the soil is formed of the decomposed ingredients. On that part of the ridge which lies towards Glen Merk, the loose stones are partly mica-slate, and partly grey porphyry.—On Cairn y Chlannan and Cairn Vardenoch, there occurred also a very few loose fragments of gneiss.

145. Glen Merk merits more attention, as it exhibits a junction between the strata and the granite. The name of Glen Merk is confined to a part of the valley along that stream, extending about two miles above its opening into Glen Tilt. At some distance from the opening, the Merk receives the Deery from the west; and, above this, the Glen has the direction of due north, being formed on the east by the declivity of Cairn Vardenoch, and on the west by that of Ben y Venny. The head of the Glen is closed in by a rocky steep, about three hundred feet high, connecting the two mountains, but deeply cut by the stream, which falls through the dark chasms of a narrow channel.

146. At the falls of the Merk, where the Glen opens into Glen Tilt, there are strata of mica-slate, stretching N. 48° E., and dipping to the south at an angle of 27° . They agree therefore with the general position of the strata through the adjoining part of Glen Tilt. In following up the side of the Merk, to where it receives the Deery, the channel affords a transverse section of the strata. They seem to be either mica-slate, or gneiss; and, as far as could be judged from a distance, they conform in stretch and dip with those at the falls.

147. Before I proceed up the channel of the river, I shall mention what we noticed respecting the mountains on each side. Along the declivity of Cairn Vardenoch, at the distance of more than a mile from the head of Glen Merk, the loose fragments shew the higher part of the mountain to consist either of gneiss, or of a granite, nearly the same in character

with that which occurred so abundantly upon it towards Glen Criny. Farther up, the fragments are chiefly of gneiss; and near the head of the Glen, they are either gneiss, or sienitic greenstone, with its gradations.—On the side of Ben y Venny, near the head of the Glen, we met with sienitic greenstone in the fixed rock, and the loose blocks that had fallen from this mountain were either gneiss, or sienitic greenstone; the latter afforded gradations into grey sienite, for quartz occurred in it frequently. Some of the blocks consisted of felspar, hornblende, and mica.—In ascending the steep at the head of the Glen, on the western side of the stream, we found the rocks, that projected in different places from the surface, to be alternately gneiss, and sienitic greenstone, but could not determine their relative positions.

148. I now resume the description of the bed of the river. On the eastern side of the Merk, a furlong above its junction with the Deery, the strata are of gneiss, stretching N. 85° E., with a southerly dip at an angle of 22° . Fifty yards farther up, the gneiss stretches N. 105° E., and dips to the south at an angle some degrees larger. An hundred and fifty yards farther, there is gneiss interstratified with beds of felspar porphyry; the stretch is here N. 46° E. and the dip southerly at an angle of 28° . Three hundred yards higher up the stream, the strata are again gneiss, stretching N. 63° E., and dipping southerly at an angle of 27° . There are here some appearances of bendings in the strata. We saw nothing but gneiss, with its dip southerly, in the fixed rocks, till we came within a quarter of a mile, or somewhat more, of the head of the Glen; when we met with a junction of gneiss and granite, close to the eastern side of the stream. The strata of gneiss are much disordered; and are cut by veins,—some of granite, that is to say, a compound of felspar, quartz, and mica, and some of felspar and mica

mica only. We saw here no hornblende. The granite is small-grained, and its felspar reddish, of the same colour with that of the gneiss. The veins in some places run parallel to the planes of the strata, and in others cross them. Sometimes there is a gradation between the vein and the gneiss, but the line of junction is often quite distinct. Detached pieces of gneiss, much bent, are imbedded in the granite rock.

