TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY,

ESTABLISHED NOVEMBER 13, 1807.

VOLUME THE FOURTH.

Quod si cui mortalium cordi et curæ sit, non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientarum filii, nobis (si videbitur) se adjungant.

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Geological Society,
July 1, 1817.

It is requested that all letters and communications to the Secretaries, and presents to the Society, be addressed to the House of the Geological Society, No. 20, Bedford Street, Covent Garden, London.

ERRATA.

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I. *Observations on the Geology of Northumberland and Durham.*

By N. J. WINCH, Esq.

HONORARY MEMBER OF THE GEOLOGICAL SOCIETY.

Read March 18th, 1814.*

CONSIDERING the great importance of the coal and lead mines, and of the quarries of Northumberland and Durham, and the opportunities which they offer to geological research, it is rather singular that no history of the physical structure of these counties has yet been laid before the public. It is however well known that much interesting information on these subjects has long been accumulating and is widely diffused among the professional conductors of the mines. I have endeavoured in the following paper to combine some of these scattered materials with the substance of my own observations, and to give a general outline of the several formations that compose our district. I have added short descriptions of the principal rocky strata belonging to these formations, and catalogues of such of their metallic ores, crystallized minerals, and organic remains, as have come under my notice.

* This paper was read at the meetings of the Society six months before the publication of the sketch of the same district by Dr. Thomson. See Annals of Philosophy, for November and December, 1814.

I. *Red Marl or Sandstone.*

In the south-eastern part of the county of Durham a series of strata occurs, among which a fine grained sandstone of a brick-red colour, effervescing with acids, predominates. This rock may be seen in the bed of the Tees at the distance of more than a mile west of Croft bridge; thence it follows the course of the river to the sea, and may be traced at some little distance from its northern bank through Hurworth, Nesham, Sockburn, &c. beyond the town of Stockton, forming rocks on the sea shore between Seaton and Hartlepool. Opposite Sockburn, Mr. Allen of Grange, lately bored in search of coal to the depth of 118 fathoms, without passing through these beds; and at Dinsdale, situated on the northern bank of the Tees, three miles and a half north-east of Croft bridge, in the year 1789, the late General Lambton penetrated to the depth of 74 fathoms without better success. I have obtained five sections of the workings at Dinsdale, and have communicated them, together with the present paper, to the Society. The strata are numerous, and consist (as far as one can judge from the miner's language) of white, grey, or red sandstone with occasional partings of a more compact nature, red or blue shale, coaly matter in thin layers, and gypsum in nodules or in beds; the latter are mentioned in one case as being three feet in thickness. The lowest bed in the two deepest workings was a strong white rock of a calcareous nature.

I should not have inserted these rude sections in the appendix (No. 1) to this paper had it not been for an opinion prevailing in Yorkshire, that coal will be found among these measures, and I hope by the publication of this document to prevent the future waste of capital on similar trials.

From one of these bore-holes, at a place called Woodhead, near the Tees, a sulphuretted water issued, similar to the Harrowgate spa.* It arose from a bed of blue stone lying beneath a bed of gypsum at the depth of nineteen fathoms two feet six inches from the surface. Another sulphuretted spring rises from similar strata at Croft on the south side of the Tees, where baths have been erected for medical purposes.

There can be little doubt that the sandstone we have been describing is analogous to that extensive formation of the same substance and colour which is found in Nottinghamshire to the west of the magnesian limestone, and it probably may be traced in continuity from the banks of the Tees through Yorkshire into the neighbouring county.

II. *Magnesian Limestone.*

To the north-west of the red sandstone the Magnesian or Sunderland limestone is found. In the cliffs at Cullercoats in Northumberland, a dyke well known by the name of the *ninety fathom dyke*, is seen dislocating the coal-measures, and passing into the sea. Here is the northern extremity of the western boundary of the magnesian limestone. A few masses again occur among the rocks of sandstone and slate-clay, upon which Tynemouth castle stands; but it is on

* Mr. Peacock of Darlington published the following analysis of this water in a pamphlet on the medical virtues of the spring.

Contents in 1 quart. .	Carbonate of Lime . . . . Grains	1.2
	Sulphate of Lime	25.
	Carbonic Acid Gas	2.
	Sulphuretted Hydrogene, containing $2\frac{1}{2}$ grains of Sulphur.	8.32
	Azotic Gas	1.5

Specific gravity of the water 1.016. Temperature at the well 8° above that of the adjoining springs.

the coast in the neighbourhood of South Shields in the county of Durham that this formation first becomes extensive. From this point it swells into a range of low round-topped hills, and is seen stretching towards the south-west, protruding into the Coal-field, and forming an undulating line by Cleadon, Boldon, Clacks Heugh upon the Wear near Hilton castle, Painshaw, Houghton-le-Spring, Sherburn, Coxhoe, Ferry hill on the turnpike road leading from Durham to Darlington, Merrington, Eldon, Brussleton, Morton, Langton, and Sellaby, till it reaches the Tees below Winston bridge thirty miles west-south-west of that river's junction with the sea, and forty-four miles from the Tyne at South Shields. The sea coast forms its eastern boundary for twenty-seven miles and a half from the Tyne to the rocks of Hartlepool, and the red sandstone already mentioned from Hartlepool to the termination of that rock west of Croft bridge.

The same bed is afterwards continued through Yorkshire, Derbyshire and Nottinghamshire, to the neighbourhood of Nottingham, where it suddenly terminates.

Of the hills of this rock, protruded into the Coal-field, Painshaw near Lambton appears to be the highest, being probably not less than 400 feet above the level of the sea. Kirk Merrington, situated on one of these hills may also be seen to a considerable distance.

The quarry at Whitby near Cullercoats affords the geologist an excellent opportunity of ascertaining that the magnesian limestone overlies the coal-measures, and that the latter were consolidated before the limestone was deposited upon them. I shall therefore describe that curious spot.

A hollow space formed like a basin or trough is filled with the limestone.* The length of this from east to west is about a mile;

* Plate 4, fig. 1.

the breadth from north to south four hundred yards, the depth seventy feet. The beds pass over the ninety-fathom-dyke; which has occasioned in them no confusion or dislocation; so that there can be little hazard in stating that the beds of the magnesian limestone belong to a more recent formation than those of the Coal-field. The limestone has been quarried across its whole breadth, and a numerous set of thin strata are thus exhibited to view. At the surface loose blocks of bluish grey coralloid limestone, the produce of the lead mine district are found imbedded in the soil. Three or four of the uppermost strata of the quarry are of white slaty limestone, which being nearly free from iron, burns into a pure white lime. Below these an ash-grey fine grained stratum is met with, which strongly resembles a sandstone, and seems to contain nearly as much iron as the ferri-calcite of Kirwan, becoming magnetic by the action of the blow-pipe: it produces a brownish yellow lime, less esteemed for agricultural purposes than the former. The beds next in succession are of an ash-grey colour, are compact in texture, and conchoidal in fracture: these afford a buff coloured lime, which sells for nearly the same price as the white. Near the bottom of the quarry the limestone alternates with shale; the whole rests upon a stratum of shale on the southern side, and upon a thick bed of sandstone on the northern. The shale has been cut through to a considerable distance from the kilns in the direction of North Shields, for the purpose of laying a rail-way to the Tyne. The thickness of the limestone strata varies from three or four inches to as many feet. Small strings of galena have been found here, and, in one of the strata that was walled up when I visited the quarry, a few organic remains have been noticed.

The stone intended to be burnt is detached from the rock by the agency of fire, during which process those portions which contain iron become of a brick-red colour. Considerable quantities of fuel are found necessary at the kiln, and some parts of the rock are too apt to vitrify in the process, an accident to which the crystalline limestone of Sunderland is not liable.

Along the coast of Durham from Shields to Hartlepool, the uppermost bed frequently consists of a species of breccia, the cement of which is a marl-like substance consisting chiefly of magnesian carbonate of lime, and with this breccia wide chasms or interruptions in the cliff are filled. The next strata are thin and slaty, but lower down the stratification becomes less distinct. The colour of this rock is then light hair brown, the texture crystalline and cellular, from which latter cause it strongly resists the stroke of the hammer. The slaty variety occurs at Bolden hills, Marsden rocks, and numerous other places; its colour is white inclining to buff; dendritical marks may be found between the thin layers into which it easily breaks; and in Marsden lane and on the sea coast a flexible kind has lately been noticed by Mr. Nichol. In the neighbourhood of Sunderland* the brown variety is generally quarried; it partakes of the nature of swinestone, and from containing some inflammable matter requires only a small quantity of coal to be reduced to lime. That worked at Denton, not far from the Tees, and analyzed by the Rev. J. Holme, is, I suspect, of this quality, for he mentions bitumen, as one of its constituents; whereas Sir H. Davy takes no notice of that substance in the rocks of Eldon and Aycliff.

* The exportation of lime from Sunderland is chiefly to Scotland, and amounts to from forty-two to forty-five thousand chaldrons of 36 bushels each, annually.

Analysis of 100 *parts of Limestone.*

By the Rev. J. Holme. From Denton.		By Sir H. Davy. From Eldon.		From Aycliff.
Carbonate of Lime	63		52.	48.9
——— of Magnesia	34		45.2	46.6
Alumina, Red Oxide of Iron, and Bitumen.	2.25	Iron	1.1	1.66
Water	.25	Residuum	1.7	2.8
	100.		100.	100.

In a quarry at Hartlepool I have noticed a stratum of hard white oolite, the grains composing it being about the size of a mustard seed; but, unlike the Ketton and Riflington roe-stones, it contains no shells or marine exuviæ. I have found at the same place a bed of pale buff coloured limestone of an earthy fracture, punctured with holes not larger than a needle's point. The ornamental parts of the old exchange at Newcastle were carved out of these two varieties of stone.

The four lowest strata of Mr. Goodchild's quarries at Pallion near Sunderland, constitute another variety. Its colour is a dirty light brown; but taking a tolerably good polish it is sold as a marble. In lustre and hardness it resembles a stalagmite; it is met with at the depth of eleven fathoms from the surface.

In Castle Eden Dean there are cliffs of this rock well worthy of notice; and the perforated rocks at Marsden and Hartlepool, and the caverns at the latter place, at Black-hall near Easington, and on the coast near Monk Wearmouth, deserve the attention of the geologist. These curious and picturesque objects appear to have been formed at no very distant date by the action at the sea, which has dissolved and washed out the soft marly limestone, with which the cavities of these rocks were once filled. From this cause the promontory, on which Hartlepool stands, is rapidly crumbling away.

It is well ascertained that the magnesian limestone of this district, as is the case with that of Derbyshire and Yorkshire, rests upon the coal-measures. No coal mine however has yet been won in Northumberland or Durham, by sinking a shaft through the limestone, although the workings of some collieries situated on its western boundary have been carried underneath it. It is therefore a matter of great importance to those who have royalties within its limits to know under what thickness of limestone the coal measures are buried; whether after passing under the limestone they continue to dip at the same angle as before, and whether the quality or thickness of the coal-seams is then altered.

I have not been able to ascertain what is the total thickness of the limestone; but at Hart, near to Hartlepool, a bore-hole was made in it to the depth of 52 fathoms, without penetrating through it. This spirited undertaking was then frustrated from the perforation being filled with sand and water. At Pallion, a little to the west of Sunderland, the limestone was only 12 fathoms thick, below which the coal measures were bored through to the depth of 140 fathoms without finding a coal seam worth working.

Along the coast of Durham from Shields to Hartlepool the limestone strata dip to the south-east. At Chapted main near South Shields, the coal measures, although approaching the limestone, rise towards the sea, in conformity to their direction on the north side of the Tyne; but at Painshaw, New bottle, Rainton, &c. they dip to the south-east, the limestone being there protruded into the Coal-field beyond the prolongation of that line, from which the coal measures that are without covering begin to rise in an eastern direction. It appears therefore that their dip is not affected by the limestone. It is a circumstance however too well ascertained to admit of a doubt, though difficult to be accounted for, that the coal is deteriorated in quality where covered by the limestone.

Galena is the only metallic ore that I have observed in this limestone. It has been found in small strings at Whitby quarry, Clacks-heugh Blackhall-rocks, Ryehope, and amongst the rocks below Tynemouth castle: at the latter place calcareous spar is the matrix.

The crystallized fossils are small crystals of calcareous spar, formed in groups of acute three-sided pyramids; sometimes white and opaque; at other times yellowish or hair brown and translucent, lining cavities of buff marly limestone; from the cliffs near South Shields and Marsden.

Botryoidal masses of fetid limestone devoid of magnesia, in balls varying from the size of a pea to two feet in diameter, imbedded in soft, marly, magnesian limestone, are found at Hartlepool, in the quarry at Building hill, near Sunderland, and on the sea-coast a mile or two north of Monk Wearmouth. These balls are radiated from the center, their colour hair brown, fracture shining, cross fracture splendent approaching to vitreous: white calcareous spar is frequently observed within them. See Sowerby, Brit. Min. tab. 38.

Stalactitical fetid limestone. See Sowerby, tab. 148. These cellular masses resemble corallines, and are also met with in the marly limestone above described.

Organic remains are rarely met with in this limestone. The most remarkable one was found in a quarry at Low Pallion. It is the impression of a fish,* which appears to belong to the genus Chætodon.

* See Plate 2.

In length it is about $8\frac{1}{2}$ inches, and $4\frac{1}{2}$ in breadth. The dorsal fin reaches from the middle of the back to the tail.

From Humbleton quarry, situated a mile from Bishop Wearmouth, on the road to Durham, I have received the following specimens, imbedded in hard buff-coloured crystalline limestone.

1. Casts of the internal part of the vertebral column of the Cap Encrinite. See Parkinson, vol. 2. tab. 10. fig. 4.

2. A species of Donax with hair-like spines.

3. Casts of reticulated Alcyonite. Parkinson, vol. 2. tab. 10. fig. 1, 2, 3.

4. Smooth shelled bivalves, from the size of a pea to that of a cockle, resembling those of the genus Donax.

5. Small round bodies, delineated by Parkinson, vol. 2. tab. 8. fig. 10.

6. Casts of bivalves, resembling muscles.

7. Casts of Arcæ and Anomiæ. Sowerby, Brit. Min. tab. 55.

8. Impressions of a reticulated marine production resembling the genus Flustra.

III. *Coal Measures.*

The coal-seams and the rocky strata which together constitute the coal-formation of Newcastle and Sunderland, are in part covered by the magnesian limestone, and rest upon the lead-mine measures. They occupy a hollow, or trough, of which the extreme length from the Aklington colliery, near the Coquet, in the north, to Cockfield, in the neighbourhood of West-Auckland, is 58 miles; and the breadth, from Bywill on the Tyne, to the sea-shore, is 24 miles. This formation first makes its appearance on the south bank of the

Coquet, near that river's junction with the sea, and bounds the coast of Northumberland in a south-south-eastern direction for 23 miles. It then crosses the mouth of the Tyne; after which the magnesian limestone begins to cover a part of it, and continues to intrude more and more upon it until both approach the Tees. The distance from South Shields to Cockfield is 32 miles in a south-westerly direction. The western side of this district cannot be so easily defined, since many of the lead-mine measures strongly resemble those of the coal-field; but when the *Mill-stone grit* (a coarse-grained sandstone so called) and the *Blue Encrinal limestone*, are seen cropping out, one may then be sure that the boundary of the coal formation is passed. However, if a line be drawn from the vicinity of Aklington on the Coquet, to cross the Tyne at Bywill, the Derwent near Allansford, and the Wear below Wolsingham, and to terminate at Cockfield, a tolerably correct idea may be formed of its western limits.

This district is characterized by low round-topped hills, which rise gently from the sea, and increase in height towards the west. Pontop pike, situated on the Derwent, not far from the western boundary of the coal-field, is reckoned by Mr. Fenwick of Dipton, to be very near 1000 feet high, and a pit sunk near the summit proves that it cannot be much less. That part of Newcastle Leases which lies close to Spring Gardens, and the western turnpike gate, is ascertained to be 190 feet above the level of the Tyne, and 205 above the sea. Benwell hills to the west, and Gateshead Fell to the south, are somewhat higher.

The inequality of the surface does not affect the dip or inclination of the coal measures; and when they are interrupted or cut off by the intervention of a valley, they will be found on the sides of the opposite hills at the same levels, as if the beds had been continuous. Thus the Grindstone bed may be seen on Byker hill, Gateshead

Fell, and Whickham Banks, though no where in the vales of the Tyne and the Team, which severally intersect those elevated portions of land. The conclusion is obvious, that the present irregularity of hill and dale has been occasioned by the partial destruction and dispersion of the uppermost rocky masses, which constitute the coal formation.

That part of the trough in which the greatest thickness of the coal measures is found, seems to lie in the vicinity of Jarrow; and from this point the beds appear to rise to some considerable distance on each side, particularly in a western direction. The average dip of the coal measures is 1 inch in 20; but this inclination is by no means uniform in every part of the district. Thus that seam of coal called the High Main which lies buried at Jarrow, under 160 fathoms of beds of stone, soon rises to the clay in a north-easterly direction, and bassets out in the cliffs between Cullercoats and Tynemouth. In its north-westerly range it reaches Benwell hills, and at Pontop nearly 18 miles due west of the sea shore at Sunderland it is met with at $38\frac{1}{2}$ fathoms from the surface. In a southerly direction it is found at 52 fathoms on Gateshead Fell, but bassets out before it reaches the Wear.

The principal substances besides coal, which constitute the Coal formation, are shale and sandstone; which as they vary in hardness or colour receive different provincial names from the miners. It is not possible to discover in the Coal measures any regular order of succession, which will apply to the whole Coalfield, and it is even with difficulty that in very limited portions of it the continuity of particular seams can be traced. This arises from the variable thickness and the rapid enlargement and contraction of the different beds; that which in one section is scarcely perceptible, having attained in a neighbouring pit the thickness of several fathoms. It is thus that the Five Quarter coal seam of the mines on the Wear is divided into the Metal and Stone-Coal seams of Sheriff Hill, and that the Low-main seam of the Wear becomes the Five Quarter and Six Quarter seams of the Tyne and Gateshead Fell. Thus also in Brandling and Hebburn collieries a parting of stone first divides and afterwards usurps the place of the High Main coal seam; and thus the two upper coal seams that are well worth working (see the section of Montague colliery north) at Kenton, are no longer so in the neighbouring colliery of Killingworth. The following is an account of a similar occurrence in Montague colliery, abridged from an unpublished Memoir, by Mr. Thomas, of Denton, on the dykes found in that mine. Within the Newbiggin Stone-Coal seam, at 20 inches from the floor, there is a band of a soft clayey substance $1\frac{1}{2}$ inch thick: but the band encreasing in thickness towards the east, the coal is divided into two distinct seams, whose aggregate thickness is less than that of the original seam. At the distance of 1000 yards to the east, and 300 yards north of the main dyke,* the band is 24 feet thick; the upper coal seam 6 inches; the lower 16 inches. The band decreases towards the north at the rate of something more than 1 inch per yard; and the coal at the same time increasing, the upper and lower parts are so nearly united at the distance of 160 yards, as to form again a workable seam. The upper coal then measures 21 inches, the lower 24, and the band 15.

It is useless therefore to attempt any general section of the Coal formation; and it will be seen in the sections subjoined to this paper, how difficult it is from want of uniformity in the beds to identify the coal seams in the vicinity of Newcastle. I refer to the

* The Ninety-fathom Dyke described hereafter.

sections of Hebburn and of Sheriff hill, as exhibiting when taken in succession, a series of Coal measures of the thickness of about 270 fathoms. In the former colliery are the beds which lie above the High Main coal; in the latter principally those which lie beneath it; together they present the entire order of the coal seams, that are best understood in the Newcastle district: but it will be seen even in these two examples, what want of agreement there is in the beds which lie in the two sections above the High Main coal.

The most valuable seam in the whole Coalfield in point of thickness and quality is that called the High Main, of the mines situated between Newcastle and Shields. It there averages above 6 feet from the roof to the floor, contains a large proportion of bitumen, and is sufficiently hard to bear carriage without breaking into very small fragments. From this the owners of Old Byker, Byker St. Anthony's, Walker, Walker Hill, Willington, Old Benton, and Flatworth mines, formerly drew their riches; and it continues to supply the present proprietors of Hartley, Blyth, and Cowpen, north of the 90 fathom Dyke; of Heaton, Bigge's Main, Wall's End, Pevey Main, Collingwood Main, and Murton Collieries on the north side of the Tyne, and of Hebburn, Jarrow, and Manor's Wall's End, on the south side of that river. I have already described in part the basseting of this coal seam along the course of an oval line, of which Jarrow is the centre; from which some idea may be formed of the extent of country which it underlies north of the 90 fathom Dyke. At a land-sale pit, a little above the Ouse burn Bridge, near Newcastle, this seam was found at 14 fathoms; but on the Town-moor, from the numerous vestiges of ancient pits, it appears to be exhausted.

The lower seams under the same lands are without doubt untouched. Wallis, in the history of Northumberland, gives an account of a fire happening in the High Main coal, about 140 years ago, on the Town-moor and Fenham estates, which continued to burn for 30 years. It began at Benwell about a quarter of a mile north of the Tyne, and at last extended itself northward into the grounds of Fenham, nearly a mile from where it first appeared. There were eruptions at Fenham in nearly 20 places; sulphur and sal-ammoniac being sublimed from the apertures; but no stones of magnitude ejected.* Red ashes and burnt clay, the relics of this pseudo-volcano, are still to be seen on the western declivity of Benwell hill, and it is credibly reported that the soil in some parts of the Fenham estate, has been rendered unproductive by the action of the fire.

At Byker St. Anthony's, and at an adjoining colliery, the Low Main coal is found at 59 fathoms below the High Main; but though the seam proved to be $6\frac{1}{2}$ feet thick, the workings of it were abandoned as unprofitable; the coal being extremely fragile, and the mines very subject to the fire damp. On the south side of the Tyne, at Felling, Tyne Main, and Gateshead Fell, the quality of this coal is very much improved, and under the name of the Hutton Main, it forms one of the most valuable seams on the Wear.

I must refer to the series of sections for a more complete view of the other coal seams.

I now proceed to give a more particular account of the substances that form the coal measures.

Of the coal itself three varieties are found; the common or Slate coal, Cannel coal, here called *Splint*, or *Parrot* coal, and *Coarse* coal, also called Splint.

The texture of fine splint is compact, the cross fracture conchoidal, and the fragments are cubical. Coarse coal is slaty in its

* See a paper by Dr. Lucas Hodgson, on the Salt sublimed, in the Phil. Trans. No. 130.

texture, and it seems to be intermediate between common and cannel coal.

These varieties are not found to occupy separate and peculiar seams of the coal formation, but alternate irregularly with one another, as layers of the same bed.

At Wylam they are met with in the following order.

			Feet	In.	Feet	In.
At 6 fathoms	High main	Fine splint.....		11		
		Stone band.....		$3\frac{1}{4}$		
		Clean coal	4	2	5	7
		Coarse coal		$2\frac{1}{4}$		
21	Five quarter........	Splint		$5\frac{1}{2}$	3	$4\frac{1}{2}$
		Clean coal	2	11		
26	Six quarter.........	Clean coal	2	9		
		Splint		$2\frac{1}{2}$	3	4
		Coarse coal		$4\frac{1}{2}$		
32	Yard coal..........	Slaty band		$3\frac{1}{2}$		
		Free coal		7	1	2
		Coarse coal		$3\frac{1}{2}$		
38	Horsley Wood seam..	Clean coal		$2\frac{1}{2}$		$11\frac{1}{2}$
		Splint		9		

Splint coal is also found at Throckley, Kenton, and some of the Lambton collieries situated on the Wear. Coarse coal occurs at Cockfield and many other places. These two varieties, containing little bitumen and less sulphur, are used in iron founderies, potteries, &c.; and splint serves as a material for building cottages and outhouses in the neighbourhood of Throckley Fell.

Potters' clay is found immediately below the vegetable soil. Its colour is blueish or smoke grey, and sometimes yellow approaching to orange, in consequence of a mixture of iron ochre. It is used in the manufacture of coarse earthenware, bricks, and tiles.

Shale or slate-clay is found throughout the Coal field, possessing various shades of colour and degrees of induration. Hard black and dark grey shale is called *Black metal* by the miners; it is used by the manufacturers of potters' saggers and fire-bricks, but for the latter purpose *Thil-whin*, or hard bituminous shale forming the floor of the coal seams, is preferred.* Shale of a blueish grey colour is called *Blue metal.* A blue bituminous shale, lying immediately below the coal, is called *Blue-thil.*

Hard blue metal is one of the most common measures in the coal-field; it is a mixture of shale and sandstone, sometimes containing scales of mica; is much harder than *Blue metal*, and from its waved structure breaks into sharp wedge-shaped fragments. Its colour varies from ash-grey to iron-grey.

Clay-stone (of Jameson) is not very common; it varies in colour from black to ash-grey, and is the *Black-stone* or *Blue-stone* of the miners, (vide St. Anthony's section,) it is fine-grained in texture, and breaks into angular fragments.

The following are the principal varieties of sandstone that occur.

White flagstone plate: a greyish-white argillaceous sandstone, hard and breaking into sharp wedge-shaped fragments. It is quarried for flag-stone at Heworth and on Gateshead Fell, where it is about two fathoms thick.

Grindstone sill or *post:* a light yellowish or buff-coloured fine-grained sandstone, loosely aggregated, and therefore not very hard. It crops out on Byker Hill, Whickham Banks, and Gateshead Fell, where it is about 11 fathoms thick. It is quarried for the well known Newcastle grindstones, and from its softer parts filtering stones are made. In many places the upper part of this bed is

* Stourbridge clay is imported for the glass-house pots.

abundantly impregnated with yellow ochre, which is sold under the name of *die-sand.*

Fire-stone resembles the grindstone in colour and fracture, but is soft when first worked. The best is quarried at Burradon near Killingworth: glass-house furnaces are constructed with it.

White post is a fine-grained sandstone, tolerably hard.

White post with whin consists of alternate laminæ of soft and hard sandstone.

Grey post is a fine grained sandstone, containing a large admixture of clay and sometimes of mica.

Brown post is a slaty micaceous sandstone.

Brown post with *Coal pipes* is a laminated sandstone traversed by strings of black shale and coal.

Brown post with *skamy partings* is a light brown sandstone with dark brown laminæ.

Grey whin or *Brown whin* is a very hard dirty-brown quartzose sandstone, sometimes specked with minute white dots, and at other times containing very small scales of mica: it strongly resembles granular quartz. A bed of this rock may be seen contiguous to the basaltic dyke in Walbottle Dean.

What is called by the miners *Band* in coal is commonly composed of bituminous shale, clay and iron pyrites; sometimes of sandstone. *Girdle* means a thin plate: thus *Post girdles* are layers of sandstone; *Whin girdles in post* are layers of hard quartzose sandstone in softer sandstone; and *Whin girdles in shale* are thin beds of argillaceous iron ore in shale.

The minerals that accompany the coal measures are,

Clay ironstone, forming either thin beds or nodules *(catheads)* in the shale.

Galena is found together with pyrites in the nodules of clay-iron-stone, that are imbedded in the shale: as at Montagu main, at the depth of 40 fathoms.

Iron pyrites is found in great abundance crystallized and disseminated in the beds both of coal and of shale: it is sold to the manufacturers of green vitriol.

Azure iron ore is not uncommon in the potters' clay at Elswick, and in other brick fields.

Calcareous spar is common, either blended with the coal or in the form of stalagmites.

The Organic remains found in the coal measures are,

Impressions of plants resembling those of the genera fontinalis and equisetum, except that the latter are destitute of the jointed stem of the true equiseta. In shale.

A fern, like polypodium filix mas, (Parkinson, vol. i. tab. 4. fig. 7.) Impressions of plants, (vide Parkinson, vol. i. tab. 3. fig. 6, 7.) In shale.

A fern, like blechnum boreale, (Parkinson, tab. 4. fig. 1, 2. and Sowerby, tab. 296.) and another like osmunda regalis; from Kenton colliery, and from the shale contiguous to the Coley hill dyke. In nodules of clay iron-stone.

Impressions of cones, (Parkinson, vol. i. tab. 9. fig. 1.) from Urpeth Dean, Durham. In nodules of clay ironstone.

Obscure impressions of a fern, from Murton colliery. In nodules of clay ironstone.

Large flattened lumps of iron pyrites, bearing the form of the stem and the impression of the bark of a plant resembling an euphorbia; called by the miners *petrified salmon.* From the floor of several collieries.

Impressions of the bark of a plant resembling a cactus or euphorbia, (Sowerby, tab. 49.) from Murton Main colliery; and (Parkinson, vol. i. tab. 1. fig. 6.) from Benwell colliery. In coal.

Vegetable impressions (vide Parkinson, vol. i. tab. 3. fig. 1.) from Gateshead Fell. In sandstone.

Cast of a cane-like vegetable, (Parkinson, vol. i. tab. 3. fig. 3.) from near Coley hill dyke; and (Parkinson, vol. i. tab. 5. fig. 8.) from Muston colliery.

An aggregate of black quartz crystals diverging from centres; having the interstices filled with yellow ochre. It is a mineralized tree, and it found at Bigge's main colliery, and often in large masses on the sea beach.

Bivalve shells * resembling those of the freshwater muscle, in dark-grey ironstone, from Wylam and Muston collieries.

Bivalve shells resembling the preceding but much less in size, in a stratum of black shale and ironstone; from the rocks in the Tyne at Low Lights, and from Heaton Dean, near Busy cottage.

Bivalve shells like the last, about half the size of freshwater muscle shells, in black shale, from Hebburn colliery, at the depth of 130 fathoms. These shells are generally less common in the shale than in the ironstone that accompanies it.

I have only to remark on the preceding catalogue that it contains no marine genera; and I do not believe that any marine shells, zoophytes, or corallines have ever been detected in the coal measures of this district.

* Very similar shells are found in the Clackmannanshire coal-field at North Alloa, in that of Staffordshire at Tividale, and in the great coal-field of Derbyshire and Yorkshire, where the bed of ironstone that contains them is called the Muscle band. [Communicated by Mr. Warburton.]

The dykes of basalt or greenstone, that intersect the coal measures, are among the most remarkable occurrences in the Coalfield.

The most considerable basaltic dyke in the immediate neighbourhood of Newcastle is that which passes through Coley hill, about 4 miles west of the town. A long range of quarries has here been opened upon it, in some places to the depth of 50 feet, and laying bare the entire width of the dyke, which is 24 feet. The dyke in this place appears to have no hade. The basalt of which it is composed is found in detached masses coated with yellow ochre. The removal of these brings to view thin layers of indurated clay with which the fissure is lined, and which breaking into small quadrangular prisms is used by the country people for whetstones: in this substance clay ironstone impressed with the figures of ferns is very abundant. The upper seam of coal is here found at about 35 feet from the surface, and where in contact with the dyke is completely charred, forming an ash-grey porous mass, which breaks into small columnar concretions, exactly resembling the coak obtained by baking coal in close iron cylinders in the process of distilling coal-tar. Calcareous spar and sulphur are disseminated through the pores of this substance.

The basalt itself when broken is of a greenish-black colour, and of a coarse grained fracture. It contains quartz, calcareous spar, and another mineral, possessing the following characters. The colour is wax-yellow passing into olive-green; the lustre vitreous, resembling that of glassy felspar; the fracture foliated. It resists the action of the blow-pipe without borax, but with it melts into a white glass. The latter circumstance, and the foliated fracture distinguish this substance from olivine, which gives a dark green bead with borax, and presents a fracture more or less conchoidal.

Passing to the east-south-east of the Coley hill dyke in the line of its direction a vein is found traversing Walker colliery, and crossing the Tyne at Walker near Mr. Reay's house. In the latter colliery it has been observed and described by Mr. George Hill, to whose accuracy I owe the plan given in Plate 3, and the following particulars.

The dyke is well defined, and the Plate represents its horizontal section taken at the level of the high main coal 100 fathoms from the surface. It occasions no alteration in the level of the coal-measures, and the depth to which it intersects them is unknown. The dyke has been cut through by horizontal drifts in four places, from which the following sections have been taken.

Sections at A. A. the two western drifts.

1. Coak	6	—	—
2. Hard greenish whinstone, firm and unbroken	3	—	—
3. A fissure filled with nodules of whinstone and post imbedded in a cement of blue slate	—	—	9
4. Loose fragments of whinstone and post imbedded in blue slate but commonly less deranged	3	2	3
5. Hard greenish whinstone similar to No. 2.	6	—	—
6. Coak.	3	1	6
Yards	22	1	6

Sections at B. B. the two eastern drifts.

1. Coak very hard	1	—	—
2. A confused mixture of nodules of sandstone, whinstone, pyrites and calcareous spar (the sandstone predominating) cemented together by pieces of blue and black slate. Water was found, and there was a plentiful discharge of inflammable gas, while the drift was being made	6	—	—
3. Compact post, with pieces of black argillaceous slate occurring at intervals	3	1	6
4. Hard greenish whinstone	8	1	6
5. Coak like that of No. 1.	1	—	—
Yards	20	—	—

Further to the south-east and in the line of the direction of the Walker dyke, a small quarry of basalt was formerly worked about 1 mile north of Boldon hills. The rock was fine grained, nearly black, and filled with small globules of milk white chalcedony, not bigger than a mustard seed.

With regard to the basaltic rocks of Coley hill, Walker, and Boldon, it is by no means well ascertained that they are portions of the same dyke, connected together below the surface; since no trace of that of Coley hill could be discovered in the very extensive and ancient collieries of Montagu and Kenton, situated in its course at a short distance to the east of it; nor was the Walker dyke found in any other colliery.

At Walbottle Dean, $5\frac{1}{2}$ miles west of Newcastle, below the bridge on the western road, a double vein of basalt* crosses the ravine in a diagonal direction, passing nearly due east and west. It hades to the north at an angle of 78°, and cuts the coal-measures without altering their dip. On the eastern bank of the ravine it is laid bare from the level of the brook to the height of about 60 feet. The northern and southern basaltic portions of the vein, the one 5 the other 6 feet in thickness, are there 13 feet apart, and are separated from one another by a confused heap of fragments of sandstone and shale broken from the coal-measures. With these fragments are found balls of basaltic tufa parting into concentric layers, and of a light yellowish brown colour: the balls are most abundant on the sides of the rubble near to the basalt.

Where the dyke reaches the surface a quarry of the basalt was formerly worked, which has lately been cleared. A small seam of coal meets the basalt at no great depth from the quarry-head, but

* Plate 4, fig. 2.

the place of contact is at present inaccessible. In the neighbouring colliery both portions of the vein hold their course through the seam there worked, and the coal is charred by their influence.

Some of the blocks from the quarry are quite black, and of an earthy fracture, and contain nodules of quartz and chalcedony, varying in magnitude from the size of a pin's head to that of a large pea. Other specimens of the rock are hard, coarse grained, and of an iron-grey colour; but in neither varieties have I found the mineral resembling adularia, so abundant in the basalt of Coley hill.

A basaltic dyke 6 feet wide may be seen among the rocks of the coal formation at the south-eastern corner of the promontory on which Tynemouth castle stands. Another, about 3 yards wide, appears in the cliffs near Seaton sluice; its direction is west-north-west, and it may again be seen in Hartley burn. A small whin dyke was formerly quarried near Bedlington; and another is found in Cowpen colliery, which has charred the coal in contact with it.

Passing to the south of Newcastle about 2 miles beyond Durham, a basaltic vein may be seen, when the water is low, at Butterby in the bed of the Wear. This vein is remarkable for a salt spring that issues from its interstices, and for a string of galena (first noticed by Mr. Fenwick of Dipton) that fills a crevice beside it. Two miles further to the south near the junction of the Auckland and Darlington roads, is another dyke, the direction of which is nearly east and west, and on which two quarries are worked, each about 10 feet wide.

Of the Cockfield dyke a section and description have been given in the History of Durham, by the late Mr. Dixon, from which work I derive the following particulars.

This dyke passes in a north-west and south-east direction from

Cockfield to Botain, situated on the western boundary of the magnesian limestone. Its width is 17 feet at the former place, where it hades to the south, and throws up the coal-measures on that side 3 fathoms. The low main coal contiguous to the basalt is only 9 inches thick, but enlarges to 6 feet at the distance of 50 yards from it. The coal is reduced to a cinder, and the sulphur is sublimed from the pyrites near to the dyke.

I have never been able to trace any of these basaltic veins into the magnesian limestone, and am almost certain that together with the other members of the coal formation, they are covered by it.

Continuing the line of direction of the Cockfield dyke from Botain to the south-east, after passing the eastern boundary of the magnesian limestone, we meet with a dyke on the banks of the Tees a little below Yarm. It there cuts the red sandstone, and continuing its course in the same direction is well known to traverse the north-eastern part of Yorkshire.

Besides the fissures filled with basalt, others of a very different nature intersect the Coal-field. These if large are also called *dykes*, but, if inconsiderable, *troubles*, *slips* or *hitches*; and are the same that some geologists have called *faults*.

I have already noticed the *main* or *ninety-fathom-dyke*, when speaking of the limestone quarry at Whitley, where it is seen dividing the coal-measures in the cliff, and passing into the sea. It receives its name from the degree of *throw* which generally attends it in the strata through which it passes, and which are cast down on the northern side about 90 fathoms. At Whitley the same bed of coal which is found at 7 fathoms on the southern side of it, is found at 50 on the northern, the measures being there thrown up on the southern side 43 fathoms. From this point the dyke ranges, though not in a straight line, through that part of the country formerly called Killingworth moor, and passing near Gosforth church, Denton hall, and by the north corner of the field east of W. Denton's house, crosses the Tyne in the direction of Reyton church, and proceeds to the south-west by Greenside and Lead-gate. Farther it has not been traced; but it is highly probable that it traverses the lead mine district; and produces lateral and valuable metalliferous veins therein.

It will appear from the two subjoined sections of Montagu Colliery, taken from opposite sides of this fissure, that 11 seams of coal (two of which are worth working) together with their accompanying strata which are found on the northern side, have disappeared on the southern. The exact throw in the measures occasioned by the dyke cannot be ascertained from these sections, one of them being that of a pit near to Scott's wood close to the Tyne, the other belonging to a shaft sunk in much higher ground $1\frac{1}{2}$ mile north of the former.

* The hade of the dyke in this colliery is imperceptible: the space between the cheeks measures about 22 yards, and is filled with soft and hard sandstone. A perpendicular fissure, the sides of which are quite smooth, divides the stony contents of the dyke into two equal parts, and when perforated was found to be filled with soft clay and water. On the south side the coal-measures preserve their usual dip of 5° until close to the dyke: on the northern from the distance of 150 yards they rise to the dyke at an angle of 20°, but at the distance of 600 yards they regain their accustomed position. In some parts the coal is deteriorated in quality to the

* I have extracted these particulars from a memoir on the Montagu colliery, by Mr. Thomas, of Denton, in which are described the dykes and slips met with in the workings of that mine. I am partly indebted to the same gentleman for the information on the direction of the main dyke.

distance of 20 yards from the dyke; but in others to that of 3 or 4 yards only.

From the southern side of the main dyke two others branch off, one to the south-east, the other to the south-west. The latter is called from its breadth the 70 yard dyke, and is filled with a body of hard and soft sandstone. This intersects the upper or Beaumont seam, which is not thrown out of its level by the interruption. The seam however decreases in thickness from the distance of 15 or 16 yards, and the coal first becomes sooty, and at length assumes the appearance of coak. This phenomenon is unknown elsewhere except in the vicinity of basaltic dykes.

The south eastern branch is only 20 yards in breadth, and hard white sandstone together with other rocky fragments fill the cavity, and are in part cemented together by calcareous spar. Although the strata are thrown up only 20 feet on the north-eastern side of the vein, yet great confusion has taken place in its vicinity, and much water was found to issue from it.

From the northern side of this part of the main dyke many small slips extend, some of which alter the level of the Newbiggin coal-seam without affecting that of the Kenton seam lying only 13 fathoms above it.

* The Birtley, Tantoby or Tanfield dyke is next in magnitude and length after the main dyke. From Tatfield on the Wear it ranges towards the west, passing through Leefield, Ouston, Birtley Fell, and Urpeth collieries: thence in the direction of Beamish hall it traverses Tanfield Moor, and crosses the Derwent near Derwent-coat Forge. In Tanfield Moor colliery it is in all an upcast on the northern side of 40 fathoms; but instead of consisting of one strong

* I am indebted to Mr. Fenwick of Dipton for the information which follows, respecting the other dykes which traverse the Coal-field.

vein, it appears to be divided into a number of small branches, some of which are upcasts and some downcasts, which break and rend the coal-measures to the width of 200 yards. In the Wear water mines it is an upcast on the northern side of 30 fathoms.

The Thistle pit dyke which is a downcast of eight fathoms to the south, and traverses the Coal-field from west to east, appears to have been as well known to the miners who lived nearly a century since, as to those of the present day. It was the southern limit of the ancient colliery situated at Heaton and Benton banks, and by perforating it the mine at Heaton was inundated on the 3d of May, 1815, when the viewer and seventy-four men and boys lost their lives.—For an account of this catastrophe, see Monthly Magazine and Philosophical Journal.

The Heworth dyke is an upcast on the southern side of 25 fathoms, and from the vicinity of Falling hall it stretches towards the west, and enters the main dyke at Ryton. The high-main coal to the south of this dyke is said to lose a strong parting known by the name of Heworth band.

At Hebburn, Oxclose, Ravensworth, Lambton, Newbottle, Lumley, Raynton, and every other colliery worked in the district, similar dykes occur; and, following the same law as the veins of the Lead-mine district, they elevate the strata on that side towards which they dip.

Whatever be the throw or difference of level occasioned in the coal-measures by these dykes, it never happens, as might be expected, that a precipitous face of rock is left on the elevated side; or that the lower side is covered by an alluvial deposit, which connects the inequality of the beds that are in situ; but the surface of the ground covering the vein is rendered level by the absolute removal of the rocky strata on the elevated side. The same phenomena have been observed in other parts of the kingdom; and render evident the operation of a most powerful agent employed in tearing up the surface, and in dispersing the fragments of the ruin.

In the coal measures near the edges of those dykes rounded pebbles of sandstone and fragments of coal cemented together by sand are sometimes met with; as in Lawson main, Sheriff hill, and Montagu Main collieries.

Galena has been found in a dyke in Willington colliery, and a small string of the same ore has been observed in the main dyke at Whitley. A salt spring issues from a slip in Birtley colliery.

The dykes are an endless source of difficulty and expense to the coal owner, throwing the seams out of their levels, and filling the mines with water and fire damp. At the same time they are not without their use; when veins are filled, as is often the case, with stiff clay, numerous springs are damned up and brought to the surface; and by means of downcast dykes valuable beds of coal are preserved, which would otherwise have cropped out and been lost altogether. Thus the high-main, the five-quarter, and the seven-quarter coal seams would not now have existed in the country to the north of the main dyke but for the general depression of the beds occasioned by that chasm.

The other irregularities observed in the coal measures are the following:

1. Large wedge-shaped portions of the strata that are occasionally found to have sunk from their level. This occurrence was noticed in Cockfield colliery by Mr. Dixon, and a section of it is given in the history of Durham. A much more serious difficulty of the same kind was surmounted within these few years in Hebburn colliery by Mr. Buddle.

2. Fissures that divide the strata, but do not alter their level,

and which sometimes do not descend lower than the upper seams of coal. These are called *gashes* by Williams, and *washes* by our miners: they are filled with water, clay, sand, and rounded sandstone pebbles similar to those in the beds of rivulets.

3. Basin-formed depressions in the floors of the mines, called *swellies* by the miners; by which the coal is considerably thickened, the roof of the seam preserving its regularity. These occur when the coal is nearly horizontal.

4. Nips, where the coal nearly disappears, the floor and the roof coming into contact. Near Fawlon Slate in the neighbourhood of Fenham, 80 acres of coal are said to be lost in this manner.

At Hetton and at Hebburn, and in other parts of the Coal-field, the coal-measures are covered by large tracts of quicksand, which appear to have been the beds of ancient lakes. Mr. Fenwick has lately penetrated through a most formidable obstruction of this kind at Hetton by means of a number of cast-iron cylinders.

Having now given a general account of the coal beds, and of the derangements to which they are subject, I proceed to the Colliery Sections, with which I commence on the northern side of the main dyke near the sea, and thence pass towards the west: then crossing to the southern side of the main dyke at Montagu colliery and returning to the east, I exhibit the strata pierced at some of the principal collieries on the Tyne, and the lower beds found at Gateshead Fell and on the Wear. Some other examples follow, which are taken from the western and south-western borders of the Coal-field.

Section of the Strata at Hartley Colliery.

	Fs.	Y.	F.	In.
Clay, Sand, &c. to the Coal-	5	—	—	—
Post	16	1	—	—
White post	2	1	2	2
Benton Seam	—	1	2	2
Clay	—	—	—	3
Ground Coal	—	—	1	4
Thil of ditto	—	—	1	—
Blue Metal	—	1	1	8
Black ditto	—	1	2	1
Blue ditto	3	1	—	5
Black ditto	3	1	—	11
Grey ditto with girdles	3	1	—	1
Blue ditto	—	1	—	11
Metal Coal	—	—	1	10
Thil	—	—	—	5
Grey Metal with post girdles	1	1	1	1
White post	—	1	1	—
Whin	—	—	1	7
White post	—	1	—	3
Blue Metal	—	—	2	6
White post	2	1	—	6
Grey Metal with girdles	—	—	2	8
White post	—	1	1	6
Grey Metal	—	—	2	4
Blue ditto	2	1	1	9
Mixed Coal and Stone	—	—	2	6
Black Stone	—	—	1	6
White post	—	—	2	2
Grey Metal	—	—	1	2
Post girdle	—	—	—	3
Grey Metal	—	—	—	4
Post girdles	—	—	—	10
Grey Metal	—	—	2	4
Blue ditto	—	—	—	4
White post	4	1	—	5
Blue Stone	—	1	2	9
Yard Coal	—	1	—	7
Carried forward	57	1	—	7

	Fs.	Y.	F.	In.
Brought forward	57	1	—	7
Grey Thil	—	—	—	3
White and Grey post	—	1	—	3
Blue Metal	—	—	1	6
Black ditto mixed with Coal	—	1	—	9
Grey post	2	—	1	4
Grey Metal Stone	1	—	—	—
Grey Metal	2	—	1	4
Black ditto	—	—	1	4
Coal with Metal bands	—	—	2	4
Thil and Grey Metal	—	—	2	—
Grey Metal Stone	1	1	1	1
Black Metal and Coal pipes	—	—	2	6
Coal mixed with Metal	—	1	—	—
Grey Thil	—	—	—	6
Grey Metal stone	—	—	2	—
Blue ditto	—	1	1	—
Grey Metal Stone	1	1	1	6
Grey Seamy post	1	1	—	6
Grey Metal Stone	—	1	—	—
Ditto with girdles	1	—	—	10
Black Metal	—	—	1	—
Coal	—	—	2	3
Grey Metal	—	—	1	1
Coal with Metal band	—	—	1	10
Grey Thil	—	—	—	4
White and Grey post	1	1	—	—
Grey Metal Stone	—	—	1	8
Blue ditto	3	—	—	—
Black ditto	—	—	1	11
Coal	—	—	—	1
Grey Thil.	—	—	—	4
Blue Metal	—	1	—	8
Grey Seamy post	—	1	1	—
Blue Metal	—	1	1	9
Black Metal	—	—	1	4
Main Coal	—	1	1	5
	83	0	2	3

Dip of the Strata west-north-west.

Strata passed through by Killingworth Sinking Pit.

	Fs.	Ft.	In.
Clay	8	—	—
Coal	—	1	3
Grey Metal	—	4	—
Grey Post Girdles	—	—	8
Grey Metal Stone	4	—	—
Strong Post mixed with Whin	—	3	—
Post	2	1	—
Black Stone	—	1	6
Coal	—	—	9
Black Stone * †	—	—	8
Coal	—	1	8
Grey Metal	1	—	—
Strong blue Stone	2	1	—
Coal	—	2	4
Grey Metal	—	2	5
Coal	—	—	6
Blue Stone	1	5	—
Whin Girdle	—	2	6
Blue Stone and Whin Girdles	—	5	—
Coal	—	—	4
Gray Thil	1	1	8
Grey post	—	2	4
Blue stone	—	2	3
Coal	—	—	4
Grey and blue Metal with Girdles	1	4	—
Blue Stone	—	4	8
Coal	—	1	10
Grey Thil	—	1	6
Strong grey post	1	2	—
Grey Metal stone	—	4	6
Slaty Coal, mixed with Black-stone	—	2	6
Grey Thil	—	—	8
Slaty Coal	—	2	—
Grey post with water	2	1	6
Grey Metal with strong Girdles	1	3	—
Strong white post	—	1	6
Grey Blue Metal with Girdles	1	3	—
Coal	—	—	6
Blue Metal	—	1	2
Coal	—	—	4
Grey post with Metal Girdles and lumps	3	1	8
Coal	—	—	2
Grey Thil	—	—	4
Coal	—	—	4
Grey and blue Metal with post Girdles	3	3	—
Coal	—	2	6
Thil	—	—	6
Grey Metal stone with post Girdles	2	—	—
Soft blue Metal with lumps	6	—	5
White post	7	—	—
Blue grey Metal	—	4	—
Grey post	4	2	4
Carried forward	65	—	1

	Fs.	Ft.	In.
Brought forward	65	—	1
Black Stone	—	4	—
Coal	—	—	8
Grey Thil and Whin Girdles	1	—	—
Strong blue stone	1	—	—
Black stone	—	3	—
Coal	—	—	3
Grey Thil	—	4	—
White post with Whin Girdles	2	3	—
Grey Metal and Girdles	—	2	—
Black Stone mixed with Coal	—	5	—
Soft grey Metal	—	3	—
Grey Metal	1	3	—
Coal	—	1	6
Grey blue Metal	—	1	—
White post	1	2	—
Blue Metal	—	1	—
Coal	—	1	10
Grey Metal with Post Girdles	2	2	—
Coal	—	1	—
Grey Metal stone	—	2	—
Grey post	1	—	—
Grey and blue Metal	—	4	—
White post	—	3	—
Grey and blue Metal with Whin Girdles	1	1	6
Black Stone	1	—	—
Coal (A)	—	2	6
White post	1	—	—
Grey Metal with post girdles	—	5	—
Whin and white post	1	2	6
Blue Metal with Post Girdles	2	4	6
Black Metal	—	3	—
Blue Metal and Girdles	—	2	—
Black Stone	—	—	9
Coal	—	—	9
Grey Thil and Whin lumps	—	4	—
Blue Metal	—	4	—
White post	3	2	—
Black Metal	—	—	6
Coal	—	—	7
Grey Metal	—	—	10
Grey post	2	4	6
Blue Metal	—	4	—
Black Metal	—	1	8
Grey and white post with metal partings	1	—	—
Grey and blue Metal	—	5	—
Black Metal	1	4	6
Coal	—	1	—
Grey Metal	—	5	7
White post with metal partings.	8	4	6
Top Coal, rather coarse	—	—	4
Clean Coal (B)	1	—	1½
Bottom Coal to be curved out.	—	—	8
Total	115	—	7½

* This Seam is found in Hebburn and Jarrow Collieries.

† This seam is generally found on the south side of the Main dyke, when the Tyne High main Coal B lies at about 112 fathoms from the surface.

Boring made at Coxlodge, November 26th, 1761.

	Fs.	Ft.	In.
Soil	—	1	—
Strong stony clay	4	4	—
Black Metal	—	3	—
Brown post	—	2	—
COAL (but will not cake or burn)	—	1	1
Grey Metal	—	2	—
White and grey post with water	1	—	—
Grey Metal	3	—	6
Grey post with water	—	1	6
Strong white post mixed with Whin	—	1	3
Grey Metal stone with post girdles	2	—	6
Blue and black Metal with Scares of Coal	1	—	—
COAL	—	—	4
Brassy lump	—	—	1
COAL	—	—	9
Soft blue and black Metal	—	—	6
Grey Metal or post	—	4	6
Thready Whin which sets away the water*	—	1	—
Grey post	—	1	6
Black skamy stone	—	—	6
Grey Metal stone	4	4	—
Soft black and blue Metal	—	4	9
FOUL COAL	—	—	5
Soft black grey Metal	—	—	10
COAL	—	1	6
Soft black danty† Metal scared with Coal	—	—	3
Grey Metal	1	3	6
Ditto and blue	—	2	6
HARD COAL	—	1	4
Black slaty stone	—	—	3
COAL, but slaty in the middle	—	1	2
Carried forward	23	4	6

	Fs.	Ft.	In.
Brought forward	23	4	6
Grey Metal	—	2	—
Blue Metal scared with Coal	—	—	3
COAL, but brassy at top	—	—	11
COAL mixed with black metal	—	—	5
Grey Metal	—	1	—
White and grey post	2	2	3
Blue grey Metal	—	2	3
Hard slaty COAL	—	—	5
Hard COAL (A)	—	1	1
Grey Metal	—	1	6
Grey skamy post with Metal partings	1	1	—
Whin, mixed with strong white post at bottom	—	2	—
Grey Metal stone with post girdles	2	—	—
Blue and black Metal	—	1	6
Grey Metal mixed with post girdles	6	1	6
Black Metal	—	1	—
Grey Metal	2	—	—
Grey and white post	2	4	6
Grey Metal	—	5	6
COAL	—	—	7
Grey Metal scared with COAL	—	—	4
Grey Metal stone	2	1	—
Soft black and blue Metal	2	5	6
COAL	—	—	8
Foul slaty COAL	—	—	5
Grey Metal with girdles	1	2	—
Strong white post	7	—	—
COAL (B)	—	4	8
Black Metal scared with Coal	—	—	2
Left off in Whitish grey post	—	2	4
Total Depth	58	3	3

N.B. This Section, as also the preceding at Killingworth, is on the north or dip side of the Main dyke.

Seams of Coal at Walbottle Colliery at the Newburn winning.

		Ft.	In.
Engine Seam	at 50 fathoms	3 —	8 thick
Main Coal	69 ———	3 —	2 ——
Splint Coal	85 ———	4 —	0 ——

The last Seam consists of 3 feet 4 inches of Clean Coal, and about 8 inches of Splint next the Thil.

* The Miner's term to express that the water escapes by percolation. † Sooty.

Seams of Coal at Throckley Colliery.

		Ft.	In.
Engine Seam . .	at 54 fathoms . .	3	8 thick
Main Coal . . .	70 ——— . .	3	0 ——
Splint Coal . .	86 ——— . .	3	3 ——

Seams of Coal at Wylam Colliery.

High Main . .	at 6 fathoms . .	5	7 thick
Five Quarter Coal .	21 ——— . .	3	$4\frac{1}{2}$ ——
Six Quarter Coal .	26 ——— . .	3	4 ——
Yard Coal . .	32 ——— . .	1	2 ——
Horsley Wood Seam .	38 ——— . .	—	$11\frac{1}{2}$ ——

Seams of Coal at Holywell Main, or Reins by Brunton.

Grey Seam, or Newbiggin Stone Coal . .	at 9 fathoms . .	4	6 thick
Five Quarter Coal .	17 ——— . .	3	9 ——
Six Quarter Coal .	35 ——— . .	3	9 ——

Section of the Strata at Montagu Main Colliery, on the North side of the Ninety Fathom Dyke.