149. The junction is exhibited with remarkable distinctness in a rock, which lies on the brink of the stream, and has received a polish from it. The surface here exposed measures a few feet each way, and is nearly in the same plane, sloping rather obliquely to the water, at an angle of about 20° . (See Plate XIX, Fig. v.) The part next the water is granite; that next the shore is gneiss, of which the strata stretch N. 83° E., dipping northerly at an angle of 42° . It will be observed, that the dip of these strata is in an opposite direction to that of all the strata through the lower part of the Glen. The line of junction runs for about four feet, nearly straight, in a northerly direction, and thus crosses the lines of stratification. It is marked with the greatest precision. About the middle, the line is interrupted by a small vein of granite, which projects from the principal mass, intersecting the gneiss parallel to the lines of stratification, and tapering away, till it is lost in the course of a few inches. Near the line of junction, is a small fragment of gneiss imbedded in the granite.—In the loose blocks along the declivity of Cairn Vardenoch, we met with many junctions of granite and gneiss, exhibiting facts analogous to those now described.

150. Eighty yards below the fall of the Merk at the head of the Glen, we found gneiss, dipping about north-east, or perhaps still more to the north, at an angle of between 40° and 45° . Near this there are large masses of granite rock, and

also veins of granite; but the circumstances of the ground render it difficult to trace the junctions of the granite with the gneiss. At the foot of the fall there is gneiss, lying nearly as that last mentioned.

151. There is an obvious analogy in the appearances, at this junction of granite and gneiss, to those at the junctions of the sienite and strata in Glen Tilt, and they afford strong grounds for adopting a similar hypothesis with respect to their origin.

ADDITIONAL

SKETCH
OF THE
COURSE OF THE RIVER
IN
GLEN TILL.

0 100 200 300 400 500
Feet. Scale.

EXPLANATION.

s.	denotes	Sienite.
r.s.		Red Sienite.
gr.s.		Grey Sienite.
st.		Strata.
l.		Limestone.
s.gr.		Sienitic Greenstone.

PLAN
OF THE
BED OF THE TILT.
at A.

Scale 50 Feet to an Inch.

EXPLANATION.
s. denotes ———— Siénite.
l. st. ———— Limestone strata.
st. ———— Strata.

ADDITIONAL NOTES.

Note A, parag. 2.

In tracing up the course of the Bruar, we made the following observations.

About a hundred yards north from the road to Dalnacardoch, the rock by the side of the river is mica-slate, stretching N. 36° E., and dipping south-east at an angle of 37° . Immediately above this, the river, in its descent through a long succession of falls, crosses the strata, and displays a deep section of them at the bottom of a ravine. The prevailing rock is mica-slate.

At the first bridge in the walks made by the Duke of Atholl, there is a bed of grey porphyry interposed between the strata of mica-slate. Its chief ingredient is a brownish-white felspar, in crystals that are crowded together, and not very distinct; and these are imbedded in a base of compact felspar, penetrated by mica and hornblende. Near the second bridge, the mica-slate stretches N. 27° E., and dips S. E. 39° .

About a mile and a half from the road, and not far from the river, there appears another bed of grey porphyry interposed between the strata of mica-slate. The base of this porphyry seems to be compact felspar, minutely penetrated by hornblende; and there are imperfect crystals of hornblende interspersed. The stretch is here N. 47° E., and the dip S. E. 53° .

A quarter of a mile farther up, the rock is of mica-slate and gneiss, stretching N. 16° E., and dipping to the eastward 23° .

In proceeding by the side of the river, we saw mica-slate in several places, to all appearance conformable, in its average dip and stretch, with that last observed.

About

About four miles from the road, we found mica-slate, stretching N. 8° E., and dipping eastward 23° .

About two miles to the north-east of this, lies Ben y Chat, the nearest of that group of mountains, which spreads between the Bruar, the Tarff, and the Tilt; but we found no opportunity of extending our examination farther towards it. Among the rolled stones in, and near, the bed of the Bruar, we saw a few blocks of sienite, both grey and red, and one large block of granite.

The course of the river Garry, above its junction with the Bruar, lies a good deal farther to the west of Blair. In following it up, along the road to Dalnacardoch, for between six and seven miles from Blair, we had frequent opportunities of seeing a fine section of the rock in the channel. The banks are abrupt, and the stream crosses the strata almost at right angles to their stretch. Our examination of them was very cursory; but they seemed to be chiefly mica-slate, and pretty uniform in their stretch and dip. About five miles from Blair, the stretch was N. 18° E., and the dip easterly 28° . Six miles and a half from Blair, the stretch was N. 29° E., and the dip easterly 29° .