	Fath.	Yds.	Ft.	In.
Soil and Clay . .	1	—	1	6
Grey Metal stone .	3	1	—	—
Strong Grey post . .	1	1	—	—
Grey Metal stone with girdles	4	—	1	6
Grey post with Metal partings	6	—	2	6
Whin	—	—	—	9
Blue Metal stone .	5	1	2	—
1*Coal (waste of the 7 quarter Coal, or Kenton Main, worked out in 1690) .	—	—	—	9
Blue Grey metal .	—	—	1	—
Grey Metal stone .	2	—	2	—
Grey post . .	1	1	—	—
Carried forward	27	—	—	—

	Fath.	Yds.	Ft.	In.
Brought over	27	—	—	—
Grey Metal stone with girdles . .	2	—	1	—
White post . .	3	—	—	6
Metal stone . .	1	1	2	—
Blue Grey metal .	—	—	2	6
Stone Coal . (2 Five Quarter or Newbiggin)	—	—	—	3
Black Metal stone (2 Five Quarter or Newbiggin)	—	—	—	2
Coal . . (2 Five Quarter or Newbiggin)	—	—	1	9
Black Metal stone (2 Five Quarter or Newbiggin)	—	—	—	2
Coal . . (2 Five Quarter or Newbiggin)	—	—	2	1
Grey Metal stone .	—	1	1	—
Strong White post .	1	1	1	—
Carried forward	37	1	—	5

* Kenton Main in the colliery of Kenton.

	Ft.	In.
Good Coal	4	6
Ditto and band . .	—	6
Good Coal	1	2
Feet	6	2

No.		Fath.	Yds.	Ft.	In
	Brought forward	37	1	—	5
	Strong grey Metal stone	—	1	1	—
	Strong white post	—	—	2	—
	Grey Metal stone	2	1	—	—
3	Coal	—	—	—	6
	Grey stone with Post girdles	3	—	1	6
	Mixture whin	—	—	1	3
	Grey post	1	—	—	—
	Grey Metal stone	—	1	2	10
4	Coal	—	—	—	6
	Grey Metal stone	—	—	—	2
5	Coal	—	—	—	8
	Grey Metal stone	1	—	—	—
	Strong white post	1	—	—	4
6	Coal	—	—	—	8
	Grey Metal stone	—	—	1	—
	Grey post	—	—	1	6
	Strong white post	1	—	—	—
	Dark grey metal	—	—	1	11
7	Coal	—	—	—	4
	Grey Metal stone	2	1	1	4
8	Coal	—	—	—	4
	Grey Metal stone	—	—	1	3
	Black slaty Metal mixed with Coal	—	—	1	—
	Strong grey Metal stone	5	—	2	11
	Strong white post with whin	12	1	—	—
	Grey Metal stone with black skamy partings	2	1	2	—
	Strong white post	1	1	—	—
9	Coal	—	—	1	—
	Grey Metal stone	—	—	2	—
	Grey Metal stone with girdles	2	—	—	—
	Strong white post with Whin girdles and skamy partings	5	—	1	7
10 Coal Benwell Main? *	Coal	—	—	2	5
	Black slaty metal	—	—	—	3
	Coal (foul)	—	—	1	—
	Grey Metal	1	1	—	—
	Strong white post	5	—	—	9
	Black Greystone	2	—	—	—
11	Coal	—	—	—	9
	Blue grey metal	—	—	—	5
12	Coal	—	—	—	4
	Blue grey metal	—	1	—	6
	Strong white post	—	1	1	7
	Carried forward	94	1	2	—

No.		Fath.	Yds.	Ft.	In.
	Brought forward	94	1	2	—
	Grey Metal stone with girdles	—	1	1	8
	Grey Metal with skames of Coal	—	—	1	3
	Grey Metal stone	3	1	—	—
	Grey Metal with a mixture of Coal	—	—	2	—
	Grey Metal stone	1	1	—	6
	Grey Metal with whin	—	—	1	6
	Grey Metal stone	—	—	2	2
13	Coal	—	—	—	10
	Grey Metal	—	—	—	6
	White post	—	—	1	6
	Grey Metal	—	—	2	6
	Whin	—	—	—	4
	Strong white post with partings	—	1	—	—
	Whin	—	—	1	—
	Strong white post	—	—	2	—
	Grey Metal stone with girdles and partings	1	1	—	6
14	Coal	—	—	—	8
	Grey Metal stone	—	—	—	4
	Strong grey and white post	—	—	1	6
	Grey Metal stone with hard girdles	—	1	2	6
	Strong white post	—	1	2	—
	Whin	—	1	1	2
	Strong white post mixed with whin	1	—	2	6
	Blue Metal	—	1	—	—
	Mixed Whin girdles or lumps	—	—	—	4
	Blue Metal	—	—	—	10
15	Coal, Beaumont seam ?	—	1	—	10
	Grey Metal stone	1	—	—	—
	Strong post with whin	2	1	1	—
	Whin	—	—	—	8
16	Coal	—	—	—	6
	Black slate with Coal	—	—	1	2
	Grey Metal	—	—	1	6
	Strong white post	—	—	2	6
	Grey skamy post	—	—	2	—
	Strong white post with whin	2	—	1	10
17	Coal	—	—	—	10
	Grey Metal stone	—	—	1	1
	Fathoms	118	1	1	0

* I cannot help thinking the identity of the seams of Coal on the south and north side of the dyke very problematical, and have therefore marked those in the north named the Benwell main and Beaumont seam with a note of interrogation.

Section of the Strata at Montagu Main Colliery, South of the Dyke.

		Fath.	Yds.	Ft.	In.
	Soil	—	—	1	—
	Clay	2	—	2	—
	White post	—	—	2	6
1	Coal	—	—	—	4
	Black stone	—	1	—	2
	Grey post	1	1	2	—
	Blue metal stone	2	1	1	—
	Grey post	2	—	—	—
	Strong white post	2	1	—	—
	Grey post	—	1	2	—
	Strong white post with black metal partings	5	—	—	—
	Grey post	—	—	1	4
	Brown post with Coal pipes	—	1	1	8
	White post	2	1	—	—
	Strong white post with whin	—	1	—	—
2	Coal	—	—	—	6
	Black stone	4	1	—	—
	Grey metal stone	4	—	2	—
	Brown post with metal partings	—	1	1	—
3	Coal	—	—	—	9
	Grey metal stone	1	1	2	10
4	Coal } Benwell Main	—	—	1	—
	Black metal band } Benwell Main	—	—	—	9
	Coal } Benwell Main	—	1	—	6
	Grey metal	1	1	—	—
	Strong white post	2	1	1	—
	Whin	—	—	2	—
	White post	1	—	2	—
5	Coal	—	—	1	—
	Black metal stone	1	1	—	8
	White post	3	—	—	—
	Black metal stone	4	1	—	—
	Grey metal	5	—	2	4
	Grey post with whin girdles	2	1	—	—
	Strong white post	6	—	2	—
	Grey metal stone	3	—	2	—
6	Coal	—	—	—	8
	Post girdle	—	—	2	—
	Grey metal stone	1	—	1	—
7	Coal, Beaumont seam	—	1	—	4
	Strong white thil	—	1	—	7
	Strong white post	2	—	—	4
8	Coal	—	—	1	6
	Black thil	—	—	2	4
	Grey metal stone	—	—	1	2
	Grey post	—	—	2	—
	Grey metal stone	—	—	2	10
	Strong white post	—	1	—	4
9	Coal	—	—	1	3
	Black stone	1	—	2	4
	Carried forward	76	—	1	—
	Brought forward	76	—	1	—
	White post	—	—	1	8
	Blue metal stone with post girdles	1	—	—	—
	Strong white post with whin girdles	2	—	1	9
	Black stone	—	—	1	5
	Grey post	—	—	1	2
	Blue metal stone	—	1	—	—
	Strong white post	—	—	1	3
	Blue metal stone	1	—	2	1
10	Coal	—	—	—	8
	Black thil	—	1	—	4
	Blue metal stone with post girdles	1	—	1	—
	Grey post	—	1	—	—
	Strong white post	3	1	2	7
11	Coal, Low Main	—	—	2	11
	Grey metal stone	4	1	—	—
	White post	2	1	—	—
	Grey metal stone with post girdles	1	—	—	—
	White post with whin girdles	3	—	1	6
	Grey metal with post girdles	—	1	1	—
12	Coal, Low Low Main	—	—	2	10
	Grey metal stone	—	1	2	—
	White post	—	—	2	—
	Grey metal	—	—	1	8
	Black stone	—	—	—	10
	Grey metal stone	1	—	2	6
	Grey post	1	—	—	6
	Strong white post with whin girdles	3	1	1	8
	Grey metal stone	3	—	2	6
	Grey post	—	—	2	—
	White post	—	1	2	—
	Grey metal stone	—	—	1	—
13	Coal	—	—	—	6
	Grey metal	—	—	1	—
	Grey metal stone with post girdles	3	—	2	2
14	Coal	—	—	—	5
	Grey metal stone	—	—	—	4
	Giey post	1	—	—	3
	Strong white post with whin	2	1	—	4
	Grey metal stone	—	1	—	—
15	Coal	—	—	—	—
	Grey metal stone with post girdles	1	—	—	—
	Strong white post with whin girdles	—	1	—	5
	Fathoms	123	—	2	3

The four workable Seams of the preceding Section are, Benwell main, Beaumont seam, Low main, Low Low main.

Seams of Coal at West Denton or Baker's main.

Beaumont Seam	at 30 fathoms	3	3
Low Main	49 ———	2	10
Low Low Main	60 ———	2	11

Strata sunk through in the F Pit Wall's-end Colliery.

	Fs.	Ft.	In.
Strong clay with tumblers	8	4	—
Brown post	2	1	—
Soft Metal stone	4	—	—
White post	—	1	—
Metal stone	5	—	—
Grey post	2	1	—
Metal stone	1	1	4
Whin	—	—	8
White post	9	1	6
Ditto and grey post	5	—	—
Black stone	—	4	—
COAL	—	—	8
Thil	—	2	—
Grey post	—	4	6
White post	—	1	6
Whin	—	1	8
Grey post	1	1	—
Blue Metal stone	—	3	6
Grey post	2	—	6
Blue Metal stone	2	—	8
Grey post	1	—	—
Whin	—	2	4
White post	2	3	2
Black stone	—	2	—
COAL	—	—	2
Grey Thil	2	1	4
Grey post	—	5	—
Whin	—	2	—
White post	—	—	6
Whin	—	2	3
White post	6	5	9
COAL	—	—	8
Grey Thil	—	1	8
Grey post	—	5	—
Blue Metal stone	1	2	—
COAL	—	1	2
Thil	—	3	—
COAL	—	—	10
Carried forward	64	3	4

	Fs.	Ft.	In.
Brought forward	64	3	4
Thil	—	2	—
Grey Metal stone	1	1	—
Grey post	—	5	—
Black stone	—	3	8
COAL	—	—	4
Thil	—	2	6
Grey Metal stone	—	2	6
Grey post	—	1	6
White post	—	4	6
Black stone	—	1	8
COAL	—	—	11
Thil	—	2	—
Grey Metal stone	4	1	—
COAL (A)	—	—	3
Grey Metal stone	2	—	9
Grey post }	2	—	9
White post } *	4	4	3
Blue stone }	—	—	6
Grey post	—	3	—
Black stone	—	1	—
Grey post	—	5	6
Blue Metal stone	—	1	8
Black stone	—	1	4
Grey post	1	3	—
Black stone †	3	4	—
COAL	—	—	3
Grey Thil	—	1	8
White post }	2	—	—
Whin (very irregular) }	—	4	—
White post } ‡	3	—	—
Whin (very irregular) }	—	4	6
White post }	—	3	—
Grey post with scares }	3	—	—
Grey Metal stone	—	5	7
MAIN COAL SEAM (B) §	1	1	—½
Outset of the Pit	—	3	—
Total	103	2	11½

* Commonly called the 70 fathom Post. † Black Stone. ‡ Main Post.

§ In the middle of the Main Coal seam is a band of 2¼ inches thick. This band lies only in a particular tract of the mine.

Strata sunk through in Percy Main Engine Pit. 1800.

Northumberland.

	Fs.	Ft.	In.
Blue Stony clay . .	13	—	6
Sand . . .	—	2	1
Blue Stony clay . .	11	2	1
Dry ditto . .	—	5	6
Leafy ditto . .	—	2	6
Sand with a small feeder of water	—	1	8
Sand and clay . .	—	2	3
Strong clay . .	—	2	4
Gravel . . .	—	1	—
Sand with water . .	—	1	11
Leafy clay . . .	1	3	6
Sand with much water .	—	4	1
Gravel . . .	—	3	10
Brown skamy post* . .	1	2	2
Very soft grey metal .	—	2	—
Blue metal . .	—	5	—
Lightish grey post . .	1	2	—
Very hard black stone .	—	3	6
Soft dark grey metal .	—	1	—
White Metal parting .	—	1	1
Grey Metal girdles .	5	—	—
Reddish post with partings .	4	3	—
Lightish grey post .	5	—	—
Reddish post with partings .	—	1	—
Whitish post . .	—	3	—
Soft red metal with partings .	—	3	—
Very course bluish post .	4	1	6
Brownish Metal mixed with post	1	2	—
Blue Metal mixed with post girdles . . . }	1	1	—
Grey ditto ditto . .	3	—	—
Grey Metal stone . .	2	2	10
Coal } Dark grey metal {	—	—	6
Grey metal } Dark grey metal {	—	2	—
Coal } Dark grey metal {	—	1	—
Whin girdle . .	—	—	6
Dark grey metal with girdles .	1	5	—
Dark blue metal . .	1	1	—
Grey metal . .	—	5	—
Carried forward	67	4	4

	Fs.	Ft.	In.
Brought forward	67	4	4
Whin . . .	—	1	6
Grey metal with Whin girdles.	1	—	8
Post girdles . .	1	2	6
Grey Metal stone . .	—	3	9
Black metal mixed with Coal	—	1	3
Grey metal . .	—	1	6
Skamy white post .	1	2	6
Grey metal with girdles .	—	5	—
Black stone . .	—	—	8
Grey metal with girdles .	2	3	10
Coal . . .	—	1	—
Thill . . .	—	1	1
Greyish post . .	1	2	9
White metal . .	—	4	—
White post . .	7	4	—
Black stone . .	—	1	9
Grey metal with girdles .	—	—	10
Coal (A) . . . }	—	—	2
Grey metal . . . }	—	2	—
Coal . . . }	—	1	2
Grey metal with girdles .	1	2	6
Grey Metal stone . .	1	—	6
White post . .	10	4	6
Black stone . .	—	1	6
Skamy post . .	1	—	—
Whin . . .	—	1	4
Skamy post . .	—	3	8
Blue stone with girdles .	1	5	—
Dark blue metal . .	1	2	—
Black stone . .	1	3	6
Coal . . .	—	—	6
Grey Metal stone . .	—	3	—
Grey skamy post .	—	4	—
Main post . .	9	—	8
Coal } Main Coal (B) . {	—	3	—½
Band } Main Coal (B) . {	—	—	2
Coal } Main Coal (B) . {	—	2	10½
Total Depth	119	1	—

* Stone Head.

Section of the Strata at Howden Pit. Percy Main Colliery.

(Bored from the High Main Coal No. 9.)

		Fs.	Ft.	In.
	Outset	—	4	8
	Surface	1	—	—
	Brown clay	1	—	—
	Leafy clay	1	5	—
	Bluish gravelly soil	4	—	6
	Brown leafy clay	1	2	—
	Sand, gravel and water	—	3	—
	Blue gravelly clay	6	—	—
	Sand and gravelly clay, with water	2	—	—
	Sand, gravel and water	3	4	6
	Alluvial	22	1	8
	Grey metal	—	3	—
1	Coal	—	—	2
	Grey metal	—	—	2
2	Coal	—	—	11
	Thil	—	4	—
	Grey metal with post girdles and water. Alternate beds of Slate clay and Sandstone	3	2	9
	Black stone (Clay stone)	—	4	—
	Blue stone with water	—	3	6
	Grey Thil	—	5	6
	Grey Metal stone with water	4	5	6
	Skamy grey post with water	5	2	—
	White post with water	10	—	4
	Grey metal	—	4	—
	White post	1	1	—
	Grey metal	1	3	—
	Black stone	1	—	—
	Grey Thil	—	5	—
	Grey metal with Whin girdles	3	1	—
	Blue metal	—	2	—
	Red metal	—	5	—
	White post with water	7	5	—
	Red Metal stone	—	5	—
	Grey Metal stone with Whin girdles	1	—	—
	Grey Thil	—	4	6
	Black stone	—	1	6
	Grey metal with Whin girdles	1	2	6
	Blue stone	—	4	—
3	Coal	—	—	6
	Grey metal	—	1	6
4	Coal	—	1	—
	Grey Thil	1	—	—
	Grey metal with post girdles	5	3	6
	Blue stone	1	—	—
	Grey Metal stone with Whin girdles	1	—	—
	Carried forward	80	5	6

		Fs.	Ft.	In.
	Brought forward	80	5	6
	Blue Metal stone with Whin girdles	1	—	—
	Grey Metal stone with Whin girdles	1	2	—
	Whin stone	—	1	6
	Grey Metal stone with post girdles	—	4	6
	Grey metal	—	2	4
5	Coal	—	1	2
	Thil	—	3	—
	Grey Metal stone with Whin girdles	—	4	—
	Grey Metal stone	1	3	—
	Post and Whin girdles	1	1	—
	Grey Metal stone	1	4	—
	Blue stone	—	2	—
6	Coal	—	1	2
	Grey Metal stone	1	4	—
	White post	8	3	—
	Grey Metal stone	—	2	—
7	Coal	—	—	10
	Grey metal	1	2	—
	Blue stone	—	4	—
	Grey Metal stone	1	4	—
	White post	9	1	—
	Grey Metal stone with post clyers	—	3	—
	White post with water	2	—	—
	Black stone	—	3	—
	Blue stone	—	2	—
	Grey post	—	3	—
	Blue stone	—	3	—
	Grey Metal stone	—	4	—
	Black stone	—	2	6
	Post with Grey Metal girdles	1	—	2
	Dark blue Metal stone	2	3	—
8	Coal	—	—	4
	Grey Thil	—	2	—
	Grey post	—	2	—
	Main post	10	4	—
9	Coal, High main	1	—	6
	Thil, Foul coal, Grey metal, and Coal	—	5	9
	Blue stone with girdles	3	1	6
	Grey metal	2	—	—
	Grey post	1	2	—
	Grey metal with girdles	1	2	9
10	Coal	—	2	—
	Fathoms	145	—	6

Strata sunk through in the A Pit, Bigge's Main Colliery. (Bored from High Main.)

		Fs.	Ft.	In.
Clay		17	—	—
Brown post with water		7	—	6
COAL		—	—	8
Blue metal		1	5	—
Strong white post with water		1	3	—
Blue Metal stone		3	—	—
COAL		—	1	2
White post		4	—	—
Grey post girdles with water		3	3	—
Soft blue Metal stone		1	—	—
Strong white post mixed with whin		4	3	—
Soft blue Metal stone		5	—	—
COAL		—	—	5
White post girdles		1	3	—
Whin		—	3	4
Strong white post		2	1	—
COAL		—	—	7
Soft blue Thil		—	5	—
Post mixed with whin and water		2	3	8
COAL		—	—	8
Blue stone		2	4	4
Ditto mixed with scares of Coal		—	—	8
White post mixed with Whin		1	4	—
Blue Metal stone		1	2	—
* { COAL		—	1	6
Strong white post with water		1	2	—
Grey post girdles		1	4	6
COAL	†	—	—	10
Grey Metal stone		2	3	—
COAL }		—	—	8
Strong white post mixed with whin	‡	5	1	—
Grey girdles	§ {	3	3	—
Blue and black Metal		2	4	—
COAL	}	—	—	5
Grey Metal stone (1)		1	3	—
Strong white post (2)		5	—	5
Ditto with Coal pipes		1	3	—
Ditto with Whin		3	—	—
Ditto with Coal pipes		1	3	—
Grey Metal stone with hard girdles		1	2	—
COAL (3) (High Main)		1	—	8
Blue stone with Whin girdles		4	3	—
Strong grey post		1	—	—
COAL	(4) {	—	2	6
Blue stone		3	3	—
COAL	}	—	—	6
Carried forward		104	3	—

		Fs.	Ft.	In.
Brought forward		104	3	—
Strong post mixed with Whin		5	3	—
COAL (5)		—	—	9
Blue stone		4	3	—
COAL	(6) {	—	1	2
Black stone		—	—	7
COAL	}	—	1	3
Strong grey post		5	3	—
Blue stone with post girdles		4	2	9
COAL		—	2	6
White post and girdles		2	1	—
Ditto with whin and water		5	3	10
Blue stone		—	3	—
Ditto and Grey girdles		1	3	—
Ditto and Whin girdles		1	3	—
Ditto mild		—	1	6
COAL	(7) {	—	—	3
Grey Thil		—	—	5
COAL		—	—	2
White Thil		—	3	—
COAL		—	—	7
Blue Thil		—	—	8
COAL		—	1	—
Blue stone		—	—	6
COAL	}	—	1	8
Strong grey post		—	5	—
Blue stone and Whin girdles		—	4	—
COAL		—	—	2
Strong white post mixed with whin		—	2	6
Whin		—	1	6
Grey post and Whin girdles		2	3	—
Blue stone		—	2	—
COAL. (Unknown seam)		—	3	1
Grey post with Whin girdles		1	—	—
Blue stone		—	5	—
COAL	(8) {	—	2	6
Blue and grey metal		1	—	6
Strong post girdles mixed with Whin		3	—	—
COAL		—	—	9
Grey Metal stone		3	—	7
COAL		—	—	2
Grey Metal stone		—	—	8
COAL	}	—	—	4
Grey post mild		—	4	—
Strong white post		4	2	—
Blue stone		—	3	—
Carried forward		159	1	4

* Called on the river Tyne, below Newcastle bridge, the 70 fathom Coal. On the river Wear it is called the Three quarter Coal.——† Supposed to be the Three quarter Coal seam divided.——‡ Called on the Tyne the 70 fathom Post.——§ Called on the Tyne the Black stone.——(1) Bottom part of Black stone.——(2) The Main Post of the Tyne.——(3) High Main Coal of the Tyne.——(4) Metal Coal seam of the Tyne.——(5) Stone Coal of the Tyne.——(6) Yard Coal of the Tyne, High Main Coal of the Wear.—(7) Supposed to be the Benshaw Seam.——(8) Supposed to be the Six quarter seam divided.

	Fs.	Ft.	In.
Brought forward	159	1	4
White post	4	1	6
COAL. (Supposed to be the Five quarter seam . . .	—	1	—
Thil	—	1	—
Grey post girdles . . .	—	3	—
Blue stone	—	3	—
Grey Metal stone with post girdles	2	4	—
Whin	—	2	8
Blue stone	—	—	6
White post girdles . .	1	1	—
Blue stone	—	4	6
White post girdles . .	1	2	6
Blue stone	—	4	8
Black stone . . .	—	5	7
Grey Metal stone .	—	4	—
Mild grey post . . .	1	5	7
COAL. (Unknown Seam) .	—	—	8
Grey Metal stone . . .	—	4	—
Mild White post . . .	1	3	8
Carried forward	178	—	2

	Fs.	Ft	In.
Brought forward	178	—	2
Whin	—	2	—
Blue stone	—	2	11
Black stone	—	—	10
COAL (10)	—	2	5
Blue metal	—	2	4
COAL	—	—	4
Whin	—	1	—
Brown post . . .	2	—	1
Grey Metal stone . .	1	5	—
COAL	—	—	4
Blue metal	—	1	8
COAL	—	1	—
Grey metal	1	2	—
White post	2	—	—
Ditto girdles . . .	2	—	1
Strong white post mixed with whin	1	5	7
Grey Metal stone . . .	1	3	1
Total Depth	193	—	10

(10) Low Main Coal of the Tyne. Hutton's seam of the Wear.

N. B. All the Seams below the YARD COAL in this section, lie so irregularly, and are so disfigured, that it is difficult to recognize them.

Section of the Strata to the Low Main Coal, at St. Anthons Colliery.

	Fs.	Ft.	In.
Soil and Clay . . .	5	—	—
Brown post	12	—	—
COAL	—	—	6
Blue Metal stone . . .	2	5	—
White girdles . . .	2	1	—
COAL	—	—	8
White and grey post . .	6	—	—
Soft blue Metal stone . .	5	—	—
COAL	—	—	6
White post girdles . .	3	—	—
Whin	1	4	6
Strong white post . . .	3	1	—
COAL	—	1	—
Soft blue Thil	1	5	—
Soft girdles mixed with Whin .	3	5	—
COAL	—	—	6
Blue and Black stone . .	3	4	—
COAL	—	—	8
Strong white post . . .	1	3	—
Grey Metal stone . .	1	4	—
COAL	—	—	8
Grey post mixed with Whin .	4	1	—
Grey girdles . . .	3	1	—
Blue and Black stone . .	2	2	—
COAL	—	1	—
Carried forward	64	—	—

	Fs.	Ft.	In.
Brought forward	64	—	—
Grey Metal stone . . .	2	—	—
Strong white post . . .	6	—	—
Black Metal stone with hard girdles	3	—	—
HIGH MAIN COAL . .	1	—	—
Grey metal	4	3	—
Post girdles	—	2	—
Blue metal	—	4	—
Girdles	—	1	2
Blue Metal stone . .	5	—	—
Post	—	1	—
Blue Metal stone . .	3	—	—
Whin and Blue metal . .	—	1	6
Strong white post . . .	3	3	—
Brown post with water . .	—	—	7
Blue Metal stone with grey girdles	2	2	—
COAL	—	3	—
Blue Metal stone . . .	3	—	3
White post	—	4	—
COAL	—	—	6
Strong grey metal with post girdles	2	—	6
Strong white post . . .	1	1	—
Whin	—	1	—
Blue Metal stone . . .	1	2	7
Grey Metal stone with post girdles	2	4	5
Blue Metal stone with whin girdles	1	4	3
Carried forward	109	3	9

	Fath.	Ft.	In.
Brought over	109	3	9
Coal	—	1	6
Blue grey metal . . .	—	3	8
White post	2	—	7
White post mixed with Whin .	2	—	—
White post	1	2	—
Dark blue Metal and Coal .	—	2	2
Grey Metal stone and girdles .	2	2	—
White post mixed with Whin .	3	—	7
Whin	—	1	—
White post mixed with Whin .	1	—	6
Coal	—	3	3
Dark grey Metal stone . .	—	3	6
Carried forward	124	—	6

	Fath.	Ft.	In.
Brought forward	124	—	6
Grey metal and Whin girdles .	1	4	10
Grey metal and girdles . .	1	3	—
White post	—	3	—
Coal	—	3	2
Blue and grey metal . .	—	4	—
Coal	—	—	9
Blue and grey metal . .	2	—	—
White post mixed with Whin .	—	4	6
Grey metal	1	—	6
Grey metal and girdles . .	1	—	9
Low Main Coal . . .	1	—	6
Total	135	1	6

Strata bored through from the High Main Coal in the Charlotte Pit Walker Colliery.

	Fath.	Ft.	In.
Sunk from surface to High Main Coal . . .	100	—	—
Box	—	5	—
Grey metal with girdles .	4	5	—
Coal C . . . . . } *	—	—	6
Grey metal . . . } *	—	1	3
Coal with sulphur . . } *	—	2	8
Grey metal with girdles .	2	—	—
Black stone	1	3	6
Coal D (Stone Coal) . .	—	—	10
Soft grey metal . . .	—	—	10
Strong ditto with post girdles .	6	5	—
Coal E (Yard Coal) . . .	—	2	9
Grey metal with whin girdles .	1	3	—
Black metal stone with ditto and sulphur . . .	—	2	—
Strong white post with whin and metal partings . . .	5	—	—
Grey metal	1	3	8
Strong white post . . .	1	1	—
Whin	—	5	—
Strong white post . . .	1	5	—
Black slate	—	—	2
Coal (Little Coal) . . .	—	—	8
Grey metal stone . . .	2	3	—
White post	1	3	—
Grey metal stone with post girdles	1	4	2
Black stone	—	—	4
Coal F. (Bensham Seam) .	—	3	—
Carried forward	136	1	4

	Fath	Ft.	In.
Brought forward	136	1	4
Grey metal stone with girdles . .	2	3	—
Coal with water and sulphur .	—	—	3
Grey metal stone with post girdles	2	4	8
Coal . . . . . } *	—	—	5
Hard band . . . . } *	—	—	6
Coal . . . . . } *	—	1	6
Grey metal with post girdles .	2	—	—
White post with partings .	5	5	—
Coal } Six Quarter Coal G	—	—	10
Blue metal } Six Quarter Coal G	—	—	5
Coal } Six Quarter Coal G	—	1	6
Blue metal with scares of Coal at top . } Five Quarter Coal H.	—	5	—
Coal mixed with black stone . . } Five Quarter Coal H.	—	3	—
Coal clean . . } Five Quarter Coal H.	—	—	10
Grey metal	—	2	—
Grey post	—	4	—
Strong grey post mixed with whin	5	1	—
Gtey metal with girdles .	1	2	6
Strong whin	—	—	7
Black slate	—	—	2
Tender Coal I. . . . } †	—	5	2
Brassy Coal with scares of band } †	—	—	11
Black slate mixed with Coal . } †	—	—	3
Blue grey metal . . .	—	—	11
Fathoms	160	3	9

The stratification above the High main Coal, that is from the surface to the High main Coal in Walker Colliery, is very similar to the section of the Wall's-end strata.

* Bandy Coal Seam. † Low Main.

Strata sunk through in the B. Pit Hebburn Colliery.

	Fath.	Ft.	In.
Clay	9	5	—
Grey metal stone	1	1	—
Post with metal partings	8	4	—
Blue metal	—	2	—
COAL *	—	3	—
Blue metal	1	2	—
Grey metal stone	2	3	—
Post with metal partings	1	4	—
Blue metal stone	—	5	6
Grey metal with post girdles	2	4	6
Blue metal stone	1	5	—
Grey metal with post girdles	5	2	—
Hard white post	1	4	—
Grey metal with post girdles	4	4	—
Grey metal with open partings	—	3	—
Blue metal	6	5	6
Black and blue metal	1	1	6
COAL	—	—	1½
Black metal	—	—	6
White thil	—	4	10½
White post	—	2	5
Blue metal	—	—	1
Grey post	—	—	6
Grey metal mixed with post	—	1	—
Strong white post	2	3	6
White post with grey metal partings	—	4	6
Strong white post	8	—	—
COAL	—	—	1½
Grey thil	—	3	10½
Grey metal mixed with thil	1	5	—
Grey metal	—	1	—
Post with metal partings	—	3	—
Strong white post mixed with whin	—	3	—
Grey and blue metal	—	4	—
Black stone	—	3	—
COAL	—	—	4
Black stone	—	1	4
COAL	—	1	—
Strong grey thil	—	2	6
Strong grey post	—	—	10
White post girdles with metal partings	1	3	—
White post	—	3	—
Carried forward	72	3	6
Brought forward	72	3	6
Thin post girdles with metal partings	—	1	—
Whin	—	3	—
White post with metal partings	—	5	6
Grey metal	—	1	—
White post	—	4	9
Blue metal and grey	4	5	9
White post	—	4	—
Blue and grey metal	2	3	6
COAL	—	—	5½
Blue and grey metal	2	5	6
COAL	—	—	2
Grey thil	—	2	4
Blue and grey metal	3	1	2
COAL A. (called the 70 fathom Coal)	—	1	2
Gray thill	—	4	6
COAL	—	—	2
Grey metal and post girdles	2	—	—
Black and grey metal	2	5	6
Post	1	1	2
COAL	—	—	4
Grey thil	1	—	—
Blue and grey metal with post girdles	3	—	6
Strong white post	4	4	6
Brown post with blue metal partings	1	1	10
Strong white post	4	2	2
Blue metal	1	—	—
Post	—	1	6
Black stone	—	5	—
White post	—	2	6
Blue and grey metal	1	5	—
Black stone	2	—	—
COAL	—	—	6
Grey thil	—	4	—
Blue and grey metal	—	5	—
Post	10	2	—
High Main COAL (B)	1	—	—
White thil	—	1	8
Slaty Coal	—	2	4
Blue metal	—	1	—
Total	131	3	11½

* This Seam lies all through Hebburn and Jarrow Collieries, and may also be found in Killingworth section.

Strata in Gateshead Fell.

	Fath.	Ft.	In.
Shiver and blue slate	3	—	—
White flag stone	2	—	—
Grindstone sill	11	—	—
White post	1	3	—
Blue plate	1	—	—
Grey post	1	3	—
Blue plate	1	—	—
White plate	1	2	—
Blue sill	1	—	—
White post	3	4	—
Three Quarter Coal A.	—	2	3
White post ⎫	5	3	—
Grey post ⎬ the 70 fathom post	1	—	—
Dun post ⎭	6	—	—
Blue plate (the black stone)	1	—	—
White post (the main post)	11	—	—
Upper Main Coal B.	1	—	—
Grey post	6	—	—
Metal plate	—	3	—
Metal Coal C.	—	3	—
White post	4	4	—
Stone Coal D.	—	2	—
Black stone	1	1	—
Bandy Coal	—	1	—
White post	4	3	—
Carried forward	70	4	3

	Fath.	Ft.	In.
Brought forward	70	4	3
Blue stone	2	3	—
Black stone	—	1	—
Little Coal	—	2	—
Grey stone	2	—	—
Yard Coal E.	—	3	—
White post	11	3	—
Bensham Seam F.	—	2	—
Blue plate	1	3	—
Bandy Coal Seam	—	2	—
White post	6	—	—
Blue plate	—	2	—
Six Quarter Coal G.	—	4	—
Grey whin, Post plate	2	3	—
Five Quarter Seam H.	—	3	—
Grey post	1	4	—
Bandy Coal Seam	—	1	—
White post	5	1	—
Low-main Coal I.	1	—	—
Thil	—	2	—
White post	3	4	—
Two Quarter Coal Seam J.	—	2	—
White post	21	1	—
Harvey's Main Coal K.	—	3	—
Total	133	5	3

N. B. The letters in the different sections refer to the respective names of the several Seams of Coal in the Newcastle district, according to the classification on the river Tyne, and are as follows, viz.

A. The Three quarter, or 70 Fathom Coal.
B. The High-main Coal.
C. The Metal Coal.
D. The Stone Coal.
E. The Yard Coal.
F. The Bensham Seam.
G. The Six-Quarter Coal.
H. The Five-Quarter Coal.
I. The Low-main Seam.
J. The Two-Quarter Seam.
K. Harvey's Low-main Seam, called also the Beaumont Seam.

Seams of Coal under Newcastle Town-moor.

			Fs.	Ft.	In.	
High Main	at 8	fathoms	1	—	—	thick
Metal Coal	$13\frac{1}{2}$	———	—	1	6	
Stone Coal	19	———	—	1	6	
Yard Coal	$29\frac{1}{2}$	———	—	2	10	
Bensham Coal	40	———	—	2	10	
Six Quarter Coal	53	———	—	4	6	
Five Quarter	58	———	—	3	—	
Low Main Coal.	66	———	1	—	—	

Seams of Coal at Kellsfield near Gateshead Fell.

			Fs.	Ft.	In.	
High Main	at 11	fathoms	1	—	—	thick
Metal Coal	19	———	—	2	3	
Stone Coal	24	———	—	1	8	
Little Coal	26	———	—	1	10	
Yard Coal	30	———	—	3	—	
Bensham Coal.	41	———	—	5	—	
Five Quarter.	61	———	—	3	—	
Low Main	71	———	—	5	6	
Harvey's Seam.	97	———	—	3	—	

Section of the Coal Strata on the Wear.

	Fs.	Y.	Ft.	In.
Soil and Clay	9	—	—	—
Brown stone	2	—	—	—
Grey Metal stone	4	—	—	—
Brown stone	2	—	—	—
White post	7	—	—	—
Blue stone	1	1	—	—
Grey post	5	—	—	—
Blue slaty stone	2	—	—	—
Grey stone	1	1	—	—
White post	3	1	—	—
Black slaty stone	2	1	—	—
Whin	—	1	—	—
Grey post	1	1	—	—
White post	2	—	—	—
Blue stone	1	1	2	3
FIVE QUARTLR COAL*	—	1	—	9
Blue metal	1	1	1	—
Grey post	3	—	2	—
Grey Metal stone	3	1	—	—
Whin	—	1	1	—
White post	4	—	—	—
Blue stone	—	—	2	—
Carried forward	60	—	—	—

	Fs.	Y.	Ft.	In.
Brought forward	60	—	—	—
HIGH MAIN COAL	1	—	—	—
Blue grey stone	2	1	—	—
White post	2	1	—	—
Grey stone with partings	2	1	1	—
Brown post	4	—	2	—
Whin	1	—	—	—
MAUDLIN COAL	1	—	—	—
Blue stone	1	1	—	—
White post	3	1	—	—
Grey Metal stone	3	—	—	—
Blue post	2	—	—	—
Blue stone	1	—	—	—
LOW MAIN COAL†	—	1	—	—
Blue stone	1	—	—	—
White post	2	1	—	—
Whin	—	1	2	—
Grey post	1	—	—	—
Blue metal	1	1	—	—
HUTTON SEAM‡	1	—	1	—
Total	94	1	—	—

* Forms the Metal and Stone Coal seams on Sheriff hill.

† Forms the Six Quarter and Five Quarter seams on Sheriff hill, and on the Tyne.

‡ The Low main at Sheriff hill and on the Tyne.

Section of the Strata at Sheriff Hill on Gateshead Fell.

	Fs.	Y.	Ft.	In.
Shiver and blue slate sill.	3	—	—	—
White flag post	2	—	—	—
Grindstone sill	11	—	—	—
White post plate	1	1	—	—
Blue plate	1	—	—	—
Grey post plate	1	1	—	—
Blue plate	1	—	—	—
Whin plate	1	1	—	—
Blue sill	1	—	—	—
White post sill	3	1	—	—
1 Three quarter Coal	—	—	2	3
White post sill	5	1	—	—
Grey post	1	—	—	—
Dun post sill	6	—	—	—
Blue plate	1	—	—	9
Eleven fathoms White post	11	—	—	—
2 High Main Coal*	1	—	—	—
Grey post sill	6	—	—	—
Metal plate	1	—	—	—
3 Metal Coal	—	—	1	2
White post	4	—	1	10
4 Stone Coal†	—	1	—	—
Black stone sill	1	1	—	—
5 Bandy Coal Seam	—	—	—	6
White post sill	4	1	—	6
Blue plate	2	1	—	—
Black plate	—	—	1	6
6 Little Coal Seam	—	—	—	6
Grey sill	2	—	—	—
7 Yard Coal	—	1	—	—
White post sill	11	1	—	—
Carried forward	88	—	—	—

	Fs.	Y.	Ft.	In.
Brought forward	88	—	—	—
8 Bensham Seam‡	—	1	—	3
Blue plate	2	—	—	—
9 Bandy Coal Seam	—	—	—	9
White post sill	5	—	2	—
Blue plate	—	1	—	—
10 Six Quarter Coal	1	—	—	3
Grey Whin post	1	1	2	7
11 Five Quarter Coal§	—	1	—	2
Grey post	1	1	2	3
12 Bandy Coal Seam	—	—	—	9
White post	5	—	—	—
13 Low Main Coal ‖	1	—	—	6
Dark white sill	—	—	1	—
White post	3	1	2	6
14 Two Quarter Coal	—	—	1	6
White post sill	21	—	—	6
Harvey's Main Coal, or Wickham Stone Coal.	—	1	—	—
Fathoms	134	—	—	—

To the Brockwell, the lowest seam; which crops out at Basty Bank near Conset Park, Durham.

	Fs.	Y.	Ft.	In.
Grey metal and Metal stone	5	—	2	10
Brockwell Seam	—	1	—	2
Fathoms	6	—	—	—

* This Seam does not extend to the mines on the Wear.

† This and the Metal Coal form the Five Quarter Coal on the Wear.

‡ Maudlin Seam on the Wear.

§ The Six quarter and Five quarter Coal Seams form the Low Main Coal on the Wear.

‖ Hutton Seam on the Wear.

Birtley Colliery.*

	Fs.	Ft.	In.
Brown post Grey Metal stone Brown stone White post Blue Metal stone Grey post Blue and grey Metal stone	32	—	—
Five Quarter Coal	—	3	9
Grey post Grey Metal stone with Whin girdles	10	2	3
Main Coal	—	5	6
Carried forward	43	5	6

	Fs.	Ft.	In.
Brought forward	43	5	6
White and brown post Grey Metal stone with Whin near the bottom	11	—	6
Maudlin Seam	—	4	6
Blue post Blue and grey Metal stone	12	1	6
Low Main Coal	—	3	3
Blue Metal stone White post and Whin	7	2	9
Hutton Seam	—	4	6
Total	76	4	6

* Communicated to the Author by the Rev. W. Turner.

Boring at East Rainton Colliery.

	Fath.	Ft.	In.
Sunk to scaffold	10	1	—
Box and Bore hole	12	—	—
Whin	—	—	10
Strong white post	—	2	—
Grey metal partings and post girdles	—	3	—
Dark grey metal (the black stone)	4	3	5
Gulbetty‡ white post with much water (the Main post divided)	—	2	—
White post with water (the Main post divided)	—	3	6
Grey metal stone and girdles (the Main post divided)	1	1	—
White post with water (the Main post divided)	2	4	—
Strong white post mixed with whin (the Main post divided)	—	2	6
White post with water (the Main post divided)	2	3	9
Strong blue metal with girdles and water (the Main post divided)	5	—	—
Soft grey metal (the Main post divided)	—	2	—
Black grey metal with scares of Coal* B.	—	3	—
Strong grey metal with water	1	—	6
Carried forward	42	2	6
Brought forward	42	2	6
Strong grey stone mixed with whin	—	4	—
Grey Metal stone with water	2	—	6
Strong Grey stone mixed with Whin	1	4	—
Whin	—	1	2
Grey metal with whin girdles	2	2	—
Foul Coal C.	—	1	8
Soft grey metal	—	2	—
Strong grey metal with whin girdles	2	4	—
Strong grey post with mixture of whin	2	—	—
Strong grey metal stone	2	4	—
Black grey metal	—	—	6
Five Quarter Coal D.	—	3	8
Strong grey metal	—	3	—
Strong post mixed with whin	—	2	—
Strong grey metal stone	5	—	—
Strong post mixed with whin	1	1	—
Strong grey metal mixed with whin	1	2	—
Grey metal	—	1	—
High Main Coal† E.	1	—	—
Total	67	3	—

‡ Full of fissures.

* Situation of the Tyne High Main Coal.

† Called the Yard Coal on the river Tyne. The Main Coal B. is seldom in perfection unless the Main post is also solid and good.

Seams of Coal at Axwell Park.

		Fth.	Ft.	In.
High Main at Windy hill	at 6 fathoms	1	—	—
Stone Coal	30 ——	—	4	—
Jet or Splint Coal	41 ——	—	2	—
Three quarter Coal	45 ——	—	2	3

The first of these seams is good Coal, but is almost worked out. The second is slaty and bandy, small and tender, but burns well. The third is a very bad seam of Coal.

Seams of Coal at Morrisfield.

		Fath.	Ft.	In.
Three quarter Coal	at 45 fathoms	—	2	3
Coal next the roof, Ft. 1 In. 3; Band of soft black stone, Ft. — In. 9; Scarey bandy Coal, Ft. 3 In. —	52 ——	—	5	—

This is a very tender and dull burning Coal. A hole was bored below it to the depth of 16 fathoms for the Shildon seam, but it was not found.

Seams of Coal at Thornley or Garesfield Colliery, two miles South of Axwell.

		Ft.	In.		Fath.	Ft.	In.
The Stone and Five-quarter Coal seams	Stone Coal	3	1	at 30½ fath.	1	2	1
	Fire clay	1	6				
	Five-quarter Coal	3	6				
Brockwell seam				at 39 fath.	—	3	4

Towards the east the Fire clay between the Stone Coal and Five-quarter Coal becomes so thick as not to be workable, and the Coal forms two distinct seams. The Coal is extremely tender and unfit for the London market.

Strata in Landchester Common.

	Fath.	Ft.	In.
Soil and clay	1	—	—
Brown post	1	5	9
Grey metal stone	3	3	—
Coal	—	—	10
Grey metal stone	2	4	—
Coal A.	—	2	—
Grey metal stone mixed	8	1	6
Coal	—	—	8
Grey metal stone mixed with Coal	—	4	9
Grey metal stone	2	—	—
Grey post	1	—	6
Grey metal stone, top thereof mixed with girdles	4	—	3
White post. Shield row post (the Main post)	13	—	10
Shield Row Coal B.	—	5	3
Whitish grey metal stone with post girdles	6	3	—
Grey post	2	3	5
Grey metal stone	—	3	—
White post	1	3	—
Grey metal stone	3	2	—
Black-grey metal stone	—	1	4
Coal, the Hard Coal Seam C.	—	4	9
Dark grey metal stone mixed with Coal	—	1	9
Coal, the Brass Coal Seam D.	—	5	3
White post	1	2	2
Grey metal stone with girdles	—	4	—
Carried forward	58	3	—
Brought forward	58	3	—
Black grey metal stone	—	1	3
Grey metal stone with post girdles	3	—	2
Dark grey metal stone with post girdles	4	1	—
Brown post	—	3	—
Grey metal stone	—	3	2
Brown post	—	3	1
Grey post	—	3	1
White post	1	5	2
Black metal stone	—	1	3
Strong white post	3	—	6
Grey metal stone	—	4	6
Strong grey post	1	3	7
Whin	—	3	—
Strong grey post	2	1	6
Whin	—	3	8
Grey and white post mixed with whin	6	5	6
Blue grey metal stone mixed with whin girdles	1	1	—
Coal, the Hutton's Seam E.	1	1	—
White post *	—	5	10
Coal F.	—	1	8
Blue metal stone	1	3	9
Grey post mixed with whin	3	—	—
Blue metal stone	1	5	—
Coal, the Low Main F or G	—	3	6
Total	96	2	2

* It is rather doubtful whether these two Coals are not the same seam divided.

Strata at Pontop Pike Colliery, situated on Landchester Common.

	Fath.	Ft.	In.
Soil and clay	1	—	—
Brown post	1	5	9
Grey metal stone	3	3	—
COAL	—	—	10
Grey metal stone	2	4	—
COAL A.	—	2	—
Grey metal stone mixed	8	1	6
COAL	—	—	8
Grey metal stone mixed with Coal	—	4	9
Grey metal stone	2	—	—
Grey post	1	—	6
Grey metal stone, the top mixed with girdles	4	—	3
White post. Shield row post (the Main post)	13	—	10
SHIELD ROW COAL. B. (High main at Sheriff Hill)	—	5	3
Whitish grey metal stone with post girdles	6	3	—
Grey post	2	3	5
Grey metal stone	—	3	—
White post	1	3	—
Grey metal stone	3	2	—
Black grey metal stone	—	1	4
COAL, the HAND COAL SEAM C. (Stone Coal at Sheriff hill)	—	4	9
Dark grey metal stone mixed with Coal	—	1	9
COAL, the BRASS COAL SEAM D. (Yard Coal at Sheriff hill)	—	5	3
White post	1	2	2
Grey metal stone with girdles	—	4	—
Carried forward	58	3	—

	Fath.	Ft.	In.
Brought forward	58	3	—
Black grey metal stone	—	1	3
Grey metal stone with post girdles	3	—	2
Dark grey metal stone with post girdles	4	1	—
Brown post	—	3	—
Grey metal stone	—	3	2
Brown post	—	3	1
Grey post	—	3	1
White post	1	5	2
Black metal stone	—	1	3
Strong white post	3	—	6
Grey metal stone	—	4	6
Strong grey post	1	3	7
Whin	—	3	—
Strong grey post	2	1	6
Whin	—	3	8
Grey and white post mixed with whin	6	5	6
Blue grey metal stone mixed with whin girdles	1	1	—
COAL, the HUTTON'S SEAM. E. (Five quarter and Six quarter Coal at Sheriff hill	1	1	—
White post	—	5	10
COAL F. (20 inch Seam)	—	1	8
Blue metal stone	1	3	9
Grey post mixed with whin	3	—	—
Blue metal stone	1	5	—
MAIN COAL. G. The Low MAIN at Sheriff hill	—	3	6
Total	96	2	2

Section of the Strata at Grienfield Colliery, half a mile West of Aukland.

No.	Stratum	Fth.	Yds.	Ft.	In.
	Soil	—	—	1	9
	Clay	—	1	—	—
	Blue metal	1	—	—	—
	Grey metal stone	1	1	—	—
	Strong grey metal	—	—	2	—
	Blue metal	—	—	1	—
1	COAL	—	—	—	9
	Sill	—	—	1	6
	Grey metal stone and blue metal	1	—	1	6
	Strong grey post	1	—	—	—
	Blue metal	—	1	2	—
	Black metal stone	—	1	—	—
2	COAL	—	1	—	—
	Sill	1	—	—	—
	Grey metal stone	1	1	2	9
	Grey post	—	1	—	9
	Grey metal	—	1	—	6
	Brown post	3	—	2	6
3	COAL	—	—	1	6
	Sill	—	—	1	3
4	COAL	—	—	1	6
	Sill	—	1	—	—
	Grey metal	1	—	2	3
	Metal stone	1	—	—	—
5	COAL	—	—	1	—
	Grey metal	2	—	1	—
6	COAL	—	—	—	8
	Carried forward	21	1	2	2
	Brought forward	21	1	2	2
	Sill	—	—	2	—
	Grey metal stone	1	1	1	6
	Strong grey stone	—	—	1	9
	Blue metal and metal stone	3	—	—	6
	Dark blue metal	1	1	2	6
	Black metal stone	—	—	1	—
7	COAL	—	—	—	9
	Band	—	—	—	9
8	CROW-COAL	—	1	1	6
	Grey sill	—	1	2	6
	White post	1	1	—	—
9	COAL	—	—	—	9
	Grey metal with brown scars	—	—	1	9
	Grey metal stone with post	—	1	—	—
	Strong white post	2	1	—	6
	Blue metal	—	—	2	—
	Strong grey metal	—	1	2	9
	Blue metal	—	—	2	6
	Strong grey metal stone	1	—	—	—
	Blue metal	—	—	1	9
	White post	3	—	2	6
	Blue metal	1	1	2	9
	Black swad	—	1	—	6
10	MAIN COAL	—	1	2	10
	Total	46	—	1	6

Section of the Strata at Cockfield Colliery.

No.	Stratum	Fth.	Yds.	Ft.	In.
	Soil	—	—	1	—
	Brown stony clay	1	—	—	—
	Grey post	2	—	1	9
	Brown and white post	3	1	1	3
	Strong white post	—	—	2	9
	White post	2	1	—	—
	Grey metal stone	—	1	—	6
1	COAL	—	1	2	9
	Grey sill	—	—	2	—
	Grey metal stone	3	1	2	—
	Black stone mixed with Coal	—	—	2	—
	Carried forward	16	—	1	—
	Brought forward	16	—	1	—
	Grey metal stone	1	—	—	9
	Whin	—	—	—	10
	Grey post	—	1	—	—
	Whin	—	—	—	6
	Grey metal stone with girdles	2	1	2	8
	Dark blue metal	—	—	1	—
2	COAL	1	—	—	—
	Grey sill	—	—	—	9
	Total	22	—	1	6

I have now concluded the most important of the geological observations I had to make upon the Coal-field, and it remains only to give some account of the mineral springs that occur within its limits, and of the deleterious gases to which the mines are subject.

The mineral springs have been found either bursting out at the surface, or have been discovered in the shafts of mines, and in the dykes that intersect the strata. Those impregnated with common salt have been noticed in the pits at Walker, Wall's end, and Percy main, and in most of the deep mines between Newcastle and Shields: on the Wear they have been found at Birtley and Lumley-thick, and appear rising to the day at Ouston 1 mile west of Birtley, and at Butterby near Durham.

The spring at Walker issues into a deserted shaft from a bed of slate-clay at the depth of 55 fathoms; but being dammed up rises 33 fathoms higher to within 22 fathoms of the surface, and 15 fathoms of the level of the Tyne. It is pumped from a reservoir in the pit for the manufacture of soda, the salt obtained in the intermediate process being exempted by an Act of Parliament from the salt duty. The following is the analysis of this water by Mr. G. Woods.

Contents in 1000 grains of water.

Dry muriate of soda	32
Dry muriate of lime	10
Muriate of magnesia	1 (together with the five items below)
Carbonate of lime	
Carbonate of iron	
Silica	
	43 grains

A little carbonic acid gas.

About thirty years since a brine spring was discovered at Birtley colliery 76 fathoms below the surface, in driving a water level through a slip of 4½ fathoms throw. The spring being found to produce 26400 gallons of water in twenty-four hours, extensive salt works were erected on the spot, which are still carried on with success. Within 50 or 60 yards north of the slip, from which the spring issues, the Birtley dyke before mentioned crosses the strata from east to west, casting up the coal measures on the northern side 29 fathoms; and the slip having a south-eastern direction probably meets the dyke and is a branch from it. The water level is driven in a bed of blue shale containing ironstone in beds and in nodules. The analysis of the water by Mr. G. Woods is as follows. *

Contents in 1000 grains of water.	grains.
Dry muriate of soda	87
Dry muriate of lime	43
Muriate of magnesia	} 1
Carbonate of lime	
Carbonate of iron	
Silica	
	131

A little carbonic acid gas.

Before the publication of Camden's Britannia in 1607, a brine spring had been observed to issue from the rocky bed of the Wear at Salt water Haugh near Butterby; for in that work it is first mentioned. In 1684, Mr. Hugh Todd drew up an account of this

* The carbonates, small as is their proportion, are sufficient to make the water appear turbid, when viewed in the large reservoirs at Birtley. They are very readily thrown down by the addition of quick-lime, and this method of purifying the solution is always pursued in that salt-work. The brine leaves no incrustation upon the evaporating pans.

and other springs in that neighbourhood, which was addressed in a letter to the Bishop of Carlisle, and inserted in the Philosophical Transactions. The spring continues to flow from the crevices of a basaltic vein for the space of 50 yards in length by 10 in breadth, and in summer, when the water is low, tinges the rocks red, and deposits a crust of salt upon them. The brine of this spring contains carbonate of iron, muriate of soda, and sulphate and carbonate of lime; but as it becomes mixed with the fresh water in issuing from the rock, the proportions of the mineral ingredients have not been well ascertained.

Within the distance of 200 yards from this spring two others of very different natures rise from bore-holes in the coal-measures. These are situated in a small dell, and according to Mr. Todd were discovered at the depth of $12\frac{1}{2}$ fathoms.

The spring furthest from the river is called the sweet well, and contains according to Dr. Clanny a small quantity of lime held in solution by carbonic acid. Half way between the sweet well and the Wear a sulphureous spring issues, and from the following analysis by Dr. Clanny, it will probably be found to possess valuable medicinal properties.

Contents in a wine-gallon of water.

Muriate of lime . . grains	5
Muriate of soda	56. 5
Muriate of magnesia . . .	4. 5
Carbonate of lime	8. 5
Sulphate of lime	3. 5
	78

Gaseous Contents.

Carbonic acid gas . Cub. In.	8
Azotic gas	3
Sulphuretted hydrogene . .	11. 5
	22. 5

Chalybeate springs, some of which deposit large quantities of yellow ochre, are common in every part of the Coal-field; and a water which flowed through the wooden pipes at Walker colliery, used to let fall a copious precipitate of gypsum. The substance formed during the twelve working hours of the mine was black, but at other times was as white, and had the same degree of hardness as chalk. A layer formed in twelve hours was about $\frac{1}{16}$ of an inch in thickness. Specimens of this sediment are to be found in many cabinets, but are now no longer to be procured, the high main coal being there exhausted, and the colliery laid in.

The *choak* damp, the *fire* damp, and the *after* damp or *stythe*, are the miner's terms for the gases with which the coal mines are affected; and of these the second both from its immediate violence and as occasioning the other kinds of damps is the most to be dreaded. The accidents arising from it have become more common of late years, but it should not for a moment be supposed that they arise from any want of skill or attention in the professional surveyors of the mines. The following seem to be the causes in which the gas originates.