From a comparison of the observations in the beds of the Tilt, the Banavie, the Bruar, and the Garry, it appears that the strata, which would be crossed by a line passing through Blair a little to the north of west, and extending about seven miles in that direction from the Tilt, are conformable in dipping towards the south-east; but vary in the extreme differences of their stretch about forty degrees.

The strata in the channel of the Garry are intersected by veins, or dykes, of porphyry. About five miles from Blair, there is a remarkable one crossing the river, and between twenty and thirty yards broad. The base of this porphyry is a reddish-brown compact felspar, in which there are imbedded small crystals of white felspar, and very imperfect crystals of hornblende. Where the porphyry joins to the mica-slate, the colour of the base changes to black by a gradation in the course of a few inches. Of this circumstance I can offer no explanation.

Six miles and a half from Blair, there is a bed of porphyry perfectly parallel to the strata, and uniform in its thickness, which is several feet.

feet. This porphyry has for its base a brownish-red compact felspar, which is well characterised, and contains crystals of quartz thinly interspersed. Its red colour makes it very conspicuous on the banks of the river, and the outgoing of the bed may be traced on both sides in the slopes of the mountains.

Note B, Parag. 120.

The minuteness, and intricate reticulation, of the smaller veins, may be urged in support of the hypothesis of secretion. In these points indeed they resemble those veins of quartz, and of calcareous spar, which are often found running in all directions through various stratified substances, and which it is difficult to conceive any other process, but secretion, to have produced. However, after having rejected the hypothesis of secretion for the larger veins of sienite, it would be absurd to have recourse to it for the origin of small veins, which are evident ramifications, and gradations, from them.

The gradation on the sides of the veins in some places may also be insisted on, as favouring the hypothesis of cotemporaneous formation by secretion. But distinctness, or gradation, on the sides of veins, are equivocal circumstances in a question about their formation. That distinctness will not prove posterior formation, is evinced by its occurring in veins, which there is every other reason to suppose secreted; as in the minutely ramified veins of quartz running through clay-slate; in the small veins of calcareous spar in limestone; in the veins of calcareous spar, which cross dykes of whinstone, and do not penetrate their walls *; also in the lenticular veins of brown spar, or
spathose

* A good example of this occurs in the dyke that crosses the Water of Leith, above St Bernard's Well.

spathose iron-ore, in nodules of argillaceous iron-stone. On the other hand, that gradation is no decisive mark of secretion, is proved by instances of it on the sides of veins, of which the posterior formation is undoubted. WERNER mentions examples of it*; and Mr JAMESON observes in his *Geognosy*, where treating of such veins, that there are "cases in which the substance of the vein is intimately mixed with its walls †." A fact of this kind was met with in Cornwall in the year 1799, when Mr PLAYFAIR and myself were in that country. A mine near Redruth, called Toll Carne, was then working in a vein containing tinstone. The walls were of granite, and crystals of tinstone were found disseminated through the granite, for a few inches from the sides of the vein. It was regarded by some experienced miners of that district, as quite a singular instance; but WERNER mentions similar facts concerning tinstone ‡.

An analogous example of gradation was described to me by Sir HUMPHRY DAVY, as having been seen by Mr GREENOUGH and himself, on the shore of Loch Erne in Ireland. A projecting rock of considerable height, so as to render it a conspicuous object from a distance, was found to consist of a large vein of trap, or dyke of whinstone, traversing strata of limestone nearly horizontal. At the distance of some yards from the vein, the limestone presented the usual characters of that substance; but, on approaching the vein, it grew more indurated, and to all appearance siliceous, and was highly so, where in contact. The softer parts of the strata were much worn away, and had left the harder parts on the sides of the vein, to form with it a projecting mass.

At Beadnel Bay, on the coast of Northumberland, there is a whinstone dyke, cutting strata, some of which are of limestone, and exhibit near the dyke a change of character very analogous to that just described.

* See *Theory of Veins*, § 58, 72, 75.

† P. 232. See also p. 239.

‡ See *Theory of Veins*, § 72.

described. An account of this dyke was laid before the Geological Society of London, in a paper by Mr BENNETT, read in March 1812. A notice of it appears in *Nicholson's Journal*, for April 1812, which is the source of my information.

Note C, Parag. 133.

When Dr HUTTON communicated his views respecting Glen Tilt to the Society, he signified his intention of giving at some future time a full description of the phenomena he had observed; and, in the first volume of his *Theory of the Earth*, he promised to introduce it in the course of the work. At his death he left a third volume of this publication nearly ready for the press. Mr PLAYFAIR has favoured me with a sight of the manuscript, which contains a more particular account of the author's observations upon the junctions of granite and primary strata, in Glen Tilt, in Arran, and in Galloway. His descriptions are not minute, but were to have been illustrated by engravings, from drawings made on the spot; partly by the late Mr CLERK of Eldin, who accompanied him in two or three of his mineralogical excursions. When describing the appearances in the bed of the Tilt, he says, "The granite is here found breaking, and displacing the strata, in every conceivable manner, including the fragments of the broken strata, and interjected in every possible direction among the strata, which appear. This is to be seen, not in one place only of the valley, but in many places, where the rocks appear, or where the river has laid bare the strata." If Dr HUTTON has called the sienite *granite*, this can hardly be considered as a mistake in nomenclature at the time when he wrote; and, though the Wernerian School have insisted much upon the distinction of those substances, it appears of little consequence in forming a theory for the origin of that great tribe of crystallised aggregates, to which they

both belong. Dr HUTTON's chief error in describing Glen Tilt is, that of stating the mountain on the northern side of the valley to consist of red granite. He was probably led to this false inference, by what he saw in the deep cut made by the Criny, and by loose blocks near its entrance into Glen Tilt.

Note D, Parag. 139.

About sixty yards above the junction of the Chlochan, there are seen, in the bed of the Tilt, strata of a white granular limestone, highly crystallised, interstratified with, and penetrated by, mica and felspar, and containing pyrites. The mica gives it a slaty fracture in the large. The greater facility with which the carbonate of lime is worn away by the water, has caused the felspar to stand up in some places, in a rough and porous crust, on the surface of the rock. The position of these strata differs much from that which is most common in Glen Tilt; for their stretch is N. 150° E., and their dip north east at an angle of 41°. Those on the eastern bank of the river are cut by red veins, either of felspar or sienite*.

A hundred yards farther up the stream, I again fell in with the dark-grey aggregate.

A hundred and fifty yards higher, there are strata in the face of the hill above the southern bank, which seem to be limestone. They dip to the eastward into the face of the hill, but are much bent.

In the course of another hundred yards, the dark-grey aggregate again occurs in the bed of the river.

A hundred and fifty yards farther up, there is mica-slate, stretching N. 128° E., and dipping to the north-east at an angle of 45°.

The stretch and dip of the strata, where distinct, continues much the same for a hundred and fifty yards, when there appears mica-slate,

* This is one of the exceptions alluded to in parag. 110.

slate, stretching N. 133° E., and dipping to the north-east from 30° to 35° . About a hundred and fifty yards above this, is the junction of the Tarff and the Tilt.

On the southern bank of the Tarff, fifty yards below the fall nearest the junction of the two rivers, the rock is of granular quartz, containing some felspar, and steatite in the small fissures. It effervesces slightly, and seems to be penetrated with carbonate of lime. The stratification of this rock is indistinct, but, as far as I could determine it, its stretch is N. 93° E., and its dip southerly 46° . On the opposite bank the rock is of the same character. Its stratification is very indistinct, but appears to be horizontal, or rather dipping to the north. On the southern bank, nearer to the fall, there are strata of mica-slate, very distinct, stretching N. 101° E. and dipping northerly 38° . Some of these strata are only thirty yards from the granular quartz, which has nearly the same stretch, and dips at nearly the same angle, but in an opposite direction. As these strata were, no doubt, once conformable, there is reason to imagine that they have undergone an extraordinary convolution, and some traces of it may be discovered in the intervening face of the bank, though it does not afford so clear a section of the rock, as could be wished.