1st. The coal appears to part with a portion of carburetted hydrogene, when newly exposed to the atmosphere; a fact rendered probable by the well known circumstance of the coal being more inflammable when fresh from the pit than after long exposure to the air. 2d. The pyritous shales that form the floors of the coal-seams decompose the water that lodges in them, and this process is constantly operating on a great scale in the extensive wastes of old mines. In whatever mode we suppose the gas to be generated, it is disengaged abundantly from the High Main, but more particularly from the Low Main coal-seam, and that in a quantity and with a rapidity that are surprising. It is well known that the gas frequently fires in a shaft long before the coal-seam is reached by the sinkers; and that the pitmen occasionally open with their picks crevices in the coal or shale, which emit 700 hogsheads of fire damp in a minute. These *blowers* (as they are termed) continue in a state of activity for many months together, and seem to derive their energy from communicating with immense reservoirs of air. All these causes unfortunately unite in the deep and valuable collieries situated between the great north road and the sea. Their air courses are 30 or 40 miles in length, and here as mignt be expected the most tremendous explosions ensue.

The after damp or stythe, which follows these blasts, is a mixture of the carbonic acid and azotic gases resulting from the combustion of the carburetted hydrogene in atmospheric air, and more lives are destroyed by this than by the violence of the fire damp.

To guard against these accidents every precaution is taken, that prudence can devise, in conducting and in ventilating the mines. Before the pitmen descend, wastemen, whose business is to examine those places where danger is suspected to lurk, traverse with flint mills the most distant and neglected parts of the workings, in order to ascertain whether atmospheric air circulates through them. Large furnaces are kept burning at the upcast shafts, in aid of which at Wall's end colliery a powerful air-pump, worked by a steam engine, is employed to quicken the draft: this alone draws out of the mine 1000 hogsheads of air in a minute. A kind of trap-door, invented by Mr. Buddle, has also been introduced into the workings of this colliery. This is suspended from the roof by hinges, wherever a door is found necessary to prevent the escape of air. It is propped up close to the roof in a horizontal position; but in case of an explosion the blast removes the prop, when the door falls down and closes the aperture.

It may be desirable to give an estimate of the quantity of coal that is annually received from the Coal-field. The annual shipment of coal for a series of years from the Tyne, the Wear, Hartley and Blyth will be found in the appendix, No. 2. From these it appears that the quantity shipped

From the port of Newcastle, in the year 1813, was of Newcastle chaldrons*	598,773
From the port of Sunderland	330,967
From Hartley and Blyth, in the year 1811.	53,958
†The quantity shipped annually from the four ports being about	983,698
The quantity vended from 35 Landsale pits in the county of Durham was in the year 1808	78,442
The quantity consumed in Newcastle, Sunderland, North and South Shields, Hartley and Blyth was computed by Dr. Macnab‡ in the year 1801, at	190,000

But there are no precise data for calculating the home consumption of the two counties. About thirty years ago a practice was adopted at the pits, where the coal was of a fragile nature, of erecting screens to separate the small from the sounder coal. This system is now become universal, and immense heaps of coal are thus raised at the mouths of the pits. These soon take fire from the heat of the decomposing pyrites,|| and not less than 100,000 chaldrons are thus annually destroyed on the Tyne and nearly an equal quantity on the Wear. It is greatly to be desired that some use should be found for the small coal in order to prevent so great a waste.

* The Newcastle chaldron = 53 cwts. or $\frac{15}{8}$ of the London chaldron.

† It appears from the table given in the Appendix, (No. 2.) that in the year 1813, 970,901 London chaldrons of coal were imported into London. Deducting from these the 50,000 chaldrons brought by canals from the midland counties, there will remain 920,901 London chaldrons = 491,147 Newcastle chaldrons of coal imported by sea into London.

‡ See his Tract on the Coal trade.

|| Beneath the heaps that have taken fire, a bed of blackish brown scoria is formed, which greatly resembles basalt, and is used for mending the roads.

IV. *Lead-mine Measures.*

The metalliferous or lead-mine measures form the northern and western boundaries of the Coal-field. This formation enters Northumberland from the northern side of the Tweed, and constitutes its southern banks from its junction with the Tiviot at Kelso to the sea. In a south-eastern direction it follows the coast from Berwick to the Coquet for 32 miles. The porphyritic mountains of Cheviot interrupt it towards the west for about 20 miles; but having passed the southernmost point of that ridge it stretches across the whole breadth of Northumberland, and is spread over the adjacent borders of Cumberland, Durham, Westmoreland and Yorkshire. It is terminated towards the west by the red sandstone near Brampton and Melmerby, about 54 miles from the sea at Tynemouth and at Seaham.

The characteristic features of the north-eastern part of this district are gently swelling hills, heightened occasionally by mountain caps of basalt, and then assuming a rugged and broken aspect on their summits. Towards the western part of Northumberland it forms sterile moor-lands and exposed sheep-pastures, being still accompanied by basaltic eminences: the river vallies, however, that intersect these wastes, are fertile and picturesque in a high degree. If a line be drawn across the island through Newcastle and Carlisle, the highest station between the German ocean and the Irish channel is not more than 445 feet above the level of the sea; upon this spot the village of Glenwhelt is built.* On the banks of the South Tyne

* From Tynemouth to Newcastle	9 miles	9 feet
From the river Tyne to the west turnpike gate above Newcastle	..	196
From the turnpike to Haydon bridge, on the same level...	27½	...
From Haydon bridge to Ridley hall on south Tyne	1½	100
From Ridley hall to Haltwhistle opposite the church	7	60
From Haltwhistle to Glenwhelt	3	80
	48 miles	445 feet

in Kearsdale, the country begins to assume a more majestic form, and rising into a mountain range it constitutes the central ridge that traverses the island. Cross Fell, situated near the junction of the five northern counties, may be considered as the summit of the whole chain. Its latitude is 54° 42′ .05″ north, and its distance from the eastern coast 55 miles. Its height is 2901 feet, and it is therefore one of the highest mountains in England.†

The strata in the southern and mountainous part of this district dip on an average 2° 15′, or 1 yard in 27 to the east 35° south, so that on crossing the range from east to west they will be seen cropping out one after the other, and forming parallel ridges extending from the south-west to the north-east. In this part of the mining field considerable uniformity may be observed amongst the sills. Thus the sections at Allenheads, Coal cleugh, Aldstone moor, and in Weardale, are allied to those above Blanchland on the Derwent, and agree very closely with one another: if therefore those of Hely field, Aldstone moor, Dufton Fell, and its sequel, be taken in succession, they will give no very inaccurate representation of the prevailing series of beds in this part of the district, and the total thickness of these beds thus obtained will be 2717 feet. In the less elevated tracts of Northumberland this uniformity is no longer preserved, and it is only a very general resemblance that the measures then bear to those of the south. On the banks of the Tweed the disagreement becomes more evident, so that it may even be doubted whether the rocks of that valley are correctly placed among the lead mine measures.

† Height of Cross Fell by geometric measurement...... 2901 feet
——— Helvellin 3055
——— Skiddaw............................. 3022
——— Saddleback 2787

Some of the members of this formation agree with those of the Coal-field, viz. coal, shale and sandstone; but other rocky masses also attend the lead mine measures and serve to distinguish them. These are the coarse grained sandstone called the millstone grit, sandstone with impressions of marine shells, shale with the encrinal fossil, the encrinal limestone, siliceous hornstone or chert, and basalt in beds or in overlying positions.

The four first of the following sections are those which I have already referred to as representing not inaccurately the series of beds in the mining field. The additional sections from Blanchland resemble the upper part of the Aldstone moor section, and that from Weardale the lower. I have added the section from Arkendale in Yorkshire for the sake of comparison.

Section of the Lead-mine Strata at Hely Field on the river Derwent.

	Fs.	Y.	Ft.	In.		Fs.	Y.	Ft.	In.
Slate sill	2	1	—	—	Brought up	35	—	—	—
Plate	3	1	—	—	Hard hazle . . .	2	1	—	—
Different Girdle beds .	2	—	—	—	Grey beds. (Thin layers of slate clay and sandstone alternating) . . .	1	—	—	—
Plate	2	1	—	—	Freestone . . .	7	—	—	—
Freestone (fine grained sandsone)	7	—	—	—	Plate	1	—	—	—
Coarse hazle	1	1	—	—	Hazle or Slate . .	2	1	—	—
Plate and Blue whin .	1	—	—	—	Plate or Famp . .	2	—	—	—
Plate and Grey beds .	—	—	2	—	Hazle and Plate . .	2	1	—	—
Hard stone and Whin .	1	—	2	—	Plate	2	—	—	—
Plate and Whin . .	1	1	2	—	Hazle or Slate . .	1	1	—	—
Plate	2	1	—	—	Plate and Grey beds .	1	1	—	—
Millstone grit . . .	5	—	—	—	Thin stratum of Grey beds .	15	—	—	—
Plate	4	1	—	—					
Carried up	35	—	—	—	Fathoms	74	—	—	—

Section of the Strata at Beldon above Blanchland on the Derwent.

	Fs.	Ft.	In.		Fs.	Ft.	In.
Low grit (A)	5	1	—	Brought up	32	4	—
Pebbles	—	—	—	Hazle	—	4	—
Plate	2	5	—	Plate	3	1	—
Lime (A 2)	—	3	—	Coal and Hard Coal sill	1	4	—
Coal	—	1	—	Grey beds	1	2	—
Plate	1	—	—	Plate and Coal	1	4	—
Hard strings	—	—	—	Low Coal sill, (Sandstone)	2	3	—
Craig's sill (B)	4	2	—	Plate	1	—	—
Plate	1	5	—	Hazle	—	3	—
Cockle shells	—	—	—	Plate	1	—	—
Pattison's sill (C)	2	4	6	Great Lime (E)	9	2	—
Plate	4	1	6	Tuft	—	4	—
Hazle	—	3	—	Grey beds	—	2	6
Plate	2	—	—	Hazle	1	1	3
Hazle	4	3	—	Plate	1	1	6
Plate	1	2	—	Hewitson's Lime (F)	—	4	—
Little Lime and Black bed (D)	1	3	—				
				Fathoms	59	4	3
Carried up	32	4	—				

Section of the Strata at Shildon above Blanchland.

	Fs.	Ft.	In.		Fs.	Ft.	In.
Hipple	7	—	—	Brought up	69	3	3
Plate	7	—	—	Hazle	—	3	—
High grit	8	3	6	Plate	2	1	—
Plate and Coal	—	3	3	Hazle	—	4	—
Plate and White sill	1	1	9	Plate	5	2	—
Plate, Coal and Plate	3	—	6	Little Limestone (D)	2	1	—
Low grit (A)	11	—	6	Plate and Coal	—	5	—
Plate	1	4	9	Coal sill	1	1	3
Pebbles	1	—	—	Plate	2	—	—
Plate, Lime, Post and Hazle (A 2)	1	4	—	Coal, &c.	—	3	—
Crag sill (B)	4	2	—	Low Coal sill	1	2	—
Plate	4	3	6	White sill	3	4	—
Pattison's sill (C)	6	4	6	Grey beds	—	—	8
White sill	2	—	—	Plate	1	—	—
Hazle	4	5	—	Great Limestone	—	—	—
Plate	4	—	—				
				Fathoms	91	—	2
Carried up	69	3	3				

Section of the Strata from Brandon Wells to Westgate in Weardale.

	Fs.	Ft.	In.
Great Limestone (E)	11	—	—
Tuft or Water sill	1	3	—
Plate	2	—	—
High quarry Hazle	1	3	—
Plate	—	3	—
Low quarry Hazle	2	—	—
Plate	9	—	—
Four fathoms Limestone (F)	4	—	—
Plate	—	3	—
Hazle	6	1	3
Plate	5	4	10
Carried up	44	—	1
Brought up	44	—	1
Three yard Limestone (G)	2	2	4
Plate	—	3	—
Hazle	6	3	2
Plate	—	3	—
Limestone (H)	3	3	5
Plate	—	2	—
High Slaty hazle	1	5	—
Plate	1	—	—
Low Grey beds Slaty hazle	1	3	—
Fathoms	62	1	—

Section of the Lead-mine Strata on Aldstone Moor, Cumberland.

	Fs.	Y.	Ft.	In.
Grindstone sill	4	—	—	—
Plate	6	—	—	—
Hazle	1	—	—	—
Plate	2	—	—	—
Limestone (1)	1	—	—	—
Crow Coal occasionally				
Hazle or Upper Coal sill	1	—	—	—
Plate	8	—	—	—
Hazle	1	1	1	—
Plate	2	1	—	—
Hazle	2	—	2	—
Plate	1	—	—	—
Upper Slate sill.	4	—	—	—
Plate	1	1	—	—
Lower Slate sill.	4	—	—	—
Plate	5	—	2	—
Whetstone sill. (Fine grained Micaceous sandstone	1	1	—	—
Plate. (Ferruginous sandstone)	2	—	—	—
Iron stone with Coal	1	—	1	—
Freestone with Iron pyrites.	5	1	—	—
Plate	6	—	1	—
Girdle beds	—	1	2	—
Plate	3	1	—	—
Pattison's sill or hazle (C). Very hard grey sandstone with specks of mica	1	1	—	—
Carried up	67	1	—	—
Brought up	67	1	—	—
Plate	3	—	—	—
Little Limestone (D)	1	1	1	—
Little hazle	—	1	2	—
Plate	2	—	—	—
Coal occasionally				
High Coal sill. (Hard grey sandstone with specks of mica	1	1	1	—
Plate	1	—	—	—
Coal occasionally				
Low Coal sill	2	—	—	—
Plate	3	—	2	—
Tumblers and Great Limestone (E)	10	1	1	—
Tuft or Water sill	1	—	2	—
Plate	2	1	—	—
Limestone post	—	1	1	—
Quarry hazle	4	—	—	—
Plate. Indurated bluish clay with laminæ of hard stone and iron pyrites	5	—	—	—
Great Girdle bed.	1	—	—	—
Four fathoms Limestone (F)	4	—	—	—
Nattras gill quarry hazle Coarse grained sandstone	3	—	—	—
Plate	6	—	—	—
Carried up	121	—	1	—

	Fs.	Y.	Ft.	In.
Brought up	121	—	1	—
TWO FATHOMS LIMESTONE (G)	2	—	—	—
Plate	—	1	1	—
Arthur's Pit quarry sill	4	—	—	—
Plate	1	1	1	—
LIMESTONE (H)	—	1	2	—
Hazle	2	—	—	—
Plate	1	1	—	—
TUMBLERS and SCAR LIMESTONE	9	—	—	—
Plate	—	1	—	—
Grey beds	2	—	1	—
Carried up	145	1	—	—

	Fs.	Y.	Ft.	In.
Brought up	145	1	—	—
Coal occasionally				
Plate	1	—	2	—
COCKLESHELL LIMESTONE	—	—	1	6
Hazle	2	1	—	—
Plate	—	1	1	—
LIMESTONE	—	1	1	6
Plate	4	1	—	—
TYNE BOTTOM LIMESTONE	3	1	1	—
Fathoms	159	—	1	—

Section of the Lead-mine Strata at Dufton, Westmoreland.

	Fs.	Ft.	In.
Great Whin sill (Basalt)	10	—	—
Plate	3	—	—
Hazle	2	—	—
Plate	2	—	—
Hazle	3	—	—
Plate	1	1	—
JEW LIMESTONE	3	—	—
Plate	1	—	—
Hazle	5	—	—
Plate	1	1	—
LITTLE LIMESTONE	1	—	—
Hazle	1	1	—
Carried up	33	3	—

	Fs.	Ft.	In.
Brought up	33	3	—
Great Hazle	10	—	—
Plate	4	—	—
SMIDDY LIME	4	1	—
Hazle	1	—	—
LIMESTONE	4	1	—
Hazle	1	—	—
LIMESTONE	3	—	—
Plate	1	1	—
LIMESTONE	1	1	—
Plate	1	1	—
ROBINSON'S GREAT LIMESTONE.	14	—	—
Fathoms	78	4	—

Section of the Strata observed to crop out from below the Dufton Sills.

	Fs.	Ft.	In.
Hazle	1	1	—
Plate	—	1	—
GREAT LIMESTONE or RUNDAL, or MELMERBY SCAR.	21	—	—
Plate	2	—	—
Freestone	1	—	—
Plate and Small Coal	1	—	—
LIME	4	—	—
Freestone	18	—	—
Plate	1	1	—
Freestone	1	1	—
Plate	2	—	—
Freestone	1	1	—
Plate	1	—	—
Carried up	54	5	—

	Fs.	Ft.	In.
Brought up	54	5	—
Freestone	1	1	—
Plate	1	—	—
LIMESTONE	2	—	—
Hard freestone	2	—	—
Plate and Coal (7 inch seam)	8	—	—
Freestone	26	1	—
Girdle bed	2	—	—
LIMESTONE	3	1	—
Freestone	30	—	—
Plate, upper part black, lower part reddish	10	—	—
Old red sandstone			
Fathoms	140	2	—

Section of the Lead-mine Strata at Arkendale in Yorkshire.

	Fs.	Ft.	In.
White grit	5	—	—
Coal	—	1	6
Millstone grit	14	3	—
Plate	5	—	—
Lime	—	2	—
Plate	3	—	—
Lime	—	3	—
Plate	1	—	—
Lime	—	3	—
Plate	4	1	—
Flinty chert	2	4	—
Plate	—	1	—
Crow chert	1	—	—
Plate	1	3	—
Second Crow chert	2	—	—
Crow lime	2	—	—
First Soapy grit	1	—	—
Coal bed	—	1	—
Second Soapy grit	1	1	—
Plate	1	2	—
Grit	11	—	—
Carried up	58	1	6

	Fs.	Ft.	In.
Brought up	58	1	6
Girdles	2	—	—
Plate	3	—	—
Chert or Iron beds	2	—	—
Red beds	2	—	—
Plate	1	—	—
Black beds	2	3	—
Plate	—	1	—
Lime	—	2	—
Plate	—	4	—
Main chert	3	—	—
Main lime	12	—	—
Dead grit	9	—	—
Underset chert	6	—	—
Underset lime	3	—	—
Underset grit	6	—	—
Girdle	2	3	—
Grit	12	—	—
Plate	5	—	—
Lime	6	—	—
Fathoms	136	2	6

The uppermost of the beds detailed in these sections consist of sandstone and shale, and they are the first that rise from beneath the coal formation. The most remarkable of the sandstones are 1. The *slate sill*, a fine grained, micaceous, slaty rock of a grey colour, used as a roofing slate in many villages of Northumberland and Durham. It is the uppermost bed in the section of Hely field.

2. The *freestone* sills: these are fine grained sandstones frequently containing vegetable impressions.

3. Hard ferruginous fine grained sandstones called *hazles* by the miners. The sandstone in the section of Aldstone moor, called nattras gill hazle, is however coarse grained. These are sometimes slaty, and occasionally bear the impressions of bivalve shells.

4. The *millstone grit;* a coarse white sandstone composed of small angular grains of quartz, with rounded pebbles of the same

substance imbedded in them. This is one of the uppermost strata on the Derwent, where it crops out, and is quarried for millstones. The quarries are on Muggleswick Fell, and also between Wolsingham and Stanhope in Weardale. The thickness of the rock at Muggleswick is about 5 fathoms. The hilly district of the lead mine country affords but one stratum of this rock, which crops out before it reaches Aldstone moor or Allendale. It is probably the same bed which is found in the section of Arkendale. A similar rock is found in the north-eastern part of Northumberland at Scramerstone four miles south of Berwick, and at Craster near Howick; and with this durable material the castle of Dunstanborough is built. The grey millstones of Muggleswick are employed for grinding rye, but those brought from Derbyshire are preferable in quality.

5. The *grindstone* sill, a fine grained yellowish sandstone, which on Aldstone moor, Coal cleugh, and Allenheads is the uppermost bed, and is found near the surface at Nent head and on the summit of Cross Fell. On Aldstone moor its thickness is about 4 fathoms. Grindstones, greatly inferior to those of Newcastle, are made of it for home consumption.

Below the limestone in the Aldstone moor section the following other sandstones may deserve notice.

1. The *whetstone* sill, a fine grained micaceous sandstone, which may be seen at this day at Burtreeford.

2. The *iron-stone* sill, a ferruginous sandstone, containing iron pyrites in abundance.

3. *Firestone*, a porous fine grained sandstone, used for the construction of furnaces, and varying from 5 to 6 fathoms in thickness.

4. *Pattison's* sill, a very hard grey sandstone with specks of mica.

5. The *coal* sills, many of them resembling the last.

6. The *water-sill*, called also *tuft*, a very porous light-coloured sandstone, of a soft texture from the loose aggregation of the small grains which compose it.

The beds of sandstone are thickest towards the lower part of the series. Thus at Hely field the freestones are 7 fathoms thick, the most considerable of the grits at Shieldon about 11 fathoms, the great hazle at Dufton 10 fathoms, and three of the freestones in the section below that of Dufton 18, 26, and 30 fathoms respectively.

The limestone beds are the most characteristic of this formation, and are the most important to the miner. Of these there are 21 beds in the preceding sections of which the aggregate thickness is about 96 fathoms, that of the whole series being, as I have already mentioned, about 458 fathoms.

The most remarkable are 1, the *great* limestone, the 3d in the series, from 10 to 11 fathoms thick, consisting of three strata divided by indurated clay. The stone is a brownish black or dark bluish grey encrinal marble in which bivalve shells are imbedded. It bassets at Frosterley in Weardale, where large quantities of it are quarried for agricultural uses and building cement, or for ornamental purposes. It burns to a lime of a mild nature, highly valued as a manure, and contains according to Sir H. Davy 96 per cent. of carbonate of lime.

2. The *scar* limestone, the 7th in the series, 5 fathoms thick, resembling the great limestone both in its colour and organic remains, and like it divided into three strata. This rock crops out in the little river Nent, and forms the barrier at the cascade called Nent force.

The aqueduct level, carried on by the Commissioners of Greenwich Hospital, begins near Aldstone, and is driven at its commencement immediately below this bed of limestone: it is now two miles long from north to south.

3. The *cockleshell* limestone, not exceeding 20 inches in thickness, and next below the scar limestone. It is of a dark iron-grey colour, and contains besides the encrinal fossil, oyster shells of the diameter of 4 or 5 inches, and other bivalve shells. It crops out in several of the small gills on Aldstone moor, where it does not exceed in thickness 20 inches.

4. The Tyne bottom limestone, the 10th in the series, 21 feet thick. It is an encrinal limestone, consisting of 3 strata, forming the bed of the Tyne for 4 miles from Tyne head to Garrigill gate, and is the lowest bed in which the mines have been wrought on Aldstone moor, though nearly the uppermost at Dufton.

5. Robinson's great limestone, the lowest in the Dufton section, and 14 fathoms thick.

6. *Melmerby scar* limestone, the thickest in the whole formation, measuring 21 fathoms in Melmerby cliff, where it bassets out. It contains the encrinal fossil, and bivalve shells.

The beds of limestone have been observed to be more regular in thickness throughout the mining field than those of shale or of sandstone.

The beds of shale or *plate* (as it is called) are very numerous, and are found alternating with the rocks of limestone and sandstone. They are seldom so thick as 7 or 8 fathoms; but the plate sill, which is the lowest bed in the section below that of Dufton, measures 10 fathoms. Shale alternating with sandstone in thin layers sometimes forms beds of considerable thickness, (see section of Hely field,) which are called *grey beds:* when containing laminæ of hardstone and iron pyrites it is called a *girdle* bed. Iron pyrites is found imbedded in the shales in great abundance, and in various forms; but owing to the high price of fuel and the great distance from any seaport it cannot be manufactured into green vitriol to advantage. *Clay* *ironstone* is found in the shale, forming either thin subordinate strata, or nodules; at Aldstone and in Teesdale it occurs forming septaria with internal divisions, such as are represented in St. Fond's travels; and at the latter place it forms the œtite or eaglestone of the old mineralogists. It is more abundant in the shales of this formation than in those of the Coalfield, but the only iron work now existing within the limits of my map is that of the Tyne company at Lemmington in the northern part of the district. The Carron company formerly collected on Holy Island a part of the ore smelted at their furnaces, but they have long since relinquished this undertaking.

About the beginning of the last century, according to Wallis, an iron manufactory was established at Lee Hall, in the vale of North Tyne near to Bellingham. The director of it was a Mr. Wood, son of the Irish projector of that name. The ore was plentiful in the strata of a romantic precipice on the east side of the river, and a good deal of bar iron was made from it; but it seems that charcoal becoming scarce the work was relinquished. Large quantities of slag are still found scattered over the surface, or forming considerable mounds, wherever the Romans carried their roads or fixed their stations.

The variety of carbonate of lime called satin spar, forms a thin stratum in a bed of black slate-clay, which crops out at Aldstone close to the brewery. The specimens are generally intersected by veins of iron pyrites and slate-clay. Some buildings stand upon the bank out of which this mineral was quarried, and the proprietor to save them from being undermined has built a wall close to the face of the rock; so that satin-spar is no longer to be procured, and is become a scarce mineral.

There are few parts of the Lead-mine district in which coal is not to be found, though the seams cannot be compared in magnitude to those of the Newcastle formation. In the mountainous parts of the district the seams are extremely limited in extent, being soon squeezed out, as the miners term it, and seldom exceeding 20 inches in thickness. In the high grounds, near the sources of the South Tyne and the Allen, Coarse or *Crow* coal abounds; and on Aldstone moor five seams of this fossil are imbedded between the grindstone sill and the Tyne bottom limestone: it does not appear among the sills on the Derwent towards the east, or of Dufton towards the west of Aldstone, but occurs near the summit of Cross Fell, where no other is to be met with. Crow coal generally rests upon a thil or plate of slate-clay; but the beds being very uncertain in their extent are seldom noticed in the Lead-mine sections. They are worked at a small expense by means of drifts into the sides of the hills, and as fuel is scarce in the mountainous district, Crow coal becomes an object worthy of attention.

This mineral is of a dirty sooty-black colour, and contains much sulphur, which renders its smoke extremely offensive. At Aldstone it is mixed with clay and made up into balls, which yield considerable heat on burning, but emit scarcely any flame.

On leaving the mountainous district, the seams of coal are found improved in point of quality and thickness, and it will appear from the following localities, over what an extent of country that mineral is found.

It occurs at Stublick, six miles south-west of Hexham; at Wall near Fallowfield; near Bellingham on the North Tyne, where many good seams are found; at Kerryburn near the foot of the Carter on the borders of Roxburghshire; in the vale of the Reed; at Elsdon; at Woolcoats on the moors near Harbottle castle; at Hesleyhurst; at Healy-coat; near Carlington castle; at Newton; at Shilbottle;

at Elginham; near Craster; near Beadnell; near Belford; and at Tweedmouth in the vicinity of Berwick.

In the north-eastern part of Northumberland, near the sea, the seams are tolerably thick, and very good in quality; that of Shilbottle for instance, which supplies Alnwick with coal, (see the section below.) The mines are usually of inconsiderable depth in comparison of those in the Newcastle coal-field; that of Shilbottle is one of the deepest, measuring 45 fathoms. That of Newton (see the section page 71,) measures 16 fathoms, and some of the pits near Berwick only 15 fathoms. The mines of Stublick and Wall, on the borders of the mountainous district, are severally 16 and 19 fathoms deep, and each contains three seams of coal. (See the sections p. 70.)

The coal alternates with slate-clay, limestone, and sandstone, and at many of the places where coal is worked, limestone is also quarried. In the maritime district, from the Coquet to the Tweed, the measures dip to the south-east, and unlike the beds of the Newcastle coal-field undulate with the surface of the earth.

The following sections will give some notion of the measures that accompany the coal to the north of the mountainous district.

Section of the Strata at Shilbottle Colliery, $2\frac{1}{2}$ miles South of Alnwick.

	Fath.	Yd.	Ft.	In.
Clay	2	1	1	—
Freestone	10	—	—	—
Blue slate	7	—	—	—
Blue limestone	4	—	—	—
1 COAL	—	—	—	4
Thil	—	—	1	—
Freestone	1	1	2	11
2 COAL	—	—	1	—
Thil	—	—	1	6
3 COAL	—	—	1	—
Thil	—	—	1	—
Main freestone	2	—	1	1
Carried up	28	1	1	10

	Fath.	Yd.	Ft.	In.
Brought up	28	1	1	10
Main slate	7	—	—	—
Blue limestone	3	—	—	—
Thil	—	1	—	—
Freestone	1	1	—	—
Metal	1	—	—	—
Blue limestone	—	—	2	—
Thil	1	—	1	—
Ironstone	—	—	—	6
Rough stone	2	—	—	—
4 COAL	—	—	2	7
Fathoms	45	1	1	11

Section of the Strata at Wall, near Fallowfield, 3 miles North of Hexham.

		Fath.	Yd.	Ft.	In.
	Soil	—	—	1	—
	Sand and bluish clay with hard tumblers	3	1	2	—
	Sand	—	—	1	—
	Strongish blue clay (stony)	1	1	2	—
	Soft grey metal with whin girdles	2	1	1	—
	Rombly* limestone	—	—	2	6
	Strong thready blue limestone	2	1	—	—
	Blue skared metal	—	—	—	4
	Strong grey metal stone	—	1	1	2
1	Foul Coal	—	—	1	2
	Grey metal	—	1	—	—
	Brown and grey thready post	4	—	—	—
	Carried up	17	—	—	2

		Fath.	Yd	Ft.	In.
	Brought up	17	—	—	2
	Brown and grey metal with sand skares	1	1	—	—
	Blue metal with skares of Coal	—	1	—	6
2	Coal	—	—	1	9
	Grey metal	—	—	—	2
3	Coal	—	—	—	5
	Grey metal skared with Coal	—	—	—	6
	Grey metal inclining to metal-stone near the bottom	—	—	1	—
	Fathoms	19	1	1	6

* Containing Pebbles.

Section of the Strata at Low Stublick, $5\frac{1}{2}$ miles South-west of Hexham.

		Fath.	Yd.	Ft.	In.
	Soil and romble	1	1	1	—
	Grey metal stone with girdles and water	3	—	2	—
	White and grey gullety post, and set away the water†	3	1	2	—
1	Coal with water	—	—	2	4
	Grey metal with girdles	1	—	—	—
	Grey metal	1	—	—	—
2	Coal	—	—	1	1
	Grey metal	—	—	2	—
3 {	Coal	—	—	—	7
	Foul Coal	—	—	—	3
	Grey metal	—	—	—	9
4	Coal with white spar	—	—	—	5
	Carried up	17	—	—	2

		Fath.	Yd.	Ft.	In.
	Brought up	17	—	—	2
	Grey metal	—	—	2	—
	Whitish grey post	1	—	1	1
	Blue grey metal	—	—	2	—
	White post mixed with whin	—	—	1	—
	Soft sandy white post	1	—	1	—
	Dark grey metal	—	1	2	6
5	Coal with white skares	—	—	—	2
	Fathoms	16	—	1	2

Seams now working, 1814.

At 12 fathoms	34 inches
16 ——	27 ——
20 ——	45 ——

† See Notes, pages 33 and 47.

Section of the Strata at Allendale Town, 7 miles South-west of Hexham.

	Fath.	Yds.	Ft.	In.
Soil	—	—	—	6
Stony clay	1	—	—	—
Rombly post	—	—	2	6
Strong grey and brown post	2	1	—	—
White grey post	2	1	2	3
Dark grey post	4	1	—	3
White grey metal with post girdles	2	1	—	—
Dark grey metal stone	1	—	1	6
White post mixed with whin	1	—	—	—
Dark grey metal	—	—	1	—
White grey metal with hard post girdles	2	1	—	—
Carried up	18	1	2	—
Brought up	18	1	2	—
Strong white post with whin girdles	1	—	—	—
Grey metal stone with hard girdles	3	—	2	—
Whin (4 days)	—	—	1	7
Strong dark grey metal with whin girdles	2	1	2	5
Blue whin (got 24th June, and continued to 6th July)	—	1	—	8
Fathoms	26	1	2	8

In the colliery of Newton, situated 3 miles north of Felton and 6 from the sea, the strata dip to the south-east 1 yard in 5.

The following is a section which I received from the overman of the mine.

	Fath.	Ft.	In.
Clay	—	4	—
Sill of limestone, consisting of 5 strata; that near the middle containing impressions of bivalve shells	4	—	—
Red sandstone and shale	8	—	—
Coal of an indifferent quality, worked for burning lime	—	2	—
Five yard limestone	2	3	—
Sandstone and shale	—	—	—
Good Coal	—	3	—
Fathoms	16	—	—

The organic remains found imbedded in the limestone shale and sandstone that belong to the lead mine measures are the following.

In the limestone.

1. Light brown impressions of the turbinite madrepore (junci lapidei) Parkinson vol. 2. tab. 6. fig. 1. In the great limestone at Frosterly and elsewhere.

2. Madrepora. See Parkinson, vol. 2. tab. 6. fig. 3. in the same limestone, and in a stratum resembling it in colour, situated on both banks of the Tyne near Glenwhelt.

3. A grey limestone may be observed in detached masses on the high banks above the East Allen composed almost entirely of a fossil called madrepora flexuosa. See Parkinson, vol. 2. tab. 6. fig. 8. The same rock also occurs above the bridge at Simonbourn.

4. Millepores, in a brown limestone from the neighbourhood of Aldstone.

5. Vertebral columns of the cap encrinite. Parkinson, vol. 2. tab. 8. fig. 4.; from the same rock and locality as 2.

6. Bivalve shells from the same rock and locality as 2.

7. Pectinite and large ostreæ. In the cockleshell limestone, and in the blue limestone quarried at Newton-Hall near to Corbridge.

In the shale.

1. Calcareous casts of the vertebral columns of the cap encrinite; (St. Cuthbert's beads) Parkinson, vol. 2. tab. 8. fig. 4. In Allendale, Weardale, &c. On the banks of the Greta, and in a stratum above Tecket water-fall near Simonbourn: also on the shores of Holy Island.

2. Impressions of pectinites about $1\frac{1}{2}$ inch in diameter: Aldstone moor.

3. At Hairshaw and at other places on the North Tyne the shale contains nodules of clay ironstone, and small muscle shells filled with the same ore.

In the sandstone.

1. Impressions of pectinites on hard slaty sandstone (hazle) in Allendale.

2. Impressions of Arcæ and Anomiæ. Sowerby, t. 35. On ferruginous sandstone from Allendale and Teesdale.

3. Impressions of Euphorbiæ on Freestone from Aldstone and Teesdale. Sowerby, t. 39 & 40. Parkinson, vol. 1. tab. 3. fig. 1.

Basalt occurs in the mining field either between the regular sills, when it is considered as one of them, or, as it should seem, in overlying positions. The great whin sill in the lead mine sections does not consist of the whin of the colliery sinkers, but is really a basalt, coarse-grained in texture, and composed of white felspar and black hornblende, the latter mineral predominating, and giving to the rock a dark greenish grey colour. This bed is placed in the section at Aldstone at the depth of 159 fathoms, and at Dufton is considered as forming the uppermost stratum; the miners indeed regard all the beds of basalt which occur in the mountainous district as ramifications from the great whin sill; but I do not think it certain that there exists this connexion between the beds of basalt found at the two abovementioned places. The thickness of the whin sill is very irregular, being only 6 fathoms in some places and 20 or even 30 at others. In point of situation it agrees remarkably well with the toadstone of Derbyshire.

By far the greatest assemblage of basaltic rocks in this part of the district is met with in Teesdale from the source of the Tees to Eglestone. At Caldron snout, situated on the moors 10 miles above Middleton, a basaltic ridge crosses the river, and occasions a succession of cascades for the space of 596 yards, which form a fine contrast with the pool of still water or *wheel* above the falls. It was here immediately under the basalt that the Rev. J. Harriman discovered small white garnets? crystallized in dodecahedrons, and imbedded in a thin stratum of pale red hornstone or chert with particles of calcareous spar. Vide Sowerby, tab. 120.

Near the steep acclivity which terminates Cronkley Fell, another range of basalt interrupts the course of the Tees, and causes the cataract called the High or Mickle force, where the water is precipitated from the height of 56 feet. The rock which here crosses the river is apparently an overlying mass of coarse-grained grey basalt, the hornblende and the felspar which compose it not being intimately blended. It rests upon the lead-mine sills, and shoots on the banks of the Tees into regular columns of considerable magnitude and elevation. A few miles below this cascade, and about three above Middleton, perpendicular basaltic rocks again form the banks of the river. To these, iron chains have been fastened for supporting Winch bridge. This remarkable structure (if it can be so called) is a plank 2 feet in breath with low hand rails, suspended 56 feet above the Tees, which is here 63 feet wide. Some miners contrived it for the purpose of passing from the county of Durham to Holwick in Yorkshire.

In the fragments of basalt which are found scattered over the surface in Teesdale, and in other parts of the district, small grains of yellow olivine and of greenish black augite are found imbedded.

Leaving the mining field at Jemming on the borders of Cumberland, and at Stagshaw bank near to Fallowfield the basalt appears to fill dykes; but in the range of hills between these places it seems to form overlying masses.

In such overlying masses it bounds the lake of Shewingshields, and the rock on its northern acclivity which is nearly perpendicular assumes a columnar shape. The Romans constructed their wall for many miles close to the edge of this natural rampart; it may be seen at this day standing 4 feet high in many places. In the interstices of the basalt I have noticed ironclay of a brick-red colour, and at Glenwhelt Mr. Fryer detected small veins of dark leek-green talc in thin leaves mixed with iron pyrites and calcareous spar. This fossil on being exposed to the action of the blow-pipe divided into extremely thin folia, and changed from green to copper colour: with the addition of borax it melted into a greenish black bead.

These overlying masses of basalt appear also at Barwesford on the North Tyne, and are continued to the vicinity of Thockrington and Bavington, to Kirk Welphington, and thence in a north-easterly direction as far as Causway-park, north of Morpeth.

Proceeding further to the north, basaltic eminences form a striking feature in the country between Alnwick and Berwick. These eminences have frequently been chosen for the sites of castles, as at Dunstanborough, Bamborough, and Holy Island. The hills near Belford, the rocks called the Staples which emerge from the sea at the distance of six miles east of Bamborough, and the Fern Islands situated half way between the Staples and the shore, are likewise composed of basalt.

At Craster near Howick, where the millstone grit is also found, basalt was formerly quarried and shipped to London for paving-stones. Craster house is fronted with this rock.

In the north-eastern face of the cliff, on which the ancient fortress of Dunstanborough stands, the following series of strata is exposed to view:

Columnar basalt - -	from 8 to 10 feet
Sandstone - - - - - - - -	2 ——
Shale - - - - - - - - -	6 ——
Basalt - - - - - - - - -	——

At Bamborough $9\frac{1}{2}$ miles north-north-west of Dunstanborough, a well was sunk in the Castle hall to the depth of 150 feet, by which it was ascertained that the overlying rock of basalt was 75 feet thick, and rested upon a fine grained red and white sandstone, parts of which fell into small round fragments on being immersed in water.

In the Heugh, the promontory on which Holy Island Castle is built so as to command the harbour, the basalt seems also to rest on a soft fine grained sandstone; on the east side of the island the sea has scooped deep caverns in the latter rock; trials have there been made for coal, and small quantities of galena have been discovered, as I have before mentioned.

Basaltic dykes, which occur in the Coalfield, are also found intersecting the lead mine measures, instances of which may be seen on Aldstone moor, in Allendale, and in Weardale. A well defined dyke may be seen a little above South-Tyne-head smelting-house, traversing the Tyne bottom limestone without altering its level. The dyke is there 36 or 37 feet wide, and is by many thought to be the same that crosses the Allen close to the bridge at Whitfield and the Wear at Burtree-ford still further to the south. This basalt is of a coarse grained texture and greenish black colour. At Egglestone three miles below Middleton a very strong vein of basalt may be seen crossing the Tees in a diagonal direction; and the mountainous moors in the upper part of the vale are covered with fragments and immense blocks of this species of rock for the distance of many miles.

I have already mentioned that the basalt appears to fill dykes at Stagshaw bank and at Jemming. Further to the north, in the village of Embleton, not far from Dunstanborough, an extensive quarry is worked in a basaltic dyke. The course of the vein is north and south, about a mile to the west of the craggy ridge on the sea coast, and between them fine grained sandstone is the predominant rock. The basalt at Embleton is black and coarse grained, and it breaks into angular masses. The latter circumstance renders it useful for the construction of walls and houses, and for the lining of limekilns; though it is commonly quarried for mending roads.*

In the crevices by the sides of basaltic veins strings of lead ore are frequently observed, but these are never known to pass through the dykes.

The fissures which contain lead ore in the mining district are exactly similar to those described by Williams in his Mineral kingdom. Such as range from north to south are called *cross veins*, or (occasionally) *dykes;* they are generally of great magnitude, and seldom carry ore; the most valuable mineral depositories are fissures from 3 to 6 feet wide, running for the most part from south-east to north-west, and cutting the cross veins; the cross veins being frequently rendered productive to some distance from the points of intersection.

The same vein is productive in different degrees at different depths according to the bed which it traverses. Generally speaking veins are most productive between the grindstone sill and the four-fathom limestone; none have been worked in Aldstone moor below the level of the Tyne bottom limestone; but the Dufton mines are situated in the lower beds, though none are worked in the Melmerby scar limestone.

The limestones are the chief depositories of ore, particularly that called the *great* limestone, which is considered to have produced as much lead as all the other sills together. Next to the limestones

* A basaltic dyke has been observed on the coast at Beadnel passing from the south-east to the north-west, of which a description as I understand has already been given to the Society by the Hon. H. G. Bennet. (See the following Paper.)

the strata of sandstone called *hazles* are the most productive of ore; but the lead-bearing veins appear compressed between these hard sills. In Arkendale the sills of chert yield considerable quantities of galena, but this rock does not occur in the mining field further north. In Shale the veins are comparatively barren, and in traversing these soft strata weak veins hade considerably.

The hade of the veins is variable in degree, and in direction. When the veins in Weardale point east and west, they hade towards the south; but in Allendale and in the Aldstone moor country they generally hade towards the north: the strata are universally elevated on the side towards which the veins dip.

Veins, that are otherwise favourably circumstanced for producing ore, are more particularly so if the throw or alteration in the level of the beds of limestone, occasioned by the vein, does not exceed 1 or 2 fathoms; for then both cheeks of the vein correspond in their nature, and limestone does not become opposed to shale or other barren stratum.

The following are some of the most remarkable veins in the mining district.

At Burtree-ford, where an alpine brook first assumes the name of the river Wear, a very strong vein, called the Burtree-ford dyke, crosses the mining field from north to south, and passing on the west side of Allenheads cuts off or at least terminates all the valuable veins discovered in that mine. This must not be confounded with the basaltic dyke which passes the river at Burtree a little above the cross-vein. In some situations this fissure appears to elevate the strata above 80 fathoms on the eastern side, and in others greatly to depress them, as may be observed at the quarries in the great limestone not far from Allenheads. Contiguous to the dyke the sills rise at an angle of 45°. Practical miners have remarked that the veinstones on the east side of this fissure are soft, consisting of calcareous and fluor spars, as is the case in all the Weardale mines; but that on the west side, as at Coal cleugh, Kilhope, Aldstone, and in Teesdale, the matrix is hard, being composed of quartz, heavy spar, and pearl spar, together with much black jack or blende. This observation however cannot apply to the veins on the Derwent towards the east, or to those on Cross Fell towards the west; for in the former quartz passing into chalcedony is the most common matrix; and in the latter amorphous fluor prevails. Disintegrated fluor was the most common veinstone at Breckensyke mine, situated on the south bank of the Wear between 1 and 2 miles below Burtree-ford, which in 1803, when I visited it, produced more ore than any other in the district.

About 2 miles west of Burtree-ford dyke, Whetstone-mea vein crosses the mining field from south-east to north-west, and passes by Coal cleugh and Kilhope. Its north-eastern side is thrown up.

At Coal cleugh and Rampsgill, Bainder end vein is met with passing from north to south. The throw occasioned by this vein is 1 yard on the west side. At Coal cleugh Moss cross vein and Handsome-mea vein have been worked. The bearing of the first is north and south, and it is an upcast to the east of 6 fathoms. The second runs south-east and north-west, and throws up the sills 13 or 14 fathoms on the north-eastern side.

On Aldstone moor the wide open vein called White-heaps, from containing large quantities of spar, was formerly worked, but like most broad fissures proved unproductive, and has long since been abandoned. Little alteration was occasioned in the level of the strata by this vein, the range of which was south-east and north-west. Linn bank cross-vein, which passes from north to south, intersects it.

The strongest vein in Aldstone mining field is old Carr's cross-vein; its direction is north and south, and the sills are from 50 to 100 fathoms higher on the western than on the eastern side of it.

Half a mile west of old Carr's, Black-Esk-gill vein is met with. In Nent head and Dowgang mines its course is north and south, and its throw 6 fathoms upon the eastern side.

The vein, called the Devil's-back-bone, is a dyke of considerable magnitude. At Newstones and in many other places on Aldstone moor, it may be traced on the surface by the rider or mass of vein stone protruding above the adjoining strata, the latter seeming to have been decomposed and washed away from each side of it. It ranges from south-east to north-west, and the sills towards the south-west are elevated 20 fathoms.

In Cross-gill burn on Aldstone moor small quantities of copper pyrites mixed with galena and iron pyrites have been obtained; but not in sufficient abundance to induce the miners to prosecute the undertaking.

A few years since a valuable vein was discovered near the top of Cross Fell, bearing ore in the rock immediately below the soil; its throw is about 1 fathom on the north side.

On Muggleswick moors near Hely-field, which is about 27 miles from the eastern coast, and at Blanchland on the Derwent, the mines first become of importance, and continue to be so to the very summit of Cross Fell. The mining field is here about 24 miles in breadth, and its length from the South Tyne to the extremity of Derbyshire may be estimated at 160. Veins containing galena, seem, however, in a certain degree to pervade the whole of this formation in the northern part of Northumberland. Thus one or more veins have been worked for several years near Fallowfield 30 miles west of Tynemouth. A small mine was lately carried on at Thockrington, and at Welphington in the same neighbourhood, 20 miles west of the sea at Camboes. Strings of ore have also been discovered on the coast of Northumberland at Ellwick nearly opposite to Holy Island, and on the eastern side of the island itself: but all undertakings begun in a flat country must be insignificant when compared with those in a mountainous district, where the mines are won by levels or drifts, which not only free the works from water, but are the means of discovering numerous rich veins by passing through them in their course.

The veins bearing lead-ore on the hills near Shieldon and Blanchland, are reported to have attracted the notice of miners at a remote period, and that part of their wealth, which lay near the surface, has been long since removed. Within these few years an attempt has been made on a great scale to win the ore supposed to lie below the level of the Derwent, by drawing the water from a considerable depth by powerful steam engines; but it is said that as yet the metal obtained repays but a small part of the annual cost of the undertaking.

In this dale the veins appear wide and open upwards, allowing water to percolate through them from the surface. In Allenheads mine, though the shaft is about 100 fathoms deep, the quantity of water is so inconsiderable, that a set of water wheels, three in number, are sufficient to raise it from the greatest depth of the workings, and to discharge it at a drift.*

* At Coal-cleugh an hydraulic machine more curious than powerful, but which fully answers the purpose for which it was constructed, is employed to pump up the water. It is situated at the further end of an adit, which serves for a water level drift, as well as for conveying the ore from the mine. A certain quantity of water from a brook on the elevated ground above the mine is made to raise nearly an equal weight from below by making a column of 20 fathoms act as a counterpoise to one of 19 fathoms. This engine

Galena is the only lead ore procured in abundance from the veins of this formation; but the white and steel grained ore are occasionally discovered. Silver is contained in the ore in different proportions, varying from 2 to 42 ounces in the fother of 21 cwts.; but 12 ounces may be considered as the general average. If $7\frac{1}{2}$ or 8 ounces can be extracted the lead is worth refining; though this must in some measure depend on the prices of silver and of refined lead when compared with that of common lead.* If the galena is good in quality 4 bings or 32 cwts. of clean ore will yield 20 cwts. of lead; but $4\frac{1}{4}$ bings or 34 cwts. are generally required to produce that weight of metal.

The following is the quantity of lead shipped at the port of Newcastle; average for 6 years previous to

1776,	per annum	$7072\frac{1}{2}$ tons.	
In 1804	. . . . .	10352	
1805	. . . .	9162	
1806	. . . .	3911	
1807	. . . .	6809	
1808	. . . .	8155	
1809	. . . .	4972 =	71041 pieces
1810	. . . .	5670	
1811	. . . .	4553 =	68940
1813	. . . .		97940

was constructed about forty years ago by the late Mr. Westgarth, agent to Sir Thomas Blackett, and the following data taken on the spot will shew its power.

Column that works the Engine	20 fathoms
Diameter of the Piston	7 inches
Length of the Stroke	5 feet
Diameter of the bucket that lifts the water	6 inches
Length of the column to be lifted	19 fathoms
Number of strokes per minute......................	9 or 10

* Price of Common Lead. April 1814. £30 per fother of 21 cwts.
of Refined Lead .... 31 ditto
of Fine Silver................ 7s. 5d. per oz.

N.B. The fother on the Tyne is 21 cwts. On the Tees 22 cwts.

The quantity shipped from Stockton is on an average about 3000 tons per annum. The whole of the lead mines in Great Britain are estimated to produce from 45000 to 48000 tons per annum.

The minerals which occur in the veins of the lead-mine district are the following.

Ores of Lead.

Galena.—Massive.

Crystallized in cubes, or with all the angles or edges of the cube truncated or bevelled in various degrees, or in octohedrons.

Occurs in cavities with fluor, and calcareous spar, pearl spar, quartz, sulphate and carbonate of barytes, iron pyrites, sparry iron ore, blende, calamine, &c.

Crystallized in 14-sided figures, imbedded in soft brown marly clay like umber, which effercesces with acids: from Kilhope mine at the head of Weardale.

Reticulated ore from Allenheads and Aldstone moor.

Steel grained ore from the Teesdale, Weardale, Allendale, and Aldstone mines.

Specular ore or slickensides in a matrix of calcareous spar; from Allenheads.

Antimoniated Lead ore—From Dufton mines.

Lead Ore with excess of Sulphur.—This ore is earthy, of a bluish grey colour, and so highly inflammable as to take fire and burn on being held in the flame of a candle. From Dufton mines.

Carbonate of Lead.—Massive. Colour grey. Lustre adamantine. From Flow-edge mine Aldstone moor.

In 4-sided tabular crystals, bevelled on the terminal planes: lustre adamantine. From Allenheads and Aldstone moor.

In aggregated acicular crystals; opake; lustre silvery. From Allenheads and Aldstone moor.

Larger crystals of the same form: lustre adamantine. From the Teesdale mines.

Black acicular crystals; Fair hill, Flow-edge.

Capillary crystals; lustre silvery. On iron-stone. From Allenheads and Teesdale.

Phosphate of Lead.—Botryoidal, of a pale dirty green colour. Grass hill, Teesdale.

Of a siskin green colour, crystallized in small 6-sided prisms, terminated by 6 planed acuminations, forming clusters in light yellowish brown marly earth: from Surside mines, Netherdale, Yorkshire. This ore yields 60 per cent. of lead, and makes a beautiful green pigment.

The following ores of lead also occur; green, yellow, and white lead ore investing galena, from Allenheads and Aldstone moor: coherent earthy lead ore of a dirty white colour, without lustre, worked in considerable quantity at Grassfield mine near Nent head: lead ore of a whitish grey colour, resembling scales of mica, the white sill of the miners, from Allenheads, &c.: friable earthy lead ore of a dark reddish-brown colour, from Aldstone moor, &c.

Ores of Copper.

Copper pyrites with galena from Cross gill, Aldstone moor.

Azure Copper ore.—In very small nodules imbedded in opake white heavy spar; found in small quantities at Wessinghope lead mine near Stanhope in Weardale in the great limestone.

Malachite.—Small quantities occur in the Dufton lead mine.

Ores of Iron.

Iron Pyrites.—Massive and Crystallized.

Carbonate of Iron.—Pearlspar; massive, mammellated, and in small lenticular crystals, yellowish white, light and dark brown, and black from decomposition; too common in all the mines.

Ores of Zinc.

Blende.—Black and brown, amorphous and crystallized; in all the mines.

Reddish brown, in small crystals, scattered over quartz and fluor spar, and in minute crystals upon stalactitical brown quartz; from Aldstone moor.

Blood-red irregular crystals on limestone, with crystals of purple fluor; from Aldstone moor.

Calamine is worked in old Hagg's cross vein near Nent head. One variety is of a yellowish grey colour; conchoidal in fracture, and in a slight degree transparent: another is snow white and perfectly opake.

Ore of Zinc.—In thin white opake layers or incrustations from Allenheads.

Salts of Lime.

Carbonate of Lime. Calcareous Spar.—In acute and obtuse pyramids, (the dog tooth and nail head spar) from Aldstone moor.

In dodecahedrons on pearl spar (Sowerby, t. 42) from Aldstone.

In 6-sided highly transparent prisms terminated by 6-sided pyramids, called Tyne bottom spar; from the Tyne bottom limestone on Aldstone moor.

In pale straw coloured 3-sided pyramids. This delicate fossil has been observed in a vein opposite New-house in Weardale.

Fibrous, of a pale pea-green colour, without the pearly lustre of satin-spar; from Arkendale mines.

Forming stalactites and stalagmites in all the mines: coating detached crystals of fluor from Allenheads.

Large quantities of calcareous spar in a state of disintegration, the fragments resembling bay-salt in size and colour may be observed on the top of Cronkley Fell.

Carbonate of Lime. Arragonite.—Flos-ferri. Beautiful specimens of this rare mineral of a snow-white colour and satin-like lustre have been found in Dufton mines.

Fluate of Lime.—Earthy, from Breckensyke mine, where the galena is also found partially decomposed.

In white, topaz and wine yellow, bluish emerald green, and most commonly in violet or purple crystals, having the form of the cube, the cube with its angles truncated, with its angles acuminated by 3 planes set on the lateral planes; also in tabular and in 24-sided crystals. From Aldstone, Allenheads, &c.

In small purple cubic crystals, bevelled on the edges, attached to sandstone; from a mine near New house in Weardale.

In cubic crystals of a bright emerald green colour, containing drops of water; from the Weardale mines.

In a state of decomposition, coated by crystallized quartz purple or blackish in colour, and sometimes appearing as if it had been in a state of fusion; from Coal cleugh and Aldstone mines.

Sulphate of Lime. Selenite.—In 6-sided prismatic crystals terminated by convex planes (Jameson, vol. i. p. 568) on pearl-spar in a state of disintegration; from Aldstone mines.

In slender detached 6-sided prisms, beautifully transparent, often tinged in the central part with a rich orange-red colour; from Aldstone mines. *Mr. Joseph Fryer.*

Salts of Barytes.

Carbonate of Barytes. Witherite.—In irregular stalactitical minute crystals, opake and white; from Aldstone mines.

In dodecahedral crystals formed of two hexahedral pyramids (Sowerby, tab. 127,) of a pale wine-yellow colour; from Arkendale mines.

In elongated hexahedral pyramids or spiculæ (Sowerby, tab. 129,) of a chalky white colour; from Arkendale mines. Massive, of a wine yellow colour; from Arkendale.

Incrusting fragments of galena, blende, and limestone; white and opake; from Aldstone moor.

Forming crystallized balls of a dirty white colour, and striated fracture, radiating from a center.

In irregular 6-sided prisms without pyramids, and perfectly transparent, occurring occasionally in the center of the balls above mentioned; from the Welhope mines in the great limestone, where the veins in the upper sills bear heavy spar.

Of a clove brown colour and striated texture, attached to galena. From Dufton mines.

Though witherite is the common matrix to lead ore in Arkendale, it occurs only rarely further to the north.

Sulphate of Barytes. Heavy spar.—Foliated, Cawk of the miners; greyish white, opake; from Aldstone moor.

In lenticular crystals (Jameson, vol. i. p. 558), cockscomb spar; from Dukesfield and Aldstone moor.

In small lancet-shaped crystals, opake and white, occasionally aggregated into a cellular mass; from Arkendale.

In transparent tabular bevelled crystals. Those from Dufton are very fine.

Of a milk white colour, not bevelled, set edgewise on quartz, blende, and galena; from Aldstone.

In 4-sided transparent prismatic crystals, acuminated by 2 planes set on the lateral planes; from a vein at Dukesfield.

A curious mineral is found in some of the Aldstone moor veins. It consists chiefly of indurated clay with a mixture of iron; is of a smoke-grey colour, very hard and sonorous, and is intersected by deep impressions of tabular crystals of heavy spar, which have in some unknown manner been decomposed.

Earthy Minerals.

Quartz.—Is found crystallized in 6-sided pyramids in most of the mines.

Asbestus.—Of a leek green colour, has been observed by Mr. Bigge in Melmerby scar, forming veins in a hard reddish brown rock resembling basalt, but not magnetic.

I am not informed of more than six mineral springs in the district of the lead-mine measures, and of these only two have attained any degree of celebrity. These are the springs of Gilsland and Wardrew, which were analyzed in 1799 by the late Dr. Garnet. The sulphuretted water issues from a thick bed comprising 3 distinct strata of shale, which is covered by several measures of sandstone, forming together a perpendicular cliff about 90 feet in height on the north bank of the little river Irthing. Two gallons and a half of water flow from the rock in a minute; it is perfectly limpid, and on being boiled loses the odour of sulphur.

The contents in a wine-gallon are

Muriate of soda - - - - -	4	grains.
Sulphuretted hydrogene gas - -	17	cubic inches.
Azotic gas - - - - - - -	4	
Carbonic acid gas - - - - -	4	

Near the inn called the Shaws at the same place a spring of chalybeate water rises to the day, of which the analysis, according to Dr. Garnet, is as follows.

Contents in a wine-gallon - - - -	Iron	2,5	grains
	Muriate of soda -	3.	
	Carbonic acid gas - -	14	cubic inches.
	Azotic gas - - - -	5	

On a moor a few miles distant from the same place another water strongly impregnated with mineral ingredients is met with. It is of a deep wine colour, and nauseous to the taste like ink; it appears to contain sulphate of iron and sulphate of alumina in large proportions.

Near Turret Burn, which runs into the North Tyne in the north-western part of Northumberland, a sulphuretted and a chalybeate spring were both detected bubbling up from under a peat moss by Mr. Joseph Fryer.

At Dukesfield, towards the south-west, a spring of limpid water holding sulphuretted hydrogene in solution has long been known, and another of the same description issues from the rocks in the bed of the Tees on the north side of the river about 2 miles above Barnaud Castle.

The Beds on the banks of the Tweed.

The beds which are found on the banks of the Tweed, from Dryburg towards the east, differ so much from the usual measures of the Lead-mine district, that I have given the account of them under a separate section. This part of the country has been explored for coal by Mr. Buddle, and it is chiefly from his pamphlet that I have derived the following information.

In the vicinity of Wark, 15 miles south-west of Tweedmouth, the beds consist of marl, micaceous sandstone, and slate-clay; and about a quarter of a mile below Coldstream, in the north bank of the river, the strata are

1.	Soil, light and sandy - - - - - -	feet 15
2.	Ditto, gravelly - - - - - - - - -	15
3.	Coarse grained yellowish white micaceous sandstone - - - - - - - - - - -	18
4.	Micaceous sandstone alternating with slate clay to the level of the Tweed.	

These measures dip to the east at an angle of 5 or 6 degrees.

At Lenel quarry, half a mile below Coldstream on the northern bank of the Tweed, the strata are,

1.	Light soil - - - - - - - - -	feet 15
2.	Soft sandstone and marl - - - - - -	4
3.	Sandstone resembling that in the last section	24
4.	Slate clay.	

At Bingham or Spring-Hill, north of the Tweed, the following is the order of the strata.

1. Light sandy soil.
2. Blue marl inclining to a greenish colour.
3. Blue limestone.
4. Marl of slaty texture.
5. Limestone.
6. Slate clay.

These strata appear to alternate to a great depth; they lie nearly horizontally, and seem to run through the whole extent of the hill. The stratification in the west side of the hill is nearly the same as the above, but in the upper stratum of slate-clay nodules of reddish *gypsum* are intermixed, and in the lower gypsum is disposed in thin irregular strata of amorphous fracture.

The nodules of gypsum contain numerous dark reddish brown crystals of selenite. Similar nodules are also found in the hillock on which Kelso is built, imbedded in blue shale. The marl of Roxburghshire, when dry, is of a dirty blueish white colour, containing small bivalve shells.

In Mellendean burn the strata, particularly on the eastern side, are exposed to the depth of 60 or 70 feet, and consist of

1. Gravelly soil,
2. Marl,
3. Blue and brown slate-clay, alternating with limestone, which contains a large proportion of sand.

Two hundred yards further up the burn, the strata in its bottom consist of very hard bastard limestone, that is, limestone containing a large proportion of sand. The beds lie horizontally. The uppermost stratum in the bank near the entrance of the Dean is composed of amygdaloid. Wacké, and amygdaloid with a basis of wacké are not uncommon in the valley of the Tweed, where they appear to occur between beds of sandstone, as may be seen at Sprouston Ferry, at the Rapids about 3 miles above Kelso, and at a fall of the river Tiviot about a mile above the same town.

The covering of Sprouston quarry is of the same kind of sandy and gravelly soil, as generally covers the vale of the Tweed. The sandstone rock of the quarry appears to be of limited extent, and of an irregular oval form, being about 300 yards long and 200 yards

M 2

broad, and cropping out on every side. It is of a blueish white colour, and close texture, well calculated for building, the best part being about 20 feet thick; but it contains in some parts nodules of a black argillaceous earth scattered through it. It is in some parts soft and slaty, with coaly matter interposed between the laminæ. Near the bottom of the quarry large irregular masses of very hard calcareous sandstone occur. Three veins pass through this quarry in a north and south direction. For the particulars respecting a vein of coal given to Mr. Buddle by the manager of the quarry, I refer to Mr. Buddle's pamphlet.

This sandstone seems to belong to a detached mass of rock, which reposes on the same kind of strata as are found in Mellendean burn; and this opinion is confirmed by the following section of a boring lately made in the eastern side of the quarry.

Boring in the East part of Sprouston Quarry.

	Fath	Ft.	In.
Bad freestone	—	2	—
Dent	—	4	—
Whin	—	1	—
Blue dent	1	3	—
Hard limestone	—	1	—
Strong brown clay	—	4	—
Blue dent	1	3	—
Very hard whin	—	1	6
Brown dent	1	—	—
Hard whin	—	3	—
Freestone	—	2	—
Clay mixed with dark blue dent	—	4	—
Blue dent	—	5	6
Blue freestone	—	4	—
Strong blue dent mixed with iron ore	1	—	—
Carried up	10	2	—

	Fath.	Ft.	In.
Brought up	10	2	—
Strong black dent	1	—	—
Hardstone	—	4	—
Blue freestone	1	2	—
Hard whin	—	3	—
Black dent	—	5	—
Whin and dent alternating the strata about 3 or 4 inches thick	2	—	—
Hard freestone	2	1	—
Stone extraordinarily hard	1	3	—
Left off in very hard brown stone, and from its weight supposed to contain ironstone	—	4	—
Fathoms	21	—	—

The quarry of Stodridge situated in the Roxburgh estate of Fleurs, is very similar to that of Sprouston.

In the vicinity of Ford castle, near the fort of the Flodden hills, a stratum of grey or greyish white arenaceous limestone bassets out.

This rock is very much like a fine-grained sandstone, and contains so large a portion of silex and clay as to be scarcely worth burning for manure. It would be called a bastard limestone. This bed appears to be one of the lowest in the series to which the metalliferous limestones belong; it occurs in the north-western part of the district, and is not uncommon in Roxburghshire, lying very near the *red sandstone.*

Porphyritic Formations of the Cheviot Hills.

A considerable tract of the north-west of Northumberland is occupied by the Cheviot hills, which rising from below the stratified country of the Lead-mine measures, stretch westward into Roxburghshire. The higher parts of these mountains being covered with peat moss, and their lower acclivities with alluvial soil, it is not easy to trace the exact line of separation between the porphyritic rocks, of which they consist, and the Lead-mine measures. It has been seen however that to the north the porphyritic rocks do not descend to the banks of the Tweed; to the south-west, limestone is quarried on the sides of Carter Fell, and a small colliery is worked at Kedderburn in the same neighbourhood. Towards the south, porphyry is seen on the banks of the Coquet at Linn-bridge, a mile and a half south of which, on the hill at Woolcoats, several coal pits are worked. For the other boundaries of this range I must refer to the map.

Cheviot, which gives its name to the whole group, is a huge round topped mountain, rising 2642 * feet above the level of the

* Leslie's Elements of Geometry, 2d edit.

sea. It is situated in 55° 32′ N. latitude, and is distant from the coast at Beadnel 19 miles. It commands a noble prospect over the surrounding country, and presents a conspicuous sea-mark to vessels coming across the German ocean. Hedgehope and Harthope are subordinate mountains, and the Flodden Hills on the north-eastern side are a still lower group. The latter descend gradually to Millfield plain, where the primary formation terminates in that direction.

At the foot of the ridge, in some places the usual attendants of primary mountains, the red sandstone and the greywacké slate, are found rising to the day. The former, which bassets out in Roddam Dean, approaches to a conglomerate; the latter, which appears on both sides of Markington burn, is fine grained in structure; but the slates there quarried do not stand the action of the air.

The blocks of stone on the summit of Cheviot consist of flesh-coloured felspar porphyry enclosing crystals of reddish white felspar, and occasionally minute crystals of hornblende, resembling in this respect the porphyry of Inverary mentioned by Dr. Garnet and St. Fond. Among the rude masses and blocks which lie scattered by the sides of the Wooler-water, porphyry slate, claystone porphyry, porphyritic syenite, granitic syenite, basalt, and coarse red jasper may be recognised, and the Coquet, Aln, Bremish, and Glen abound with agates.

One of the beds which produce the latter mineral is a reddish brown amygdaloid with a basis of wacké, the geodes of which are coated, as usual, with green earth. This rock may be observed in situ on the banks of the Coquet a little above Linn-bridge.

Hornblende rock is by no means uncommon among these hills. Housy crag, which rises above the farm house near Langley ford, in the valley between Hedgehope and Cheviot, is composed of a coarse grained variety of this rock, closely allied to the porphyry, and the perpendicular cliffs of Hellhole on the opposite side of the Cheviot consist also of the same rock.

The only metallic ores known to exist in this district are, bog iron-ore, which is found in the bottoms of morasses, and red ochre with nodules of hematite from a small vein traversing the rocks above Langley-ford. The shepherds use the latter for marking their sheep.

Alluvial matter found on the surface of the preceding formations.

Blocks or detached masses of different rocks are found scattered over the surface of all the preceding formations and imbedded in the soil.

Masses of blue coralloid limestone, the produce of the lead-mine district, are found at the surface at Cullercoats above the magnesian limestone. Similar blocks are found dispersed over the other formations.

Masses of close-grained sandstone occur every where in like manner.

Masses of hard black basalt are found every where in abundance. From this stone the ancient inhabitants of Britain formed the heads of their battle-axes, which the people call Celts. They resemble in shape the tomahawks brought from the South Sea islands. Barbed arrow heads, neatly finished, and made of pale-coloured flint, are frequently picked up on the moors, and are called elf-bolts.

Masses of porphyry, resembling that of Cheviot, and of the Cumberland mountains, and of green basaltic porphyry are common. The base of the latter is of a greenish black colour, and contains large crystals of greenish white felspar. Blocks of it are found in the bed of the Deals water at Dilston near to Hexham.

Blocks of porphyry slate are found on the banks of the Tyne near to Horsley, and masses of the same rock, including small red garnets, in the bed of the Deals water.

Masses of fine-grained granite appear on the surface over the whole country. Those from the banks of the Tees and other parts of the south of Durham consist of small grains of white quartz, black mica, and flesh-coloured felspar.

Considerable quantities of marl have been discovered on the west side of the river Till in situations which seem to have been the bottoms of lakes; and in this alluvial matter horns of some species of bos and cervus are found imbedded. The marl is of a light grey colour, and contains bivalve and univalve shells which retain their pearly lustre. This substance has been noticed at Wark, Sunnylaws, Learmouth, Mindrum, the Hagg, the Hopper, and at several other places in that neighbourhood. It probably rests in some places on the beds that I have described as prevailing on the banks of the Tweed, and at others on porphyry or grey-wacké.

[The following passage should have appeared in the paper after the account of the Walker dyke at page 22.]

The next basaltic dyke worthy of notice is one which, passing from west to east under Tynemouth Priory may be seen to divide the strata at the south-east point of Prior's haven, where it forms a wall 12 feet broad in the cliff and in the rocks below. A vein or fissure 12 inches in breadth and filled with tufaceous matter intersects the dyke from top to bottom near its center, and the basalt strongly resembles the Coley Hill stone.

APPENDIX, No. 1.

Sections of the Strata at Dinsdale, situated on the North Bank of the Tees, 3½ miles east-north-east of Croft Bridge.

No. 1.

	Fath.	Ft.	In.
Clay	4	1	6
Blue stone-clay with whin tumblers	—	3	—
Blue sand	—	2	6
Blue stone-clay	—	5	6
Foul Coal	—	—	6
Brown sand	—	2	3
Foul Coal	—	—	5
Blue sand with water	—	—	4
Stone-clay with large whin tumblers	3	—	—
Red stone	—	2	—
Fathoms	10	—	—

No. 2.

Near the Fishery, 180 yards from the Garden House.

	Fath.	Ft.	In.
This account begins at	56	1	—
Red stone and white post, and post girdles with water	1	5	—
Red metal stone with blue and white scars	3	1	6
Redish post, and scars of blue and white leek chalk of alabaster	3	5	6
*Chalk of alabaster	—	3	—
Strong white post of a limestone nature	—	1	7
Fathoms	65	5	7

No. 3.

	Fath.	Ft.	In.
Soil and clay	2	—	6
Darkish stone-clay with whin tumblers	3	2	9
Red metal stone with grey post girdles	8	—	—
Red stone and white chalk lumps	2	—	—
Fathoms	15	3	3

* Gypsum.

No. 4.

	Fath.	Ft.	In.
Soil and brown sandy clay	—	3	6
Gravel and sand	—	1	4
Stony clay	1	5	—
Brown sand and scars of Coal	—	4	—
Leafy clay and sand	1	—	—
Blue stony clay and beds of sand	2	4	8
Brown sand	1	3	—
Coal and scars of sand	—	1	9
Brown sand with scars of Coal	—	1	6
Darkish heavy clay	2	3	6
Darkish stone clay and sand with scars of Coal	3	4	9
Red sandstone with white scars	—	5	—
Fathoms	16	2	—

No. 5.

Section at Woodhead near Tees side.

	Fath.	Ft.	In.
Soil and brown clay	—	4	—
Darkish stony clay with whin tumblers	3	2	9
Red metal stone with grey girdles	8	—	—
Red stone with white girdles	5	1	3
White and grey stone	—	4	—
*Chalk with white flinty lumps	1	1	—
Blue whin with water like the Harrowgate Spa 19 2 6	—	1	6
Strong white post with whin girdles	1	—	6
Bastard whin	2	—	—
Strong white post with whin girdles	6	—	6
Blue grey metal stone with white scars	1	2	—
*Chalk (called in another boring alabaster)	—	2	6
Soft red stone	1	—	—
Red and white post	3	1	—
White post with red scars	3	—	—
Red, white and grey post, with partings of red metal	4	3	—
Soft blue grey metal	—	4	—
Grey and white post	5	3	—
Strong blue-grey stone	—	5	—
Strong white and grey stone	10	—	—
Whin	—	3	—
Mixture whin	1	3	—
Strong white post, supposed to be of a limestone nature, and whin girdles	13	1	4
Here the undertaking was abandoned.			
Fathoms	74	1	4

* Probably Gypsum, which is found in the same bed at Newark, and other places in Nottinghamshire and Derbyshire.

APPENDIX, No. 2.

Vend of Coals from the Port of Newcastle.

Shipped of Newcastle Chaldrons

Year	Coastways	Oversea	Total
1772	....	....	351,890
1776	....	....	380,000
1791	404,367	45,702	450,069
1792	456,106	42,993	499,099
1793	465,549	34,105	499,654
1794	387,460	40,461	427,921
1795	463,496	40,342	503,838
1796	438,777	42,778	471,555
1797	459,166	38,149	497,315
1798	394,369	44,722	439,091
1799	447,819	43,366	491,185
1800	537,793	47,487	585,280
1801	452,192	50,401	502,593
1802	490,488	44,001	538,489
1803	505,137	44,324	549,461
1804	579,929	52,589	632,518
1805	552,827	49,573	602,400
1806	587,719	46,107	638,826
1807	534,371	27,342	561,713
1808	613,786	15,661	629,447
1809	550,221	14,632	564,853
1810	622,573	19,261	641,834
1811	634,371	18,054	652,325
1812	638,158	24,994	663,151
1813	584,011	14,762	598,773

Vend of Coals from the Port of Sunderland.

Shipped of Newcastle Chaldrons

Year	Coastways	Oversea	Total
1791	246,708	54,150	300,858
1792	256,889	53,313	310,102
1793	255,011	50,064	305,075
1794	243,939	38,885	282,824
1795	282,946	5,884	288,830
1796	249,246	6,293	256,538
1797	279,581	6,434	285,016
1798	274,132	5,111	279,344
1799	298,570	4,039	302,609
....	....	....	....
1806	296,552	2,622	309,174
1807	291,317	4,274	295,591
1808	348,938	2,058	350,996
1809	324,455	973	323,428
1810	371,120	1,889	373,009
1811	331,305	1,729	333,034
1812	....	....	326,865
1813	....	....	330,967

Vend of Coals from Hartley and Blyth Collieries.

Shipped of Newcastle Chaldrons

Year	Coastways	Oversea	Total
1791	39,619	127	39,844
1792	38,400	234	38,634
1793	38,550	48	38,698
1794	37,652	128	37,830
1795	31,494	48	31,542
1796	29,723	542	30,265
1797	39,606	32	39,638
1798	37,833	166	37,999
1799	41,689	127	41,812
....	....	....	....
1809	....	....	48,052
1810	....	....	47,330
1811	....	....	53,958

Coals imported into London.

Of London Chaldrons

	Coastways
From 1776 to 1779 on an average yearly	658,643
1801	862,088
1802	902,224
1803	940,470
1804	947,001
1805	971,270
1806	987,750
1807	933,148
1808	1,088,050
1809	923,440
1810	1,120,237
1811	1,115,171
1812	1,071,361
1813	970,901

50,000 Chaldrons a year by the Canal.

APPENDIX, No. 3.

Estimate for boring to the depth of one hundred fathoms in the counties of Roxburgh or Berwick, under the usual risks attendant on such operations; by Mr. Buddle in 1807.

	Shillings	£	s.
Boring 5 fathoms at	6	1	10
5 ditto	12	3	—
5 ditto	18	4	10
5 ditto	24	6	—
5 ditto	30	7	10
5 ditto	36	9	—
5 ditto	42	10	10
5 ditto	48	12	—
5 ditto	54	13	10
5 ditto	60	15	—
5 ditto	66	16	10
5 ditto	72	18	—
5 ditto	78	19	10
5 ditto	84	21	—
5 ditto	90	22	10
5 ditto	96	24	—
5 ditto	102	25	10
5 ditto	108	27	—
5 ditto	114	28	10
5 ditto	120	30	—
100		315	—
Carriage of the rods, tagle legs and gin blocks, rope and other apparatus, and fitting the same		100	—
Sharpening the geer, finding grease, coals, a horse to draw the rods, and sundry other charges during the boring		200	—
Accidents in boring		345	—
Extra expence in boring through Whin		140	—
		£1100	—

Estimates for boring to such great depths cannot in general be offered as accurate, from the stone to be perforated being in some cases so hard as hardly to be bored through at all, and from the great risk of breaking and losing the rods in the hole during the boring.

II. *On a Whin Dyke traversing Limestone in the County of Northumberland.*

By the Hon. HENRY GREY BENNET, M.P. F.R.S.

VICE-PRESIDENT OF THE GEOLOGICAL SOCIETY.

[Read 6th March, 1812.]

I BEG leave to communicate to the Geological Society some particulars of a whin dyke, which traverses a portion of the limestone strata in the northern district of the county of Northumberland, and projects into the sea on its north-eastern coast.

It is seen most distinctly at Beadnel Bay, and may be traced a few miles inland from this spot, where it forms a species of pier into the sea. The surface strata have been washed away, and the dyke itself is left some few feet higher than the rock on each side of it. Upwards of 300 yards are thus seen at low water running in a right line from the sea towards the north-west, 27 feet in width. It rises in a perpendicular position through all the strata, without making the least alteration in the dip or inclination of those that are adjacent: but some short distance from the place where it is laid open to view, the limestone strata are much broken and dislocated. The qualities of the different strata in contact with the dyke differ materially from those of the same strata at some distance from it, particularly the limestone, which when lying in the immediate vicinity of the whin will not burn into lime of any value. This deterioration diminishes in degree as the distance from the dyke increases, and it is about 20 feet before the limestone acquires its perfect properties of burning into good lime. The same thing is observed in both the strata of limestone. The stratum of what I shall term a species of tuf, composed of felspar and carbonate of lime, is indurated as it approaches near to the whin, and it then resembles in structure and colour the whin itself; it is much fuller of joints near the dyke, than at a distance from it. In no case did there appear to be a complete junction of the whin with the limestone, or with the tuf; but there is invariably a small fissure, that seems to separate them to a great depth, on the edges of which the limestone sometimes assumes a sparry structure, and is in some places considerably mixed with pyrites. In one part of the dyke a piece of the tuf is enveloped in the middle of the whin; this fragment is about 60 feet in length, and 2 feet in breadth at its broadest part, and the two ends terminate in points.

The following is a section of the strata, obtained from the information of the proprietor of the lime works.

	FEET.
Limestone	22
Tuf	39
Black metal, argillaceous slate	27
Limestone	16
Slaty and micaceous sandstone and black metal	27
Coal, a thin seam.	

That part of the strata, which the workmen called argillaceous, I had not an opportunity of examining, at least where it was in contact with the whin, it being under water. Neither could the coal be seen, as it is at too great a depth.

The strata dip about one yard in six to the south; but their general inclination in this district is to the east and north-east.

The specimens that accompany this paper will shew to the common observer the difference between the limestone when in contact with, or at a distance from the dyke, as well as that between the dyke itself and the ordinary whin rocks of the county, such as those which are found on the Cheviot, and which form large masses on that range. Indeed all the whin dykes that I have seen in the northern district of Northumberland, the two which are so near to each other in Holy Island, and those which form the Fairn Islands, no less than that at Beadnel, bear a striking and uniform resemblance to each other; and are unlike those ranges of whin which are composed principally of hornblende, and which prevail to such an extent in the north-western parts of the county.

III. *Description of an Insulated Group of Rocks of Slate and Greenstone in Cumberland and Westmoreland, on the east side of Appleby, between Melmerby and Murton.*

By the Rev. W. BUCKLAND,

PROFESSOR OF MINERALOGY IN THE UNIVERSITY OF OXFORD, AND

MEMBER OF THE GEOLOGICAL SOCIETY.

Read March 28th, 1815.

FEW rocks in this country present in a small compass a structure more complicated and difficult to be understood than those which occupy a small district in Cumberland and Westmoreland, on the east side of Appleby, between the villages of Melmerby and Murton, which I visited in September, 1814, accompanied by my friend G. B. Greenough, Esq.

The town of Appleby is situated about 12 miles from the upper extremity of the great plain through which the rivers Eden and Petteril have their course, and which continues across Solway Frith into Scotland, increasing considerably in breadth on the north of Carlisle.

The stratum composing the greater part of this Plain is a red sandstone affording gypsum in many places. Its breadth near Carlisle from east to west is about 15 miles, but it becomes gradually contracted as it approaches the south till it terminates near Brough and Kirkby Stephen, being encircled by hills more elevated and of higher antiquity.

The west and south-west boundary of this plain are the slaty mountains of Cumberland winding from Ravenstone dale to near Hesket, Newmarket, Ireby and Cockermouth; a belt of entrochal or mountain limestone covered by a concentric belt of coal measures separates the red sandstone from the slaty rocks just mentioned.

The same plain is bounded on the east by an almost precipitous escarpment, extending north and south from near Brough by Dufton Fell and Cross Fell to Croglin, Castle Carrick, and the hills south-east of Brampton. The elevation of great part of this escarpment is considerable, varying from 1000 to 2000 feet; Cross Fell, its highest point, is 2901 feet. It displays the outcrop, and is chiefly composed of the lower members of the great series of strata described by Mr. Winch as occurring between Newcastle and the base of Cross Fell.

The regular structure of the plain of sandstone at the base of this escarpment is interrupted near Appleby by projecting masses of slate and greenstone, attended by some broken strata of lime and coal measures, which it will be the object of this paper to describe.

These rocks (as may be seen by reference to the annexed map)* form an insulated group extending nearly north and south along the base of the escarpment of the great limestone series of Cross Fell, and of which the lowest stratum is stated by Mr. Winch to be incumbent on the old red sandstone (Geol. Trans. vol. iv.) This old red sandstone, which it is of the highest importance to distinguish from that more recent red sandstone which forms the plain of Appleby and Carlisle, appears here in its common form of a coarse puddingstone, and may be traced along the scar in the place thus assigned to it from Melmerby to a spot called Highcup near Murton.

Coextensive with this conglomerate is a subjacent mass of slate which forms a kind of broken under-terrace at the base of the great

* Plate 5.

escarpment from Melmerby scar on the north to Murton Pike on the south. This narrow line of slate is bordered on its west side by an irregular but nearly parallel range of greenstone. The breadth of both these rocks together seldom exceeds a mile, and towards their north extremity is contracted to the compass of a few yards; here they appear also much disturbed and confusedly mixed together; the spot is marked in the map as Melmerby Lane End, about one mile south-east of the village of that name. They assume greater strength in their progress towards the south, and the position of the greenstone becomes more decided on the west of the narrow line of slate.* The variety of proportions in which its ingredients are found combined is quite endless; every hill, almost every block, gives a new character of it.

These rocks of slate and greenstone form two parallel narrow ranges, displaying on the surface an irregular outline, and attracting attention by the striking feature of three lofty conical pikes, distinguished by the names of Knock pike, Dufton pike, and Murton pike.† Of these the former, which is the most northerly, is chiefly composed of greenstone. Dufton pike, the central one, contains both greenstone and slate; and Murton pike, which is the most elevated, and at the south extremity, appears to be composed almost entirely of slate.

We found no greenstone indeed within a mile of Murton pike, it seemed to terminate at Keisley about one mile south-east of Dufton, a spot which I shall again notice as affording a singular mass of limestone.

Though the exact limits of these two ranges might possibly be ascertained by careful and patient investigation, their line of junction

* See Map and Section, plate 5. † See Map, plate 5.

is not distinctly marked; the eye cannot trace it in the outline of the hills, nor is it laid open in many places by sections of the water courses.

Their order of superposition (if there be any) is equally indeterminate; sometimes they abut abruptly against each other, sometimes the slate is uppermost, at others, indeed most frequently, the greenstone.

Imperfect roofing slate has been dug at each extremity of this range, on the south at Langdon moor near Murton pike, and on the north at Middle Rig near the head of Melmerby Beck.

Slate pencils also may be obtained from many parts of the slate rock. Places named to us were **Knock Fell* on the east of Knock pike; *Flasker*; *Ashlake Pike*, half a mile north of Ardale water; *Gale intack*, Melmerby Lane End, also a field half a mile south of Murton in the valley towards Brough, and Rickargill Beck 4 miles north of Melmerby under the continuation of the escarpment northwards. I mention this last place because (if the information was correct which we received on this point from two competent witnesses) the existence of these pencils shews the presence of the slate rock four miles north of the spot where it seemed to end near Melmerby. We did not examine this line ourselves, but could hear no tidings of slate or greenstone at any place north of Melmerby, excepting Rickargill, and we know from observation that they do not exist a little further to the north at Croglin, or between Croglin and Castle Carrock.

At Swinedale Beck, between the south base of Knock pike and Dufton Fell, the slate contains one or two thin beds of blackish transition limestone, which are laid open in the water course at Cater-

* The places printed in Italics are not mentioned in the map.

pallet, a hillock one quarter of a mile east of Gale Hall, and between one and two miles south-east of Melmerby. The slate is cut by a broad dyke, of which the direction is nearly east and west, and its breadth about 25 feet. The substance of this dyke is composed of reddish compact felspar mixed with talc, and the latter becomes more bright and distinctly visible where the rock has undergone decomposition.

Under the south base of Knock pike close to the Swinedale Beck is a small portion of rock composed chiefly of dark mica, occasionally interspersed with small crystals of felspar, disseminated uniformly through the mica. On this lies a mass of highly compact whitish felspar and coarse greenstone.

On the summit of this Pike, which is nearly conical, and steep on all sides, is an outlying hummock of coarse grained sandstone, agreeing in substance with one of the lowest strata in the neighbouring escarpment, and more recent than the old conglomerate. Whether this latter rock, or any traces of slate, are interposed between the summit of the pike and greenstone of its base, we had no opportunity to ascertain. I have specimens of the grit taken from the summit.

At the west root of Dufton pike, in a field called Banky Close, and surrounded on all sides by greenstone, is a species of granite that is extracted to build field walls. It consists of bright salmon coloured felspar, in which are disseminated at very irregular intervals plates of bright silver coloured mica, varying in diameter from an inch to a line, and interspersed with a few small specks of quartz. This granite was so covered as to be visible only at a small ridge where the quarry was wrought. It might either be the projecting crest of a subjacent fundamental mass, or it may be a dyke cutting through the greenstone. In the quarry it is 15 yards broad, and seems to run east and west. It is found also two fields below in a westerly direction.*

About a mile south of Dufton pike, in the direction of Keisley, in a streamlet that joins the Keisley Beck, and runs down to the village of Dufton, in a field or farm called Hindrigs are other traces of granite exactly like that of the hills on the south-west of Shap, containing large flesh coloured crystals of felspar; it appears to be in its natural position, and (like the neighbouring granite of Banky Close under Dufton pike) either a dyke or the projecting back of a substratum of this substance.

The part I saw uncovered was about 10 feet square, and had no appearance of being a rolled block. The watercourse, 10 yards off, passed over a small portion of the same granite in a little cascade; but here also it was so covered with grass that absolute demonstration could not be obtained. I am inclined however to think, that this granite is the point of a subjacent rock, and a new locality of that variety which is so different from all other English granites, and so strongly characterised at Shap Fell.

In the field adjoining the Hindrigs granite immediately above and on both sides of the water course were large blocks composed entirely of dark mica, which lay half buried in the soil, and appeared

* This granite much resembles that of a dyke which at a place called Demming or Red Crag at the highest point of the road about half way between Shap and Kendal, and near the mass of the granite of Shap and Birbeck Fells, is clean extracted from a long narrow quarry by the road side, so as to prove decidedly that it is a dyke about 30 feet in breadth, and lying between two side walls of course slate.

We were told that this dyke runs off nearly north and south, a mile or two south-south-east, and nearly a mile north-north-west of the spot where we saw it by the road side.

Its south-south-east portion keeps nearly along the crest of the hills of grauwacke and grauwacke slate that run south-east from Birbeck Fells to Tebay on the Lune near Orton, in their course towards Sedburgh and Ingleton.

to have been derived from a subjacent rock of mica connected with the granite.

Having described as far as I know the extent of the slate and greenstone, with the subordinate rocks and dykes that accompany them, I will now consider the strata by which they are encircled, and which on the east side are widely different from those on the west.

On the east side beneath the outcrop of the great limestone series of Cross Fell, (of which Mr. Winch gives the thickness at 450 fathoms,) the old red sandstone, in the form of a conglomerate, is regularly interposed between the lowest stratum of the above series and the slate, with no appearanee of any great derangement. But on the west side of the line of greenstone there are evidences of disturbance, on a scale of considerable magnitude.

There is not a trace of those beds that are so regular on the east side, and appear there in such enormous thickness, and except in a few spots which will immediately be described, the red sandstone of the plain of Carlisle abuts abruptly against the greenstone and slate,* as it does also against the truncated extremities of the lower strata of the great limestone series† along the base of their escarpment on the north of Melmerby towards Brampton, and on the south of Murton towards Brough, beyond the north and south terminations of the slate and greenstone that have been described.

The village of Melmerby stands upon this red sandstone; a small stream that runs down to it (called Melmerby Beck), from the base of the great escarpment of the scar, has its course for three quarters of a mile above the village in the red sandstone, which here also

* See Section No. 1, Plate 5, letters A. B. C. † Ibid. letters C. D. E.

contains gypsum as in numerous other places on the banks of the Eden and the Petteril, and in the great valley of Carlisle.

At the distance above mentioned the sandstone abruptly ceases, the water course (a ravine about 30 feet in depth) which till now had traversed the red sandstone in a direction east and west, suddenly turns at a right angle to the south, and continues its bearing exactly along the line of junction, having its east and west banks composed of materials very different.

At the point where the water course turns suddenly to the south the sandstone abuts abruptly against a dark compact greenstone, red externally, and very ferruginous.

This last rock with its varieties forms the east, and the sandstone the west cheek of the ravine for a quarter of a mile up the stream southwards, the excavation being so exactly along the line of junction that no contact or order of superposition can be distinguished.

Here, at about a mile above the village along the Beck (the name of the spot is Melmerby Lane End,) the greenstone on the east bank becomes mixed confusedly with considerable masses of slate, and the channel ceases to have the red sandstone on its west flank, which becomes occupied by shattered fragments of limestone and coal measures.

These last beds extend from hence in a line nearly parallel to the slate and greenstone ranges, being interposed between them and the red sandstone of the plain for nearly three miles south from Melmerby Lane End towards Kirkland,* but are so dislocated and confused that the coal seams (which are very thin, often less than a foot,) are in many places quite vertical, and extracted by sinking perpendicularly downwards as in a well; but they occur no where

* See Section, Plate 5, No. 2, letter A.

in great quantity, as from the shattered condition of the strata, the coal is soon lost without a clue to lead to its recovery. It has no regular roof or floor, but is rather inclosed by broken side-walls, and sometimes is found lodged in confused nests and heaps: it is now seldom wrought.*

The edges of these highly inclined and broken strata may be traced by a very low scar,† or kind of escarpment slightly rising towards the east and running parallel to, and along the base of the greenstone hills from Melmerby towards Kirkland.

The limestone accompanying these coal measures is but in thin beds, and equally dislocated and shattered, so that no order of superposition can distinctly be made out. I saw it at one place nearly vertical, its dip being to the west; it was on the north side of the Ardale water, as marked in the map; it lay between two beds of sandstone that had the appearance of coal grits, and within a few yards of the slate and greenstone which are here confusedly mixed together. The lowest grit bed touched the slate.

Vertical coal measures are seen touching the greenstone at a section in Ousby Beck at the corner of the highest inclosures in ascending the stream from the village of Ousby.

The following are localities where coal has been dug within the limits above mentioned.

Melmerby Lane Head, Hag Gate, Gale Hall, and Ousby Town Head, &c.

Limestone is dug near Hag Gate, Gale Hall, and Ardale water, &c.

* Similar cases of beds of coal becoming vertical by dislocation will be recognized in the perpendicular bed of coal described by Mr. Bakewell at Bradford near Manchester, (Geol. Trans. vol. ii. p. 283,) and in the Mendip collieries near Mells, where a bed of coal is said to be bent backwards to the shape of the letter Z. I have this fact on good authority but have not seen it.

† See Section, Plate 5, No. 2, letter A.

These limestone and coal measures occupy no great breadth, and run north and south in a line nearly parallel to the ranges of greenstone and slate, being generally in contact with the former of these substances. Their extent longitudinally is from Melmerby Lane End to the Ardale water. From the latter stream southwards to the village of Murton, the red sandstone abuts for the most part against the greenstone. One exception occurs at Keisley about one mile south-east of Dufton, in the direction of Murton pike, where there is an insulated mass of stratified entrochal limestone several fathoms in thickness, and occupying superficially a little more than an acre of ground. It is inclined to the west at an angle of about 80°, and covers like a shield the abrupt end of a hill of greenstone, known by the name of Keisley pike, but insignificant in comparison with the three great pikes before described.

This limestone seems to bear the same relation to the greenstone as did the shattered coal measures and limestone before mentioned near Melmerby. It dips so rapidly that it disappears immediately at the base of the hill towards Appleby, and is at once lost under the red sandstone.*

We did not examine the base of the continuation of the great escarpment from Murton pike southwards towards Brough, but the concurrent testimony of many experienced miners leaves no doubt that the slate terminates a little south of Murton pike, and the red sandstone of the plain closes up against the escarpment from thence to the town of Brough.

It was stated at the beginning of this paper, that it is of the highest importance to distinguish this more recent sandstone of the plain of Carlisle from the old red sandstone or conglomerate that divides the great limestone series of Cross Fell from the slate.

* See Section, Plate 5, No. 3.

It is important because it has been stated by Mr. Forster (in his section from Newcastle to Cross Fell) that this red sandstone of the plain is the lowest stratum of the above series, and because its position at the base of the escarpment, both on the north of Melmerby towards Brampton, and on the south of Murton towards Brough, would without careful investigation lead to such a conclusion.

But the section that has been described from Melmerby to Dufton proves that the old conglomerate is the only rock that exists there between the limestone series and the slate, and our examination of the base of the escarpment north of Melmerby from Croglin to Castle Carrick pointed out the source of this error, which is so common that we could not find an individual who did not believe in it, though not one had ever seen a section that proved the fact.

The source of this natural and almost necessary error, is the low position of the red sandstone at the base of the immense escarpment,* where it abuts so bluff against the abrupt and truncated extremities of the lower strata of the great limestone series, is in such absolute contact with them, and so accommodated to their irregularities, which it fills up, and seems as it were to notch into them, that it would be almost impossible to avoid the error which is so popular, without looking to the general history of this stratum, and to the sections which display junctions at the edges of the plain of Carlisle, in which this new red sandstone forms the upper and most extensive deposition.

One of these sections has been given near Melmerby: another may be seen in the cliffs between Whitehaven and St. Bees Head.† These are lofty, and present a distinct perpendicular section, in which it is seen at the point of the junction nearly two miles south-

* See Section, Plate 5, No. 1, C. D. E. † Plate 5, No. 4.

west of Whitehaven that the upper beds of the coal measures lie under a stratum of magnesian limestone. On the limestone is immediately superimposed the immense deposit of red sandstone that forms the entire thickness of the cliff from this point to St. Bees Head.

The dip of the coal measures and magnesian limestone is nearly south-west towards St. Bees, which brings them under the red sandstone at the point of junction above described, where there is also a large gypsum quarry in the lowest part of the red sandstone.

It would not be within the object of the present paper, (which is to describe the district between Melmerby and Murton pike,) to enter into the detail of these sections or the general history of this stratum. These however lead to a conclusion almost inevitable, that the Carlisle red sandstone is the same with that of the vales of Cheshire, of Salop, Lancashire and York; the matrix of our great quarries of gypsum and rock salt; and a deposition more recent than that magnesian lime which is incumbent on the upper strata of the principal English Coal-fields.

IV. *Observations on the Mountain Cruachan in Argyleshire, with some Remarks on the surrounding Country.*

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[Read 2d December, 1814.]

THE geological history of this mountain being, as far as I know, unrecorded, I shall relate the few observations which I made on it, as they are sufficiently numerous to form at least a basis for future and more accurate investigation.

It is evident to any eye in approaching through the vales of Glenorchy or Glenara to the head of Loch Awe, that the nature of the country has changed. The rugged forms and rocky faces characterizing those hills of mica slate which bound Loch Lomond, Loch Long, Loch Fyne, or Strath Fillan, have disappeared; the mountains assume a more uniform flowing line, their sides are more completely covered with herbage, and exhibit fewer denuded rocks; their summits are less serrated, and are almost the only parts which exhibit the naked rock, while at the same time they are strewed with heaps of fragments, a character from which the hills of mica slate are almost always free. On approaching nearer to their bases, the red colour of the fragments which have fallen down from their sides, and the rounded pebbles of granite and porphyry which are met with in the beds of the torrents, give the mineralogist pretty plain intimation of the causes of this change of feature.

Except in the rolled fragments however, no appearance of granite is visible as we skirt the sides of Cruachan from Dalmally to Inverawe. Every where we observe schistose rocks, which have been laid bare, sometimes by the operation of natural causes, but more generally by the process of making the road. This schistus possesses in different places different features. Sometimes it is a compact mica slate, where the mica and the quartz predominate by turns, but its more general tendency is toward clay slate, of which it often exhibits very well characterized examples of various colours, varying from dark lead-grey to pale greyish-green. These in many places, and particularly where in contact with the veins about to be described, assume an extreme degree of hardness, putting on the aspect of that which is called Lydian stone and flinty slate. It is impossible to assign the breadth of the zone occupied by these schistose rocks, as, independently of the turf upon the sides of the hills, the lower skirt is clothed to a very considerable elevation with an impenetrable covering of mixed coppice and underwood. It is probable however, that the incumbent schistus does not any where extend very high, as it may be found terminating at a low elevation on that part of the hill which is naked and accessible, and which impends over the course of the river Awe.

Numerous veins, of very variable but generally large dimensions, appear traversing this schistus throughout the course I have described. They are of various composition, but consist in general of different coloured porphyries. Their directions are as various as their colours, but their position is generally perpendicular, or nearly so. Together with these veins of porphyry, a few veins of trap, exhibiting the several aspects of greenstone, greenstone-porphyry, and even of genuine basalt, may be observed; and, from some fragments of amygdaloid which I picked up by the road side, it is probable that more numerous varieties which did not come under my observation may be found to exist.

Arriving at the high bridge which crosses the river Awe, the mineralogist will be surprised to meet with a secondary stratum in a situation certainly as unexpected as can well be conceived. A small portion of it only is denuded by the action of the river, and exhibits two distinct beds, the lowermost consisting of the well known red sandstone spotted with white, which occurs near Dumbarton, in Arran, and elsewhere, and the uppermost of a coarse grained white calcareous grit. This stratum is elevated at a small angle, and shelves away towards the side of Cruachan as if it was about to dip under the mountain: its junction with the primary schistus is not visible. I could not trace it upwards on the opposite side of the river in the direction of the stratum, although it is probable that from the red colour of the soil some portion of it exists where the road is made. It may be traced a little way down the course of the river, but the ground being much encumbered and difficult to examine, it soon disappears. I attempted in vain to find it on the flat tract at Bunawe, nor did I succeed any where from Tyanuilt to the sea in recovering any portion of this stratum; the low land being always covered with alluvial matter, and the denuded rocks appearing every where to consist of schist and granite traversed by veins of porphyry. It affords a remarkable example of a deposit of secondary rock, not many hundred yards square, entangled in the middle of a primary district, and separated, apparently by many miles, from any other similar rock. I shall hereafter however attempt to give a general sketch of the connection of Cruachan with the surrounding country, when the recurrence of the same circumstance will be described, which, if it diminishes the surprise at first excited by its solitary and unconnected appearance here, increases its general interest, while it naturally leads the geologist to inquire into the state of things under which so remarkable a dismemberment of these strata has taken place.

In quitting this part of the skirt of Cruachan it is necessary either to rise to a considerable elevation, crossing above the woods of Inverawe, or to avoid it altogether and make a circuit by Bunawe. We then reach the shore of Loch Etive, and may continue our observations on the base of the mountain. As we ascend to cross the foot of the hill granite appears exclusively, generally in the shape of loose blocks accompanied by similar pieces of porphyry, but sometimes *in situ*. On reaching the shore beyond Bunawe the appearances become more interesting. The junction of the granite with the schistus is here clearly seen. Large veins may be observed proceeding from the great mass of the mountain, and ramifying into innumerable small divisions penetrating and traversing the schistus in every direction. No where can this appearance which has excited so much attention, be more distinctly perceived, and it is moreover attended here by some interesting circumstances, which as far as I have observed do not occur in the junctions at Loch Ranza, in Glen Tilt, or at Locheil. Two distinct varieties of granite appear in this place; the one a granite according to the strictest acceptation of the term, consisting of reddish felspar, quartz, and mica; the other a syenitic granite, or a compound of white felspar, mica, and hornblende. These are coexistent in every respect and seem to pass into each other, while both of them ramify in a similar manner through the schist, a sufficient proof, if any were wanting, of the geological identity of these two rocks which have so improperly been distinguished by the accidental presence or absence of the single ingredient hornblende. Although the granite veins sometimes run through the schist in a distinct form, just as they do in the junction of Loch Ranza, yet in many places they are intermingled with it in a very remarkable manner. Crystals of the hornblende may be observed shooting far into the body of the schist, so as to render it often difficult to assign the limits of each rock. In a less degree the quartz and felspar exhibit the same appearance. Together with this, the schist is singularly contorted, being bent, broken, and intermingled in a most confused manner with the rock that traverses it, while distinct detached fragments are often involved in the mass of granite. In many instances these fragments either exhibit at their edges a change into a substance resembling basalt, or are actually converted into a black matter which has at first sight the aspect of a fine grained hornblende rock or a basalt of the blackest hue, and which only an accurate inspection discovers to be modified fragments of schistus. The schistus in general which lies in the immediate vicinity of the granite vein is highly indurated and gives fire readily with steel: in other respects it retains its general character, a laminated structure and alternating stripes of colour.

Independently of the peculiarities now described which characterize the junction of the granite with the schist at this place, the passage of the porphyry veins may be observed in great perfection, and as they form an important feature of the character of Cruachan and occur in all parts of it, I shall here describe them at some length.

These veins are of different sizes as well as aspects, varying from the breadth of three or four feet to that of fifty, or more: they are all very erect, and in a general view appear perpendicular. They traverse both the schist and the granite, and are to be observed in this part of the hill, cutting the vein equally with the schist in all directions, as may be seen in the accompanying sketches. They are uniformly well defined, neither intermixing in any respect with the granite nor with the schist, nor apparently producing any disturbance in the course or direction of these rocks. They are, as I before remarked, of various colours and compositions, and two veins may often be seen running parallel and in absolute contact with each other, without interference or disturbance, the one of a dark red, and the other of a light grey or some other colour, as represented in one of the sketches.* They are so numerous that perhaps a fortieth or fiftieth part of that region of Cruachan which I examined consists of porphyry veins. The principal varieties both of colour and composition which I remarked, are the following, and their basis consists of that rock which is now by general consent, called compact felspar, but which has at times been designated by the term hornstone.

Brick red porphyry, the base of compact felspar with imbedded crystals of the same colour: a very few specks of white felspar and of greenish hornblende are dispersed through it.

A mixed granular basis of reddish-grey compact felspar, with crystals of a larger size and paler colour, containing also grains of pyrites and long slender crystals of hornblende in abundance.

Base of an uniform dark grey compact felspar with crystals of white felspar.

The same, but with the addition of black mica, hornblende and pyrites.

A grey ground with very large crystals of pale grey felspar; these crystals themselves containing crystals of hornblende. The base contains crystallized mica.

A purple ground with crystals of brownish yellow felspar.

A brown uniform ground with rare and minute crystals of felspar.

* Plate 6, fig. 2.

A similar greyish basis with dispersed crystals of hornblende only.

A basis of hornblende with distinct crystals of felspar; of a porphyritic character.

An uniform mixture of hornblende and felspar, approaching to common greenstone, and at length not to be distinguished from it.

These latter varieties appear to form a regular series of a transition from porphyry to trap, of which I shall immediately speak; first remarking that besides these leading varieties which I have now described, there are many others which it would be superfluous to notice, as the variations of colour, aspect, and composition, are endless. Together with the veins of decided porphyry, various parts of the mountain are intersected by veins of grey rock, having as I have just remarked, the general character of the trap rocks, and sometimes porphyritic. Veins of perfectly characterized basalt also occur in some places, and these, or fragments of them may in particular be observed in great quantity strewing the top of the first summit, (that one which is marked by two cairns,) and laying fair claim to an equal antiquity with the veins of porphyry. It is easy to procure detached specimens of the junction between the granite and basalt in great variety and abundance. The line of junction is in all cases clear and well defined, but does not admit of ready separation even after long exposure to weather. My observations on the base of the hill were terminated here, some way before the place where the foot of Ben Starive interferes with that of Cruachan.

I have already said that in ascending Cruachan the schist soon disappears: at the same time the accumulation of soil and the covering of plants are so great, that it is scarcely possible to meet with the natural rock for at least half the ascent. Many masses which appear to be in their places, turn out on examination to be only large rolled stones, and these invariably consist of granite and porphyry. It is not till we have attained about two thirds of the height of the mountain, that the natural rock makes its appearance in an unquestionable manner. From this part to both the summits there are abundant opportunities of examination, as immense faces of it are left uncovered even on the southern side where the acclivity is easiest. To the north it presents a range of nearly perpendicular precipices extending many hundred feet down the mountain. The mass of the mountain is easily seen from this point to consist of granite. This appears to be of uniform composition on both the summits, and to be formed of a very equal mixture of reddish felspar and white quartz with very little mica, nearly resembling the granite of Cairn Gorm. The porphyry veins which traverse it are here also as visible as they are below, but if there is any difference they appear of greater magnitude, and the red variety predominates. There are immense fissures on the northern side, which seem to have resulted from the wasting of these veins. It is on the lower of the two summits, as I before said, that the junction of the basaltic veins with the granite is visible.

I have remarked in a former paper* that the magnet is much affected by the granite on the summit of Goatfield. This is still more strikingly the case in Cruachan, its affections being indeed stronger here than they are even on many of the basaltic rocks of Canna. Both the porphyry veins and the granite affect it, but the former in the greatest degree. Having had occasion to observe these two instances of a fact but little noticed, I think it right to add, that in both cases I found this property confined to the masses which occupy the summits of Goatfield and Cruachan, and that I did not perceive it either in the rocks or detached masses at the foot of these

* Vol. II, page 430.

mountains. I do not mean to say that this is likely to prove general, but I merely point it out as an accompanying circumstance, to be confirmed, or perhaps contradicted, by future and more numerous observations.

Having thus determined the nature of Cruachan itself, it will be useful to trace its connection with the surrounding mountains, and in defect of more satisfactory observations, to conjecture by their external aspect and by analogy, the nature of their composition. It forms the highest point of a complicated group, which to the south-east is bounded by Loch Awe, to the south-west by Mid Lorn, and to the north-west by Loch Etive, but which extends towards the north-east in a continuous line, uniting itself with the ridges of Schihallien and Ben Lawers. The part of this group which the great elevation of Cruachan brings almost immediately under the eye, is coextensive on the three quarters first enumerated with the boundaries there mentioned. To the north it does not extend further than Buachaille Etive, while it is in some measure separated from the eastern mountains by the lower land of the Black Mount over which the military road passes. Within this space the whole of the mountains, including both boundaries of Loch Etive, appear to consist of granite, and to be of the same composition with Cruachan; there being no perceptible difference either to the naked eye, or when seen through the telescope, between their general outline, fracture, mode of disintegration, colour, or form. How far this conjecture may be confirmed by actual examination, or to what extent they may resemble it in the minor circumstances, the intersections of porphyritic veins, can only be known by inspection of the rocks themselves, a task not likely to be soon accomplished, since it is scarcely possible to discover a mode of traversing this region, which, in addition to its extent and difficulty, is nearly void of inhabitants. Whether it be well founded or not, the rocks which form this mountain can be traced, under certain modifications, beyond the boundary here mentioned, and as they add useful illustrations to the subject, while they also serve the purpose of determining a difficult tract in the geological topography of Scotland, I shall make no apology for describing them.

Granite is found at Balahulish, extending round the shore of Loch Leven on its southern side towards Appin, assuming during this course, various aspects; but it is generally grey and small grained, and of the most ordinary appearance and composition, consisting of quartz, mica, and felspar. Superadded to these, it frequently contains hornblende, or else it consists of quartz, felspar, and hornblende, a circumstance which as I have before remarked forms no distinction geologically considered.

It appears here to be the basis on which micaceous schistus and quartz rock repose, both of which conjoined form the group of mountains called Ben na vear, which rises above the house of Balahulish. It is not necessary for the purpose I have now in view to inquire into the further extent of these rocks. Branches of the same granite in no way altered in character pass through the schist, and probably the quartz rock, although I did not detect their actual junction with this last. I can only conclude that as the schist and quartz rock alternate, that vein which traverses the one must also traverses the other. The schist which is traversed by the granite often much indurated, and approaches by various undefinable gradations to a sort of hornblende slate. Masses of a similar substance may be found imbedded in many parts of the granite. Occasionally these masses appear on close examination to be only irregular spots of hornblende, such as occur not unfrequently in those granites of which this mineral forms an ingredient. More often however their shape is perfectly defined, and they appear to be laminæ of which the edges are truncated or broken at angles with the plane. In some places this appearance of fracture is so precise, that when two fragments occur together in the granite the imagination as easily replaces the separated parts as it does in the brecciated marbles or agates: nay, further, the fragment will sometimes be found to consist of an argillaceous or slightly micaceous schistus, maintaining this character with scarcely a perceptible alteration, and sometimes only approaching to hornblende schist at its exterior parts. It is also worthy of remark that these fragments sometimes exhibit at their edges stripes of different colours and degrees of hardness, arising from the varying texture of the laminæ which compose them. The masses vary in size from an inch to a foot and upwards, but whatever their size may be they have almost invariably parallel sides. The examples of this appearance are very numerous both at Balahulish and in the rolled fragments of granite which are spread over the Black mount to the eastward of Glenco, and we shall presently see that the same granite with similar connections occupies a very large tract of country. The frequency of the occurrence also enables an observer to examine the specimens without difficulty, and to compare their various aspects and circumstances. From these I have no scruple in saying, that the granite now described contains fragments of schist imbedded in its mass, generally so altered in their original appearance by their connection with the granite, as to approach to, or partially to assume the character of hornblende slate, but often also possessing the characters of micaceous schist unchanged, and under all the varieties of aspect by which it is characterized in the surrounding country.

I shall continue to describe this rock as far as I have traced it, since if not strictly a part of the professed object of this paper, it will, in addition to the contribution which it forms to the mineral topography of the country, either assist future geologists in connecting their own observations, or present them, in a tract among the most desert and difficult of access in Scotland, with a point of departure from whence they may prolong their observations over the adjoining country.

In leaving Balahulish to proceed westward we almost immediately lose sight of the granite, which occupies here only the lowest position, and is scarcely to be found above the level of the sea. The schistose rocks which cover it do not however accompany us long, being succeeded at the mouth of Glenco by a mass of rocks appertaining to the porphyry family, which I shall recur to when I have traced the granite. This becomes again visible as we approach the King's house, and, quitting the rugged hills which separate Glenco from Loch Etive and from Loch Leven, enter upon the wide, trackless, and solitary moor of Rannoch. This extensive and barren tract is elevated at a very considerable height above the sea, and, although unascertained, it probably does not fall much short of a thousand feet. Its surface in a general sense is flat, when compared with the ordinary aspect of a Highland moor, yet it is diversified by low rocky hills and undulations, covered with a deep peat which conceals the subjacent rock. There are notwithstanding abundant indications of its nature in the beds of the streams which flow over it, by which the naked rock is completely exposed to view, while every protuberance which time or accident has laid bare, and the detached blocks that are strewed over its surface, confirm its identity with the granite of Glenco. It can be thus traced to the head of Loch Rannoch, a distance estimated at 24 miles, with no variation of character; but of its breadth between north and south I am unable to speak, the country being absolutely trackless and uninhabited.

It appears to me however that it extends, perhaps with some interruption, from the schistose rocks to Ben Vualach by which it is connected with the granite district of Loch Ericht; and there is equal reason to suspect that to the westward of this it will be found similarly connected with the granite of Ben Nevis.

Where it terminates, at the head of Loch Rannoch, it forms hills of moderate elevation, and these are immediately followed and covered by a succession of schistose rocks, consisting of quartz rock, micaceous schist, and an obscure variety of gneiss which I have already had occasion to describe in another place.* The junction of the two may be observed in different places, in all of which it is invariably accompanied by the appearances already noticed at Balahulish, namely, fragments of the different schists imbedded in the granite.

The schist which is here imbedded in the granite is often composed of black scaly mica with a high lustre. Towards the junction of the fragment with the surrounding rock it generally contains crystals of hornblende. The fragments vary much in size, and I must add that they differ completely in aspect from those accumulated plates of mica which are found in the granite of Aberdeen, as well as in many other granites. In other cases the imbedded fragments consist of the same quartz rock and gneiss which form the general body of these schistose rocks. If any mineralogists are unwilling to consider them as imbedded fragments, it can only be said that if they were really detached fragments they could possess no other aspect than that which they now have. The head of Loch Spey,

* Vide Paper on Quartz Rock, Vol. 4.

a tract far removed, yet possibly not unconnected with this, is also composed of granite; and among this are found perfect granitic conglomerates, in which fragments of mica schist, equalling in quantity the substance which connects them, are seen imbedded in a paste of granite.

Occasionally the fragments are confounded with the mass at their edges, but at times they are so defined, and even so separable, that I procured a specimen with the distinct vacant impression of a rectangular fragment which had probably been detached. Cavities left in this way by the wearing out of the schist occur frequently in the rocks throughout the moor of Rannoch. The union between granite and the schists which it touches when passing through them in the form of veins, is known to be subject to similar variations. I may here add that the same appearances, though more rarely, may be found in Mar, and in the granite which occurs near Comrie.

It is well known that the passage of granite veins through schist is commonly well defined, and that the two are generally easily separable by the action of the weather. But the district of Rannoch offers a multiplicity of veins which are so confounded with each other and with the rocks which they traverse, that their appearances cannot be described. They frequently vanish so imperceptibly both in the quartz rock and the mica slate, that a perfect passage from the one to the other is visible, while the accessions of additional veins, traversing and often shifting the already intricate structure, increase the unexampled confusion which reigns among them. The granite is often found imbedded in detached lumps in the schist, and I must remark of these lumps and veins, however minute they may be, that contrary to the granite veins and detached masses of Glen Tilt or Corpach, their character is perfect even to the minutest division.

I shall add but one remark more on this subject. Although the schistose rocks are seen only at the two ends of this prolonged tract of granite, the imbedded fragments can be traced throughout the whole. Hence it might be supposed that they were independent of the vicinity of the great schistose masses, whereas in the view which I have taken of them I consider them as connected with and dependent on them. It is plain that the absence of schist at present from the surface of the granite which forms the moor of Rannoch, proves no negative in this case, as we have abundant examples every where of the removal of great tracts of rock from parts of the earth's surface, and of the consequent denudation of the inferior substances; a change which may easily be conceived to have occurred here, thus leaving exposed that very surface of the granite which once was in contact with the superincumbent beds of schist.

Having thus traced the granite district of which Cruachan forms the most conspicuous portion as far as means of observation were afforded, I shall point out, under similar limitations, the porphyry which fell under my notice, since it will tend to illustrate the great predominance of the porphyritic veins in that mountain, as already described. I must however say that I consider the few following remarks, like those on the granite of Balahulish and Rannoch, in no other light, since they cannot be viewed even as a sketch of one of the most complicated and interesting districts in the whole range of Scottish geology. It will presently be seen that the great extent, the divided disposition, and the almost impracticable nature of the country throughout which these rocks are scattered, would require a very different investigation from that which a few distant and rapid visits permitted me to bestow on it.

The various schistose rocks, consisting of quartz rock, mica slate, clay slate, and limestone, cease at the place where Glenco first begins to contract its dimensions as we proceed from Balahulish eastward. From this point till we arrive at the King's house, or near it, the mountains on each side consist of porphyry, or of the different simple substances which form its bases, these simple rocks being indeed much more prevalent than those which are, strictly speaking, porphyritic. As these hills subside at their eastern end in the moor of Rannoch, the mass of porphyry disappears, and is succeeded by the granite already described; but veins of all the different varieties are found connected with it, every where intersecting the latter rock, and although gradually diminishing in frequency as we recede from the great mass, still admitting of being traced even to its very extremity. I have no means of assigning the boundary of this porphyry towards the north, but as the same rock is found to form the summit of Ben Nevis, it is probable there is some connection, more or less interrupted, between them. It is easily seen that towards the south it forms both the mountains which go by the name of Buachaille Etive, the conoidal and acute forms of which are visible from a great distance throughout the surrounding country. From these it extends along the eastern side of Corrich y bae, but as the southern sides of their declivities have not been examined, it is impossible at present to state the limits here between the porphyry and the granite which I have conjectured in a former part of this paper to extend from those mountains to Cruachan.

The vertical structure of this rock explains the cause of the abrupt and perpendicular faces which give the peculiar character to the dark, solemn, romantic Glenco. Together with that it presents the same laminar tendency which is so remarkable in the rock of Devar, described in a former paper.* In many places there is an appearance

* Geol. Trans. Vol. 2.

of veins proceeding from the mass, rendered conspicuous by their projection and superior durability, but in examining the surrounding rocks where in contact with them, no difference of structure or composition is perceptible. I did not any where perceive a tendency to the columnar form.

Although the naked surfaces of these rocks might lead us to suppose they were inimical to vegetation, this effect must rather be attributed to the steepness of their declivities, which prevents the accumulation of soil. From whatever cause it may arise, they seem particularly subject to be destroyed by the action of the mountain torrents, whence the enormous piles of fragments which annually overwhelm the road and are fast raising the level of the valley.

The simple rock, which, as I have already said, prevails over the porphyritic varieties, is at one extreme a claystone, and at the other a compact felspar, varying through several intermediate stages of hardness. In the intermediate stages of transition to porphyry, a single crystal only of felspar will sometimes be found in a large fragment, the ultimate accumulation of which produces porphyries of an infinite variety of aspects. Every variety of this substance indeed, whether in colour or composition, which occurs in veins throughout Scotland, is here found mixed together in the mass, sometimes placed side by side with a sudden and decided transition, at others graduating into each other by imperceptible degrees. The colours graduate into each other in these cases just as do the different structures, and among these gradations the most striking are those where black passes into red. It would be an useless task to describe the varieties of colour which occur, but the different shades of grey, purple, and red, are the predominant ones. In some cases dark blueish specimens are found veined with red, producing very beautiful and remarkable varieties: in others, the red colour is so bright, and the texture so compact, that they can scarcely be distinguished from jasper, a rock which, I may remark, although hitherto but little examined in its geological relations, possesses a very near affinity to the family of porphyry, as well in the extensive independence of its position among the regular rocks, as in its appearance and composition.

The occasional minerals which are found in these rocks are hornblende, quartz, and epidote, all of them entering into the composition of some of the varieties, and the latter in particular forming a very conspicuous feature among them, being disposed either in the form of veins, or in amygdaloidal cavities, or else in occasional grains. Hard breccias, of which the structure can scarcely be detected except on the weathered surfaces, and exactly resembling those so conspicuous on Ben Nevis, also occur dispersedly among the more simple rocks, the fragments consisting only of different varieties of the same substance.

Before quitting these rocks it will not be uninteresting to mark the principal circumstances in which they differ from the analagous rocks which occur in Arran, in the Ochil hills, and in many other parts of Scotland. They all consist alike of claystone and compact felspar, simple or porphyritic. But they differ in situation, the hills of Glenco reposing on granite and the older schists, while the former lie above the red sandstone. They also differ in their general features, since the former assume a spiry shape, while the others present a succession of tame and rounded outlines. They appear equally to differ in durability, since although the hills of Glenco are destroyed by the effects of the mountain torrents, they are not like those of Arran subject to decompose by the ordinary action of the atmosphere. In the variety of composition there is also a conspicuous difference, the infinite number of hard, coloured, and compounded porphyries that occur in Glenco and correspond with those which are every where found in veins among the older rocks, being entirely absent in those which lie above the red sandstone. Are we to attribute these diversities to a different era of formation? Unfortunately our knowledge of these rocks is as yet so limited that this question cannot be answered; but the few remarks which precede may for the present remain as slender contributions towards their history, independently of the local interest they may possess in illustrating the description of Cruachan.

The next rock of which it is necessary to take a somewhat more extended view, for the purpose of illustrating the structure of this mountain, is the red sandstone, together with the white calcareous sandstone which lies above it. As the former is of frequent occurrence while the latter is only occasionally present, and as there is no difficulty respecting the consecutive position of these rocks, I shall neglect it in the short notice here to be given.

It has been shewn that these sandstones occur at the foot of the mountain, occupying a very small space, and that no continuation of them can be traced to the immediate vicinity. But in traversing a larger portion of this tract of Argyleshire a similar phenomenon is found frequently occurring, which, if it diminishes the suprize at first excited by this very limited extent of the secondary strata in the spot above described, adds a much greater interest to the fact, while it naturally leads the geologist to enquire into the circumstances under which so remarkable a dismemberment of these strata has taken place. Their continuity and extent as they occur on the eastern and southern skirts of the highland mountains are too well known to require notice, and they will be found to occupy an extent similarly continuous, as far as geographical circumstances will permit, on the north-western coast of Scotland and in the islands connected with it. The interval between these two principal masses of sandstone may be said, in a general way, to extend from near the Mull of Cantyre to Kintail, and the predominant rocks throughout this space are gneiss, micaceous schist, quartz rock, and a variety of analogous substances which it would be out of place to enumerate here.

It is in this interval that the scattered fragments of the sandstone strata are to be occasionally found, sometimes like that near the foot of Cruachan, connected only with the more ancient rocks, in other places associated with and covered by a variety of rocks more or less appertaining to the trap family, or to the porphyritic rocks which accompany them. It would lead to a length of description unfit for this paper to describe the places where they are to be seen, but I may mention two which are remarkable on account of the narrow space which the sandstone occupies, still more limited than even in the spot which has led to this discussion. These are the island of Seil, and Inish capel, in the latter of which their total extent only amounts to a very few yards. It is remarkable that in all these cases, as far at least as I have examined them, their dip is toward the west, however limited this may be, and that this is also the dip of the leading masses both at the southern side of the interruption above quoted and at its northern extremity where the same strata are found occupying parts of many of the islands, and extending for a considerable space between Kintail and the Ru Storr in Assynt.

The uniformity of their dip proves that these independent masses have not been separated by any disturbance from below, and we have therefore to chuse only between two explanations; either that they had been originally independent deposits, or that they had formed one mass subsequently disjoined either by the operations of water or of other destroying forces acting on the surface, or else by the intrusion of some other rock. The uniformity of their dip seems a sufficient reason to reject the former explanation, and their present appearance is more probably derived from both the last mentioned causes acting on different points. Concerning the action of water or other similar causes we can only conjecture, but of the latter we have occasional proof in the actual existence of masses of trap rock overwhelming them in some places, and doubtless concealing them entirely in others. It may perhaps be owing to this rock and to its subsequent destruction only, that their present state is to be referred. I shall therefore conclude these illustrative remarks by a few words respecting the trap rocks which occur in the vicinity of Cruachan, and which are in many places so intimately connected with these detached portions of the secondary strata.

The nearest mass of these substances is a long mountain ridge which occupies part of the northern shore of Loch Etive, descending towards the western sea and skirting the plain of Connel. It is in this place well known to all who have travelled the west Highlands, since the road passes under large rocks of the conglomerate which is connected with it. It is equally familiar to those who visit Oban, since the surrounding country and the neighbouring islands are covered with more or less extensive masses of it, in some cases reposing on the older schists, which form the visible basis of this country, in others upon the sandstone strata already described. It is in this latter case that it produces the effect already alluded to of partially concealing the masses of sandstone, so as to give an appearance of separation where no real one exists. In some cases it is also probable that it has actually dislocated and separated them, intruding among them as all the rocks of this family do, from below. Hence it assists us in explaining the state of the sandstone formerly described, although, from the circumstances already mentioned, that separation is in many cases independent of it. It is far beyond the bounds of this paper to pursue further the very interesting circumstances under which the whole of this formation of trap appears; and I shall probably take some future opportunity of entering at large into its history. I shall here therefore terminate these miscellaneous remarks, which appeared to me necessary to illustrate the description of Cruachan.

V. *Account of some remarkable Disturbances in the Veins of the Mine called Huel Peever, in Cornwall.*

By JOHN WILLIAMS, Junr. Esq.

HONORARY MEMBER OF THE GEOLOGICAL SOCIETY.

[Read 2d June, 1815.]

THE county of Cornwall, in whatever part it has been explored in the working of its numerous mines, has been found so devoid of perfect regularity and agreement, either as regards the course, dimension, or contents of its veins, or the uniformity of the country they traverse, that the history of any one mine can by no means be considered as exhibiting a portrait of them in general. Each mine, not to say each vein, will be found to have some peculiar claim to attention. It is not perhaps hazarding too much, to presume that a knowledge of what occurs, even to the limited depth to which the Cornish veins are followed, may be found to throw some light on a branch of science which is yet involved in considerable obscurity, but it is to be lamented that facts have not hitherto been sufficiently attended to with a view to their preservation. The object of the miner is the most expeditious manner of arriving at gain; his knowledge is derived from the book of his own experience: but so greatly do the circumstances attending veins differ, that they sometimes set at defiance his experience, however great or general it may be. Some of the most interesting phenomena attending the veins of Cornwall are the interruptions they meet with from each other; these are of various descriptions. In the mine of Huel Peever, which is the object of this memoir, almost every species of interruption occurred to which the veins of Cornwall are liable; and so completely was the skill and experience of the miner baffled in the progress of its workings, that its tin vein having been heaved (to use a technical phrase) by other veins, it was not discovered again by the exertion of much labour and expense during a lapse of nearly forty years. It may perhaps serve to render more intelligible the following description of the remarkable circumstances attending the veins of Huel Peever, if we notice on the subject of veins in general that those of which the direction is north and south are rarely metalliferous; that the veins containing copper and tin run, with little exception, about east and west. Their downward direction is seldom quite vertical; there is however a species of vein having also an east and west direction which is never metalliferous, but consists generally of clay; this vein is for the most part found to take a course under-ground much less approaching the perpendicular than the metalliferous veins. This variation from the perpendicular in an east and west vein, whether it be towards the north or south, is called the underlie, and when its direction or dip is opposed to that of the metalliferous vein, it mostly disturbs the direction of the latter. The east and west non-metalliferous veins either from their customary effect in respect to other veins, or from their generally quick underlie, or from both, have obtained the name of slides.

The mine called Huel Peever is situate in the parish of Redruth, about one mile and a half north-east of the town of the same name. Its veins, to the extent of their workings both in length and depth, were found to pass only through schist, occasionally of a micaceous appearance, but in many parts the mica not being perceptible, it assumed the character of argillaceous schist.

By a reference to the accompanying ground plan of the mine, Pl. 7, fig. 1, it will be seen that it consisted of one tin vein *a* and one copper vein *b*; the latter called John's Gossan, running in the direction of east and west, and forty fathoms south of the former; two other veins *c* and *d* not metalliferous, took the same direction, one 25 fathoms south of the copper vein, and the other 23 fathoms still further south. Many fathoms north of the tin vein, but at what exact distance is not precisely known, a channel of porphyry *f*, or in the language of the miner, of elvan, also ran in the direction of east and west, and a copper vein *e* near it. It will also be seen that there were three cross veins, not metalliferous, technically called cross courses, the easternmost of which *x* runs from 10 degrees west of north to 10 degrees east of south, that next to it *y*, about 9 fathoms to the west, runs a little more to the west of north, and east of south. The precise direction of the westernmost *z*, which was 145 fathoms distant from that next to it on the east, is not known; nor is that essential to the present object, since as it formed the utmost limits of the workings of the mine on the west, and was situate in the poorest part, it was not found to contribute any thing towards the strange circumstances which have rendered the history of this mine so well deserving of detail and preservation.

The tin vein *a* is from three to thirty feet wide, but its general average may be estimated at about eight feet. The copper vein *b* is about three feet wide. It is almost needless to observe that these veins were not equally productive in every part; in some places, they were very rich, in others quite poor; but it is worthy of notice, that where the tin vein was thirty feet wide, its substance consisted of a mass of *rich tin ore* extending several fathoms in every direction. The substances enclosed in the copper vein, consisted, near the surface, of quartz and iron ochre, or gossan, amongst which was interspersed a little yellow copper ore, accompanied by quartz, chlorite and iron pyrites to a considerable depth. Both the tin and copper veins have been traced for about a mile in length.

The two slides which run parallel with the metalliferous veins afforded no trace of either copper or tin. The northernmost of the two is from 4 to 12 inches wide; the southernmost from 2 to 3 inches. They were found to consist wholly of an argillaceous clay, called by the miner flucan. These veins, as will hereafter be seen, notwithstanding their poverty, were one principal cause of the remarkable incidents attending this mine.

It will be seen by the ground plan that the eastern cross course *x*, (which was about 4 feet wide, consisting of $3\frac{1}{2}$ feet of quartz on the western side, and 6 inches of flucan on the eastern,) traversed the channel of porphyry, the tin and copper veins, as well as the two slides, heaving them all 54 fathoms to the north on its western side, where they maintain the same distance from one another as on the eastern side. The cross vein *y* next on the west, which consisted of the same substances as the cross vein *x*, and on the surface where it cut the tin vein at P was distant from it only about 26 fathoms, had precisely the same effect on all the east and west veins, except that the distance of the heave north was only 18 fathoms, so that the tin vein, at its place of contact with the west side of the cross vein *y* at P was exactly 72 fathoms north of that part of it in contact with the eastern side of the cross vein *x* at Q. Of the cross vein at the western extremity of the mine, (as has before been noticed) little is known. But the two former have been traced nearly five miles in length intersecting every tin and copper vein, and from every observation, it seems probable that they extend from the Bristol to St. George's Channel, and are very distinctly seen in the cliffs near Porthtowan on the northern coast.

The intersection and heave of the east and west veins by the north and south veins in Huel Peever, form an interesting part in the detail of its history; although such occurrences are by no means rare, as they are found to exist in a greater or lesser degree in almost every mine traversed by north and south, or non-metalliferous veins. But some remarkable and almost peculiar circumstances belonging to the downward direction or underlie of the several veins in Huel Peever remained to be noticed: these are of so complex a nature, as to render a verbal description difficult; but they are of great interest in a geological point of view.

The channel of porphyry, and copper vein near it, being in no degree connected with the ensuing detail, are wholly omitted in the accompanying transverse section,* which represents the underlie of the tin, copper and flucan veins on the west side of the cross vein *y*.

The underlie of the tin vein is towards the *south*, 2 feet in every fathom, that of the copper vein is towards the *north*, 4 feet in a fathom, so that the horizontal distance between them at the surface being 31 fathoms, they would have come in contact at the depth of about 31 fathoms, but for the intervention of the flucan vein on the south of the copper vein. The underlie of this flucan is towards the north, and much quicker than that of the copper vein, being about 14 feet in every fathom; and by the transverse section it will be seen that the flucan overtook the copper vein at A, and cut it short at the distance of about 22 fathoms, measured along its inclination, from the surface; whence pursuing its direction in a strait line about 14 fathoms, it met with, and in like manner, interrupted the course of the tin vein at B at about 26 fathoms measured along its underlie, or 24 fathoms perpendicular from the surface; after which the flucan or slide proceeded regularly.

* Pl. 7, fig. 2.

It next became the object of the miner to discover the parts of the copper and tin veins, which had been severed and carried away by the flucan. This after much labour and expence was effected. On pursuing the downward direction of the flucan vein, after it had quitted the tin vein at B, it was found that the copper vein had been carried down about 18 fathoms from A to C, and the tin vein as much from B to D.

The working of the tin vein being the object of the miner, he found it proceeding in its underlie from D in the same direction as it had assumed between the surface and its place of intersection with the vein of flucan at B; but after sinking upon it about 9 fathoms, it was found (to use his phrase) *cut out* by the copper vein at E, whence a new and unlooked for delay and expense were incurred. It was at length discovered that the effect of this intersection was immediately opposed to that occasioned by the flucan vein, for the tin vein was as it were, heaved up by the copper vein 8 fathoms to F, whence it resumed its customary underlie and direction, and was followed for about 42 fathoms in depth to G, where it was intersected by the south slide *d*, by which it was heaved up about nine feet; it afterwards continued its course downwards as before, and was worked about 38 fathoms below to H. The south slide underlies towards the north about six feet in a fathom.

The accompanying longitudinal section of Huel Peever is along the run of the tin vein, and supposes its south side or wall taken away in order to exhibit the workings of the mine; and for the same reason also supposes a perfect continuation of the tin vein from the eastern side of the western cross vein *z* to the western side of the eastern cross vein *x*, although the fact was, as has been already noticed, that the tin vein was separated by the slide at 26 fathoms on its underlie from the surface, and carried away 18 fathoms towards the north, and also that the tin vein was 18 fathoms further north between the western and the middle cross vein than between the latter and the eastern cross vein. The workings to the east of the latter are not exhibited in the longitudinal section, in consequence of its being another mine called Old Huel Peever.

By the longitudinal section it will be seen that the downward direction of the eastern cross vein *x*, towards the west, was 4 inches in a fathom, the underlie of that 17 fathoms on the west of it at the surface at *y*, was towards the west one foot and a half in a fathom. The underlie of the cross course at the western extremity of the mine *z*, was in opposition to the latter, being very little towards the east, though nearly perpendicular.

c c, *d d*, Represent the north and south slides intersecting the tin vein, the former at 25 fathoms perpendicular from the surface at the engine shaft, and the latter about 50 fathoms below. 9, shews the situation of the shallow adit or water course, and 10, the deep adit; all the other horizontal lines represent the passages or levels made by the miner in the search after tin, or for the convenience of his occupation. The dark parts of the longitudinal section shew the places in which tin was found.

Pl. 7. fig. 3.

VI. *Description of the Tunnel of the Tavistock Canal, through Morwel Down, in the County of Devon.*

By JOHN TAYLOR, Esq.

TREASURER OF THE GEOLOGICAL SOCIETY.

[Read 6th May, 1814.]

MORWEL Down is a hill, lying between the River Tamar, which divides the counties of Devon and Cornwall, and the River Tavy, which rises in the forest of Dartmoor; and after passing the town of Tavistock, flows on the eastern side of Morwel Down, and falls into the Tamar, a few miles nearer Plymouth.

The neck of high land separating these rivers, extends southwards from Morwel Down, and includes the parish of Beer, in which are situated the Beeralstone Lead and Silver Mines, not far from the point of the peninsula, the lode crossing a part of it in a line from north to south.

In pursuing the Tavy towards its source, the country rises irregularly, and the rocks are found to consist of killas, to the borders of Dartmoor; the same appearances are to be observed by taking a survey of the hills situate between the eastern bank of the river and the range of granite mountains which form the peculiar feature of Dartmoor. True granite has not been found intermixed in the central part of the range of the killas rocks of this neighbourhood, in any instance within my recollection. In the valley through which the little river Walkham flows, and near the point at which it falls into the Tavy, a remarkable change of strata occurs; the side of a very abrupt hill, on the top of which is West Down, in the parish of Whitchurch, is composed of a considerable cluster of detached masses of granitic rocks, which are piled on each other in the most picturesque manner, and form a lofty and steep bank to the river. Killas occurs in the same hill, on each side, and is the only rock observable on that which rises from the opposite edge of the valley.*

If we turn from the country on the east and north of Morwel Down, to that on the west of it, we shall find that the Cornwall side of the river Tamar is more diversified in the rocks that occur; killas generally prevails, but granite crowns the summit of Kithill, which rises gradually from the banks of the river to the height of 1400 feet, and the same rock is to be found near the base of the mountain, at Gunnis Lake Copper Mine, near New Bridge, and again a little higher up the stream, at a place called the *Clitter*, a provincial word, signifying a collection of loose masses of rock.

The killas district is nearly surrounded on the three sides above

* The situation of these rocks would point out a connexion between them and some of the beds or veins of porphyry which are to be described as occurring in the tunnel through Morwel Down; the line of their direction would lead us to this point, and the inference is strong that this is a part of one of them. It is however rather extraordinary that it should have escaped notice in the deep valley of the Tavy, where it must pass, and where I have little doubt it will be found from a recollection of the general features, though unfortunately it did not occur to me to look for it at the time when I could have done so. It may likewise probably be traced through Morwel Down to Gunnis Lake Mine, which is mentioned in the following paragraph.

I do not venture to decide on what this rock should be called; in describing the strata of the tunnel I have assumed that it is porphyry. That which occurs in the Walkham valley has much more the character of granite, and so I should incline to call it.

The specimens will enable more competent judges to decide.

mentioned by the granite, the line of division of the two rocks describing an irregular horseshoe form, while the southern side of the killas extends to the coast and joins the Plymouth limestone.

The surrounding granite mountains rise to an elevation of from 1400 to 1900 feet above the sea, while the hills of killas keep a much lower range; Morwel Down, through which the tunnel is passing, is one of the highest in the central part of the killas, and is about 700 feet above the tideway in the river Tamar, which washes its base.

The killas district, which is attempted to be here described, is every where intersected with veins, or as they are technically called, *Lodes*. Those which are worked for copper or tin have universally a direction from north-east to south-west, or nearly so; those which run in other courses have all the appearances of a newer formation, and are generally unproductive of metal, if we except two instances, one of which is the lode on which the Beeralstone mines are working to a considerable extent, and the other the lode in Wheal Betsey Mine, in the parish of Mary Tavy, both of which produce lead and silver.

In the last 20 years this district has been the scene of very active exertion in the pursuit of mining, and the most spirited efforts have been made for tracing the veins, and instituting trials upon them for the discovery of their contents. These effects, as in most similar cases, have been attended with very various success, though on the whole, the result has been a favourable one. On many lodes considerable sums of money have been expended, without discovering sufficient quantities of ore to repay the disbursements, and on many the loss has been heavy; in other instances, though the fewer in number, mines have been established which have produced very large quantities of ore, principally of copper, and have paid the adventurers veiy handsome profits.

The most important of these mines are *Wheal Friendship*, in the parish of Mary Tavy; *Gunnis Lake* and *Drake Walls* mines, in Calstock, on the Cornish side of the Tamar; *Wheal Crowndale*, on the banks of the Tavy, below Tavistock; *Beeralstone mines*, in the parish of Beer; *Wheal Betsey*, in Mary Tavy; *Wheal Crebor*, at the foot of Morwel Down, discovered in consequence of the undertaking about to be described, and some others of inferior note.

I am not able to state any account of the produce either of *Gunnis Lake* copper mine, which has been very considerable, or of the *Beeralstone mines*, but exclusive of these the others have returned since the year 1805, from 3 to 4000 tons of copper ore annually, and the quantity now raising is at the rate of at least 5000 tons in the year. There has likewise been a considerable quantity of lead raised at *Wheal Betsey*, and of tin at *Drake Walls*.

All the lodes that have been worked, are in killas, excepting that at *Gunnis Lake*, where the copper is found in granite. The ores of this mine differ very much from those of the other mines; those of the latter are almost entirely copper pyrites or yellow copper ore, varying in their proportions of metal from 5 to 15 per cent. while in the former mine are found besides the yellow copper ore, carbonates of copper, grey copper ore, arseniates, &c. This fact is the more striking, as the vein is certainly the same as that worked at Wheal Crowndale and Wheal Crebor, where it traverses the killas, and at Gunnis Lake passes into granite.

About the year 1802, when the mines of this district were assuming an importance they had never before attained, and their prospects were such as to encourage fresh adventures, the proprietors of the principal ones were led to think of the scheme of driving a tunnel through the hill, which is the subject of the present remarks. The chief inducements were, that Morwel Down was known to be traversed by numerous lodes, which might be discovered and worked by such an undertaking, and that while a tunnel should be carried in a direction to cross them all, it might make a navigation practicable from the vicinity of Tavistock and the adjacent mines, to the river Tamar where the produce of the neighbourhood is shipped.

In 1803 an Act of Parliament for cutting a canal from the town of Tavistock to *Morwelham*, a quay on the river Tamar, was obtained, and the driving the tunnel was immediately begun.

A canal from the north end of it to the town of Tavistock was soon after cut, by which means a copious stream of water was obtained from the Tavy, which was carried across a valley upon an embankment 50 feet high, and afforded the means of working an overshot water-wheel of immense power, which was required for sinking the requisite shafts on the hill through which the tunnel was to pass.

It is unnecessary here to enter into further detail of the nature of the works, as they may be understood from a collection of reports on the subject, which I have formerly laid on the table of the Society; it is sufficient to remark that this tunnel, which was to pass through hard rock for a length of nearly a mile and three quarters, and for the principal part at a depth of about 130 yards from the surface of the hill, was an undertaking of no small enterprize, and that difficulties of various kinds presented themselves in its progress.

The tunnel, as may be seen by the section, is not yet complete,* but the obstacles are all surmounted, and nothing now remains to be done but the simple operation of driving. The draining the deep shaft in the centre of the hill, and the ventilation of the tunnel, having been some time since provided for.

* See the Postscript to this Paper.

It does not often happen that the processes of the miner lead to so much geological discovery as might be expected; the works he undertakes follow the course of the vein he is exploring, or are confined within a small space bordering upon it. As the veins are sought after in but very few varieties of rock, so the number that are laid open to view is generally limited compared with those that exist in mining districts.

A tunnel of such an extent as the one now to be described, in such a district, crossing the direction of the metalliferous veins, and passing at such a depth under the surface, could hardly fail of proving an interesting object to the geologist as well as the miner.

Two facts have been ascertained by its progress:

1st, Relative to the rocks, that the killas of which the hill is mainly formed, is traversed by beds of other rock, whose direction is inclined to that of the metalliferous veins, and which have a pretty uniform dip or underlay to the north.

2d, Relative to the metallic veins or lodes, that they traverse all the strata, and that they have a remarkable difference in their dip or underlay on the two sides of the hill. Those on the north side dipping to the north, and those on the south side to the south.*

Commencing at the north end of the tunnel, I shall proceed to detail the strata that have been passed through, referring to the section accompanying this paper to shew their position, and to the specimens of the rocks themselves which I have selected to exhibit their character.

* Since the paper was written it has been ascertained, as I have been informed, that some veins lately discovered in the space between Renfrews shaft and Brays shaft underlie to the south, which is an exception to the preceding observation. But it may be observed that this deviation takes place near the centre of the hill.

I give the provincial names of the rocks as they are in general use among the Cornish miners.

A	—	311	fathoms	Killas	
B	—	11	———	Elvane	Chlorite and Quartz
C	—	23	———	Killas	
D	—	6	———	Grouan	Clay Porphyry
E	—	12	———	Killas	
F	—	26	———	Grouan	Clay Porphyry
G	—	} 436	———	Killas	
H }	—			Ditto	
I				Ditto,	with veins of Quartz
K	—	15	———	Elvane	
L	—	3	———	Killas	
M	—	7	———	Grouan	Porphyry
N	—	12	———	Elvane	Quartz, granular and crystalline
O	—	408	———	Killas	
		1270.	Whole length of the tunnel.		

The direction of all these beds seems to be parallel, and to range nearly east and west.

All the veins that at present are known in the part of the hill which the tunnel will intersect are shewn in the drawing, by lines, which describe their dip as nearly as is ascertained from the little that has as yet been seen of most of them.

Some of these lodes have been discovered by the tunnel, and some are known by old works upon them near the surface.

It was not to be expected that any great proportion of the number would turn out productive of ore, or at least that they should be so at the exact point where the tunnel cut them. One or two, if rich in ore, might render the speculation a profitable one, and it is rather extraordinary that the first which was discovered, at the commencement of the work at the north end, should be one of that description. It is called *Wheal Crebor* lode, and has already been worked about 60 fathoms deep under the level of the tunnel, and has produced between 8 and 9000 tons of copper ore; its direction is as usual from north-east to south-west, and it has been traced to be the same vein that is worked at *Wheal Crowndale* mine to the east, in killas; and at *Gunnis Lake mine* to the west in granite; at both of which concerns very large quantities of ore have been raised. The lode at *Wheal Crebor* is in some places fourteen feet wide, though in others not as many inches. It is traversed by cross veins which *heave* the lode, as the miners call it, a few feet.

The mine is now producing near 4000 tons of ore in the year: a specimen will be found with the others.

The next lode found in following the course of the tunnel southwards contained tin, but not in any great quantity, and very little work has been done upon it in the way of trial in consequence.

Further south is a lode called Wheal Georgiana, which has produced some rich copper ore in the porphyry, where the tunnel discovered it. It has been pursued into the killas, but in this rock it appears to be less productive of metal.

At the present end of this part of the work which is approaching the centre of the hill, a vein has just been met with holding copper, but too little is yet known of it to afford any description.*

In the space yet unopened between *Bray's* shaft and the end approaching it from the south, is a lode called *Holming Bram*, which was formerly worked for tin, and on which considerable expectation is grounded. Having simply stated the facts as far as my knowledge of them goes, I abstain from speculating on the

* This vein underlies to the south, and is mentioned in a preceding note as an exception to the usual dip of the lodes on this side of the hill.

support they may afford to any hypothesis on the formation of the rocks or the veins, though they may offer some hints on the subject.

Imperfect as this sketch is, it may serve to lead the attention of some more able member of the Society to the consideration of the appearances of this district, which I thought sufficiently curious to encourage an attempt at their description.

POSTSCRIPT,

December, 1816.

I have lately visited the tunnel in consequence of its completion, and therefore am enabled to complete the section of the hill, shewing that no new strata have been discovered since the preceding paper was written.

I have likewise ascertained more satisfactorily the dip or underlay of the lodes near the centre of the hill, and inserted them in the section with two cross lodes or cross courses, which traverse the lodes near that place. A remarkable alteration in the texture of the killas occurs on each side of one of these cross courses, it is found in such a decomposed state that it is converted into a soft clayey matter, so as to be very difficult to preserve a passage through until it can be securely arched.

A period of thirteen years has been occupied in bringing this great work to a conclusion, and it has not been done without the anxieties consequent on such an undertaking.

Two things of great importance in the practice of mining may be remarked of this work. First, the extreme accuracy of the line of direction which has been preserved in so long a drift, although the junctions were made from several different points.

Second, the small number of shafts, and consequently the length of tunnel between each, which was ventilated during the progress of the work. I am inclined to believe that it exceeds in this respect all other attempts of a similar kind, and the section may therefore, in the hands of the Geological Society, be a useful document for future engineers. The means which I adopted for obtaining perfect ventilation will be found to be described in the Transactions of the Society for the Encouragement of Arts, Manufactures, and Commerce, for the year 1810.

VII. *Corrections and Additions to the Sketch of the Mineralogy of Sky, published in the third volume of the Transactions of the Geological Society.*

By J. MacCulloch, M.D. F.L.S. President of the Geological Society, Chemist to the Ordnance, Lecturer on Chemistry at the Royal Military Academy, and Geologist to the Trigonometrical Survey.

[Read March 7th, 1817.]

When the Sketch of the Mineralogy of Sky was drawn up for the Society's volume in 1813,* I had no prospect of again visiting that remote country. Circumstances having led me to traverse the

* The differences between the map of Sky which accompanies this supplementary paper, and that formerly given, require some explanation, that the readers of the Geological Transactions may be able to appreciate the reasons which have led to the alterations, and account for those which, in a geological point of view, will be shown to be more apparent than real, and to see what degree of confidence they may repose in the present one.

In laying down the places of the different rocks, I formerly made use of the documents from which Mr. Faden's travelling map was constructed, and I was guided in the examination by Mackenzie's chart. The incorrectness of these has been the leading cause of the apparent differences in the relative extent of the rocks as they have been delineated, while their insufficiency for the purposes of a *reticulum*, arising from the great distortions of the outline of the country and their deficiencies in its internal features, prevented me from laying down many of the places where the existence or boundaries of particular rocks had been accurately ascertained. Hence the geological delineation bore no proportion to the accuracy of the observations. To these defects if there be added the blanks which the partial nature of the former survey necessarily left, the discrepancies of the two will not appear so considerable as they seem at first sight. I may also add, that it has been found expedient to change the colours by which the different rocks are denoted; another apparent cause of difference.

For the present observations I have made use of Mr. Arrowsmith's map, with certain variations which I think it necessary to explain, that the degree of confidence to be reposed, whether in the original or in the alterations, may be understood.

same ground in much greater detail, I have been enabled to supply the deficiencies which were acknowledged in that paper, and to correct the errors into which I had unwarily fallen. I hold it my

A line drawn from the head of Loch Snizort to that of Loch Slapin will, under slight exceptions, separate the estate of Lord Macdonald from those which lie to the westward of it. It is not too much to say of the latter division that the outline of the coast is incorrect, and the internal features something worse than conjectural. But the division which constitutes Lord Macdonald's estate, having been taken from a survey of that district executed by an intelligent provincial surveyor for his Lordship, is deserving of considerable confidence, and will be found over most parts sufficiently accurate in its internal features for the purposes of the geological record. Even in the latter I have found it necessary to make some additions and alterations; in the former part of the island these are considerable. I must however say, that even in this case I have limited the corrections to those parts of the map where it was necessary to denote the boundaries of different rocks; the northern parts, presenting only one substance, were not in immediate need of it, and I do not pretend to arrange the geography of the island. It is necessary to point out the alterations which have been made.

The region lying between Loch Eishort and the foot of the syenite hills, which includes the valley of Strath, has been redrawn and reduced as far as was possible to the present size, the intricacy of the position in the rocks which constitute it absolutely requiring a more accurate detail of the leading features of the ground. Slight alterations have been made in the shades which indicate the relative altitudes of the hills, wherever that was called for, and the result will be apparent to those who shall compare the present map with Arrowsmith's. At the point of Sleat and in the Kyle rich two or three alterations have been made in the line of coast, these being absolutely required; others which might have been made have been omitted, as they were not wanted for the particular objects of this work.

The changes made on the eastern side are much more important. The estate of Strathaird which includes Blaven and Coruisk, has been corrected from a private survey in possession of the proprietor, Mr. Macalister. The Cuchullin hills are in the original map entirely misplaced, while the remarkable lake above mentioned has been omitted. These I have rectified as far as was in my power, since both their form and extent were important. The tract to the north of this including Mr. Macleod's property, remains with very little alteration, since its uniformity of composition did not call for any particular care.

The directions of the strata are marked by prolonged lines extending to the neighbouring shores or islands wherever they presented the same substances, and on these the tendency as well as the quantity of the dip is occasionally pointed out by an appropriate index and numbers, wherever it seemed necessary to specify them.

Finally, whatever corrections may be found in this map are merely intended to serve the purpose of this paper; the formation of a correct map of Sky must yet be considered a work far distant.

duty to supply the one and to correct the other; and consider that an acknowledgment of the latter is the greatest mark of respect I can pay to that body under whose protection they were laid before the readers of its Transactions.

No apology can be offered for want of industry; but the extent of this island, the difficulty of traversing it, and the intricate disposition of its rocks, offer some excuse for deficiencies, where want of time was further superadded to all other obstacles. For errors there is no excuse, but in correcting them it will not be useless to point out the causes from which they arose, since other observers may take warning from them, and learn to mistrust all observations which are not founded on rigid investigation, free from conjecture, and free from system.

To conclude respecting what is, from that which ought to be, will lead, as it has already led, to greater errors than those which I shall have to record. Equal hazard arises from judging of the structure of a district by the examination of specimens only. In rocks the specimen is not always an abstract of the geological nature of the series in which it occurs, and the mistakes which have here arisen from this cause will be equally apparent with those which have resulted from the preceding one. The last source of error which I shall notice was the imperfection of the outline of the island as it is given in Mackenzies chart by which I was guided. Here, among other similar errors, the distance between the head of Loch in daal and that of Loch Eishort, which scarcely exceeds a mile and a half, is marked at five miles. Hence, finding my observations to disagree with the map on which I attempted to record them, I abandoned altogether a pursuit which, had I continued it, would have led me at that time, as it has since done, to determine the sandstone series to a much greater extent than I then imagined it to occupy.

The most leading error is that which states the promontory of Sleat as composed of micaceous schistus. This substance occurs in several places, and often in distinct beds of considerable thickness, while in others it consists of mere laminæ interposed among the other rocks. These rocks are of very various composition, but as gneiss occurs in considerable quantity among them, exceeding greatly the space occupied by the micaceous schist, the latter will probably be considered by most geologists as subordinate to the former, and the gneiss as being the lowest and fundamental rock of Sky. But the truth is, that this series is not amenable to any systematic rules, and it will be better to state the fact as it exists, than to incur the risk of a similar error by transferring to gneiss that rank which I had before conferred on micaceous schist. It will be seen that the series presents anomalies which cannot be removed by any theory of subordination, and that the history of the district of Sleat is not the least interesting part of the unexpected appearances presented by this very instructive island.

The characters of the gneiss are so strongly marked in one part of the space which it occupies, that there can be no difference of opinion respecting it. Besides mica or hornblende it contains a conspicuous proportion of high red felspar and quartz, being at the same time distinctly laminated, and from the contrast of its colours, very remarkable.

From this regularity of structure and composition it passes into a substance for which there is no name in the present nomenclature of rocks, and which can only be ranked with gneiss by assuming a considerable latitude of character. This rock is a compound of felspar and quartz with chlorite schist, these substances being still interlaminated as before, so that each mineral generally occupies a distinct portion of the specimen, the latter becoming substituted for the mica that characterizes the regular varieties. By degrees the chlorite schist becomes predominant, and at length the felspar is excluded, so that all appearance of gneiss ceases and a simple series of chlorite schist remains. I suppress a detail of the endless varieties found through this series, as such substances can rarely be rendered intelligible in description. But I may add that hornblende schist, so generally found to accompany gneïss, alternates here also with it under many different aspects.

With respect to the position and boundaries of this series, it is found occupying beds of which the elevated edges present a rectilinear direction towards the north-east, dipping to the eastward in an angle which varies between 30 and 50 degrees. Its boundary towards the west lies near the small island Oransa, where it is succeeded immediately by the graywacké schist and the accompanying quartz rock or hard sandstone which were described in the original paper, but which I shall presently describe again in greater detai!, having had an opportunity of verifying much of that which was only conjectural, and of extending its limits to a much greater distance than I had foreseen.

Although the boundary of this series, in which gneiss and chlorite slate form the principal parts, is thus defined at the northern end of its western side, no such decided change is perceived at the southern end of the same line, which, if protracted from the place first mentioned near Isle Oransa, would cut a point on the western side of Sleat. The interior of the country is too much encumbered with peat and with vegetation to permit of any decision on a subject so obscure as is the point of change between the gneiss series and the rocks which follow it, and I must therefore limit myself to the appearances which occur on the sea shore, where every change can be traced in the most minute manner. Here there will be found a transition, unexpected and improbable as it may at first seem, between the two series, that of the gneiss, and that of the graywacké and sandstone which follows it; but at what point between the two extremities of the gneiss boundary a decided change takes the place of a gradual transition it will be for ever impossible satisfactorily to determine. I must add that the limit of the gneiss series on the eastern side of Sleat is the sea shore itself.

I must now proceed, before entering further on the transition of the gneiss series, to describe that which in the original paper I called the series of blue quartz rock and schist, in which there is somewhat to amend and somewhat to supply. With this I must here include the red sandstone, formerly separated from the other two rocks on the same systematical views which led into the other errors already mentioned. The conclusions then drawn were sufficiently justified by the partial view of the country which I had at that time obtained, but they were founded on observations too limited. A more complete investigation, with a greater disregard of theoretic views, would not only have led to sounder conclusions, but have removed many difficulties which I encountered both in the examination and in the attempt to reconcile discordant phenomena.

Although on reviewing the places I examined before, I find the description formerly given of these substances locally correct, and the conjecture I had formed of the nature of the rocks toward the Kyle ri‘ch equally so, yet an examination of additional parts of this series renders it necessary to remodel the whole description, as it possesses a degree of intricacy which it was impossible to suspect, and which nothing but a very accurate examination could ever have induced me to credit, since it is at variance with the usual phenomena that attend these rocks.

The whole series presents from one end to the other a repetition of the same parts, although the several substances are in different places differently proportioned, the one exceeding in one place, while in another a different member of the series will be found predominant. One exception to this rule will afterwards be noticed.

The rocks which compose the series are the following.

Red sandstone, more or less indurated, of which the general characters were formerly described.

Quartz rock, or, as some may prefer to name it, indurated sandstone, passing from lead blue to grey and brown, sometimes pure, at others containing felspar.

Schist, which is sometimes not to be distinguished from ordinary clay slate, and at other times contains particles of quartz and mica. If one term is to be used for the whole it must probably be called graywacké schist.

White compact quartz rock: this substance is found only in one part of the series.

In the original paper I described the red sandstone as following the blue rock and schist in conformable order, which it in fact does throughout a considerable tract without any repetition of the two latter. But on pursuing these beds further than I then did, whether backwards or forwards, according to their relative inferiority or superiority, repeated alternations of all those substances occur.

The dip which I also described as constant and westerly, is only thus regular from that part of Loch Eishort whence my examination at that time commenced, to its upper portions, ascending according to the order of the beds. In tracing from that point towards the last, or downwards according to the order of the beds, through those parts of the country respecting which I formerly offered only conjectures on the similarity of the series, I do not find those conjectures verified; the position of the beds becoming first vertical and then reversed and irregular; ultimately settling in a dip towards the east, the reverse of that which predominates on the western or upper side of the series. But whatever irregularities are found in the dip, there are none in the direction, which with a slight local disturbance near Ord is invariably rectilinear, and on the north-east line or nearly so.

On the north-eastern end of this series, where it forms the mountains of the Kyle, the rocks can be traced perfectly from the gneiss at Isle Oransa to the commencement of the limestone near Broadford, this space comprising the collective thickness of the strata; but through this tract the quartz rock or indurated sandstone is predominant. If these strata are prolonged toward the south-west their characters change, or they are discontinuous in composition according to the line of their direction, since the schist and quartz rock are most abundant toward the north-eastern end, while red sandstone prevails at the opposite one.

The space which they have been represented to occupy on the original map must also be extended, and to a certain degree this may be done by prolonging the line of direction from that point near Isle Oransa where the junction of the gneiss is found.

I have already related the error committed by allowing too much space to the micaceous schist, which occurs only as one of the members of a series principally formed of gneiss and chlorite schist. Another of the sources of that error will now appear when I describe the last enumerated member of the red sandstone series; and it will no less excite surprise than operate as a caution in the present state of geological science, against judging of rocks by analogies, or by any other evidence than that of actual and careful examination.

Meeting near Loch Eishort with the white compact quartz rock which was described in the original paper, I concluded that here, as elsewhere, it was a member of the primary rocks, and therefore without hesitation laid it down among the series which I considered to be micaceous schist, concluding also that I had in reaching it arrived at the bottom of that series which contained the blue quartz rock and schist. That white quartz is however a member of this very series, holding a parallel course with it, and being preceded as it is followed by red sandstone, blue quartz rock, and graywacké schist. This circumstance forms a material addition to the history of quartz rock, and an alteration no less material in that of the series to which the red sandstone belongs.

I must here remark that in calling so complicated a series of rocks by the title of only one of its members, the red sandstone, I have done so only on account of the necessity of using one term for the temporary purpose of a geological description, and that this one was chosen from the predominance of that substance. I can only add that this predominant member corresponds in mineral character with the other red sandstones which in Scotland occupy the intermediate place between the primary rocks and the secondary strata containing organic remains, and that it is connected by visible indications with many similar portions of the same rock to be found not only in Sky but in the neighbouring islands. As it is also followed in a conformable order by the limestone series formerly described, it possesses another common character with the usual red sandstone of other districts. If any person shall think that the whole of this series should be ranked under graywacké and called a *transition* series, I can have no objection, but am at the same time unable to see what advantage is gained by the substitution, or in what respect the science is aided by it; while at the same time the red sandstone will be as much transferred from its usual place in the one case as the graywacké is in the other. But the island of Sky is very often unsystematical: that which follows perhaps still more so than that which has preceded.

In attempting to trace the red sandstone below, or rather beyond the white quartz rock, it is not found to terminate on the north-western shore of Sleat, at the place where, according to the line of direction prolonged from Isle Oransa, it should end. Instead of that, the alternations of sandstone and schist continue. Gradually however they increase in frequency, and becoming at length undulated and contorted, they cannot at a distance be distinguished from gneiss in their general aspect and disposition. In examining the substances, the first alteration perceived is the gradual induration of the sandstone, which becomes first a compact quartz containing grains of red felspar. At length the felspar acquires a laminar tendency, the schist still remaining unchanged, the rock thus becoming an irregular gneiss (if it may be so called) consisting of laminæ of quartz, felspar and graywacké schist. Approaching the point of Sleat the schist gradually becomes green and glossy, thus passing into chlorite slate, and here we arrive by an insensible gradation to the variety of gneiss which I formerly described as found there. In thus pursuing the red sandstone on the western side of Sleat, the reason appears why I could not when speaking of that rock, define the boundary of the gneiss on this side of the island, and I need now scarcely repeat, that any attempt to examine rocks so constituted, in the interior country, would leave nothing but doubt and uncertainty; for which reason I have limited the description to the sea coast, where every foot of the rock through all its transitions admits of free examination.

I have no commentary to offer on these facts, which seem calculated, if not to excite disbelief, at least to set our present systems at some defiance. It is possible to reconcile them only by supposing that the red sandstone series belongs to the primary rocks, and the whole of these strata which extend from the point of Sleat to the limestone of Strath, will thus form a succession of rocks alternating with and graduating into each other. That the gneiss is a primary rock can, I imagine, admit of no dispute.

In formerly describing the limestone district, I expressed my expectation that the strata of Kilbride and those at the entrance of Loch Eishort would be found identical with those at Broadford, and that expectation has been realized by a complete examination of the district in question.

On the Broadford shore the commencement of the limestone beds is found near a small farm called Lucy, but their actual contact with the sandstone cannot be seen, on account of a sandy beach which covers the junction. It is probable that some conglomerate exists in this interval, as detached masses of such a rock are found in different places in the hilly grounds between Strath and Loch Eishort; but I need not dwell on a circumstance so common every where that it can scarcely fail to be present here. As the inclinations of the sandstone and limestone are in the same direction near this junction, the latter however dipping only five degrees to the north-west while the former dips ten, there can be no doubt but that they are connected in the usual regular order of succession.

From this, which I shall call the lowest line of the limestone, it can be traced under various interruptions along a high ridge of hills to Loch Eishort, where it coincides with the beds formerly described as found there. Independently of this connection, the identity of the whole is proved by the correspondence of the organic remains, which at Broadford however are more abundant than on the opposite side. The principal difference at the two extremities consists in the numerous beds of shale and sandstone that alternate with the limestone strata on the Broadford side, and in the inferior solidity and thickness of the calcareous beds; while at the same time the harder schist, which divides them on the south-western shore, is absent, the one appearing to be a substitute for the other. The shale is a mixture of black clay, sand, and mica, thickly and imperfectly fissile, and the sandstone which is of different colours, but generally brownish, contains much clay and calcareous earth, the organic remains being found in each of these beds just as they are in the limestone.

The interruptions, to which I have here alluded, that prevent us from tracing the limestone over the hills that bound the southern side of Strath, arise partly from the boggy and covered nature of the ground, and partly from the intrusion of a hill of syenite, which extends far from the portion formerly noticed, towards Broadford, and which can in many places be distinctly traced overlying the limestone, shale, or sandstone, as either of these happens to be present at the point where the contact is exposed. There is no satisfactory evidence to be procured here of that change from the stratified to the unstratified limestone which I have described in the original paper, since there is no situation where the contact of the two can be precisely traced. Yet there is even here sufficient evidence to give rise to such a suspicion, and more than enough to confirm the observations formerly recorded, and to justify the conclusions deduced from them. To enter into further details on this subject would now be superfluous, as the feebler evidence is of little value where the stronger has preceded. I shall only add, that beds of ordinary quartz are in one place found regularly interstratified with the marble limestone, as if the power which had converted the common limestone into this one, had also changed the sandstone into quartz: and that many gradations by which the ordinary limestone appears to pass into the marble, can also be traced, although in consequence of the irregular nature of the ground they are widely dispersed. I ought also to add that in one of these intermediate portions I found layers and scattered specimens of bodies having the general aspect of those obscurely organized fossils which have been all confounded under the name of alcyonia, consisting of a calcareous carbonate whiter than the surrounding rock, their surfaces being covered with minute but irregular crystals of the same substance, and being so much more durable than the surrounding materials as to remain protruding after these have been washed away.

To the topographic detail as given in the original paper, I must now also make an addition, the nature of which will be better understood by inspecting the improved map.

The strata on the Broadford shore may be traced to a place opposite Scalpa, but without a name, where they terminate in a succession of beds consisting of the shale only. After some interruption, in consequence of the intrusion of a mass of syenite and trap, a small patch of irregular limestone is seen, which soon ceases in consequence of the renewal of the syenite, not to appear again till we arrive at Loch Sligachan.

On this shore the overlying position of the syenite can be easily traced at the places of contact, demonstrating that it here combines the same double relation to the stratified secondary rocks which it is found to bear elsewhere; cutting through them at the same time that it covers them.

The boundary between the upper portions, or the north-western line of the Strath limestone and the syenite, is extremely irregular, although it is not often possible to procure a sight of the actual contact, or even of the probable junction of these different rocks. It is however a sufficient proof of that irregularity, that as marble is found at the foot of the ascent of Ben-na-caillich, so syenite abounds on the opposite side of the valley, while every where throughout it patches of the latter rock, often of very small extent, are found surrounded on all sides by limestone.

I must further add to the description of the limestone that pectines of considerable size are found among its upper beds, together with terebratulæ, and numerous fragments of shells of which some resemble portions of mytili, but the whole in too imperfect a state to admit of accurate examination.

The description of the limestone of Sligachan having in the original paper been left imperfect, I may now add to it the following particulars. Beds of the stratified limestone and shale, succeeding a narrow portion of the red sandstone, and precisely resembling the strata of Broadford, extend from the portions of irregular limestone before mentioned to the shore of the loch. These also dip to the north-west, but at a considerable angle, and the direction of their elevated edges, like that of all the regular rocks of Sky, is to the north-east, or thereabouts. It is evident that this limestone is a portion of the same series which occupies Strath, the intermediate parts having been either displaced or overwhelmed by the syenite.

The circumstance of greatest difficulty in comparing these two portions of limestone, is the intervention of the red sandstone, in conformable position, and therefore apparently alternating with them, since the angle of inclination has in all the same tendency. It is not easy to admit of this alternation consistently with what we know of the relative positions of the red sandstone with limestone of this character in other places. Unfortunately Sky itself offers no clue by which we can trace this connection more intimately, or on which we could found some theory of it less at variance with ordinary experience. Whatever the nature of this difficulty may be, I must for the present suffer it to remain unexplained, since without detailing the history of all the islands in the vicinity which partake of and elucidate the structure of Sky, no adequate conjecture can be offered respecting it. There is here no room for such a description, but I hope on some future occasion to give a collective view of the whole group, and thus to render the geological history of the principal island less incomplete than I am still compelled to leave it. The connections of the western islands with each other and with the main land are so intimate, and the light obtained from one portion is so necessary for the elucidation of others, that the separate description of any individual of the group must always be imperfect.

The account of the limestone which is found near Ord on the southern shore of Loch Eishort was in the original paper imperfect, as well in respect to its topography as its mineralogical description. It occupies a small hill which includes the house of Ord, and is singularly irregular in its position, as well with respect to its own arrangement, as to its connection with the neighbouring rocks, among which, as I have already shown, there occurs a great degree of confusion. Notwithstanding this irregularity, a careful and close investigation of it will leave no doubt respecting the superiority of its position to the sandstone with which it is associated, and however widely separated from the more regular beds on the opposed shore, there is no want of indications to prove that it forms a portion of the limestone of Strath; its present confusion appearing, like that of the neighbouring sandstone, to have arisen from some common cause acting on both, to which also we may perhaps attribute the peculiarities which its structure and composition present. Its stratification is in general sufficiently apparent on the great scale, although in the more detached portions often invisible, in which respect it possesses a resemblance to the marble limestone formerly described. But I need not detail those peculiarities of structure which can scarcely be rendered intelligible by words. That which is most remarkable is the large quantity of siliceous matter it contains. This is found dispersed through it in irregular nodules, often scarcely differing from common flint, or rather resembling that variety of chert which in other situations is found in limestones. These nodules are white, grey and mottled, in some places of an obscure pale red, and they are so predominant in a few situations as nearly to exclude altogether the calcareous matter.

In the original paper I represented the sandstone of Strathaird as a portion of a series superior to the limestone of Strath, and a subsequent and more extensive examination of the country enables me to confirm this view. But I may add to it the following remark, which is not unworthy of notice. The trap veins which form so conspicuous a feature on the eastern side of this promontory are crowded together in the manner already described only along a certain, though by far the greatest, portion of the shore. At the extremity of the promontory they are rare, and are scarcely found on the western side. They appear indeed to be connected with the body of the trap which was described as covering the stratified rocks, and to be ramifications or processes from that mass. On the western side, and at the point of Aird, where they are rare or altogether wanting, the strata consist of a soft white calcareous sandstone, and are nevertheless apparently continuous with the hard ones formerly described as occurring where the trap veins predominate; while the identity is still further marked by the correspondence of the same complicated schistose structure, that structure being even more apparent in the softer rocks, as more readily yielding to the action of the elements. I remarked formerly that these strata, however separated in position, were analogous to the white sandstone which occurs at Portree and elsewhere in the north-eastern portion of Sky, and is accompanied by limestone, shale, and coal. Having then but little acquaintance with that part of the island, the description of these strata was avowedly left imperfect, and it is now necessary to supply the deficiency.

As I remarked not long ago that a description of the neighbouring islands was requisite to throw light on the obscure connection of the red sandstone with the limestones of Strath and of Sligachan, so I may here repeat that the history of the uppermost strata of Sky, which I now propose to sketch, would be materially elucidated by that of Rasay. But as the description of this island would be here inadmissible, I can only say generally, that the deficiencies of connection which occur in Sky, and which compel me on many occasions to have recourse to inference and analogy, are in a great measure supplied by the structure of that island, which, while it is more continuous and accessible, is at the same time such as to leave no doubt respecting the identity of strata separated at present by a narrow arm of the sea.

It has been seen that as the gryphite limestone immediately follows the red sandstone, so it is succeeded by the calcareous white and grey sandstone of Strathaird. The same succession may be traced in a more circuitous manner by comparing the strata of Sligachan, Scalpa, and Rasay. But it is apparent on considering the map of Sky, that the portion of these uppermost strata which occupies the district of Trotternish is separated from the gryphite limestone by an interval, partly the result of the direction of the shores, and partly produced by the intervening mass of trap and syenite. There is no actual contact of the two to be seen, but the nearest indication of a connection between them is to be found at Loch Sligachan. I have already described the limestone which occurs on the southern shore of this inlet. On its northern side there are seen a few beds of white, brown, and black sandstone, separated from that limestone by the breadth of the loch only, but lying in a regular order conformable to it, and doubtless connected with it under the depths of the sea. These are immediately cut off by a mass of trap, which extends without interruption for nearly two miles along the shore, thus depriving us of all means of tracing any connection between them and the next stratified rock. That rock appears at Conurdan, occupying a low situation on the sea shore, in a thin series of nearly horizontal but somewhat irregular beds surrounded on all sides by trap. These beds consist of a brown calcareo-argillaceôus sandstone, similar to one of the beds at Loch Sligachan, and characterized by the spheroidal concretions which prevail through the greater part of the sandstone of this district. After an interval of trap the same sandstone re-appears as we approach Portree, but still scarcely visible except in the natural sections of the shore, since the whole interior surface of the land is covered by the superincumbent trap, which conceals the structure of this country from the most watchful eye. Here it immediately presents a collection of beds of enormous thickness rising into lofty cliffs, which, although inaccessible, may be approached in favourable weather so near from the sea as to leave no doubt respecting their nature. This is the hill of Camiskianevig which forms the southern side of Portree harbour.

The mass of trap which overlies these strata cuts through them in the interior of the harbour, and thus forms another interruption between them and the corresponding ones, which again appear with similar dimensions on the northern side of the harbour. From this place they continue to form high cliffs, covered in a similar manner by trap, and extending along the coast for a considerable space towards Holme. Limestone occurs together with the sandstone in the interval last described, but the shore is so difficult of access on account of its rocky boundary, the want of creeks or harbours where a boat may land, and the general prevalence of a heavy sea, that it is not possible to trace every point, nor, consequently, to perceive where the changes of the strata take place; while, from the mural front and excessive height of the cliffs, they are themselves absolutely inaccessible. To add to the difficulty, the limestone when weathered puts on the grey colour and aspect of the sandstone so perfectly, that it is often difficult to distinguish them, when even within reach, without the assistance of a recent fracture.

I must here premise that the whole of the strata hereafter to be described, as well as those now mentioned, have a regular and even dip towards the north-west, which is at a small angle, although no opportunity is offered of ascertaining its quantity. In this respect they are conformable, if they are not absolutely consecutive, to the Strath limestone, and I may add that this dip is apparent over the interior country wherever they can be seen, while at the same time it is indicated generally by the gradual disappearance of the lower beds on the west side of the promontory, their thickness amounting on that shore to a few feet only, while on the east side it reaches to many hundreds. I need scarcely say that cases of obvious disturbance connected with the interference of trap must be excepted from this general rule.

Passing Holme the shore becomes occasionally more easy of access, although the mural line of cliff continues, and here limestone strata are found to have succeeded to the sandstone. These strata contain spheroidal concretions similar to those which attend the sandstone, and which increase the difficulty of distinguishing between the two substances at that distance from which alone they are visible. Hence it is with some doubt that I must speak of the absolute nature of the whole strata between Portree and Holme; a matter fortunately of no serious moment, as geologists are well aware of the intimate connection subsisting between these strata, which have been fully examined and described in many parts of the British islands.

Alternations of micaceous shale and of brown sandstone are found in the calcareous beds, of which the colour and composition vary materially, although the predominant colour is smoke-grey, the aspect earthy, and the composition argillaceous. The only organic remains which I could find among them were a large ammonite and a belemnite often exceeding a foot in length. As far as I can discover, our conchologists have not yet ascertained these species or distinguished them by specific names.

But it is unnecessary to enter into minute details respecting this limestone, since it must be already seen that it belongs to the lias, a rock well known to geologists, and already often described under all its varieties of aspect.

I shall take some future opportunity of describing this important series as it occurs throughout the western islands, since it is so dispersed as to involve the history of many of them, and to render it impossible to give an adequate account of it in a paper so local as this.

Proceeding northwards along this shore, it appears that the beds which follow are superior in position to the preceding. This should result from their general dip, but it cannot be distinctly ascertained. Here, common shale begins to appear in alternation with the other substances, and the quantity of siliceous schistus strewed on the shore proves that this substance also exists somewhere in the cliffs; doubtless under the same circumstances which I formerly described at Duntulm. I must add that the specimens sometimes contain shells, and that, resembling basalt in appearance and texture, they confirm the truth of those suspicions respecting the asserted existence of organic substances in that rock, which it is here sufficient to have mentioned.

Together with these detached blocks of siliceous schist are found similar fragments of a cherty substance, extremely hard and brittle, and breaking into acute conchoidal fragments, but possessing an earthy aspect. Its colours vary from greyish white to dark smoke-grey, and I may add that its degrees of induration are also various. Occasionally, portions of the siliceous schist are attached to it, the separation being marked by well defined planes, and, from the contrast of colour, very conspicuous. If there were any doubt that this chert was originally a portion of the lias indurated by the same process that has converted the shale into siliceous schist, it would be removed by the fact that on the western shore of this district the two substances are found *in situ*, associated in the same manner and in various states of transition from common lias and shale to chert and siliceous schist.

The last portions of limestone to be seen on this shore occur at the island of Fladda, occupying a very low position, and at length disappearing gradually below the trap, which beyond this point forms the whole coast as far as Duntulm, constituting also the islands of Trodda and Fladdahuna, as well as the various picturesque rocks which are scattered to the north of the point of Hunish. This bed of limestone abounds in organic remains, but so condensed together, and so broken, as to present no specimens capable of being ascertained: they resemble fragments of some sort of cockle and of anomiæ, or perhaps ostreæ.

If we proceed to the western side of this promontory for the purpose of recovering these strata, we find them at Duntulm, from which place they extend interruptedly for a few miles along this shore, when they finally disappear. The same organic remains, the same shale, the same limestone, calcareous sandstone, and siliceous schist, mark the identity of these with the strata on the eastern side, an identity still further confirmed by the prevailing correspondence of their inclinations. I may at the same time add that a greater facility of access to the upper beds, the only ones here to be found, assists us in obtaining a more correct notion of those beds which from their elevation above the shore are inaccessible on the east side, and that we thus become acquainted with those numerous varieties of the lias limestone, which having often been described by geologists, serve to confirm the nature of these last and uppermost of the stratified rocks of Sky. The nature and origin of siliceous schistus can here also be traced in many other places besides that most conspicuous one at Duntulm which I formerly described; and so many gradations between that rock and shale are to be observed that the most satisfactory evidence of their connection can be obtained.

From a comparison of these several facts, the details of which I have from the nature of this supplementary paper thought it necessary to condense, it is apparent that the fundamental rocks of the district of Trotternish, are those secondary and stratified substances which are connected with the lias formation, and that these are both surmounted and intersected by trap. If but little additional evidence of this view can be obtained from an examination of the interior country, that little is at least satisfactory. The same substances occur in numerous places, where precipitous faces or the sections formed by rivers expose the rocks that lie beneath the trap. If they are disjointed in position, or if they appear promiscuously scattered, they still retain their natural connection, while the identity of their mineral structure is every where consistent. In one place only some strata of a quartz rock are to be seen, which might lead us to hesitate did we not recollect that in other instances the same causes which have converted shale into siliceous schist have also been found to change sandstone into quartz.

The same causes which formerly prevented me from examining the strata of Trotternish, the deficiency of which I have now supplied, also impeded the investigation of the coal which is connected with them. Although I have since followed and traced the appearances of this mineral in those places where it has been observed, there is but little satisfactory information to be obtained respecting it. The cause of this obscurity is easily understood. It has been remarked that although the basis of this promontory consists of the stratified rocks which have been just described, the whole is surmounted and intersected by trap. The decomposition of this rock, and that of the softer strata which lie beneath, have moreover covered the whole country with a deep soil, which from its fertility tends further to conceal the nature of the rocks on which it reposes. Hence it is only in the casual exposure of some jutting rock or broken face, some denuded acclivity or bed of a stream, that any access can be procured to the stratified substances, and from this cause it is rarely, if ever, possible to trace the relations of the particular stratum which comes into view. It is among such dispersed portions of strata that the appearances of coal are observed. They are not unfrequent, but are always extremely scanty, both in their thickness and in their apparent horizontal extent, since the strata which contain them are every where cut off by veins or by masses of trap. They are interposed, as we might expect, among the shale and sandstone, and, as we may conclude from the general bearings of the strata already described, occupy the upper beds of this formation. It is impossible to say that they do not exist at a greater depth, since the inferior strata, as I have already shown, can scarcely be considered sufficiently accessible to enable us to determine on the absence of a substance of which the thickness does not exceed a very few inches. Nevertheless, no indications of coal can be perceived along the eastern line of cliffs, where the deeper strata are exposed, and we may therefore for the present conclude that they lie above the lias and its associated sandstone, or at least among its uppermost beds. It can serve no purpose to enumerate the places where these indications of coal have been observed, since they cannot be verified on the map, and are indeed generally nameless. As the strata rarely exceed an inch in thickness, it is equally evident that those which are visible are worthless in an economical view, while the certainty of a speedy interruption from the intrusion of trap removes all temptation to penetrate to greater depths, or to expend capital in a more effectual research.

While on the subject of coal, I may add to the former account, that I have observed portions of wood coal in more places than those originally enumerated, but they are no where of sufficient importance, or marked by any such peculiarities as to require further description.

In describing the several trap rocks of Sky, I am sensible of having often spoken generally, when the circumstances might perhaps have admitted of more accurate details. The cause of this however is principally to be sought in the imperfect acquaintance which geologists still possess with this infinitely varied and obscure class of rocks, an obscurity which increased experience is daily tending to remove. Repeated and careful examination of them as they occur in the western islands, have, since the time at which the original paper on Sky was drawn up, enabled me considerably to amend their history, and to dispose of them in a more exact and connected manner; but as the detail would here be inadmissible, from the length of discussion to which it would lead, I shall make no attempt to improve the former imperfect remarks, but reserve that which might be here added, for some future communication. I shall however attempt to amend one or two of the descriptions contained in the former paper, where I had been obliged to rely on a distant view, and was therefore compelled to speak only in the most general terms.

The first of these portions of trap is that which occupies the district of Trotternish, of which, as well as of the stratified substances but just described, I had formerly an opportunity of forming only a very superficial notion.

As I have just shewn, it both intersects and surmounts the secondary strata, while in many places it appears also to be horizontally or conformably interstratified with them. These interferences are very remarkable, and exhibited on a scale of such extent as to include every circumstance which has yet been described on the subject of their junctions. But without numerous drawings no adequate idea of them can be conveyed, and as there is little to be said respecting them which would not be a repetition of the remarks which have on numerous occasions been made on similar appearances, I shall forbear to enter into details respecting them. I shall only observe, that all these irregularities occur in a mass, which taken in a general view, has the character of a stratified trap, since notwithstanding them it bears a strong parallelism to the already parallel strata with which it is associated. It is abundantly plain that the appearance of stratification in the trap is here the result of the form of the rocks on which it is placed, or among which it has intruded, in the former case surmounting them, and in the latter appearing to alternate with them. The instances of this apparent alternation are highly interesting, from their great extent, as well as from the perfect conviction which they present of the fallacious nature of this supposed connection. In many cases the alternations of the trap are as regular, as decided, and as evenly parallel, as those of the stratified rocks themselves, the sandstone and limestone among which it lies. Yet in no instance does it not happen, but that at some point or other the alternating bed of trap will detach an intersecting vein, unite itself to the superincumbent mass, or, quitting the interval between two given beds of limestone or sandstone, make its way across the one immediately above or below, and then proceed with a regularity as great, for another long space, between some other pair of proximate strata. In one or more instances I have observed this to happen after more than a mile in extent, throughout all which space not the minutest irregularity had appeared to indicate any thing else than a perfectly conformable and alternating stratification. I have no doubt that, could such extensive exposure be oftener procured, all the instances of supposed alternation between the trap rocks and the stratified ones would prove similar to these.

With respect to the trap itself it is most generally amorphous. As we approach however towards the northern end of the promontory it becomes columnar, and this character prevails round the points of Aird and Hunish beyond Duntulm, where it at length terminates. Although the columns are formed on a large scale, and are individually rude and imperfectly defined, yet their picturesque effect, when seen from a point of view where they can be properly comprehended as a whole, is not less symmetrical than that of the faces of Staffa, while at the same time they far exceed it in grandeur as well as in absolute magnitude. Their height reaches from 200 to 300 feet and upwards, a dimension, however large, not sufficient to overpower the due proportion which should exist between the aggregate structure and the parts of which it is composed, since the magnitude of the columns is proportioned to their height, and the total effect therefore similar to that of Staffa, where the proportions are so nicely adapted for beauty.

With respect to the composition of this variety of trap, there is necessarily some uncertainty, since the great extent of it, as well as the inaccessible nature of most parts, renders it utterly impossible to examine it throughout. We also know that the various members of this family are often found irregularly intermixed, so that to have ascertained the composition of one portion of a mass, gives us no assurance that we have made ourselves acquainted with that of the whole. Yet I am inclined to think that the greater part will be found to consist of a substance analogous to greenstone, in which augit occupies the place of hornblende, a rock of great frequency in Scotland, and often, perhaps generally hitherto confounded with common greenstone, unless in a few such remarkable cases as that of Rum, where the substances are too distinct to admit of mistake. It may be called augit rock, without introducing any confusion into mineralogical nomenclature.

For the sake of topography I must here mention a small mass of trap, lying on a part of the coast of Sleat not easily visited, and omitted in the original paper. It occupies a projecting point south of Talivil, where its place has been marked in the amended map. It covers a space of about a mile in extent, lying over the red sandstone. It is rudely columnar and slightly porphyritic, and is also remarkable for a schistose fracture parallel to the axis of the columns. It is accompanied by a small and very unintelligible fragment of limestone breccia, which appears here totally out of its place, and unconnected with the surrounding rocks.

I formerly represented the difficulties which impede the examination of the Cuchullin hills. Since that period I have obtained access to a larger portion of them, but still there is much unseen, probably inaccessible to human footsteps. That portion however is important, and I shall here describe it, although much remains to be done before the history of this division of Sky can be considered complete.

I remarked in the former paper that hypersthene was found united to felspar and hornblende in the rocks which surround Coruisk, but in the same place I also stated that a large portion of these rocks consisted of common greenstone. I have now reason to think this observation incorrect, and that the only greenstones (formed of felspar and hornblende) are found in veins. The difficulty of distinguishing between hornblende and hypersthene when the parts are very minute, was another cause of error, which a more intimate acquaintance with the place and a far more extended examination of specimens have enabled me to correct. In thus correcting my own errors I shall also correct those of other observers, since I may point out a well known district, Airdnamurchan, where the same rock as that of the Cuchullin hills has been hitherto mistaken for greenstone.

Although the hills themselves which encircle the romantic valley and water of Coruisk are utterly inaccessible on this side, yet it is easy every where to examine their bases, while the continuity of the beds or sheets of rock, from the foot to the very summit of the ridge, and its remarkable external characters, leave no doubt respecting the identity of their composition throughout. This is the rock on which the elements seem to make no impression, and on which no soil accumulates, causes which equally determine the permanent and rugged nature of their spiry outline. I have no hesitation in saying that the whole of the group as far as it is visible from Coruisk, as well as the opposite side of Garsven far on towards Loch Brittle seaward, and the smaller mountains which separate this valley from Blaven, consist of the same rock, but to what extent it may reach northwards cannot be determined until the whole shall have been traversed, unless the rugged outline and external general characters are admitted as a proof of identity of composition. In this case the whole of the Cuchullin is a mass of hypersthene rock, with the exception only of the veins which it contains, which consist of basalt, compact felspar, augit rock, syenite, felspar-porphyry, and lead-blue claystone. I have chosen the term hypersthene rock to designate this new and important member of the trap family, since like that of augit rock it is explicit, and introduces no confusion into the existing nomenclature.

There appear but two prevalent varieties of composition. In the first the mixture consists of hypersthene with greenish compact felspar, and in the second with crystallized white felspar possessing generally a slight glassy lustre. This latter variety seems to predominate, and is much more easily recognized than the former, which from its greenish hue and the minuteness and intimacy of the admixture, is often difficult to be distinguished from common greenstone. The principal variations of appearance are produced by the greater or less proportion of the hypersthene, by the varieties of its colour, and by the unequal magnitude of the crystals. While on the subject of Coruisk I ought to add, that the sonorous rock formerly described is either a compact felspar or a compound of that substance and augit in minute admixture, and not a greenstone; a term which has been too indiscriminately lavished on many of the obscurer members of the trap family.

The last circumstance respecting trap which requires correction is the account of a vein passing through the marble quarry in Strath, and supposed to terminate in a mass of syenite. I did not in the original paper lay much stress on the conclusions which might be drawn from it, but I can now however say that no instance has occurred to me in Sky of a trap vein being cut off by the syenite. The half opened state of the quarry at the time I saw it, and the rubbish with which it was encumbered, misled me into the report which I gave; a report which a moment's view of its present exposed state was sufficient to rectify. The trap veins (for there are two,) enter it on one side together, appearing at first like one; and being cut deeply through on that side of the excavation, while they were not to be seen on the other, I readily concluded them to be terminated. By a very singular coincidence they diverge from each other immediately at the place of entrance, branching away in an angle greater than a right one, and in this interval the excavation was effected, without exposing the separated veins, which I afterwards traced through the soil on the opposite side, after the rubbish was in some measure removed. The remainder of the error consisted in mistaking an irregular lump of a very anomalous kind of sandstone which is entangled among the marble and the trap veins now described, for the syenite which is in the immediate vicinity similarly interfering with the limestone, and of which, pieces detached by the workmen were lying upon this sandstone as if they had been recently separated from it. If care and caution are required in examining the most simple appearances among the regular rocks, a tenfold portion is necessary when we are engaged in investigating the irregular ones. The whole of the original remarks on this quarry must therefore be obliterated from the record.

There yet remain with respect to the trap rocks of Sky many facts which have resulted from the later more extended examination I bestowed on them. But as these would lead into details inconsistent with the purposes of this paper, and as they are important rather in a general view than as illustrating the history of that island, I shall reserve them for some future communication.

Having thus made the additions and corrections which appeared of most importance in the geological history of Sky, I shall proceed to enumerate some minerals which were either entirely omitted or but imperfectly seen.

In the small island of Oransa, and still more conspicuously in an islet adjoining to it, there is to be found a mass of actinolite rock, which can also be traced to the adjoining shore of Sky near to Camiscross. It lies among the gneiss, holding an uniform and parallel course with it, and as the beds of gneiss are here nearly vertical, it presents the appearance of a vein, its edge alone being visible. Nevertheless, its conformity with the gneiss, the analogy which it bears to common hornblende-schist, and its actual gradation into that substance, leave no doubt respecting its true character. The edge of this bed is very irregular, as the bed itself is interrupted and split in various places by intruding laminæ of gneiss, thus contracting in some places to the breadth of two or three inches, and again enlarging to that of as many feet. It is formed of a confused crystallization of actinolite of a pale green colour, the crystals being almost always very minute, and so entangled that the fracture often appears as much granular as it does schistose. It does not present those varieties which occur in the well known rock of Glen Elg, where the fine fibrous, granularly schistose, and distinctly crystallized, occur together, nor does it, like that one, contain talc. Its analogy to hornblende slate in a geological view is as obvious as is the resemblance of the two minerals, and its passage into that rock is here effected by the addition of crystals of black or greenish hornblende, which gradually increase in number till the actinolite is entirely excluded.

I have in another place mentioned the regular north-easterly direction of the gneiss, and I think it interesting to remark that the actinolite rock of Glen Elg corresponds with this one, as well in direction as in quality. If a north-east* bearing be taken from it on the map so as to intersect Glen Elg, it will be found to touch a point near Eilan reo'ch, as near to the place of the actinolite rock there situated as it is reasonable to expect from the nature of the map, and I may add that the direction of the gneiss on both sides is correspondent. There is therefore every probability of its being a prolongation of the same bed, but to what further extent it may be traced is beyond the bounds of this investigation to enquire. The total distance included between the two points is about seven miles.

In formerly enumerating the members of the zeolite family which are to be found in Sky I mentioned laumonite on the authority of others, although I do not know the name of the individual to whom the discovery is attributed. Since that period I have myself found it in the same place between Loch Eynort and Loch Brittle in which the decomposing stilbite formerly described is to be seen.

* Allowing 24° for the variation of the needle, the bearing of this bed appears to be north-east by east, but as the variation on this coast is not at present accurately known, as no examination of local irregularities has been instituted, and as the maps themselves are erroneously laid down, I have in this as in other instances held it fruitless to state their bearings with rigid accuracy.

It is occasionally mixed with the stilbite, but is also found in very large masses, either alone or intermixed with crystals of calcareous spar. These masses have fallen from the cliffs above, and lie detached on the shore. They consist principally of a confused crystallization, but cavities are also found in them in which the mineral has crystallized at liberty and in its regular form. These crystals exceed a quarter of an inch in length, and the substance is here invariably of a white colour. There is nothing more remarkable in this mineral than the contrast between its present and its original state with respect to hardness. The lumps which I have described sometimes exceed twenty pounds in weight, yet they remain entire on the beach notwithstanding they must have fallen, together with the other rocks which are here found, from an elevation of many hundred feet. At the present time the slightest contact causes them to crumble into atoms.

To the varieties of analcime which were formerly enumerated I may add another which is also to be found at this spot. It is of a brick-red colour, but not crystallized, and is largely mixed with the amygdaloidal rock that predominates at this place.

I formerly mentioned that epidote was found crystallized in cavities of the different trap rocks both in Garsven and in Glamich. In addition to that, I may here say that fragments of the same rocks are to be found at the foot of the former hill, in which this mineral appears to form a constituent part of the trap, being uniformly mixed with the other ingredients throughout the whole mass.

It has been said in some of the popular accounts of Scotland, that agate pebbles were found near Dunvegan, but having never seen specimens from Sky, and doubting the authority on which the report was founded, I took no notice of this circumstance in the former paper. I have now however found them, although in no great abundance in the same place where the laumonite occurs, a part of the coast so very rarely accessible, and under the most favourable circumstances so hazardous to attempt, that it will not fall to the lot of many to follow me to the same spot. They are of a grey colour, zoned in the usual manner, and sometimes contain cavities lined with quartz crystals. Similar geodes of quartz, of considerable size, are found in the same rocks, without the investing coat of agate; and it is further not unusual to find crystals of stilbite, of chabasite, and of filamentous mesotype,* sprinkled over their interior surfaces.

Since the former account was drawn up I have also found olivin, a mineral which, however common among trap rocks, must be rare in the Western islands, as this is the only instance in which I have ever observed it. A single block detached from the cliffs above, in the place last mentioned, contains it in great abundance. It is imbedded in a rock the basis of which is a black indurated clay, the same as that which here constitutes the greater part of the amygdaloids. It forms an equable mixture with this substance, being in the shape of small irregular crystals, which, when after exposure to weather the clay has decayed, appear so conspicuous, that the whole seems a solid mass of granular olivin.

The last mineral to be added to the former list is manganese. This is found, but in very small quantity, in an unexpected situation, being mixed in the form of its red oxide with the white marble, and accompanying the steatite of Strath already described.

I shall conclude this supplement with an account of an alluvium which I lately found in a part of the island not formerly visited, and which is deserving of notice on account of its independent

* This mineral proves to be needlestone; a distinction not understood when the original paper was drawn up.

nature, and the difficulty which will be found in giving an adequate explanation of its origin.

It is to be observed near Kylehaken, occupying a space of about a mile on the shore, but not exceeding a few hundred yards in breadth, terminating in one side on the elevated ground, as it does in the sea on the other. It seems to be the remains of a plain once much more extensive, since its boundary towards the sea consists of a series of straight lines, the loose materials assuming the usual angle and exhibiting precisely the same appearances which characterize the terraces that line the alluvial vallies through which active rivers have cut their way. The bar of Kylehaken harbour, and the gravelly soundings of this shore, which render it an insecure anchorage, equally indicate an extent once more considerable, and confirm the supposition produced by its straight edge and the angle of its declivity. Its surface is about 60 or 70 feet above the level of the sea.

No rivers at present flow in the vicinity of this plain, nor is there, from the form of the ground, any reason to suppose that they have ever flowed so as to enable us to account for this deposit of loose materials. The substances are nevertheless rounded, and consist of those rocks which are seen in the neighbourhood, presenting a large proportion of the various hard sandstones, with some occasional pebbles of gneiss and of hornblende slate. It might perhaps be imagined that the ordinary fragments of the mountains which back this little plain, descending to the sea and there rolled, might have been rejected by the tides so as to form these banks, but this supposition is invalidated partly by the presence of gneiss and hornblende slate, which do not occur among these mountains, and partly by the altitude of the banks above the present high-water mark. It must doubtless be granted that if at some more ancient period the strait of Kylehaken was narrower than it now is, the same tide-wave which now passes through it would cause a much more considerable elevation of its tides. But it is already very narrow, and no possible contraction that can be imagined would be sufficient to produce a difference of elevation so great as would be required for this purpose. It must be added to this difficulty that the uniformly level surface of the plain is an insurmountable obstacle to this supposition.

In defect of any other solution it can only be supposed that this is a fragment of some ancient diluvian deposit, instances of which, although very rare in the islands, are sufficiently abundant upon every part of the continent of Scotland. No estimate can be formed of its original extent, nor can any valid conjecture be offered of the mode in which it has been so abruptly cut down. It is however likely that although the present direction of the tides is such as not materially to exert any action on it, that direction may have varied in the progress of time, from alterations in the shape of the bottom of this very narrow channel, subjected four times in every day to the alternating action of a most rapid stream, as well as from the probable removal of a similar alluvium from the opposite shore of the main land. As we find analogous causes producing daily and visible changes of the same nature in the courses of rivers, the supposition is not incompatible with facts, since the narrowness of the Kylehaken channel and the rapidity of its tide, give it in this respect all the characters of an inland river as far as the contraction extends. We may perhaps indulge our conjectures still further in supposing that Sky was once united to the main land by means of this alluvium, and that the gradual effect of the tides circulating through the bay on each side had at length produced the effect in question; an effect not at all inadequate to its powers, and of which parallel examples occur in the lateral action of rivers on the alluvia of vallies; on the banks of the Tay and in many others of the principal rivers of Scotland. Greater effects have often been attributed to the corrosive powers of the sea, and in indulging this speculation I have kept far within the range commonly occupied by geologists. I may remark that the narrowness of the channel, which in one part does not exceed a quarter of a mile, and the shallowness of the soundings compared with the depth of those which separate the other parts of Sky from the main land, are friendly to this supposition. These scarcely exceed ten fathoms in the middle, although there are some deeper holes on each side ranging to thirteen, the bottom being every where gravelly, as if, like the banks, it was the remains of some former alluvium.

VIII. *On the Strata in the Neighbourhood of Bristol.*

BY RICHARD BRIGHT, M.D.

MEMBER OF THE GEOLOGICAL SOCIETY.

[Read 15th November, 1811.]

With Notes extracted from the Communications of

GEORGE CUMBERLAND, Esq.

HONORARY MEMBER OF THE GEOLOGICAL SOCIETY.

AN elevated ridge of land divides the vale of Bristol from the plain which is watered by the Severn. The parallel strata which compose this ridge rise towards the north-west at an angle of about 45° emerging from beneath the horizontal beds upon which the lower part of Bristol is built, and are afterwards broken off as they come in succession to the surface. At the base of the western escarpment of this ridge the lowest of the highly inclined strata abut with their broken edges against the horizontal beds of another formation, which there occupy the plain forming low hillocks almost to the Severn. The Avon passing through a precipitous ravine cuts all these strata almost at right angles to their planes, and exposes a section of them which may easily be observed, and has supplied me with the principal materials for the present paper.

In the channel of the New River at Bristol a stratified red and yellow sandstone may be observed in strata nearly horizontal, but a little inclined to the north-west. The thickest of these strata are singularly divided into regular cubical or rhomboidal concretions,* the planes of which cut the planes of stratification at angles of about 45°. Some parts of this rock make a fine building stone, as may be seen in the docks, where the stonework is constructed of it. There is a number of small cavities in the sandstone filled with crystals of sulphate of strontian of a red or dull white colour, both colours appearing sometimes in the same crystal.

In the low ground, on which great part of Bristol is built, hollows occur in the surface of the sandstone, which are filled with alluvial matter, such as clay, peat, &c. The clay is of a blue colour, and from 10 to 20 feet thick. On digging the channel of the New River 12 or 14 feet below the surface, a bed of peat was found more than 2 feet thick. At the top of the peat were a number of oak trees, tolerably sound, all lying towards the north.†

On rising from the vale of the Avon to the higher part of Bristol a siliceous iron-stone appears. Great part of Clifton is built upon this rock, which is also found in the country south of the Avon, forming that part of the hill above Ashton on which Sir H. Smith's house stands, and passing a little to the south-east of Belmont. It is in the cavities and veins of this rock that the beautiful quartz crystals, called Bristol stone, are found. They form 6-sided

* George Cumberland, Esq. of Bristol, has observed the same concretions, of which he has presented to the Society a drawing. According to Mr. Cumberland the sandstone alternates in its lower part with layers of a blue or greenish colour, and abounds with sulphate of strontian, the masses of which contain in their cavities crystals of the same substance of a lanceolate form and of an opake white colour. The masses are very fragile, and fall to pieces on attempting to disengage the crystals by the hammer. Sulphate of barytes is also found in the sandstone, but in small quantity.

† In the alluvial matter the horns and teeth of deer, the grinders of the boar, and nuts have been discovered. Blue phosphate of iron has also been found imbedded in a brown clay. The trees, according to Mr. Cumberland, had all fallen towards the south-west. Water worn pebbles and rounded blue flints were found at the bottom of the Canal near to the dam.

pyramids; some are of the highest lustre and transparency, others variously coloured by iron ore, or containing acicular crystals of that substance, or of manganese; some are said to be pierced with needles of sulphate of strontian.

Behind Brandon Hill there are beds of sand highly impregnated with iron, and containing impressions both of shells and vegetables.* In the descent on the south of Brandon Hill some singular masses of breccia project from the ground, containing rich iron ore, and assuming nearly a cubical form. The siliceous iron-stone of Brandon Hill has been found to make the best grinding stone for enamel colours. Below the siliceous iron-stone, upon the banks of the river near the Hot-well House, three small beds of coal make their appearance. These have been worked close to the river on its southern bank: and on the northern at the distance of two miles, near the Fort, a trial for coal was made some years since, but the seams found were not worth working.

Upon the banks of the Avon, immediately below the coal, there is found an extensive series of beds consisting principally of limestone, which form that high ridge of land which has been already noticed. This ridge passes on the north to Almonsbury and Alveston, and on the south to Clevedon, where the coal field of Nailsea begins. These beds upon the banks of the Avon are remarkably regular in their stratification, being all nearly parallel to one another and dipping to the north-west at an angle of about 45°. They are better observed on the northern than on the opposite bank, being on the former very much exposed by the operations of the quarrier.

Upon the top of this ridge and upon the fractured edges of the limestone strata, behind Clifton, there has been a partial deposition

* Mr. Cumberland mentions the anomia producta as found in the sandstone which lies above the limestone.

of stratified yellow sandstone, forming what has been called an up-filling. In the fissures of this rock crystals of carbonate of lime are found, and crystals of sulphate of strontian, which often assume a radiated form. This sandstone, having sometimes the appearance of a breccia extends to Redland. It is probably spread over the surface of the siliceous iron-stone already described; and in such a position it seems to have been found on Kingsdown in digging the vaults of Portland Chapel. The sandstone was there less firmly agglutinated, and the sulphate of strontian occurred about 4 feet below the surface in large irregular balls weighing many pounds.* At Redland this sandstone and the strata upon which it rests are rather abruptly terminated, being covered by a limestone stratified horizontally in thin layers, containing ammonites, gryphites, and anomiæ in abundance, and agreeing in all its characters with the well known limestone called *lyas*. The lyas extends to Cotham, where some of the strata are remarkable for taking a beautiful polish, being known at Bristol by the name of the Cotham stone. This lyas burns to a brown lime which sets hard under water.

But to return to the limestone. I do not intend to describe in detail all the beds of it; but the following are what I thought best deserving of notice, from their commencement immediately below the coal down to the lowest in the series. The first part of the series is best observed on the northern bank of the river.

* A beautifully crystallized specimen from these excavations was presented to the Society by Mr. Cumberland. It was found together with many other masses of the same substance imbedded in yellow marl. On digging the excavation for some houses at Clifton, according to Mr. Cumberland, the following minerals were found, but it is not known in what bed the vein occurred to which they belonged. Crystals of galena with foliated sulphate of strontian upon a matrix of sulphate of barytes. Quartz crystals enveloping needles of sulphate of strontian. These excavations are now closed, and the ground being built upon the minerals can no longer be procured.

1. A mass of limestone composed almost entirely of organic remains, and containing much iron, with madrepores between the strata . . . . 90 feet

2. Ten thin beds of blue and close-grained limestone, with clay between them, in which madrepores are imbedded . . 8

3. Limestone composed entirely of particles bearing marks of organization 18

4. A very thin stratum of red clay, covering

5. *A layer of coaly matter, one inch thick.

* *The following more detailed section of the beds lying above the coal marked No. 5, in the text, has been communicated to the Society by G. Cumberland, Esq.*

	Ft.	In.
1.—Sparry limestone, the edges of which being tinged with iron resemble lepidolite .... feet	10	
2.—Red, blue and white schistose clay	26	
3.—A stratum very full of fissures, the laminæ composed of quartzose sand united by a quartzose cement	9	
4.—A stratum of what is called "Dun marle," containing very angular fragments of limestone and ironstone: the marl is red, blue and white, and is speckled with ferruginous sand and pieces of schistose clay	6	
5.—A very hard mixture of ironstone and quartzose sand with portions of an oolitic texture	9	
6.—A ruddy and arenaceous limestone, ochreous, passing into ironstone of a fine grain	2	
7.—A stratum of ironstone 1 inch thick; then a very hard and fine grained arenaceous stratum	6	1
8.—A fine grained arenaceous stratum	2	6
9.—A stratum containing fragments of shells	4	
10.—A stratum containing fragments of shells and corals, in part argillaceous, and having the oolitic texture; of a brown colour	4	
11.—Three inches of ochreous clay with blue schistose clay, with oblong geodes of red iron ore very compact and hard		3
12.—Limestone having throughout the oolitic texture	12	
13.—Schistose clay or stone with nodules of coral		5
14.—Very arenaceous limestone with oolitic texture	1	
15.—Schistose wet clay coloured by iron with nodules		2
16.—Limestone, somewhat oolitic, tinged with iron, containing broken shells..		4

6. Blue clay divided by bands of yellow clay . . feet 12

7. Limestone resembling No. 3, this occurs at the distance of about 100 yards west of the Well house.

8. Limestone that is quarried as being fit for burning, forming magnificent cliffs about ¼ mile beyond the Hot-well house.

	Ft.	In.
17.—Dove-coloured, oolitic limestone with broken shells. The strata cracked.	8	3
18.—Grey compact limestone, irregularly oolitic	6	
19.—A stratum somewhat arenaceous, tinged with iron	2	6
20.—A schistose limestone	1	
21.—Two layers of soft limestone tinged with iron, separated by a layer of schistose clay 2 inches thick		
22.—Dark and fine grained limestone, divided in part by loose schistose clay ..	2	
23.—Seven thin layers of schistose limestone, separated by loose friable schistose clay with nodules, the whole containing many shells of the winged anomiæ and the anomia producta, with coralloids	3	
24.—Light coloured and fine grained limestone without animal remains, in texture resembling No. 22	1	
25.—Limestone with small broken encrinites	2	
26.—Dark oolitic limestone with broken shells	2	
27.—Limestone with broken shells throughout	1	
28.—Schistose clay..		3
29.—Fine siliceous rock without shells	1	6
30.—Rock with oolitic structure partially coloured by blue clay	2	3
31.—A reddish limestone with small arms of the encrinite, their cavities filled with ochreous matter	6	
32.—Coal about 2 inches thick, resting upon ironstone and red schistose clay, three or four inches thick..		6

Of these strata only two will burn into good lime, the rest being too arenaceous for the purpose. The organic structure observed in No. 3, of Mr. Bright's section is the oolitic texture noticed by Mr. Cumberland. Mr. Cumberland observes that although this texture is still visible in the arenaceous rocks of a mixed nature, it disappears in those which are purely siliceous. He also mentions that an oolitic limestone may be observed lower in the series of the east side of the combe that separates the pure limestone from the black rock or swine-stone. The fossils of the black rock are the winged anomiæ, and rarely the anomia producta, the palates of fishes, the claws of crustaceæ, corallines of various kinds, the mycetitæ of Woodward, the medusa encrinite, and millions of the stalks of encrinites,

9. Limestone in thin strata, impregnated with ochre so as to be unfit for burning.

10. Ferruginous marl, containing a great many madrepores and shells quite detached from the rock.

11. The first quarry of limestone.

12. The second quarry of limestone. In the limestone of these two quarries the strata although separated by no intervening substance are very perceptible, preserving an uniform direction.

13. Several thin beds of limestone which are not worked.

14. At the distance of three or four hundred yards from No. 12, the assemblage of strata begins, which forms what is called the Black rock, so called from the dark colour of the stone. A third quarry is worked here. This rock is less tinged with ochreous infiltrations than the rest usually are: it contains a great many shells and entrochi, and in its cavities are found dog's-tooth spar, cubes of purple fluor, acicular crystals of sulphate of strontian, and of oxide of iron. Similar cavities occur in the rock of the preceding quarry.

15. Many thin beds of limestone divided by clay, some being very full of shells and entrochi, and others having scarcely any traces of organic matter. Some of these strata from the number of shells they contain may be recognised again on the rising ground at the foot of Leigh Down near the village of Leigh, on the southern side of the Avon.

both round and oval. There has likewise been found in it a complete specimen of the head of an encrinus, and other heads of the encrinus have been observed imbedded in the limestone, and but little distorted. They were first noticed by Mr. Miller surrounding calcareous concretions in the black rock, which are penetrated with petroleum.

Petroleum sometimes exudes from the rock in small quantity; it is very hot to the taste, and is used by the masons for an external application, assisted by friction, to remove rheumatic pains. The black rock is quarried for paving stones.

16. A thin bed of limestone breccia containing rounded pebbles, and organized substances resembling the palates of fish. This bed has not been traced on the southern bank.

17. Limestone highly crystallized, containing much iron, and composed in a great measure of organic matter. It is seen very distinctly on the northern bank of the river cropping out amongst the wood, and resembling a wall about 8 feet high.

The limestone of St. Vincent's rocks when calcined yields a very pure lime: large quantities of it are exported for the use of the sugar works in the West Indies, in an unslaked state and packed in tight casks, and it is used extensively for building. All the roads in the neighbourhood of Bristol are repaired with the limestone, as are those in the neighbourhood of Gloucester, whither it is conveyed by means of the Severn.

Calamine is the most important mineral in point of frequency and value that the limestone yields. It is found in veins of calcareous spar crossing the limestone, accompanied by heavy spar and frequently by galena. The calamine is either amorphous or assumes the form of calcareous crystals which have been encased by it and since removed. The calcareous crystals in these veins have generally the dog's-tooth form; the heavy spar is not crystallized, but appears fibrous or composed of thin laminæ lying above one another. The galena sometimes presents very regular cubes, the angles of which are generally truncated. The calamine has hitherto been worked in a very imperfect manner: the vein is broken into, when it meets the surface; a rough windlass is placed over the hole, and a bucket is attached to a few fathoms of rope; two or three men work at the vein as long as the ore is found in abundance, or until the water impedes their progress. The mine is then deserted, but the heaps of rubbish at the mouth of the pit are often so rich in ore that considerable sums are paid for the privilege of washing them.

Manganese is also found in this district: it has not however been worked to any extent. The principal pit from which it is taken is in the parish of Ashton on the slope of the hill overlooking the valley to the west of the church. It is found in an iron-stone vein crossing the limestone. What little is found is used at the glass-houses and potteries of Bristol, and at the bleach yards in the neighbourhood.

To the limestone succeed other beds, in which a red siliceous sand is the prevailing ingredient. They lie in very regular strata from a foot to two inches thick, and parallel to those of the limestone. They are best observed on the southern bank of the river along the towing path for the distance of about half a mile from where the limestone terminates. These beds extend on the south of the Avon to Leigh, Failand and Charlton, and on the north they pass near to Sneed park towards Westbury. Some of the beds of this formation near to Abbots Leigh make a fine stone for building.

Among the uppermost of these beds are several composed of sandstone, the fissures of which are coated by calc-sinter, then a thin stratum of sandstone with evident marks of vegetable remains; below which is a red slaty sandstone very micaceous, and then a bed of siliceous puddingstone about 12 feet thick containing in some parts a number of white quartz pebbles.

About the middle of this series of sandstones there is found a singular stratum about 3 feet thick, composed of irregular balls of limestone packed closely together, the intervals being filled with fine sand. Below this the red slaty micaceous sandstone is repeated and at length disappears, being the last of the highly inclined strata that can be distinguished.

The last of these highly inclined strata at the base of their western escarpment are generally covered by beds of a very different character, which lie in horizontal layers upon the broken basset edges of the lowest beds of sandstone. This arrangement of the two formations may be observed to the south of the Avon on the towing-path just where the beds of sandstone terminate, and to the north of the river near to Sneed Park; at these places the sandstone is covered by horizontal beds of that kind of breccia which I shall presently describe. These horizontal beds form a series of low hillocks extending from where the sandstone terminates to within two miles of the Severn. They are best observed on the southern bank of the Avon, at Hung-road near to Crokerne Pill, where their section is exposed at low tide in a perpendicular cliff nearly 60 feet high. The beds consist of a red loamy earth and of breccia arranged in the following order.

Breccia . . . . 3 or 4 feet
Red loamy earth, about 30
Breccia extending to the base of the cliff, and quite below low water mark.

The upper and lower beds of breccia present nearly the same characters. They both consist of calcareous and siliceous fragments cemented together by a calcareous base, having cavities in it, which are filled with calcareous and siliceous crystals, and sometimes with sulphate of strontian. The calcareous crystals have either the form of the primitive rhomb, or of the dog's-tooth spar, and are sometimes covered over with an incrustation of smaller crystals of carbonate of lime. The quartz is crystallized in six-sided pyramids. Besides the sulphate of strontian which is found crystallized in the cavities in small quantity, it occurs in large masses either imbedded in the breccia, or lying between the two beds of it. It occurs in blocks of many cwts. in the fields between Ham Green and Leigh, and I am inclined to believe that these are derived from the red loam which lies between the two beds, for I found a mass of it in a ditch lately dug on the slope of the hill below the basset of the upper breccia; but the circumstances were not altogether decisive. The sulphate of strontian from this place is seldom found well crystallized, the best of the crystals that I have met with being tables not exceeding $\frac{1}{4}$th of an inch in length. The entire masses are generally snow white, having the appearance of a coarse grained loaf-sugar, but sometimes they acquire a reddish hue from a small quantity of ochre.

Small veins of galena are found in the breccia. The breccia is found near to Abbot's Leigh, from whence it extends in a position almost horizontal to Crokerne; and it probably occupies the whole space included by a line drawn from Leigh through Failand, Charlton, Portbury and Portishead, and thence returning again through Crokerne to Leigh. On the opposite side of the river it forms the stratum beneath Shirhampton, and runs up the valley below King's Weston hill, extending to the east as far as Sneed Park. In some parts it is found at so high an elevation as to lead to a belief that there may be more than two beds of the breccia: in whatever situation however it is met with its general characters are the same.

The red loamy earth at Hung-road is traversed by veins of fibrous carbonate of lime, which are about an inch thick, and contains hollow calcareous nodules which are often lined on their inner surfaces with beautiful calcareous and siliceous crystals. The quartz varies but little in form; it is almost always in very short six-sided prisms terminated by two six-sided pyramids. It sometimes contains acicular crystals of iron ore: is generally transparent and colourless, but sometimes assumes an amethystine tint. The calcareous crystals vary very much in form, sometimes exhibiting that of the primitive rhomb, sometimes that of the dog's-tooth, and sometimes very complicated figures with numerous truncations. The whole cavity of the nodule is generally lined with small crystals, which are highly phosphorescent when thrown on an iron plate heated almost to redness.

On cutting through the loam there is generally found a bed of ochreous iron-stone about $1\frac{1}{2}$ foot thick. It is not known to what distance this bed of loam extends. The nodules have as yet been found chiefly in Hung-road wood, and some varying a little in appearance are seen on the opposite side of the river.

To the west of Crokerne Pill you find only a low alluvial plain, scarcely raised above high-water mark, and this continues on both sides of the Avon until it falls into the Severn.

With regard to the springs in the district I have been describing, it may be observed that those in the limestone are low and situated in the ravines, breaking out in many cases between high and low water mark. The hot spring at the Wells rises in the limestone 26 feet below high water mark, and 10 feet above low water, and no water is found at Clifton until the wells are sunk nearly to that depth. When you come to the sand-ridge upon which Leigh is situated, the springs are always found to rise in a high level, and they afford a good supply of water. In the horizontal strata to the west of Leigh very good water is obtained by sinking to the second or thick bed of breccia, or at the utmost by sinking a few feet into the stratum. There is a little spring in Hung-road wood which though perfectly clear has the property of covering every thing over which it flows with a brown calcareous crust. The quantity of water is small, and in summer the stream is frequently dried up.

As to the nature of the soil, the valley of Bristol and Ashton is as verdant an extent of pasture land as any in the kingdom. Its rich green colour is contrasted with the dark foliage of the elm, which is the prevailing tree of the county, very few oaks of considerable size being now found.

The limestone district has as yet produced little but heath and fern, the rock in general approaching too near the surface to be favourable to vegetation. Much of it however has been lately enclosed on the southern side of the river, and a part of that is of good promise. Within the limits of the sandstone and of the breccia there is very fertile grazing land.

Note on Magnesian Breccia.

By HENRY WARBURTON, Esq.

VICE PRESIDENT OF THE GEOLOGICAL SOCIETY.

[Read 21st June, 1816.]

THE great stratum of magnesian limestone which passes from Sunderland in the north of England through the centre of the midland counties, suddenly terminates, as is well known, in the vicinity of Nottingham; and I am not aware of its reappearance in the south of England having been noticed except perhaps on the north-eastern border of the Ashby de la Zouch coal-field, where it is said to occur in great insulated masses.

The geological relations of this rock to other strata appear to have been well ascertained in the northern and midland counties, where it is described as forming horizontal beds, and as lying under and parallel to the red marl, or occasionally as alternating with it. It has been ascertained by numerous sinkings in the same counties that the magnesian limestone lies over the coal measures; it is doubtful however whether the coal measures are conformable with the strata of the magnesian limestone; and it is not improbable that they lie under it, having the edges of their tilted and broken sills abutting against the lower surface of the superincumbent rock.

The red marl is so widely distributed in that part of England which lies between Lancashire and the southern coast of Devonshire, and is so frequently found in that district in the same geological position which it occupies in the northern and midland counties in alliance with the magnesian limestone (lying for instance in horizontal strata upon the inclined coal measures, and bounding them at their basset) that it might be expected in some part of its course to discover traces of the magnesian rock. Accordingly I shall mention some instances of the occurrence of a magnesian limestone in the district above referred to, where it either alternates with red marl, or may be considered as connected with it.

In the course of a valuable paper on the Rocks in the vicinity of Bristol, which was long ago presented to this Society, the author, Mr. Bright, has given an account of the strata of red marl which lie along the banks of the Avon. The red marl is there found either lying upon the coal measures, or filling up the vallies that are occasioned by the breaking off of the inclined strata of limestone, where instead of the series of inclined strata that should rise from beneath the limestone, horizontal strata of red marl are found resting upon the broken edges of the limestone or of the first of the rocks beneath it. It is in the red marl last described, as it occurs near Hung-road on the Avon, that Mr. Bright discovered a limestone breccia, of which there are two beds alternating with red marl.

Having examined this breccia on the spot, after having consulted Mr. Bright's paper, and having seen some breccias from the Mendip

Hills of which I knew the nature, and which very much resembled those from the banks of the Avon, I had no difficulty in ascertaining that the cement of the latter was composed of *magnesian* limestone; of which indeed the characters are so strongly marked as to be evident on mere inspection. This breccia consisted of rolled fragments of milk white quartz, and of angular fragments of limestone and sandstone such as are found in the neighbouring inclined strata cemented together by yellow magnesian carbonate of lime; the cement being in great excess. I must refer to Mr. Bright's paper (which I understand will soon be published) for the further description of this rock.

Shortly before seeing the rocks of Hung-road, I had been with the late Smithson Tennant, Esq. to examine the magnesian breccia which he had observed on the Mendip Hills near to the celebrated cliffs of Cheddar. The southern declivity of that limestone chain is there deeply furrowed by wide and extensive combs, in which immense blocks of the breccia many yards in diameter are found lying upon the surface of the limestone. The strata of limestone dip to the south under an alluvial valley, by which they are separated from a low chain of red marl that is found at the distance of about half a mile to the south.

The breccia of the Mendip Hills very much resembles the breccia from the Avon, consisting of fragments of limestone, magnesian limestone, and sandstone cemented together by a yellow magnesian carbonate of lime; but I never discovered in it any of the quartz pebbles which are imbedded in the breccia from the Avon.

Until I had seen the breccia at Hung-road I was unable to account for the presence of these immense insulated blocks upon the sides of the Mendip; but I have since ventured to conjecture that they once formed a subordinate bed in the strata of red marl which are found on the other side of the alluvial valley of the river Axe, and which perhaps were originally continuous across the valley and rested mediately or immediately upon the limestone; but which have since been removed by denudating causes, the hardest and most durable part of their mass, the magnesian limestone, being left behind.

I have heard of the following additional cases in which a magnesian breccia is found in connection with red marl. Dr. Wollaston in the first instance and afterwards Mr. Greenough informed me that a similar rock was found near to Cowbridge in South Wales, a specimen of which was presented by the latter to the Society. Mr. Aikin also has noticed a breccia of the same description at Cáerdeston and Loton in Shropshire.

In thus comparing the magnesian breccia of Bristol with the yellow limestone of the northern and midland counties, I have assumed that the red marl which lies above the coal measures is of the same order with that which lies at the bases of those escarpments, where strata of mountain limestone are broken off; and where instead of the lower beds rising from beneath the limestone we find horizontal strata of red marl filling the plains. I am not prepared to establish this by any positive proof; such evidence as the geology of the plain of Carlisle would afford is already in the hands of Mr. Buckland;* the appearances that are to be sought after for determining this question, and which perhaps may be observed in the neighbourhood of Bristol, are the following: no disposition of the strata is more common in the country between Bristol and the Mendip than that described in Mr. Bright's paper; where a ridge of mountain limestone separates two plains from one another, each containing horizontal beds of red sandstone or marl, the one lying above the lime-

* See his paper, page 105 of the present volume.

stone with the intermedium (perhaps) of the coal measures, the other abutting against the broken edges of the strata of limestone at the base of its escarpment. Perhaps there may be found some valley of denudation connecting together the two plains, which being itself filled with red marl of the same description, there may be an uninterrupted bed of marl through the valley from one plain to the other.

The determining of this question would be of some importance as a matter of speculation, and of some practical consequence to the coal viewer. Those who consider the red marl as one of a complete series of beds succeeding one another in a uniform order, will in every case expect to find the coal measures on sinking through the red marl. If on the contrary we suppose denudatory or other disturbing causes to have been in action previously to the deposition of the red marl, we might expect to find the red marl immediately incumbent upon any rock from the coal measures to the granite inclusive, just as the alluvial beds in which the bones of elephants are found in consequence of previous denudation are discovered resting either upon the blue clay of London, upon the Oxford oolite, or any other bed: and on this view of the subject the red marl will no more be an indication of coal than of any other member of the lower strata.

IX. *On the Magnesian Limestone and Red Marl or Sandstone of the neighbourhood of Bristol.*

By W. H. Gilby, M.D.

[Read November 15th, 1816.]

THE present communication originates from my having discovered in this neighbourhood the magnesian limestone which exists so extensively in the North of England; and as its position with regard to the other formations is remarkably distinct, we have here at least an opportunity of ascertaining its true geological rank, concerning which much uncertainty has prevailed in other quarters.

In the description which I have given in the Philosophical Magazine of the geology of this neighbourhood, it will be seen that we have here two grand divisions of rocks, one occurring always in inclined, and another in horizontal strata. The lowest formation of the first class is the first flœtz or old red sandstone, exceedingly well characterized. It is only in certain tracks that this rock constitutes hilly ground so as to be visible to the eye: but the first flœtz or mountain limestone which rests upon it, has a very extensive range, describing in its course an irregular ellipsis, the direction of which it will here be unnecessary to repeat. I may however remark that analogous to what has been observed with regard to the ellipsis of mountain limestone in South Wales, the dip of its strata varies remarkably in different parts of its course. At the north the strata dip south, and at the south, north. On the east they have a western dip, and on the west an eastern one. In this way the strata tend every where towards a common centre. In the hollow of the basin so formed is deposited a very extensive coal formation, for the particulars of which I refer to the above description. It is sufficient to say that the coal beds and coal measures are always inclined, and when contiguous to the mountain limestone they always dip conformably with it.

It is upon the tops or edges of the inclined strata of these formations that we find the strata of the second division, that is, the horizontal rocks, superimposed in an unconformable position. These horizontal rocks are the same with those occupying so large a portion of the south and south-west of England. The lowest of them are the beds of the red ground, as this formation has been absurdly denominated, consisting of a coarse limestone conglomerate, above which lies a calcareous sandstone, red and white in different places, and then a deposit of red clay, containing gypsum and sulphate of strontian. Above this red ground formation occurs the well known lyas limestone, then the oolites or Bath stones, and lastly the chalk.

The basis of the red ground conglomerate I have generally found to be a common limestone; but being lately at a village on the Bristol Channel called Portishead, I was surprized to find the basis of the conglomerate of a yellow colour, and resembling in appearance some varieties of the Yorkshire magnesian limestone. Upon analysis I found that it did contain a considerable quantity of carbonate of magnesia, the proportion of which varies in specimens taken from different strata. In some strata the basis is so much mixed with sand as to give more than 20 per cent. of insoluble matter, consequently the quantity of carbonate of magnesia is much diminished. The fragmented portions are generally limestone or red sandstone, but we find some strata destitute of sand and fragments, forming in fact a hard compact magnesian limestone. This variety will give 36 or 38 per cent. of carbonate of magnesia. All the varieties are of a yellow colour, and like the magnesian limestone of the north, it often exhibits black spots throughout its substance, and it frequently contains impressions of shells.

The analysis of the compact variety, conducted in the usual way, gave me of

Carbonate of lime . .	53.5
Carbonate of magnesia .	37.5
Oxyd of iron . . .	.8
Insoluble matter . . .	7.
Loss	1.2
	100.0

Now with regard to its geological relations, it in no respect differs from the limestone conglomerate which I have mentioned as the lowest bed of the red ground formation. I have traced it in a continued line by the sea side from Portishead to Clevedon, and it every where contains the same fragments and every where lies horizontally and unconformably upon the inclined strata (which are there the old red sandstone,) in the same way that the usual red grained conglomerate does. It is therefore plainly to be considered as the lowest stratum of the red ground formation, and consequently succeeds immediately to the coal deposit.

It seems to me that the magnesian limestone of the north of England may be referred to the same formation. In Thomson's Annals there is lately a short notice of a paper read before the Geological Society by Mr. Winch, upon the magnesian limestone in the north of England, in which it is stated that the Tees flows over beds of white and red calcareous sandstone containing gypsum, which rests upon magnesian limestone. Now this gypseous calcareous sandstone may be said to characterize the red ground, therefore the magnesian limestone in that district may be safely referred to that formation, and consequently may be regarded as the rock next in succession to the Durham coal deposit. This indeed might be collected from the imperfect sketch Dr. Thomson has given us of its occurrence in that quarter. In a late number of the Philosophical Magazine, it is said that the coal formation of Whitehaven is covered at St. Bees Head by bituminous clay, over this is a limestone containing magnesia and iron, and above this is a red sandstone, connected with which is clay, marl, and *gypsum*. This it will be perceived is almost an exact account of the succession of the red ground strata in this quarter. In Derbyshire we are informed that the magnesian limestone lies in an unconformable and horizontal position over the inclined strata, after the manner of its occurrence in this quarter, it therefore plainly belongs to the same formation, the red ground.

It may seem at first very remarkable that the basis of the limestone conglomerate should be in one place merely a common limestone, and that in another spot, not far distant, it should contain a considerable proportion of magnesia. To those however who have seen how widely the same rock formation, nay even the same stratum, will vary in its colour, hardness, and general structure in different parts of its course, this will cease to be a matter of wonder. In attempting to explain these singularities, it seems to me that we must resort to one of two suppositions: we must either conceive that the fluid menstruum during the deposition of any particular and extensive formation, must have contained in different places different chemical ingredients; or we must conclude that the alteration in structure in an individual formation, has not so much been derived from the addition or substraction of certain chemical ingredients as from the proportion in which these ingredients have crystallized. According to the latter view, during the consolidation of any particular formation, the constituent particles, although few in number, may in different parts of the crystallizing mass have been attracted together in new proportions, so as to give rise to those variations in colour and structure which we so frequently witness. The originality of this theory of crystallization belongs to Professor Jameson, and it seems to me very happily to explain many anomalous appearances of disorder and brecciated structure, which have caused great embarrassment to geologists. In some cases however this theory cannot be applied with any degree of probability. Where we see a particular assemblage of strata, as the limestone conglomerate, manifestly of the same formation, exhibiting in several parts of its extent changes of composition altogether depending upon a difference in its chemical constitution, it is impossible to explain such an occurrence but by supposing that the fluid menstruum must have contained in different places different chemical ingredients. Every geologist will figure to himself illustrations of the want of uniformity in the same rock formation. I may mention however two other striking facts of this nature. The red clay of the red ground is met with in almost every part of England, and almost every where does it contain or is connected with gypsum; but besides gypsum, in this neighbourhood only, it abounds with sulphate of strontian in the form of veins and even large beds. From Mr. Webster's account of the strata above the chalk in the Isle of Wight, it seems quite manifest that what he calls the first fresh water formation was formed at the same period with the marl and gypsum of the Paris basin, containing the bones of birds and fish, but an important difference is that the English strata are destitute of gypsum.

We sometimes meet with magnesian limestone subordinate to the first flœtz or mountain limestone. Sometime ago I discovered a very beautiful sparry dolomite lying in conformable strata upon the mountain limestone near Ross in Herefordshire. This variety contains 44 per cent. of carbonate of magnesia. A small ridge of rock, about four miles north-west of Bristol, upon which Lord de Clifford's house is built, is entirely composed of a magnesian limestone abounding in shells, entrochi, and madrepores; and in an adjoining hill which overlooks Blais Castle it occurs, as far as I can understand, interstratified with the mountain limestone.

A specimen of this variety I find to be composed of

Carbonate of lime	58
Carbonate of magnesia . .	38
Oxyd of iron	1.
Silica and bituminous matter	1.5
Loss	1.5
	100.0

I may remark that this magnesian limestone varies remarkably in specimens taken even from contiguous situations, both in colour and other external characters. It is therefore probable that these varieties would afford slight differences in their chemical ingredients.

I am entirely indebted to Mr. Bright, of Ham Green, for being able to give the last mentioned locality of this rock; for upon informing him of my present pursuit, he desired me to examine the ridge to which I have just alluded, as he conceived it to be composed of a magnesian limestone.

X. *On the Strata at Whorlbury Camp, in Somersetshire.*

By GEORGE CUMBERLAND, Esq.

HONORARY MEMBER OF THE GEOLOGICAL SOCIETY.

[Read 3d November, 1815.]

WHORLBURY CAMP is a considerable Roman station situated just above Weston-super-Mare on a high and well defended promontory that projects into the Severn sea. At the foot of the promontory, and at its northern extremity, is a small island, connected to the main land by a bank of rocks, and always accessible at low water. The island contains about three acres of green sward, the remainder of the surface consisting of limestone rocks, which are deeply excavated. It serves during the sprat season as a place of resort for fishermen, who have extended their *sprat-hangs* from the island to the main land.

A narrow horse road forms the descent from the downs in the island to the level of the sea, and it is just where the road begins to quit the sward on the left hand side opposite the sea, that a narrow stratum of soft red sandstone appears. This sandstone is of the consistence of schist at its surface, and has its laminæ divided by a hardened ochreous marl. Its whole thickness is about 6 feet, and it dips at an angle of about 47°.

In the marly part of this stratum a fossil is found resembling a cane or jointed bamboo. It is rarely obtained more than five inches long, generally curved, but sometimes straight, and of all degrees of thickness from a quarter of an inch to five inches. These fossils lie in great disorder, and are apt to separate at their joints on extracting them from their matrix; and many appear to have had their joints separated as they lay in the sandstone, the ends of the joints being covered with a thin coat of quartz. Many of these fossils have their hollows between the joints filled with hard sandstone, but the greater part have their centres quite filled with the hardest white quartz; and where there are cavities, which rarely happens, they are sometimes found to contain crystals of calcareous spar.

When I first discovered these fossils, ten years ago, I found them upon the beach just under the sandstone rock, and took them for corallines; but having since found them abundantly in situ, and examined a number of them more minutely than before, I am induced to regard them as juncous bodies. I know not at least how to class them as corals, since they have not the smallest trace of any passage from one joint to another. Should they be ranked however among the coralline bodies, they must be allowed to be of a very singular nature.

Below the beds containing these fossils a grey limestone is found, in which no traces of marine bodies appear.* On the top of this limestone is a thin bed of very yellow marl, and then a thin bed of purple and blue marly earth. Then appears the red sandstone containing the cane fossils, six feet thick. Above it is another bed of

* Upon the summit of the hill at Uphill (which forms the point of the bay of Weston opposite to Whorlbury) the canes are found in a coarse grey limestone, and may be observed on the same spot in the stones of a ruined mill accompanied by small shells of the winged anomia.

blue and purple marl about three feet thick, and above that a considerable bed of limestone of a reddish grain, over which is found a bed of compact red limestone, without fossils. Above this is a vast mass of coarse limestone without fossils, and beyond it many considerable strata of grey limestone, succeeded by others that are thin and exhibit on their surfaces, when exposed to the action of the sea, some traces of the fossil I have been describing.

Just above the ends of the strata that contain the cane fossil, which at the distance of a few feet would have cropped out on the sward of the downs, there is found a mass of a partially indurated pale yellow sandstone, separated into strata by thin layers of sand. This sandy mass is in part soft, and in part indurated, and contains cavities filled with loose sand. It dips at a very small angle in a direction opposite to the strata which contain the cane fossil, and lies upon the ends of these strata as sand would lie that had been thrown over them by a stormy sea. It seems no where more than a foot thick, and is covered with limestone rubble to the depth of two feet, upon which reposes the turf.

In this sandstone are long stalks of alcyonia, resembling those at the back of the Isle of Wight, but the mass in which they are found being of inconsiderable size, I have not been able to find in it any heads or roots of that fossil. These stalks are white like lime, and although in general much decomposed, exhibit their cylindrical forms very exactly, and if taken in fragments look like carious bones.

I observed in a broken piece of the sandstone upon the horse road already mentioned, a stalk of the alcyonium about two feet long, and branching at one extremity. I also found among the rubbish other fragments of stems, which must have been of considerable magnitude.

The under part of this thin bed of sandstone is stalactitical, forming friable concretions of sand, dependent chiefly from the stems of decayed alcyonia. Were it not for these alcyonia, and for the limestone rubble which is found upon the surface, any one would suppose this bed to be of very recent production, formed of sand and ochre concreted by the action of the sea.

XI. *Observations on the Hill of Kinnoul, in Perthshire.*

By J. MAC CULLOCH, M.D. F.L.S. President of the Geological Society, Chemist to the Ordnance, Lecturer on Chemistry at the Royal Military Academy, and Geologist to the Trigonometrical Survey.

[Read March 4th, 1814.]

IN transmitting to the Society the specimens from the hill of Kinnoul which accompany this paper, I have thought it necessary to enter into a description somewhat detailed, of appearances attended with considerable interest, and involving some difficulties. We are yet, it is to be feared, in want of a theory capable of solving all the cases which the increased activity of geological research is daily bringing to light. It is among difficult and unexplained phenomena that we are to seek for the stimulus which will lead us to pursue those researches on the multiplication of which alone we can hope to found a true system; and it is to a salutary distrust of the all-sufficiency of any hypothesis, that we must look for protection from its paralyzing effects.

The hill of Kinnoul, from which the specimens now before the Society were selected, has been frequently visited by geologists and mineralogists, more perhaps with a view to the minerals which the rock contains than for the purpose of examining those remarkable geological phenomena which it exhibits. Except the account of it in the travels of Faujas de St. Fond, I know not that any description of this hill has been laid before the public. The peculiar opinions of that author are well known, and I believe that in this country it is not necessary to enter into any refutation of his conclusions. As far indeed as the appearance of the trap rocks and their peculiar mineralogical character are concerned, the Huttonian theory offers an explanation better able to fulfil the requisite conditions than his hypothesis. I shall therefore decline entering into a comparative statement of systems so well known, or investigating the solidity of the examples which the French geologist has adduced from Great Britain. Although never formally discussed, the arguments and objections are familiar to most of those who have engaged in geological researches, and a full examination of his individual cases would lead into a dissertation foreign to the purpose of this notice. I may therefore briefly remark that the chief part of the hill in question consists of trap, which, like the other rocks of this family that alternate with secondary strata, is known in the Wernerian nomenclature, by the term of *floetz trap*. I do not pretend to name its rank in the several *formations* enumerated under this general title, as I much doubt if the assigned characteristics are constant. If they are universal it will not be difficult to give it its place in the system when I have described its features and connections.

The phenomena which are most interesting in this hill render it necessary to take a range somewhat wide before describing the rock itself, without which we should be unable to trace its connection with the neighbouring rocks and the surrounding country.

Those who are acquainted with the mineral geography of Scotland know that a great portion of its northern district is separated, in many places very accurately, by a tract of breccia from the secondary rocks which occupy its middle portion. An irregular line drawn through Troup head, Dunnotter, Blair gowrie, Delvin, Creiff, Tillycoultry, Callander, Aberfoyle, Drymen, and other almost nameless places to the westward, marks the range of this breccia, leaving on the north side all those rocks distinguished by the name of primary, with many of those which bear the name of *transition*, and being followed to a certain distance southward by the usual series of sandstones and other secondary strata. In the middle of this secondary tract arises the hill of Kinnoul, forming the westernmost part of a long irregular ridge which extends from the north of Dundee to Perth, where it terminates. Through part of this course it exhibits an abrupt elevation to the south, subsiding northward by a more gentle declivity into the great plain of Stormont and Strathmore. Its visible boundary to the south is the alluvial plain of Gowrie, while to the north the red sandstone and that breccia which accompanies or precedes the sandstone, form the only rock for a distance of many miles, till we arrive at the mountain schistus. I am not acquainted with the connection of this ridge at its eastern end.

The height of Kinnoul, (that part of the ridge which I purpose to describe) is 600 feet above the plain of the Tay, and it occupies a length of a mile or thereabouts, exhibiting many abrupt faces in a state of constant ruin and degradation, which have thus formed a rapid slope at the feet of the precipices.

The rock itself contains many of the most remarkable varieties belonging to the tribe. It will be sufficient to give a general description of them, as no purpose could be served by an attempt to define rigidly either the spaces which they respectively occupy, or the order which they follow, circumstances which are subject to such variations as to obey no general rules. In some places a black basalt may be observed, but it is every where amorphous and approaches here and there to the most ordinary kinds of compact greenstone. This variety is the least abundant. It occasionally assumes a brownish or reddish colour, retaining its original compactness and uniformity of texture, and thus forming a member of the trap family, to which no distinct name has been assigned. This becomes at times porphyritic, containing numerous minute crystals of felspar imbedded in a blackish or brown basis, and forming a showy variety of trap porphyry. The felspar, as far as I have observed, is always opaque. Sometimes the rock is both porphyritic and amygdaloidal, but perhaps the greater part of the whole hill consists of a rock merely amygdaloidal, the base of which is either the well characterized basalt above described, or that variety which is less marked, or else a rock intermediate between this latter and indurated clay.

The character of the amygdaloid varies considerably according to the substances which it contains, and these are green earth, calcareous spar, quartz, and chalcedony.

Green earth or chlorite, is the substance which perhaps occurs most frequently, and it is indeed that by which the trap of Kinnoul is particularly distinguished from almost all the rocks of this tribe in Scotland. The nodules vary but little in size, and although they are occasionally met with of the bulk of a filbert, they are generally little larger than a grain of mustard. But they vary much in colour, assuming all shades from greenish black to the brightest verdegris green. They differ equally in texture, being sometimes minutely powdery, at other times of a large scaly fracture, like the chlorite which occurs in primary rocks. It is this substance which Faujas has called steatite ; no real steatite being found in the trap of Kinnoul, although it is common in that of the island of Sky.

When calcareous spar forms the amygdaloidal nodule, it is commonly invested with a coating of chlorite. These nodules are generally of a small size, and of a spheroidal or ellipsoidal form. Their fracture is crystalline, and they are often perfectly transparent, but in all cases where they are in immediate contact with the trap they possess no external crystallized form. It is only when in contact with quartz or agate that they exhibit an external as well as an internal appearance of crystallization. In other words, they appear to bear the impression of the basalt when they are in immediate contact with it, while on the contrary, when in contact with quartz or agate, they impress their forms on these. Calcareous spar thus assists in forming a compound nodule not uncommon in these rocks. The spar is sometimes crystallized at liberty in a cavity of quartz or agate; at other times it is closely invested by quartz, forming the center of a solid nodule, or is dispersed in small crystals irregularly scattered through the whole pebble. Both these substances occasionally retain their perfect characters, even when in immediate contact; while in other instances the quartz for some small distance in the vicinity of the calcareous crystal is converted into chert or into agate.

Quartz is found among these rocks in the usual variety which it exhibits when it is an inmate of trap. In its simplest form it is a crust investing a cavity, and terminating interiorly in assemblages of crystals of various sizes and of various colours, white, brown, and amethystine. The exterior quartzy crust often puts on the character of chert, sometimes that of chalcedony; not unfrequently the chalcedony appears in the form of a stalactite, of which the several icicles are encrusted with beautiful and crowded assemblages of crystals. These stalactites of crystals depend, as is usual in stalactites, from the upper parts of the cavity. The nodules of this description are of various magnitudes and often of a foot or more in diameter, and, like the smaller ones, are shut in and surrounded by the solid rock on all sides. It is more common for the boundary of the quartz in the immediate vicinity of the trap to be formed of various zones of coloured chalcedony. The quartz in this case assumes a peculiar well-known aspect, and is called in the Wernerian nomenclature, amethyst, although most commonly of a white or watery appearance. Different zones of chalcedony and quartz will even at times succeed each other in the same nodule.

But the imbedded mineral from which this place has acquired its greatest celebrity, is the agate, or coloured chalcedony, with which it abounds, but which it possesses only in common with many other places in Scotland. The nodules of this substance vary exceedingly both in size and colour, and their general aspect is much too well known to need any description; yet a few circumstances respecting them deserve to be considered, as they involve difficulties which it is incumbent on any general theory of the formation of these rocks to explain. Their external surfaces, I believe invariably, bear those marks of indentation by the surrounding rock which determines their posteriority of formation, or at least their posteriority of induration, to that of the rock in which they are imbedded. Their internal structure is also most commonly zoned, with irregularities corresponding to those of the external boundary; but in some cases they exhibit a complication of structure, which as it cannot be well described in words, I have ventured to represent in the accompanying sketches. In the first example, a stalactite may be observed occupying a portion of a hollow cavity, marking as in the case of the larger quartz cavities described above, the gradual deposition of siliceous matter by infiltration.* The change of disposition in the zones in the figures N° 2 & 3,† seems to be the result of a similar process, the horizontal parallel lines

* Pl. 10. N° 1. † Pl. 10. N° 2 & 3.

appearing to be the stalagmite formed on the bottom of the cavity, and proceeding from below upwards in successive additions, in a way similar to that which may be observed in the complicated chalcedonies of Faroe. The peculiarity observable in the fourth ‡ example can be explained only by a similar supposition.

Such are the circumstances of chief importance which occur in the trap nodules, and which, although by no means limited to this place, appear deserving of notice, on account of the intimate relation they bear to any general theory. It is incumbent on that hypothesis which explains one of these difficulties, to explain the others also, or at least to require nothing which shall exclude the means of explaining them. It is almost needless to say that I here allude to the different explanations which the aqueous and the igneous theories of the origin of trap have given of the imbedded nodules. Each hypothesis has its difficulties when it refuses to yield ground to its antagonist ; yet, is each perhaps incapable of exclusively and clearly explaining the appearances in question. The stalactitical forms which line the hollow cavities, can perhaps have resulted only from watery infiltration, yet the existence of the previous cavities can scarcely be accounted for by that hypothesis which considers trap as a deposit crystallized from an aqueous solution of earths.

Different substances are found occupying veins as well as nodules in this rock ; among these, calcareous spar and quartz are the most common. Sulphate of barytes occurs more rarely, as do chert and agate, the latter of which often exhibits the same zoned appearance in the veins which it does in the nodules.

The great abundance of chlorite in this trap might have rendered it probable that the rare mineral heliotrope was an inmate of it:

‡ Pl. 10. N° 4.

accordingly I have laid before the Society some small specimens found there by Lord Gray's workmen in removing earth at the foot of one of the precipices. It forms veins of different dimensions in the fragments of rock, with which it is intimately united: it is of a finer green colour than that which is found in Rum, but none of the specimens which I procured contain the red spots for which this mineral is principally valued. It sometimes is associated with a green quartz, coloured apparently by the same material, the more transparent parts having the aspect of plasma, which not improbably owes its colour to chlorite. I did not succeed in finding this mineral in the face of the rock from which these specimens appear to have been detached, but among the agate pebbles there to be seen I obtained some which present appearances illustrative of its composition. These pebbles are frequently incrusted with a coating of chlorite, and in those to which I allude the chlorite penetrates the external part of the agate to the eighth of an inch, so as to convert the outer crust into heliotrope. I may here also add that I have observed this mineral among the agates found in Ayrshire, and that it occurs in the island of Mull, where it forms spheroidal nodules in basalt, so that it is not rare in Scotland. When I say that zeolites are not found in Kinnoul, I ought to add, that I picked up one loose and bad specimen of red stilbite.

On the top of the great mass of trap which I have now described, there is to be seen a portion of a bed of conglomerate, consisting of trap pebbles imbedded in a cement of the same nature, a rock improperly designated by the name of trap tuff. The origin of this rock is not easily explained, but I must defer the remarks that might be offered on this subject to some future opportunity.

The last and most remarkable circumstance occurring in Kinnoul is that of an extensive range of those junctions with other rocks which are supposed by many persons to demonstrate the igneous origin of trap.

About the middle of the broken face of the hill a portion of a stratum of sandstone is to be observed entangled in the mass of the rock, and at the same time much broken and bent. But there is nothing in its appearance so very different from the other instances of this fact which have been frequently described, as to call for a particular detail.

Proceeding from this point eastward another set of junctions is seen, of which I have not met with any resemblance in other places, and which offers some anomalous appearances. The stratified rock which is here conjoined with the trap, is perfectly similar to the best characterized graywacké slate, of a fine grain and greenish hue. It is easily separated into flakes, and on being broken, exhibits slender scales of mica. A remarkable change of its aspect may be seen where it approaches the trap, and before it comes into actual contact with it. If the weathered surface only be examined, it shews a series of solid laminæ alternating with, or rather graduating into other laminæ which have a spongy appearance, or abound with open cavities similar to those of weathered amygdaloids. These cavities increase in number and magnitude towards the middle of the spongy laminæ. The same appearance of pores or cavities is to be observed at most of the points of contact where the graywacké is much contorted and mixed with the trap. A good illustration of this appearance may be given by comparing it with that assumed by the burnt micaceous schist sometimes found in the walls of the vitrified forts, and which by the action of the fire on some of its laminæ is swelled up and thickened, apparently from the disengagement of aeriform matter. When, however, this stone is broken, the cavities are found to be filled by calcareous spar, and exactly resemble those which occur in the trap rocks themselves.

I remarked above, that the schist is often much contorted and mixed with the trap. This mixture affords a great variety of appearances, a variety so great that no limited series of specimens, nor any drawing less than that of the whole face of the hill itself, could give an adequate idea of them. *The accompanying sketch exhibits one of the most general. In many parts innumerable detached fragments may be seen imbedded in the trap, the whole of the schist displaying a greater disorder and confusion than the sandstone does in any of the instances hitherto described. In a few places another singularity may be remarked. Veins of different dimensions, and ramifying in different directions, are to be found traversing considerable portions of the rock, and in some instances terminating in the schist, with which they are continuous. As the schist graduates into the vein, its laminated texture disappears, but in other respects there is an identity of composition between the vein and the laminated schist, at least for a considerable space. The same loss of the laminated texture of the schist takes place wherever, from its proximity and intermixture with the trap, it is materially perverted from its original even direction. In other respects the identity of substance is here, as in the other case, preserved, nor is any decided line drawn to determine the discontinuation of the laminated structure, either in the progress to contortion or ramification. However contradictory it may appear at first sight, that the same substance should exhibit both the character of a laminated and bedded rock and that of a vein, the state of the incurvated and contorted masses may perhaps by analogy assist in solving the difficulty. It is not an unreasonable supposition, that

* Vide Plate, 11.

a rock in a condition to be bent and incurvated, should by a peculiar application of external force admit of that more continued prolongation which in certain circumstances would produce a vein. The analogous incurvations indeed, and the evident prolongations which take place among the laminæ of mica slate, and in the contorted veins of granite and quartz which traverse them, offer cases of parallel difficulty. If the solution which I have offered be incompetent to this purpose, it is only one more added to the numerous unexplained phenomena which are to be found attending the subject of geology wherever we turn our regards: for we can then look to neither of the prevalent hypotheses for an adequate explanation of this case; the mechanical structure of the schist as indicated by the parallel disposition of the mica, combined with the want of similar mechanical arrangement in the vein, offering a difficulty to the one as great as it is to the other. I speak of a mechanical arrangement in the schistose rocks as if it were admitted by all, because it appears a circumstance attending on many of these rocks, as perfectly demonstrated as any thing of which we have not actually witnessed the creation, can be demonstrated to our senses.

For the same reasons I speak without hesitation of the displacement, fracture, and incurvation of the graywacké which is imbedded in the trap, and in so doing it is not my wish to speak the language of an hypothesis, but to describe a fact, in such terms as can alone convey an adequate notion of the appearances to a mind divested of all hypothesis. If Nature has really produced imitations of mechanical arrangement by processes unknown to us, it is to be wished that the mode in which they have been produced may be shown, either by means of experiments, or by analogies drawn from that science of which the laws regulate the great proceedings of Nature as they do the narrow operations of our own laboratories. Till that be done, it is not only legitimate, but it is indispensible for the purposes of accurate reasoning, to describe facts by their most obvious analogies where we cannot pronounce on their nature, to call that a mechanical arrangement in Nature which bears a resemblance to mechanical arrangement in the products of art, and to consider that only as the result of chemical action in Nature, which is imitable by chemistry under the direction of art, or has been demonstrated to be in other cases the result of chemical laws.

It appears then that at Kinnoul portions of schist are found presenting an obscure appearance of connection with the red sandstone. It also appears that this rock exhibits but a small portion of a bed, instead of that great and extensive continuity in which it is generally disposed. And it is further seen that this portion is entangled and almost surrounded by a mass of rock of a peculiar aspect, which bears no mark of stratification or of mechanical arrangement, and that it is much bent and contorted, so as to be irregularly intermixed with the unstratified mass. Lastly, it is to be remarked, that appearances of fracture as well as contortion occur in the stratified rock; that veins pass from it, and that fragments of it are dispersed throughout the unstratified one; as far at least as a judgment can be formed from the only view we can obtain of the imbedded portions.

It is difficult to see on what other ground these and similar appearances can be explained than on that of motion; the action of the unstratified on the stratified mass, and that stratified mass existing in two different conditions, a state of softness capable of extension, and a state of hardness capable of fracture. Further than this the facts visible at Kinnoul do not perhaps bear us out, and beyond this point it is not my design to venture, since the simplest record of facts is perhaps the most important service which can now be rendered to geology.

Before concluding this paper I must add, that at the eastern end of Kinnoul a sandstone breccia may be observed, apparently lying below the trap, and similar to that which is the lowermost of the secondary strata throughout the whole of this district.

XII. *An Account of some attempts to ascertain the angles of the Primitive Crystals of Quartz and of the Sulphate of Barytes, by means of the reflecting Goniometer; together with practical reasons for presuming that the admeasurements assigned by Haüy to several varieties of the parallelopiped and of the octohedron are inaccurate.*

By WILLIAM PHILLIPS, Esq.

MEMBER OF THE GEOLOGICAL SOCIETY.

[Read 16th June, 1815.]

THE primitive crystal of quartz is considered to be an obtuse rhomboid, of which the angles are given by Haüy in his 'Tableau comparatif,' &c. as being 94° 24′ and 85° 36′: that of the sulphate of barytes is a quadrangular prism with rhombic terminations, the angles of which according to the same authority are 101° 32′ 13″ and 78° 27′ 47″. The results of some attempts to verify these admeasurements by subjecting the natural planes of the crystals of both these substances, as well as some regular fragments of the latter, to the reflecting goniometer, form the particular object of the present communication.

The first attempts to ascertain by this means the angles of the rhomboid of quartz, were made upon some minute primitive crystals from Bristol: seven of these gave incidences on the one angle varying from 94° 12′ to 94° 17′, and on the other from 85° 44′ to 85° 52′; not more than two or three agreed. But the reflections afforded by these crystals were not perfectly clear, probably owing to their enclosing a multitude of very minute diverging fibres, perhaps of the oxide of iron. Numerous attempts were afterwards made upon some crystals obtained under the name of Bornholm diamonds; many of which exhibit, on the primitive crystal, the planes of the modifications producing the pyramids and the prism, not in a very advanced state; the measurements they afforded were much the same as, and by no means more regular than, those obtained from the primitive crystals from Bristol.

I next carefully examined about 300 very small, brilliant, and colourless crystals of which I became possessed under the name of Gibraltar diamonds, and selected a large number presenting the most perfect reflections. These crystals generally shew both pyramids, separated by a very short intervening prism. But even those that were found to reflect the best, did not all present similar results.

Several of these however afforded perfect co-incidences of 94°. 15′ on the one angle, and 85°. 45′ on the other. Two of the seven crystals from Bristol, and two or three from Cornwall, with brilliant reflections, gave exactly the same admeasurements: and since these are the only incidences that were found to agree, I am induced to suppose that they approach, if not actually constitute, the true value of the angles of the primitive rhomboid of quartz. It will be observed that the former of these differs from that given by Haüy, in being 9′ less; the latter, in being 9′ more. It seems requisite to add, that among the very numerous crystals that I have attempted to measure by means of the reflecting goniometer, not one has afforded results agreeing with Haüy.

From among several hundreds of detached crystals of the sulphate of barytes, eight were selected, which afforded reflections so perfect, that the expectation of actual agreement in the admeasurement to be obtained from them, naturally arose; but in this I was disappointed on finding them to vary on the one angle from 101°. 25′ to 101°. 51′; and on the other, from 78°. 10′ to 78°. 28′.

This want of co-incidence in the admeasurements obtained from crystals which, on account of their brilliancy, seemed unexceptionable, induced me to submit to the reflecting goniometer some cleavages made in the direction of the primitive planes, and selected with the utmost care. Six of these agreed perfectly in affording on each of the acute angles of each fragment the incidence of 70°. 18′, and on each of the obtuse angles that of 101°. 42′; the former being 9′. 47″ less, and the latter, in being 9′. 47″ more, than the value assigned to these angles by Haüy.

This remarkable agreement afforded by the cleavages of the sulphate of barytes, induces regret that it is not in like manner practicable to obtain regular fractures of quartz. The evidence above cited in regard to the difficulties attending the measurement of that substance, by means of the reflections afforded by the natural planes of its crystals, tend, it must be owned, to render it somewhat uncertain whether the only co-incidences obtained, viz. those 94°. 15′ 85°. 45′, are the true angles of its primitive rhomboid; but the co-incidences given by the fracture of the sulphate of barytes, seem to authorize the conclusion that the true value of the angles of its primitive crystals are 78°. 18′ and 101°. 42′.

It would not perhaps be reasonable to draw, from evidence relating only to two substances, the inference that the actual value of the angles of mineral substances in the general cannot by any means be obtained by admeasurements attempted upon the natural planes of their crystals. The difficulties attendant on many of them will be found to be very great; in regard to some they seem insurmountable. Of a very large number of crystals of the red oxide of copper in my possession, some hundreds of which were selected on account of their extraordinary brilliancy, solely with the view of subjecting them to the reflecting goniometer, I have not been able to find a single crystal of which the primitive planes are adapted to its use.

The attempt to measure the angles formed by the meeting of the primitive planes of the red oxide of copper, may reasonably be supposed to have been made only for the sake of corroborating the results of calculation. These results cannot perhaps be doubted, when it is considered that the primitive crystal of this substance is the regular octohedron, which is often found to pass into the cube; for the angles of the one being known with certainty, it follows that those of the other may be calculated with precision. This observation will apply to all those substances which have for their primitive crystals, either of those solids, or the rhomboidal dodecahedron, the regular tetrahedron, or the hexahedral prism.

But there are many forms of primitive crystals, included under the term parallelopiped (amongst which are those of quartz and the sulphate of barytes,) as well as several varieties of the octohedron, both acute and obtuse, which do not, with the same ease, seem susceptible of equal certainty in the determination of the value of their angles. I am induced to believe that many, if not most, of these, which have already been given by Haüy, will be found to demand revision.

As it may be expected that reasonable cause should be shewn for doubting authority so eminent, I shall briefly subjoin the reasons that have principally led me to adopt this opinion.

The first step towards ascertaining the value of the several angles at which the numerous planes of crystals meet each other, is altogether a mechanical operation dependent on the skilful use of the goniometer; and for this purpose doubtless brilliant and well defined crystals have been selected. Having arrived at the admeasurement of some one prominent angle, by means of the goniometer in common use, it can scarcely be doubted that its value has been assumed as a basis on which to calculate the rest. This, there is reason to believe, was the process adopted by Haüy in regard to his determination of the angles of the primitive crystal of the sulphate of barytes, which he has given to *seconds*, and which the common goniometer will not indicate. It must be obvious that the perfect fidelity of this preliminary mechanical determination is most essential.

It is no trivial argument against the accuracy of this practice, that those who are the most skilful in the use of the common goniometer, have differed in the results obtained from the same substances. But, even were it possible to depend upon the accuracy of the instrument, and upon the skill of the hand using it, there seems much reason for doubting whether the planes of such crystals as are best adapted to its use can be relied on. I allude of course to such as are of considerable dimension. These, when submitted to the reflecting goniometer, rarely agree with each other; and the measurements they afford almost always differ very considerably from those obtained upon small crystals; which much more frequently give similar results, but which are too minute, as it seems to me, for the accurate use of the common goniometer.

The difficulties already described as having attended my numerous attempts to verify the admeasurements of Haüy in regard to the primitive crystals of quartz and the sulphate of barytes, belong not to the crystals of these two substances only. I have found these difficulties to exist in different degrees in respect to more than twenty others, of each of which I possess very numerous isolated crystals. Amongst these, the red oxide of copper already mentioned is one, though of comparatively little importance; because, as the real value of the angles of the cube, which it occasionally assumes, are known, the rest may be calculated with precision.

But there is still another circumstance which forcibly shews the great difficulties attending the accurate admeasurement of the angles formed by the meeting of the natural surfaces of crystals, by subjecting those surfaces to either goniometer. It is not often found that the best selected afford incidences corresponding with the results obtained by calculation, even where we must be assured that calculation may be relied on; as is the case in respect of all those substances which assume the cube, the regular octohedron, the rhomboidal dodecahedron, or the hexahedral prism. The angles formed by the meeting of the planes of these solids are known, yet rarely do the best selected crystals accurately afford the admeasurements which belong to them in their perfect state. It is not sufficient that they approximate; they should be precise.

The foregoing are my principal reasons for adopting the belief that many of the determinations of Haüy in regard to the admeasurements given by him of the primitive crystals comprehended in the term parallelopiped, and of the numerous varieties of the octohedron, will be found inaccurate. It is probable that the reflecting goniometer will render service to science by detecting some of the inaccuracies incident to the use of the common goniometer.

The accuracy of which the reflecting goniometer is capable, requires, for the reasons above assigned, great patience and perseverance in measuring the angles of crystals on their natural planes; and the chief, if not the only, difficulty attending its use, is the finding of crystals that are adapted to it. It is requisite not only that their planes should be brilliant, but also that the image of the line or bar reflected upon them should be perfectly defined; its edges should be seen with an exactness which they who have not given attention to the subject will scarcely believe to exist on surfaces so small. No reliance can be placed upon a solitary admeasurement taken upon the natural planes of one crystal, however brilliant and perfect they may appear; it is essential that several should be found to exhibit a perfect agreement, before it can be assumed that the actual value of any angle has been obtained. From one crystal of quartz, nearly perfect at both terminations and affording pretty clear reflections, I obtained six admeasurements of the same angle from its various planes. One of 94° 9′, another of 94° 12′, a third of 94° 16′, and three of 94° 11′. I did not discover one crystal whose planes were sufficiently perfect to enable me to obtain corresponding measurements from plane to plane, around it.

It cannot however, be doubted, that much of the labour attendant on the use of the reflecting goniometer in the measuring of the angles of crystals on their natural planes, will be spared, and that the results will be much more satisfactory, because more accurate, whenever cleavages can be obtained sufficiently brilliant for its use. In almost every instance in which I have tried it upon the planes produced by good fractures, the success has been complete. The great value of this instrument, which may be used with readiness and ease, demands the attention of every one who has the slightest pretension to crystallographical research. I feel much pleasure in adding an instance of the accuracy of which it is susceptible. Having seen in some periodical publication, a notice that Dr. Wollaston had discovered differences in the value of the angles of the primitive rhomboids of the carbonate of lime, the bitter-spar, and the brown-spar, which had previously been considered to be alike, and conceiving them to be erroneously quoted, as in fact they were, I submitted to the reflecting goniometer some cleavages of the two former, not having a portion of the latter adapted to its use. I afterwards called on my friend Arthur Aikin, Esq. who shewed me an account of the exact admeasurements obtained by Dr. Wollaston, and had the satisfaction of convincing him that those obtained by me perfectly coincided therewith.

I possess thirty-eight varieties of crystals of quartz, resulting from the combinations of eleven modifications on the primitive rhomboid; and of the sulphate of barytes I have one hundred and thirteen varieties, the result of eighteen modifications of the primitive crystal; the former are principally foreign, the latter chiefly from the north of England.

XIII. *On the measurements, by the reflecting Goniometer, of certain primitive Crystals; with observations on the methods of obtaining them by mechanical division along the natural joints of Crystals.*

BY WILLIAM PHILLIPS, ESQ.

MEMBER OF THE GEOLOGICAL SOCIETY.

[Read 6th December, 1816.]

IN a communication read before the Society about the middle of last year, I detailed some reasons for concluding that the angles of some primitive crystals included in the terms parallelopiped, as well as some varieties of the octohedron, had not been accurately ascertained. Since that time, further attention to the subject has confirmed those observations. I proceed to lay before the Society the results of investigations in regard to ten other substances, two or three of which have been measured by the assistance of the reflecting goniometer only upon their natural planes, on account either of their not yielding to mechanical division with sufficient freedom, or not yielding to it at all. The rest have been fractured with exactness enough to allow the use of that instrument; and for that reason, the results allow of more complete confidence, than if there had been a necessity for relying on their natural planes.

It would have spared me much time and difficulty, if to the other labours of the Abbé Haüy and the Count de Bournon, they had added some account of the means by which the mechanical division of each substance may be most readily attained. Concluding that the same difficulties are felt by others, I shall add some remarks on that subject, in regard to such of the substances as I have been able to cleave with regularity, presuming that it may tend to render the way more easy for those who may desire to attain the same object. It must be obvious that very different means have been resorted to; for no one will imagine the same to be applicable to the sulphate of barytes and the sapphire: one of them soft, and yielding to mechanical division with the utmost ease; the other, the hardest of all the earthy minerals, and splitting only by the application of great force, and even then, not without much difficulty and perseverance in more than one direction. Still further remarks will be needful in regard to one of the substances, the sulphate of lead, since the mechanical division it affords has necessarily led me to differ from the Abbé Haüy and the Count de Bournon, as to the form of its primitive crystal.

The following pages would not have been offered to the notice of the Geological Society, but for such reasons as belong to the importance of determining with precision not only the forms, but the measurements of the angles of primitive crystals. If it should be thought that it is assuming too much, to differ from authors so distinguished as the Abbé Haüy and the Count de Bournon, I beg to offer the same apology as was offered by the latter for differing from the former in the same respects. 'The attainment of truth is the great object that every man ought to propose to himself, who has any pretension to science.' *

Such of the figures in the accompanying drawing † as suited my purpose were copied from those of Haüy, and when compelled to alter the form, the letter by which he designates each plane, has been studiously retained for the more ready reference to his works.

* Catalogue, p. xvii. † Pl. 12.

Nothing having been said in my papers on the oxide of tin, and the sulphate of barytes and quartz, on the mode of cleaving them, they are now placed in the following table at the head of the ten substances forming the particular objects of this communication, chiefly to allow the opportunity of saying a few words on the subject of splitting them.

Substance.	Primitive Crystal.	References to Plate 12.	Measurements. According to Haüy.	According to Bournon	By the Reflecting Goniometer
Oxide of Tin	An obtuse octohedron of which the common base of the pyramids is square. Haüy.	Fig. 1. P on P	67° 42′	. . .	67° 50′
		P on the opposed plane over the apex	. . . .	. . .	112° 10′
Sulphate of Barytes	A right prism, with rhombic bases. Haüy	Fig. 2. M on M	101° 32′ 13″	. . .	101° 42′
		M on the adjacent plane, over the edge A.	78° 27′ 47′	. . .	78° 18′
Quartz	A slightly obtuse rhomboid. Haüy.	Fig. 5. P on P	94° 24′	. . .	94° 15′
		P on P′	85° 36′	. . .	85° 45′
Zircone	An obtuse octohedron; the common base of the pyramids is square. Haüy.	Fig. 1. P on P	82° 50′	. . .	84° 20′
		P on the opposed plane over the apex	. . . .	. . .	95° 40′
Staurotide	A right rhomboidal prism Haüy.	Fig. 2. M on M	129° 30′	. . .	129° 20′
		M on the adjacent plane over the edge A.	. . . .	. . .	50° 40′
Anatase	An acute octohedron; the common base of the pyramids is square. Haüy.	Fig. 4. P on P	137° 10′	. . .	136° 47′
Specular Iron	A slightly acute rhomboid. Haüy.	Fig. 3. P on P	87° 9′	. . .	86° 10′
			92° 51′	. . .	93° 50′
Diopside	An oblique rhomboidal prism. Haüy.	Fig. 6. M on M	87° 42′	. . .	87° 5′
		M on the adjacent plane, over the edge A.	. . . .	. . .	92° 55′

Substance.	Primitive Crystal.	References to Plate 12.	Measurements. According to Hauy.	According to Bournon	By the Reflecting Goniometer
Cyanite	An oblique prism of which the plane P is very nearly a rhomb. Haüy.	Fig. 7. M on T	106° 6′	. . .	106° 15′
		M or T on the adjacent plane, over the edge A.	. . . .	. . .	73° 45′
Corundum	A slightly acute rhomboid. Haüy & Bournon.	Fig. 3. P on P	86° 38′	86°	86° 4′
		P on P′	93° 22′	94°	93° 56′
Sulphate of Strontian	A right prism with rhombic bases. Haüy.	Fig. 2 M on M	104° 48′	. . .	104°
		M on the adjacent plane, over the edge A.	75° 12′	. . .	76°
Carbonate of Lead	An octohedron, of which the common base of the pyramids is rectangular. Haüy.	Fig. 8. M on the opposed plane over the apex	70° 30′	. . .	71° 40′
		M on M	. . . .	. . .	108° 20′
		P on its opposed plane over the apex	62° 56′	. . .	62° 42′
		P on P	. . . .	. . .	117° 18′
	A rectangular tetrahedral prism with square bases. Bournon.				
Sulphate of Lead	A rectangular octohedron. Haüy.	Fig. 9. P′ on P′	78° 28′	. . .	
		P on P	109° 18′	. . .	
	A right tetrahedral rhomboidal prism with rhombic bases. Bournon.	Fig. 11. P on P	. . . .	101° 30′	
		P on the adjacent plane over the edge *a*.	. . . .	78° 30′	
			. . . .	. . .	
	A right prism with rhombic bases. W. P.	Fig. 13. P′ on P′	. . . .	. . .	76° 18′
		P′ on the adjacent plane over the edge *a*	. . . .	. . .	103° 42′

Oxide of Tin.

Pl. 12. Fig. 1.

The crystals of this substance admit of cleavage parallel with all the sides of the common prism, and of its diagonals, as well as the faces of the primitive octohedron, which is obtuse. The first is more readily obtained than the second, but it is extremely difficult to effect it parallel with the primitive planes. Yet having sacrificed very many crystals in the pursuit of this object, I possess several fragments in each direction, having brilliant surfaces. The hardness, and at the same time, the brittleness of the substance were obstacles to the discovery of its natural joints, which it was difficult to find the means of overcoming; but, after resorting to various expedients, I found the employment of a pair of steel pincers the most certain mode of effecting it. Being sharp, with edges about an inch long, they seize on the square prism, equally throughout its whole length; and, if the edges be carefully placed along the center of the prism, or parallel thereto, it splits, by considerable pressure, shewing planes parallel to two of the four sides of the prism. By the same means, it may again be split at right angles. In the endeavour to obtain cleavages in the directions of the diagonals of the prism, I found it impossible to lay hold of the sharp edges lengthwise, because the edges of the instrument were also sharp; and therefore took off the pyramid as nearly at right angles with the prism as possible, producing a plane, parallel to which it was requisite to procure another at the other end of the prism: applying then the pincers to these parallel planes, and in the direction of the diagonal, the prism sometimes yielded in that direction. But the crystals of tin are most readily split according to their natural joints, by placing them for some time in a common fire or a smith's forge; a slight blow with a hammer afterwards reduces them into numerous small pieces, and amongst such, I have found fragments in all the directions above mentioned; indeed this was the only means I could devise for obtaining them parallel with the faces of the primitive octohedron. The subjecting of the crystals to the action of heat, has however some disadvantages: not only are the fragments less brilliant than such as are obtained by the pincers, but it appears that the tendency of heat to separate the natural joints has also the effect of cracking the crystal in other directions in which there is no regular cleavage; so that, if the blow of the hammer be not gentle, the consequence commonly is that the crystal is reduced almost to powder.

Sulphate of Barytes.

Fig. 2.

In almost every flattish crystal of considerable dimension its natural joints are apparent when holding it between the eye and the light. If not, a slight blow will cause them to appear; and if by design or accident, the crystal fall flat upon the floor, it immediately breaks parallel with some of the planes of the primitive form and frequently even into the form itself, which is, a right prism with rhombic bases. It follows that a substance whose laminæ are held together by so slight a crystalline polarity, may be cleaved or split by various means; the same may be observed of the fluate and carbonate of lime, the crystals of which likewise generally present indications of their natural joints. But the most certain and least injurious mode of cleaving these substances is, by placing the crystal, if it be large, on a table; when, if the edge of a sharp and strait knife be placed in the direction of the natural joints, a slight blow with a hammer on the back of the knife readily separates the crystal along them. If on the contrary the crystal be small, the object is perhaps more easily attained by the assistance of a sharp penknife, while holding the crystal between the finger and thumb, more especially if it be very flat and thin; in which case, a slight blow with the hammer, even if the edge of the knife be precisely along the natural joints, is apt to have the effect of splitting it in various directions.

Quartz.

Fig. 5.

Since the time of presenting to the notice of the Geological Society, the memoir on the measurements of the angles of the primitive crystals of quartz and the sulphate of barytes, several other crystals of quartz with perfectly reflecting planes have corroborated the opinion therein stated, that the angles of the primitive rhomboide, which is slightly obtuse, are 94° 15′ & 85° 45′; which have also been further strengthened, and I may say confirmed to be their true value by co-incidences obtained by means of the reflecting goniometer from some fragments, exhibiting brilliant planes parallel with those of the rhomboide.

Crystals of quartz do not often present clear indications of their natural joints. By consulting Haüy, Traité Pl. XL. fig. 3. it will be observed that the primitive rhomboide is so situated in a dodecahedral crystal, that six of the twelve planes of the latter figure are alternately parallel with the primitive planes; the other six being the result of a modification explained by fig. 2 of the same plate. If therefore we would cleave a prismatic crystal of quartz, we are by the above circumstance assured, that by striking the prism diagonally and parallel with any plane of the upper or lower pyramid, it will be parallel with one or other of the planes of the primitive rhomboide, and, of course, in the direction of its natural joints. It will be well to attend to this observation, if if we would methodically seek to obtain the nucleus. By following this plan, I have occasionally succeeded by the assistance of the pincers, or by sharply striking a piece of steel long enough to extend across the surface, with its edge placed on the quartz in the direction of its laminæ. That neither of these plans often succeeds, and I know of none more effectual, is to be attributed to the great brittleness of the substance, which renders it liable, even when struck in the direction of its natural joints, to present fragments wholly irregular, or in various degrees approaching the conchoidal form. Quartz may however, though with still greater difficulty, be split in two or three directions which are not parallel with the planes of the primitive rhomboide.

Zircone.

Fig. 1.

Several substances, not essentially differing in composition or in their crystalline form, are by Haüy arranged under the general term zircone. Their primitive crystal is described in the Tableau Comparatif, as an obtuse octohedron with square bases admitting of regular fracture parallel with sections passing through the apices, and through the centers of the edges D. D. The jargoon of Ceylon does not admit of being split with the same ease as the hyacinth of France, of which I have obtained and possess regular cleavages in the directions mentioned by Haüy, and also parallel with sections that would divide the octohedron into four parts by passing along all the edges of both pyramids.

The fractures in the direction of the primitive planes were most difficultly obtained, and though numerous, are not sufficiently brilliant for the use of the reflecting goniometer; that instrument therefore, in regard to this substance, has been used only to measure the angles by means of the reflections of the natural planes of the crystals; but as the hyacinth of France is always too much water-worn to present those well defined reflections which alone can be relied on, and which frequently occur on the smallest and most transparent crystals of the jargoon, I first depended on the latter, but have since been enabled by the examination of a large quantity of hyacinths, to find some crystals which, though dull, afford the same results.

These results differ from those obtained by Haüy, no less than one degree and a half, which caused me to measure over again the whole number of crystals, but without discovering any error. The incidence of P on P is given both in the Traité and Tableau Comparatif as 82° 50′, leaving of course the incidence, of P on the opposed plane over the summit 97° 10′, as the complement. But as the crystals of jargoon in my possession, rarely exhibit both pyramids, and never sufficiently brilliant to be relied on, I have been compelled to depend on measurements obtained on the plane P and the opposed plane over the apex. Clear reflections agree in five instances in affording 95° 40′, in two or three 95° 35′, and in one instance 95° 30′; while the only incidence of P on P is 84° 15′, being five minutes short of what I conceive to be the true value of the angle, viz. 84° 20′. Two fragments exhibiting planes parallel with the faces of the primitive octohedron, but not sufficiently bright for the use of the reflecting goniometer, afford by that in common use, an angle of about 95° 40′; two others of about 84° 20′.

I have now stated the reasons which induce me to assume the true measurement of P on P to be one degree and a half greater than that assigned to it by Haüy. However it must be allowed that, on taking into consideration the circumstances that all the brilliant crystals did not agree in yielding the same results, and of my being compelled for want of brilliant fractures, to depend on the natural planes, it is possible that the measurements on which I rely may not be absolutely correct.

Like most other hard and brittle substances, the hyacinth most readily yields to the pincers.

Staurotide.

Fig. 2.

In regard to this substance also I rely on the measurements obtained by means of the reflecting goniometer on the natural planes. The form of the primimitive crystal is a right rhomboidal prism (fig. 2) of which the admeasurement of M on M is given by Haüy as 129° 30′. Two of the only three crystals that were submitted to that instrument agree in affording, each two measurements of that angle 129° 20′, and each also two of M on the adjacent plane over the edge A 50° 40′. The other affords one of 129° 20′; only two of its planes give clear reflections; which on the faces of the other two crystals were remarkably clean and well defined. These crystals are from St. Gothard.

Anatase.

Fig. 4.

The form of the primitive crystal of anatase is an elongated octohedron of which the common base is square. Of nine isolated crystals in my possession only two are sufficiently brilliant for the use of the reflecting goniometer; these agree in the incidence of P on P as 136° 47′, given by Haüy as 137° 10′. These crystals are very small, and as they differ from each other, and exhibit the planes of some modifications not hitherto described, I have not found courage to run the hazard of sacrificing them, incidental to the attempt to cleave them in the direction of their natural joints.

Specular Iron.

Fig. 3.

This substance, a variety of the fer oligiste of Haüy, may be split in the direction of its natural joints when held in the hand, by means of the pincers, care being taken to place their edges parallel with the primitive planes, which are generally observable on the edges of the crystals from Elba. In this manner I have procured six fragments, one of them the primitive rhomboide, which is slightly acute, nearly complete, and all of them having two or more planes sufficiently brilliant for the use of the reflecting goniometer, and all afford the measurements of 86° 10′ or 93° 50′, some of them both; the former being 59′ less, the latter 59′ more than the measurements obtained by Haüy on the natural planes by means of the common goniometer. The perfect agreements afforded by the fragments, have so far satisfied me that the results are the true value of the angles of the primitive rhomboide, that I have not attempted to measure its angles by means of the reflections to be observed on the natural planes, which are often very brilliant; for experience has confirmed me in the opinion that as the natural planes do not often yield results agreeing amongst themselves, they cannot be relied on with the same confidence as the planes obtained by cleaving crystals in the direction of their natural joints, which almost always agree; when they do not, the cause may always be discovered by the observer.

Diopside.

Fig. 6.

The crystals of this substance in my collection are not brilliant enough on the natural planes to give perfect reflections. On applying the pincers to one of them parallel with the planes of its prism, I found that it did not yield in that direction, but in that of its diagonals. The only three fragments submitted to the reflecting goniometer agree in affording the measurement of M on M, 87° 5′; being 37′ less than that obtained by Haüy on the natural planes. Two of these fragments also yield the complementary incidence of 92° 55′; being the angle of M on the adjacent plane over the edge A.

The diopside is considered by Haüy to be a variety of the pyroxene. In the attempt to cleave the latter substance, I have not been able to overcome the difficulties it presents. One crystal yielded to the equal pressure of the edges of the pincers, but did not present brilliant surfaces in more than one direction. It may therefore be true of the pyroxene as of many other minerals, that its cleavage is more difficult in one direction than another; but the circumstance just mentioned may perhaps in this instance be attributable to the heat which this crystal had the appearance of having undergone. Two others, of considerable external lustre, fell into powder under the pressure of the pincers. Two crystals presenting clear reflections on the natural planes, gave the incidence of M on M, one 86° 55′, the other 87° 5′. Two others, also brilliant, gave the value of M on the adjacent plane over the edge A, each 93°.

Cyanite.

Fig. 7.

On submitting some brilliant crystals to the reflecting goniometer, it became evident that no reliance could be placed on their natural planes. The form of the primitive crystal is an oblique prism. The incidence of M on T, given by Haüy as 106° 6′, varied very much; 106° 6′, 106° 10′, 106° 20′.

This substance is considerably hard and brittle; but in the attempt to cleave it in the direction of its natural joints, the same means did not succeed that usually does with other substances possessing those characters. The pincers always bruised the laminæ in separating them, which was fatal to precision. The most effectual means to avoid this, I found to be that of placing the crystal on a table, and supporting its under part in such a manner that the laminæ to be separated should be perfectly at right angles with the table. A sharp penknife then being placed in the desired direction, a smart blow with a light hammer usually produced the effect. Several fragments procured in this manner agreed in the incidence of M on T, 106° 15′, and that of T on M on the adjacent plane over the edge A 73° 45′; the former being 9′ more than the measurement obtained by Haüy from the natural planes by means of the goniometer in common use.

A regular fracture in the direction of the terminal planes of the primitive crystal is not so easily obtained as those parallel with the lateral planes. I obtained one considerably brilliant, but not sufficiently so for the use of the reflecting goniometer.

Corundum.

Fig. 3.

The form of the primitive crystal of corundum is a slightly acute rhomboide. From among the numerous fragments in my possession, two were selected, in the form of the primitive crystal, which, from the unusual splendour of some of their planes, gave reason for supposing they might be adapted to the use of the reflecting goniometer; one of these yielded the incidences of 86° 18′ and 93° 45′. The other one incidence of 94° 3′. These angles are given by Haüy 86° 38′ and 93° 22′, and by the Count de Bournon as 86° and 94°.*

In searching for the cause of so great difference in fragments of the same substance, it occurred to me that it arose from the nature of the substance itself, or rather from the peculiar aggregation of its laminæ. Though the corundum is one of the hardest substances in nature, it is well known that its laminæ may be separated without the application of any violent mechanical force, and in some specimens, even with ease. Hence it occurred to me that this must be the consequence of some foreign substance being interposed between the layers of the substance itself; and that, if this were the case, it could not be expected to give coinciding measurements, because of the doubt whether the interposed body could be disposed with perfect regularity. There seemed therefore no hope of attaining the desired object, unless the specimen could be reduced into laminæ so extremely thin that there should remain nothing but corundum. Finding that this was not to be expected from the common varieties, I sought, and fortunately found a small fragment, nearly colourless

* Phil. Trans. 1802.

and transparent, and bearing at first sight as much the aspect of quartz as of corundum. From this, I succeeded in obtaining, among others, four very minute portions with brilliant and perfectly reflecting planes. These were procured by the assistance of the pincers; but it must be confessed that, as the directions of the natural joints were not at all visible, it was more by chance than regular design that they were obtained at all. Owing to the extreme hardness of the substance, I found it requisite, after placing the specimen in the pincers, to envelope it and them in a piece of cloth, to prevent the escape of the fragments; as the force which it is requisite to use would otherwise have caused them to fly in various directions. The same mode was for similar reasons pursued in regard to the oriental ruby and the sapphire: the latter may be cleaved with the utmost beauty and regularity in one direction; in the others it is difficult.

One of the fragments of corundum yields the measurements of 86° 4′ and 93° 56′; the other three, each 86° 4′. Two minute portions of the sapphire give each 86° 4′; another 93° 56′. One fragment of the oriental ruby yields 86° 4′. In the whole seven corresponding measurements of 86° 4′ and two of 93° 56, which therefore I consider to be the true value of the angles of the primitive rhomboide.

Sulphate of Strontian.

Fig. 2.

The form of the primitive crystal of the sulphate of strontian is considered to be a right prism with rhombic bases. Its angles are, according to Haüy, 75°. 12′. and 104°. 48′. On submitting several crystals with perfectly reflecting planes to the goniometer, I found the measurements of the obtuse angle vary from 103°. 45′. to 104°. 17′, the greater part of them being 31′ less than that obtained by Haüy, as I presume also on the natural planes.

These disagreements induced me to attempt the splitting them parallel with the natural planes of the prism ; for which purpose those from the neighbourhood of Bristol, being flat, nearly transparent, and almost always exhibiting the directions of their natural joints, seemed well adapted. But the result was not at first equal to the promise. For though they were readily split, the fragments first obtained yielded results agreeing scarcely better than those procured from the natural planes ; the cause of which, not being then able to discover, I was compelled to forego the hope of determining the point by such means. On resuming these fragments sometime afterwards, their examination induced the suspicion, that the differences in their results under the reflecting goniometer, arose from the numerous crevices observable, when a fragment was held between the eye and the light, in almost all the flat crystals from the neighbourhood of Bristol ; but which were no doubt increased in the fragments just alluded to by the manner of cleaving them ; not having then discovered the best mode of effecting it. I determined therefore to reduce these fragments, until small portions with splendid surfaces should be obtained, nearly or wholly free from any crevice. And as the crystals are at once soft and very brittle, the utmost care was requisite. When laid on a table, with the edge of a sharp penknife placed in the direction of their natural joints, the pressure or slight blow requisite to divide the laminæ, injures the crystal by increasing the crevices. The only way in which I could succeed was by holding the specimen flat between the left forefinger and thumb, and applying without much force a sharp penknife to the thinner edge of the tabular crystal, pressing at the same time the nail of the right thumb in the opposite direction. But if the blade of the knife be not held perfectly level with the direction of the natural joints, it is apt to injure the brilliancy of the plane it produces. The terminations of the crystals being in general most free from crevices, and most transparent, are therefore best adapted to the purpose I have been describing.*

Five very small fragments procured in this manner, yielded by the reflecting goniometer, co-incidences on the obtuse angle of 104°, and one of 76° on the acute angle of the prism; the one being 48′ less, the other 48′ more than the measurements obtained by Haüy.

A prismatic crystal from Sicily, having the primitive planes brilliant at one end, gave the incidence of 104°. and planes obtained by fracture at the other end, gave the same result.

Carbonate of Lead.

Fig. 8.

The primitive crystal of the carbonate of lead is, according to Haüy, a rectangular octohedron, measuring one way over the summit of the same pyramid (P on the opposed plane) 70°. 30′; the

* Many other substances also possessing the characters of brittleness and softness at the same time, may be likewise split while held in the hand, with the greatest success. Other substances yield best to the same mode, for other reasons. Blende is one of these. It may be cleaved in so many directions, that if attempted to be split by means of a blow on the back of a knife whose edge is placed parallel with the natural joints, it is most probable that a fracture will ensue, which, though in the direction of the laminæ, is not in the desired direction. A specimen of no particular external form, but internally laminated with great regularity, and about an inch and a half square, and half an inch thick, lately yielded me, I believe, all the forms into which blende can be cleaved, and even duplicates of them. Haüy considers its primitive form to be a rhomboidal dodeca-

other way (M on the opposed plane) 62°. 56′. The Count de Bournon however considers the primitive crystal to be a rectangular tetrahedral prism with square bases. This determination arose on his part from having cleaved in directions parallel with the planes of that solid, some crystals in the form of square laminæ, which are often extremely thin, and which always yielded in those directions. These crystals, he adds, are found in Derbyshire, in the Bannat, and in Siberia.*

From an amorphous specimen of this substance I succeeded in extracting a solid in the form of an octohedron almost entire, and having more or less of every plane brilliant enough for the use of the reflecting goniometer. The results of measurements taken in the same directions as those given by Haüy were, for the first 71°. 40′, being 1°. 10′ more; and for the second, 62°. 42′, being 14′ less; and not only did this fragment yield each of these measurements twice, but also the complementary numbers of 108°. 20′ (P on P) and 117° 18′. (M on M), each also twice. Several other fragments gave perfectly coinciding results.

This substance may be split with about equal ease by the assistance of a sharp knife, whether it be held in the hand or placed on a table; provided the blade of the knife be carefully placed in the direction of the laminæ, and the back gently struck by a light

hedron, its substractive crystal an obtuse rhomboide, and its integrant molecule an irregular tetrahedron. I obtained solids not only in these forms, but also others in the form of an octohedron of 90° over the summit, and of a plane of one pyramid on the adjacent plane of the other, and of 120° of one plane of either pyramid, on the adjacent plane of the same pyramid; I procured also others in the form of an acute rhomboid of 60° and 120°. These measurements were obtained by means of the reflecting goniometer, which also gave those of the obtuse rhomboid 60° and 120°, which by Haüy, are said to be 70°, 31′. 44″ and 109°. 28′. 16″. Hence blende may be split into five different solids.

* Catalogue, p. 339.

hammer. Instead of a table, however, I frequently place the crystals of such substances as may be best divided by a blow, on a slab of steel, polished on one side for the sake of a perfectly level surface, which is advantageous because the resistance given by steel is greater than that of wood. A lighter blow is therefore effectual, and hence there is less danger of cracking the crystal in directions opposed to its natural joints.

Sulphate of Lead.

Fig. 9, 10, 11, 12, 13.

The form of the primitive crystal of this substance is considered by Haüy to be a rectangular octohedron (fig. 9.) the angle formed by the meeting of one plane of the upper pyramid, with the adjacent plane of the lower, being in one direction (P on P) 109° 18′ and in the other direction (P′ on P′) 78° 28′; and he says, ‘ Cet octaèdre se soudivise sur les arêtes contiguës.’

The Count de Bournon, for reasons given in his ‘ Catalogue,’ &c. (p. 357) considers the primitive crystal to be a right rhomboidal tetraedral prism, with rhombic bases, of about 78° 30′ and 101° 30′ (fig. 11.) which are about the measurements of P on P, and P over the elongated edge of a crystal represented by fig. 10. He adds that the sulphate of lead is among those substances in which there is no trace of natural joints, no possibility of obtaining a cleavage.*

* From the circumstance of the Count de Bournon having attributed to the angles of what he conceives to be the primitive prism, measurements nearly approximating to those of P on P, and of P on the opposed plane over the elongated edge of a crystal similar to fig.

The crystals of the sulphate of lead, as well those from Anglesea as those from Cornwall, have so great a tendency to become prismatic by the lengthening of what Haüy considers to be an octohedron, and the Count de Bournon the primitive prism, that from among several hundred crystals in my possession, I have been able to select only one, having the appearance of an octohedron with pointed apices, and that this elongation always takes place in the same direction is manifest both from the uniform position of the secondary planes in relation to those which are elongated, and by the measurements afforded by numerous crystals; for although in the latter respect there is not a perfect coincidence, the results are sufficiently near to assure us of the fact.

The common base formed by the meeting of the two pyramids of the octohedron described by Haüy as the primitive crystal, (fig. 9.) though rectangular, is not square. The meeting of two adjacent planes on one pyramid, with their continguous planes on the other, will therefore be at different angles, as is the case also in respect of the primitive octohedron of the carbonate of lead. The angle formed by the meeting of P′ with P′ is according to Haüy 78° 28′, and that of P with P 109° 18′. Six or seven crystals submitted to the reflecting goniometer varied in P′ on P′ from 76° 4′ to 76° 20′. Nine crystals affording 16 measurements of P with P varied from 101° 12′ to 101° 28′; and the same crystals gave 17 measurements of P on the opposed plane of the same

10, which is common to this substance, it may be assumed that he considers such a crystal to be a rhomboidal prism with diedral terminations. It will appear that I agree with the Count de Bournon in assuming the right rhomboidal prism with rhombic terminations as the primitive form; but differ from him in the manner in which that form lies (if it may so be said) in a crystal represented by fig. 10. He conceives the planes P P, to be primitive: I am on the contrary induced to suppose the planes P′ P′ to be primitive planes; we consequently differ in the angles of the prism.

pyramid, varying from 78° 35′ to 78° 48′. One elongated crystal similar to fig. 10, gave P′ on the opposed plane over the summit 103° 40′. All these crystals reflected with uncommon brilliancy. One of eight crystals, sufficiently bright to afford clear reflections on each of the four elongated planes P P (fig. 10.) and more nearly approaching to agreement than any of the others, gave on the two obtuse angles 101° 12′ and 101° 15′, and on the two acute 78° 40′ and 78° 43′. Another among them gave one incidence of 78° 35′, and another of 78° 48′ on the two acute angles.

I am induced to be thus particular, not only on account of the vast difference between the measurements given by Haüy and those obtained by means of the reflecting goniometer, but also because it is scarcely possible to find another in the whole range of mineral substances, which seems to unite more decidedly the characters of perfect crystallization and brilliant surface. It seemed therefore pre-eminently adapted to the use of the reflecting goniometer. The result however proves that the sulphate of lead is one among many minerals, on even the perfect reflections of whose natural planes no reliance can be placed without numerous coinciding results; if indeed it would be possible to obtain them at all.

In the endeavour to cleave this substance parallel with its natural joints, I was at first greatly foiled by its extreme brittleness, which without great care causes its fracture to assume the conchoidal form. The directions for finding the joints given by Haüy, are quoted in his own words; if I comprehend them they are not accurate, but they are not expressed with his usual perspicuity.

As the elongated planes present the largest surfaces, it was an inducement to attempt a cleavage parallel with them in the first instance, on the presumption of their being planes of the primitive octohedron; but after destroying a large number of crystals, I was still unsuccessful. In the direction of the lesser planes (P′ P′) and parallel with them, a cleavage is not only practicable, but may readily be obtained by the assistance of a sharp penknife, when the crystal is pressed on the fore finger beneath the thumb nail, which is the most effectual mode I have been able to find. The crystals are also divisible parallel with a section passing along the elongated summit and down the centers of the planes P′ P′ of a crystal formed like fig. 10. The search for natural joints in any other direction was fruitless.

If therefore we divide an elongated crystal (fig. 10.) in the direction of the dotted lines *a b c d e* and *b c d*, being parallel sections in the direction of its natural joints, we shall obtain a solid represented by fig. 12, which occurs in nature, and greatly resembles some crystals of the sulphate of barytes. If then this solid be cleaved parallel with the planes P′ P′, we shall obtain a nucleus similar in form to the dotted lines within it, and of course to fig. 13, which, though not in the same position, resembles in form, but not in measurement, the primitive crystal of the sulphate of barytes (fig. 2.); it is a right prism with rhombic terminations. Of these solids obtained from amorphous specimens of the sulphate of lead, I possess several, and am led to the conclusion that if we are to depend on the cleavage of minerals for a knowledge of the forms of their primitive crystals, this solid is that of the sulphate of lead.

In my collection there is an amorphous specimen from the Lead Hills, exhibiting natural joints parallel with all the planes of a right prism with rhombic terminations. It is covered on one of its larger sides by long and nearly flat crystals with diedral terminations, lying on the mass with the terminations parallel with the natural joints observable in it; and there is a still more perfectly characterized specimen in the collection of Mrs. Lowry.

On submitting to the reflecting goniometer several crystals cleaved parallel with the planes P′ P′, they all afforded the result of 76° 18′, coinciding therein with several fragments in the form of the primitive crystal fig. 13, which also gave 103° 42′ as the value of the obtuse angle. I am therefore induced to conclude that the primitive crystal of the sulphate of lead is a right prism with rhombic terminations, whose angles are 76° 18′ and 103° 42′.

XIV. *Supplementary Observations on Quartz Rock, made in* 1814.

By J. MAC CULLOCH, M.D. F.L.S. President of the Geological Society, Chemist to the Ordnance, Lecturer on Chemistry at the Royal Military Academy, and Geologist to the Trigonometrical Survey.

[Read 17th February, 1815.]

HAVING had an opportunity during the present summer of adding some further remarks to the observations on quartz rock, I have here arranged them as a supplement to the former papers, for the purpose of extending the history and connections of this important member of the more ancient strata. As I had not the means of examining a very wide extent of country, I have not been able materially to enlarge its geographical boundaries, yet the Society will see that it constitutes a very considerable part of the country I did observe. It is found in most parts of the valley of the Tumel, which extends from the head of Loch Rannoch to the junction of the Tumel with the Garry. Throughout this whole extent it alternates with schist, sometimes micaceous, now and then containing felspar and thus resembling gneiss in composition, but oftener argillaceous, and very hard, from the large proportion of quartz which it contains. As we approach the lower end of this valley the quartz rock diminishes, while the schist increases, until the former at length disappears. Beds of limestone are found alternating with it throughout this course: it also contains porphyry, of which numerous masses are to be seen on the sides of Loch Rannoch. These masses are sometimes truly porphyritic, containing crystals of felspar, while at other times they consist of an uniform reddish compact felspar, the usual basis of those porphyries which are found associated with the primary rocks. There is much difficulty in determining the true nature of these porphyritic masses. Occasionally they seem to cut the strata, while in other places there can be no question that they are parallel to them. Nevertheless I am still inclined to think that even those which are occasionally seen conforming to the position of the strata in which they lie, are, like the masses of trap which have a direction parallel to the associated beds, only veins, of which the direction is so far parallel to the position of the beds in which they are found.

From Loch Rannoch the quartz rock is seen crossing the mountains to Loch Ericht, accompanied in the same way with the various schists, and finally terminating in different places round the outskirts of Ben Vualach, where its junction with the granite of this mountain is visible. It may then be traced along the southern border of Loch Ericht, where it joins with a similar series of rocks that will be found extending from Dalwhinnie along the course of the Truim, and then along that of the Garry all the way to Blair. A fact of some importance is visible at Loch Ericht which I will mention here, although not particularly connected with the history of quartz rock. About half way between the top and bottom of the lake on the south side, a large slide of the mountain is to be seen; the ruin is still so entire, of such magnitude, and so little encumbered with recent accumulations of soil, that there is no difficulty in tracing the fallen masses to the broken summits whence they were detached. The quartz rock here, as in all the outskirts of this granitic country, is traversed by granite veins. A few fallen stones have formed a sort of cave capable of containing three or four persons, and known to the neighbouring shepherds, who, still mindful of their ancient allegiance, show the spot where, among many others, the unfortunate Prince was for a time concealed. The minuter fragments of quartz rock and granite have here formed themselves into angular conglomerates, which are in some instances perfectly compact, the smaller cavities having been filled up by siliceous matter, while the larger fragments, touching only by small surfaces, have left considerable openings between them. Here then we have an example of a breccia formed in times comparatively recent. The conglomeration of the fragments is not the effect of the accidental presence of iron, so commonly the cement of modern breccias, but is evidently the result of a deposition of siliceous matter. This could only have been brought into solution by the rains, or by the operation of common water, since the stones are out of the reach of other causes, and it serves to prove that the solution of silica in water, a circumstance which some have supposed limited to the ancient state of the Globe, is a process still going on. I have indeed noticed in the former remarks on quartz rock the same fact as proved by the enamelled and polished surface which its exposed parts so often assume. We have no means from historical record of determining the antiquity of this *slide*, but as far as any conjectural evidence can be adduced from the little accumulation of soil which has formed on the horizontal surfaces, and the bare aspect of the faces, on which scarcely a lichen has yet planted itself, it cannot be of very high antiquity. The observation is further of importance as illustrating the origin of the brecciated jaspers, as well as that of the other breccias formed of angular fragments.

From Loch Ericht the quartz rock branches away to the mountains that skirt Ben Nevis and Glenco, as I noticed in the above mentioned paper. I have already observed in that paper that it constituted a portion of Schihallien and of the northern side of Glen Lyon, terminating in the micaceous and chlorite schist of the ridge of Ben Lawers. Taking it up now from Blair we shall find it occupying a large proportion of the whole group of hills which lies between the Bruer and the Tilt, lying over the granite and stretching away towards Glen Dee, and thus uniting with that tract of it which I also described last year as skirting the great granite mass of the Grampians towards its eastern declivity. Returning again to Blair it is found extending over the whole ridge of Ben Gloe, and here it scarcely ever alternates with schist. From Ben Gloe it may be traced over the Scarsough into Mar, forming at the same time Cairn ree and a considerable extent of the hills which skirt Glen Fernat and Strath Airdle to the eastward. From Mar it is then seen to form a principal portion of the tract which bounds Glen Shee on both sides, but further into the hills of Angus I have had no opportunity of following it. If the several spaces which I have described here and in the former paper, be marked on the map, it will be seen to occupy a very large portion of the country, and one which will I doubt not be easily extended. I do not mean to lay it down as a rule, (since the irregular position of this class of rocks is such that they scarcely admit of any rule), but I think it will be found here most abundant in the vicinity of the granite, while the micaceous schist on the contrary lies at the greatest distance from it. A mineralogical map of Scotland, a work as yet far distant, will probably confirm the generality of this remark.

I have but little to add to the particular description of the rock and of its several varieties given in the above named paper, but there are a few circumstances worthy of record.

In Ben Gloe it is found incurvated and contorted in the manner of micaceous schist, a proof that, like all the other schistose rocks with which we are acquainted, it has occasionally been in a flexible state. Some beds are also to be found there towards the east, on that shoulder of Cairn Gower which hangs towards Loch Lochs, containing rounded pebbles, such as I before described as occurring in it at Jura. The beds in which this variety is found consist indeed entirely of a loose aggregation of large and small rounded gravel. This is only the second instance in which I have noticed a coarse conglomerate mass as forming one of the varieties of quartz rock. The pebbles are of considerable magnitude, and bear just such marks of attrition as do those which have been rolled on a sea shore: if they are not mechanically rounded pebbles I know not where such can be found. I have little doubt that this variety will oftener occur when these rocks shall have been more extensively examined; but I trust this fact is no longer necessary to prove that quartz rock bears the marks of a mixed mechanical origin, and that it thus serves to determine in some measure a corresponding set of circumstances in which the schistose rocks associated with it were formed.

Near Blair it may be observed passing into a regular granite in a very distinct manner. Many of the specimens found were transported stones, but in many other instances, which I have had occasion to notice in a paper on Glen Tilt,* the transition from quartz rock to granite is to be seen *in situ*. I have there also noticed that, which ought for the sake of uniformity to be repeated here, that the beds of quartz rock which are in immediate contact with the granite often pass into it by insensible degrees. It is well known that there is a gradual transition from mica slate into gneiss, and that this rock again by degrees equally evanescent passes into granite. I have shown that quartz rock is here in contact with granite, and it is not therefore surprizing that it should, like the mica slate with which it

* Geo. Trans. Vol. III.

forms but one great deposit, undergo analogous changes when it approximates to this rock. The transition is in fact more easy and the boundary less definable, since many varieties of quartz rock, formed of felspar and quartz in varying proportions with an occasional mixture of mica, only require to assume that crystallized appearance which the vicinity of granite is so apt to produce on the neighbouring rocks, to become undistinguishable from it. The quartz rock in these specimens contains mica, disposed at first in a parallel form, so that it might equally be ranked among the varieties of micaceous schistus or of gneiss. By degrees the mica loses its parallel disposition, and at length the whole assumes the aspect of granite. This transition therefore adds one more to those passages into mica slate, clay slate, and graywacké, which I formerly described as occurring in quartz rock. Loose specimens are found both at Blair and in Ben Gloe containing drusy cavities, of which the siliceous crystals, though more minute than a pin's head, are perfectly defined. These crystals are evidently of posterior formation to the general mass of the rock, and have resulted from the infiltration of a watery solution of silica into previously formed cavities. They prove nothing therefore relating to the chemical nature of this rock, of which, mixed with its mechanical formation, there are every where to be found abundant examples, some of which I have formerly enumerated.

In Glen Tilt I have taken out specimens from the beds exactly similar to those long compressed and smooth cylindrical bodies which are sometimes found in secondary sandstones. This shows another distinct point of agreement between quartz rock and those sandstones. In the same place is found a very interesting variety. It consists of a regular and repeated alternation of quartz with common argillaceous schist; the smoothest variety of clay slate. The quartz at the same time is compact and crystalline, differing in no respect from the most common specimens of this substance. The alternations are such and so frequent that a cross fracture of this rock may almost be compared to the striped leaf of arundo colorata.

In another situation I observed specimens consisting of pure quartz without any such mixture of clay, but so fissile as to scale off in leaves as thin as paper.

Although garnets abound so much in mica slate, I have only met with one instance in which they occur in quartz rock; this is at the west end of Mar forest near the Dee. The garnets however are very incomplete, although large in size; they occupy only the intervals between the layers of the stone, and on splitting it are found as if compressed between the surfaces.

Another remarkable variety of this rock also occurs in Glen Tilt. It resembles precisely the schistose sandstones which accompany the coal strata, and is found in distinct laminæ from an eighth to a quarter of an inch in thickness, detached from each other and separated by thinner laminæ of loose mica or clay. It offers another example of the striking resemblance between quartz rock and the secondary sandstones; an agreement much more remarkable than that of the mica slate which generally accompanies it, with the slate clay which is the associate of those sandstones. It would seem as if the quartz rock from its greater simplicity of materials, a simplicity less liable to chemical changes, had undergone fewer alterations during the progress of time and of those actions by which its present form was produced, than the more compound schist with which it was originally associated. In those varieties of quartz rock which are, like that last described, formed of distinct laminæ, natural joints occur resembling those of clay slate and producing on fracture, rhomboidal tables. In this respect it bears a considerable analogy to the clay slates with which it is so often associated.

Among the varieties found in Ben Gloe I remarked some others worthy of notice, considering the novelty of this subject and the necessity of describing every remarkable feature of a rock so long overlooked or confounded with others. The most singular of these is of a beautiful pink colour, equal to that of the well known rose quartz, with the semi-transparency and fine grain of the most highly refined sugar: it forms interesting specimens for collectors of minerals. I have mentioned it in describing Glen Tilt. Another is of a dark brown colour, apparently from containing much carbonate of iron, but when it is exposed to the weather the surface is bleached to the depth of a quarter of an inch and becomes of a snowy whiteness. A third is of an ochre yellow colour and loose texture, and in hand specimens not to be distinguished from a common secondary sandstone, while at the same time it contains distinct concretions of crystallized carbonate of lime irregularly dispersed through it. A variety equally resembling some of the secondary sandstones which occur among the coal strata in the vicinity of Glasgow and elsewhere, is found near Balahulish. It is distinguished by the frequent alternation of black laminæ, of which the cross fracture represents delicate lines, and it serves with others already enumerated to confirm the strong affinity of the recent sandstones with quartz rock, the sandstone of former ages.

Among the various modifications of quartz rock which I have observed in the different districts now described, a great many exhibit the characters of the avanturine, the quartz avanturiné of Brongniart. I have frequently noticed the transition which takes place between quartz rock and mica slate, a transition so gradual and so perfect that it is often impossible to assign the limits of the two. The quartz is often hyaline, while the mica is disseminated through it in scales of which the tendency, notwithstanding the crystalline state of the quartz, is parallel either to the laminæ or to the beds of the stone. These specimens when polished exhibit the characters of the most perfect avanturine, but their colours are only white or greyish. I have never yet met with the most esteemed, the yellow variety. As the quartz rock approaches more nearly to mica slate, the character of the specimens which resemble avanturine changes, until they resemble the variety of this ornamental mineral found at Ekaterineberg. In many cases the scales of mica have a considerably greater dimension in one direction than in another, from which the stone acquires a fibrous aspect. This variety, of a fine blue grey colour, occurs in Glen Fernat in large beds, and when polished does not yield to some of the most beautiful foreign specimens of avanturine. There is yet one other modification of this mineral, of which the splendour results merely from the varying position of the quartz grains which form it. The most crystallized and pure specimens of quartz rock afford this variety, and examples of it are to be found every where among the more compact beds of that rock. We may therefore conclude that the avanturine, so much esteemed and long so ill understood, is a variety of quartz rock; a circumstance likely to give this rock that importance among collectors of specimens, which I have attempted to claim for it among geologists.

Further Observations.

[Read 20th December, 1816.]

For the sake of rendering somewhat more complete the history of this substance, I shall here subjoin an account of a considerable body of it which is to be seen in a very unexpected situation in Sky. Although it will be found mentioned in the present volume, in a supplementary paper on that island, it will not be irrelevant to describe it in somewhat greater detail here.

A series of stratified rocks is found extending from the Kyle ric'h, on the eastern side of this island, to Loch Eishort, on its western side, and occupying a considerable space laterally, or consisting of a frequent repetition of the substances which constitute it. While the nature of these strata, which present alternations of red sandstone with graywacké schist, and with indurated grey and blue granular quartz, would incline us to rank them among the secondary rocks, some doubt is thrown on that conclusion in consequence of the peculiar relation they bear to the older rocks which they follow, the gneiss, and the micaceous and chlorite schists. But I must refer to the paper on Sky itself, for the history of these strata, and limit myself to the description of the particular rock which is the object of this note.

It forms a large mass of strata in an erect position, running parallel with the red sandstone and the graywacké schist, which, in repeated alternations, lie on each side of it. These strata, always highly elevated, are in some parts vertical, while in others they incline, like the rocks by which they are accompanied, sometimes in one direction and at others in the opposite one, from the perpendicular, their bearing being north-easterly. Although the accompanying strata extend from one shore of the island to the other, the quartz rock in question does not attend them throughout, the total length which its leading mass occupies being limited to about five miles, as nearly as that can be ascertained. Its south-western end will be found in the hills behind the castle of Dunscaich, and its north-eastern approaches the shore of Loch Eishort, nearly opposite to a small island which forms the innermost harbour of that branch of the sea. The collective breadth of the strata where they are widest, appears to be about a mile and a half, while at each end it is much less, but the nature of the ground does not permit their whole extent or geographic shape to be accurately ascertained. In a general view they form two irregular ranges of parallel elevations, with shallow intermediate vallies, and as these summits maintain scarcely any vegetation, while they are composed of white compact quartz, their effect is very striking, even at a great distance; presenting the appearance of a fall of recent and thin snow.

Besides this leading mass, many detached portions of strata of the same substance are to be seen in the neighbourhood, and they are most accessible on the shore from Dunscaich to Ord. In these places their alternation with the red sandstone and greywacké schist can be traced with great ease and satisfaction, while at the same time their stratified disposition and their angles of inclination may be examined in considerable detail. The small island of Dunscaich, remarkable for the remains of a Danish strength, and a more probable residence of the traditional king of the Isle of Mist than the neighbouring promontory, affords particular facilities for examining the nature and disposition of this rock. Here it is disposed in thin beds, rarely exceeding a few inches in thickness, and is inclined towards the east in an angle of about 26 degrees. These beds are divided by natural joints, at angles with the plane of stratification, and in consequence of this they break into prismatic rhomboidal or triangular fragments, which on the upper and long-exposed surfaces are so numerous and minute that the whole presents at first sight a set of sharp points and projections, among which the stratified disposition is scarcely perceived until they are more closely examined. The same disposition into thin strata is every where found throughout the larger masses, and if sometimes more obscure, it can nevertheless be always discovered by an attentive examination.

With respect to the composition of this rock it is almost always found to be a compact splintery quartz, scarcely distinguishable in small fragments from that mineral as it occupies veins. Occasionally it becomes more or less granular, and now and then will be found to contain grains of felspar, as it does in so many other places. Its prevalent colour is white, but it sometimes assumes a rusty colour at a small depth from the surface, and in some rare instances may be observed of a pink and of a brown-reddish hue.

If there is any transition between this rock and those with which it is associated, it must be sought among those beds which approach to a granular structure, between which and the most compact varieties of the red sandstone the difference is not extremely great. I cannot say that I have positively ascertained such a transition, nor am I aware that the nature of the ground is such as to admit of an examination sufficiently connected and extensive to answer this purpose. I shall however point out to geologists that part of the shore which lies to the eastward of Ord, as particularly interesting in this view; since, if it does not present examples of an exact and satisfactory transition between the two rocks, it affords very instructive views of the change which, under particular circumstances, occurs in the sandstones, from the distinctly granular and arenaceous to the compact and quartzose state.

XV. *Description of a series of Specimens from the Plastic Clay near Reading, Berks: with Observations on the Formation to which those Beds belong.*

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[Read 6th January, 1816.]

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HAVING an opportunity to visit Reading in July, 1814, I collected a series of specimens numbered as below, which I beg leave to present to the Geological Society. The pits whence they were obtained are at the Catsgrove Hill Brick kilns, distant about half a mile from the town of Reading, on the south-west, where the works have been carried on for more than a century, and at this time present the following section, beginning from the lowest upwards.*

Section of Catsgrove Hill.

No.		Thickness in Feet.
1.	Chalk containing the usual extraneous fossils and black flints	*unknown*
2.	Siliceous sand mixed with granular particles of green earth, and containing both rolled and angular chalk-flints, oysters, and many small and nearly cylindrical teeth of fish from a line to an inch in length	3
3.	Quartzose sand of a yellowish colour with a few small green particles, and containing no pebbles or organic remains	5
4.	Fullers' earth	3
5.	White sand used for bricks	4
6.	Lowest brick clay of a light grey colour mixed with fine sand, and a little iron-shot	5
7.	Dark red clay, mottled with blue and occasionally a little iron-shot. It is used for tiles	6
8.	Bed called the White vein. A fine ash coloured sand mixed with a small portion of clay, and in some parts passing into loose white sand. It is used for bricks	5
9.	Fine micaceous sand laminated and partially mixed with clay, and occasionally iron-shot. It is used to make tiles	4
10.	Light ash coloured clay, mixed with very fine sand of the same colour. It is used for bricks	7

* The measures in this and all the following sections were taken by the eye and do not pretend to extreme accuracy.

11.	Dark red clay partially mottled and mixed with grey clay	4
12.	Soft loam, composed in its upper region of fine yellow micaceous sand, mixed with flakes of a delicate ash coloured clay, which become more abundant in the deeper portions of the stratum, and having its lower regions much iron-shot, and occasionally charged with ochreous concretions, and decomposing nodules of iron pyrites. It is used to make soft bricks for arches	11
	Total	57
13.	Alluvium composed of clay, sand, and gravel, the gravel chiefly consisting of chalk flints, both rolled and angular, with a few pebbles of quartz, and of brown compact sandstone. This alluvium is covered by vegetable mould - - - - - - - - - - - - - - -	—

The oysters of No. 2 are remarkably perfect when first laid open, and seem to have undergone no process of mineralization; they soon fall to pieces by exposure to air and moisture. The chalk flints contained in it are many of them in the state of small rounded pebbles; in others the angles are unbroken. Both varieties are covered with a crust of greenish earth of the same nature with the green particles in the sand. The angular flints appear to have been derived from the partial destruction of the bed of chalk immediately subjacent, of which the upper surface in contact with the sand is considerably decomposed to the depth of about a foot, and its fissures and numerous small tubular cavities (the latter derived apparently from the decay of organic substances,) are filled with granular particles of the green earth and siliceous sand of the incumbent stratum.

An appearance somewhat analogous is noted by M. M. Cuvier and Brongniart (Essai sur la Geog. Min. des Environs de Paris, p. 17,) in a coarse variety of the French plastic clay which immediately covers the chalk at Meudon; where a breccia composed of fragments of chalk imbedded in a kind of argillaceous paste has filled the fissures and irregularities which existed on the surface of the subjacent chalk before the deposition of the plastic clay.

The same thing may be seen on a small scale in the chalk pit at Woolwich, where there are fissures extending some feet downwards into the body of the chalk, varying in breadth from an inch to more than a foot, and sometimes spreading laterally so as to form considerable cavities, which together with the fissures are filled with sand that has been introduced from the incumbent stratum.

At Reading the chalk is quarried below the green sand containing oysters (No. 2) to the depth of about 25 feet, when the workings are stopped by water at a point nearly on a line with the leve of the river Kennet, below which there can be no discharge of water from the chalk, through the medium of the neighbouring springs. In this thickness of 25 feet of chalk, there is but one regular and continuous course of flints, and in this they are disposed in tabular masses, for the most part of about two inches in thickness. (This bed is but a few feet above the water). In the chalk that lies above this siliceous stratum, the flints are disposed irregularly with their usual characters and eccentric forms, derived, in many instances, from the organic remains which they envelope. They are collected for the use of the porcelain manufactories. The chalk itself is extracted largely from under the sands and clays, by means of shafts and levels, to be burnt into lime. There are no septaria or concretions in any of the strata above the chalk, nor the smallest traces of animal or vegetable remains, excepting in the green sand, (No. 2.) The same barrenness of organic remains is noticed in the purest beds of the French plastic clay, and by Mr. Webster (Geol. Trans. vol. 2, p. 200), in the plastic clay of the Isle of Wight and Corfe Castle.

The section given by Dr. Brewer, in the Phil. Trans. for 1700, differs as little as might be expected from that which is now exposed at Reading. Beginning from the bottom, he gives the following strata:

No.		Feet.
1.	Chalk rock - - - - - - -	—
2.	Green sand containing oyster shells - - -	2
3.	A bluish sort of clay, very hard, brittle, and rugged (called pinney clay); it is of no use - - -	3
4.	Fullers' earth - - - - - - -	$2\frac{1}{2}$
5.	Clear fine white sand - - - - - -	7
6.	Stiff red clay used for tiles, the depth of which, he says, could not conveniently be taken from the heighth of the hill, at the top of which, he adds (immediately under 2 feet of common earth) the red clay appears, and is used for tiles.	

The thickness of the beds which Dr. Brewer did not measure was probably made up of those from No. 7 to No. 12 inclusive, in the section I have given, in which also the beds below No. 6 correspond very nearly with his account, which I had not seen till my own was finished as it now stands.

In a hill called David's Hill, west of the town of Reading, on the opposite side of the Kennet to that of the Catsgrove brick kilns, and about one quarter of a mile distant from them, are other large quarries of brick earth, in which many of the subdivisions which have been noted at Catsgrove are not to be recognised, and the entire thickness of some of the pits is made up of the same sands and clays as on the opposite side, but more uniformly disseminated through the whole mass, forming a kind of loam more like No. 12 than any of the other beds that have been there described; ochreous concretions and pyritical nodules abound in it as in No. 12. The total thickness of this deposition at David's Hill above the chalk is about 40 feet. Water occurs in the subjacent chalk, as soon as they sink 30 feet into it. It is separated from the incumbent brick earth by the bed of green sand, with the same oysters as at Catsgrove.

The whole of these beds above the chalk at Reading (those at Catsgrove as well as at David's Hill) appear to be subordinate parts of one formation, the next in order of succession above the chalk, older than the London clay and calcaire grossier of Paris, and contemporaneous with the lowest strata of the plastic clay formation nearest the chalk, the general history of which we propose more fully to consider.

On the north side of the town of Reading these strata do not occur, being cut off by the great valley through which the Thames passes, and which has been excavated to a considerable depth in the subjacent chalk. But they occupy much of the ground between Reading and Newbury, and are seen at Hermitage, on the N.E. of Newbury towards Hamstead Norris, whence a range of low hills composed of them stretches eastwards towards Reading, and westward to Boxford, Wickham, and the neighbourhood of Hungerford, interrupted by vallies, which are often cut down into the subjacent chalk.

The breadth of this deposition on the north and south of Newbury, is from Beedon Hill six miles north on the road to Market Ilsley, to Whitway near Highclere four miles south of

Newbury on the road to Whitchurch. On the west of this line, drawn through Newbury north and south, the breadth of the beds on the chalk is gradually contracted till they entirely cease near Hungerford (See Mr. Webster's map, Geol. Trans. vol. 2, pl. 10). On the east side of the said line they occupy the vale of the Kennet till it falls into that of the Thames, near Reading; whence they extend eastward, widening as they advance through Surry and Middlesex, into Kent, Essex, Suffolk, and Norfolk.

In many parts of this great valley or trough of chalk we recognize our Reading beds in their proper place, as the inferior strata of the plastic clay formation; and though with the exception of the lowest bed they do not agree in minute detail with those of the Reading section, as to thickness, or exact order of superposition, nor is the presence of shells or pebbles constant in the beds of clay or sand, yet an attentive examination of the general points of resemblance in the substance of the clays, sands, and pebbles, forming these irregular alternations above the chalk, added to the identity of their organic remains when any occur, leaves no doubt as to their being members of one great series, of nearly contemporaneous depositions, intermediate between the chalk and London clay, and which it may be convenient to associate in a natural family, as members of that formation of which it is one leading feature to contain those peculiar varieties of clay which the French naturalists have characterized by the appellation of plastic clay. As there can be little doubt of the origin of the French beds being contemporaneous with those in England we are now considering, it will assist us in connecting our strata with those of the Continent, to designate them by the appellation appropriated to them in France.

Near London these beds occur with well defined characters; at

Blackheath, Lewisham, Charlton, Woolwich, and on the east of Plumsted. In all these places the thin bed next above the chalk, which at Reading contains fishes teeth and oysters, is seen composed of a similar substance of loose green sand mixed with chalk flints, both rolled and angular, and generally coated with a dark green crust; but here they contain no organic remains, and seldom exceed two feet in thickness. Above this thin bed is a thick stratum of fine grained ash coloured sand, destitute of shells or pebbles, and varying in thickness generally from 30 to 40 feet. This stratum is seen to the greatest advantage in the Woolwich sand pits, where is an enormous artificial section, presenting the following order of succession: *

Section of the Woolwich Pits, ascending from the lowest Strata.

(See coloured Section, Pl. 13, No. 1).

No.		Feet.
1.	Chalk with beds and nodules of black flint - -	—
2.	Green sand of the Reading oyster bed, containing green coated chalk flints but no organic remains - -	1
3.	Light ash coloured sand without shells or pebbles - -	35
4.	Greenish sand with flint pebbles - - - -	1
5.	Greenish sand without shells or pebbles - - -	8
6.	Iron-shot coarse sand, without shells or pebbles, and containing ochreous concretions disposed in concentric laminæ - - - - - - - -	9

* Although a Section of these pits is already before the Society, it seemed necessary to insert that I am now giving, as it differs from Mr. Webster's (Geol. Trans. vol. 2, p. 195.) in a few minute particulars, and was the result of a careful examination by the Rev. Wm. Conybeare and myself, in April, 1815. I have also the sanction of Mr. Conybeare's authority, and am indebted to his observations, confirmed subsequently by my own, for the Notices, Map, and Sections, which I have given of the neighbourhood of Blackheath.

7.	Blue and brown clay—striped and full of shells, chiefly cerithia and cythereæ - - - - - -	9
8.	Clay striped with brown and red, and containing a few shells of the above species - - - - -	6
9.	Rolled flints mixed with a little sand, occasionally containing shells like those near Bromley; e. g. ostrea, cerithium and cytherea. (These shells occur disseminated in irregular patches) - - - - -	12
10.	Alluvium - - - - - - - -	—
	Total thickness	81

No. 1 and 2 are not laid open in the great sand pits, but are seen in a chalk pit adjoining to the eastern extremity of the sand pit.

The following section at Loam Pit Hill, near Lewisham, about three miles south-west of Woolwich, presents analogies that identify many strata in the two sections, as from the chalk upwards to No. 8; in each inclusively the principal difference consists in the presence of fewer or more pebbles, in beds of sand evidently contemporaneous.

Section of three Pits on Loam Pit Hill, near Lewisham.

(See coloured Section, Pl. 13, No. 2*).

LOWER PIT.

No.		Feet.
1.	Chalk with beds and nodules of flint - - - -	—
2.	Green sand identical with the Reading oyster bed, and in every respect resembling No. 2 at Woolwich - -	1

* These beds cannot all be observed at one section, but may be traced along the sloping surface of the hill, at three successive apertures near each other, in which the upper stratum of each lower pit is dug into, and forms the floor of the one next above it.

In the section No. 2, the intermediate spaces are unnaturally contracted, and expressed by two narrow caps of alluvium.

No.		Feet.
3.	Ash coloured sand, slightly micaceous, without pebbles or shells - - - - - - - - -	35

This bed, though below the general floor of the middle pit, is sunk into from it by deep shafts.

MIDDLE PIT.

4.	Coarse green sand, containing pebbles - - - -	5
5.	Thick bed of ferruginous sand, containing flint pebbles	12
6.	Loam and sand, in its upper part cream coloured, and containing nodules of friable marl, in its lower part sandy and iron-shot - - - - - -	4
7.	Three thin beds of clay, of which the upper and lower contain cythereæ, and the middle oysters - -	3

UPPER PIT.

8.	Brownish clay containing cythereæ - - - -	—

This is the lowest bed sunk into in the upper pit, and is not there penetrated to a depth exceeding one foot. The interval between this and No. 7, which occupies the summit of the middle pit is not exactly ascertained, but cannot be considerable; probably - - - - - - - 6

9.	Lead coloured clay, containing impressions of leaves -	2
10.	Yellow sand - - - - - - - - -	3
11.	Striped loam and plastic clay, containing a few pyritical casts of shells, and some thin seams of coaly matter -	10

No.		Feet.
12.	Striped sand, yellow, fine, and iron-shot - - -	10
13.	Alluvium * - - . - - - -	—
	Total	91

At a point still higher on this hill than No. 12, is a thick bed of dark blue clay, without shells, which is used to make tiles and bricks, and which appears to continue upwards from this brick kiln to the summit of the hill, forming a thick cap over the sands and clays mentioned in the section, and is probably an outlying hummock of the London clay, separated only by a small valley from the extensive mass of that stratum which is found two miles south-west in the Sydenham hills, and being placed between and connecting them with the London clay of Shooter's hill.†

* In this alluvium four large and entire tusks of elephants were discovered a few years ago, in a garden opposite the chalk pit, at the base of Loam Pit Hill, and on the north side of the turnpike road; they soon perished by exposure to the air, but were for some time in the possession of Mr. Lee, the owner of the extensive brick works on Loam Pit Hill, to whom I am indebted for this information.

† Mr. Webster mentions (Geol. Trans. v. 2, p. 235) that rounded flints are found in the sand strata, at the bottom of the blue or London clay, in several parts of the London basin. And again (p. 185), that the abundant supply of water which is constantly found in boring through the same clay, indicates an extensive deposition of three beds of sand. The sandy strata containing pebbles, and the watery sand thus alluded to appear to be the continuation of the upper strata of the plastic clay formation, and connected with those of Loam Pit Hill.

In the shaft at the northern extremity of the tunnel under the Thames, near Rotherhithe, these same beds were found, covered by more than 30 feet of London clay, although from their rapid rise under the bed of the Thames towards the south, the shaft on the south side (of which Mr. Webster has given a section, p. 197) exhibits only nine feet of this clay incumbent on the watery gravel and subjacent beds of the plastic clay formation.

A curious section is preserved in Sir C. Wren's Parentalia (p. 285), obtained in preparing the foundations of the present cathedral church of St. Paul, in London.

A similar section to that at Woolwich and Loam Pit Hill may be traced round the sloping terrace that bounds the north-west and south sides of the plain of Blackheath.

On the east side the beds composing this plain appear to be covered by the clay of Shooter's Hill, an outlying summit of the London clay, like the hills of Sydenham and Highgate, and which probably at one time were all united in a continuous stratum covering the entire series of the plastic clay formation, which is now exposed between the intervals of its remaining fragments. (See map and section, Pl. 13.)

The plain of Blackheath (being a portion of the strata thus laid open,) is covered at the surface with a bed of rounded pebbles, sometimes 20 feet in thickness, which appear to be alluvial, but are of nearly the same substance with the gravel of the neighbouring strata, from which it is therefore matter of great difficulty to distinguish them. Beneath these pebbles is a bed of sand identical with

The Surveyor observed that the foundations of the old church stood upon a layer of very close hard pot earth, which he therefore judged firm enough to support the new building; and on digging wells in several places he found this pot earth to be about six feet thick and more, on the north side of the church yard, but thinner and thinner towards the south, till it was scarce four feet upon the declivity of the hill. Below this he found nothing but dry sand, mixed sometimes unequally, but loose, so that it would run through the fingers. He went on till he came to water and sand mixed with perriwincles and other sea shells; these were about the level of low water mark. He continued boring till he came to natural hard clay.

The upper stratum of pot earth had been used at a Roman pottery, near the N.E. angle of the present church, where they found urns, sacrificing vessels, and other pottery in great abundance, and were interrupted in digging the foundation of the N.E. angle of the church, by the quarry from which the pot earth had been extracted: the subjacent sand and gravel beds being considered too loose to support the weight of the intended building, it was thought necessary to secure this part of the foundation by erecting it upon an arch. The outer or N.E. pier of this arch stands in the old clay pit, in a shaft sunk to receive it more than 40 feet below the stratum of pot earth that had been removed, and descending through the beds of sand and gravel above mentioned, to the subjacent stratum of hard clay.

No. 12 at Loam Pit Hill. This sand lies on a bed of plastic clay which supports the water of the well in Mr. Conybeare's garden, and of all the wells on the plain of Blackheath at no great depth; it possesses the same peculiar dark red colour, with the plastic clay of Reading, Corfe Castle, and Paris, and has been used for pottery.* Beneath this clay the Woolwich shell beds and subjacent thick ash coloured sand are to be seen in several parts of the sloping terrace that surrounds the Blackheath plain. Under these on the north and west sides appears the chalk, separated from the ash coloured sand by the same thin pebble bed as at Reading. This pebble bed not attaining the thickness of one foot may be seen at the junction displayed by the descent to some ancient subterraneous quarries in chalk, called the caves, on the north side of the road ascending to Blackheath from Deptford; it may be seen also on the south side of the same road in some chalk pits on the slope of the hill: in both places it is covered by the thick ash coloured sand.

In the lane that leads down from the village of Charlton to the Thames, is a good section shewing the Woolwich shell beds incumbent on the ash coloured sand which appears there in great thickness.

The church of Charlton is on the edge of the continuation of the

* It is probable that the plastic clay contains at Blackheath as at Corfe Castle, Alum Bay and Loam Pit Hill, the remains of vegetable matter in a state approaching to coal; and that this circumstance has given origin to the erroneous opinion so prevalent, that there is good coal at Blackheath if Government would allow it to be worked.

The very high improbability of finding good coal above the chalk is acknowledged by all who have even the smallest acquaintance with the geological relations of the English coal mines. The presence of black vegetable matter in a state approaching charcoal in almost all our secondary argillaceous strata, has caused endless vain attempts to search for useful coal in formations where the discovery of that substance would be contrary to all experience in this country. No good coal has I believe been yet found in England in any stratum more recent than the new red sandstone, or red rock marl. That of the Cleveland Moors in Yorkshire, being above lias and in the oolite formation, is of so bad a quality as scarcely to form an exception to this position.

plain of Blackheath, which extends thence eastward to Plumsted Common and Boston Heath. (See map, Pl. 13.)

On the inner edge of this platform at the Plumsted Common brick kilns, which are at the base of the north-east extremity of Shooter's Hill, a large section exposes the London clay, abounding in selenites and septaria. This clay is dug for brick tiles and coarse pottery. In the same field with the clay pits and on the north side of them a shaft is sunk 120 feet to the surface of the subjacent chalk, which has been extracted to the further depth of 24 feet, being the object for which the shaft is made. The upper portion of this shaft is in alluvial gravel, between which and the chalk occur the Woolwich sands. Another shaft was begun in the same fields still nearer to the base of Shooter's Hill, but abandoned from the quantity of water that came in when they were at a depth of which the plastic clay should be found if continued to this point from Woolwich in the same relative position which it there occupies. The same thing happened in an adjoining field, where the shaft for chalk was stopped by the water at the depth of 36 feet.

In a ravine at the east end of Plumsted Common that falls towards the Thames, the plastic clay that upholds the water of these wells and shafts, is laid open on each side of the hollow way, and throws out a line of springs at its junction with an incumbent stratum that is identical with the bed covering the plastic clay at Blackheath and Woolwich. On the east of this ravine in a deeper hollow called the King's Highway we recognise the sand and gravel beds below this plastic clay corresponding with Nos. 4, 5, 6, of the Woolwich Pit, and 4, 5, 6, of the Loam Pit Hill section; beneath these is the ash coloured sand No. 3 of Woolwich. The King's Highway descends into a still deeper valley (through which runs the road leading from Plumsted to Wickham); this valley is cut to a considerable depth in the chalk.

The north-east side of it is steep, and has at its base a large chalk pit, the top of which displays the Reading oyster bed one foot thick between the chalk and incumbent ash coloured Woolwich sand.

The plain at the summit of this bank is Boston Heath, where a well has recently been sunk about 200 feet; through gravel 65 feet, sandy beds 65, chalk 70. The water stands five feet deep in the chalk. I could get no accurate detail of the sinkings, but learnt that in descending they came to water far above the chalk though not in quantity sufficient to supply the well. The upper gravel in this well, and in the shafts at Plumsted, appears to be alluvial, though like that at Blackheath composed almost wholly of pebbles of rolled chalk flints, such as the neighbouring strata of the plastic clay formation contain abundantly, and from which they were probably derived.

The thickness of the alluvium in this district is exceedingly irregular, swelling suddenly, and as suddenly disappearing. It covers however nearly the whole surface of the under table land extending from Blackheath to Plumsted Common and Boston Heath, and is found also on the upper table of the summit of Shooter's Hill, as well as on many parts of the slope of its sides. The slopes that fall from the under table to the valley of the Thames are so frequently and so completely covered by this alluvium that except in places where they are laid open by artificial sections, it is difficult to discover the existence of any strata of the plastic clay formation. A striking example of this fact may be seen in the Park at Greenwich, where nearly all traces of the subjacent beds are concealed by a mass of alluvium along the steep slope where we might expect to see them exposed, and where there can be no doubt of their existence from the strength and regularity in which they appear at Charlton and Woolwich on the east, and near Deptford on the west of Greenwich Park along the continuation of the same escarpment.

In the banks of the Croydon canal at New Cross near Deptford is another section that confirms the place that has been assigned to the Woolwich beds below the London clay, and connected with the plastic. The section does not penetrate so deep as the thick ash coloured sand of Woolwich; but in the canal bank above the bridge we have the following beds laid open, though not sufficiently to ascertain their exact thickness, it does not however vary much from that of the upper beds in the Woolwich pits.

Section at the Canal in New Cross, beginning from the lowest bed.

No.

1. Plastic clay abundantly charged with the same shells as in the Woolwich pits.
2. Bed of small pebbles chiefly of rolled chalk flints.
3. Sandy loam and plastic clay.
4. Blue clay full of small selenites, probably the London clay.

The blue clay, No. 4, probably owes its selenites to the decomposition of its shells and iron pyrites; at present no shells are visible near the surface. Its juxta position to the London clay of the Sydenham Hills, of which it seems to be the continuation at their north-east extremity, goes far to identify it with that formation. The plastic clay, No. 3, is used for bricks and coarse pottery in a field adjoining this canal called Counter Hill, close to the New Cross on the east; and the Woolwich shell beds may be seen again at a lock of the canal about a mile above New Cross towards Croydon, in the plain that lies under the east side of the Sydenham Hills. At this lock Mr. Warburton pointed out to me the following shells. Ancilla buccinoides, cerithium denticulatum, cyclas deperdita, a small buccinum, and a small nerite.

It is mentioned by Woodward that the Woolwich shells are found at Camberwell and Beckenham, on the north-west and south-east sides of the Sydenham Hills. I have other authority for their occurrence at the following places on the south side of the Thames, Camberwell, Redriffe Tunnel, New Cross, Lewisham, Blackheath, Woolwich, Plumsted, Beckenham, Bromley, Chislehurst, Bexley, Cockleshell Bank, two miles south of South Fleet, Windmill Hill near Gravesend, and Higham on the Thames and Medway canal. They are found also at Rungewell Hill near Epsom, and at Headley between Epsom and Dorking.

These localities seem sufficient to warrant us in concluding that the formation of plastic clay extends over a large space in the south portion of the valley of the Thames from Reading to Gravesend.*

Woodward mentions oysters as being found on the north side of the Thames in a stratum of sand that covers the chalk near Hertford; this probably is one of the oyster beds of the plastic clay formation.

I remember that in 1806, fire bricks were burnt from some beds of fine sand and clay in the Park at Bulstrode, by the late Duke of Portland, and that moulds for refining sugar were (and are still) made within a mile of it, at some clay pits on the north side of the

* In Chislehurst, at the north-west angle of the park at Camden Place, the section of a chalk pit displays a great thickness of the ash coloured Woolwich sand, separated from the chalk by the thin pebble bed as at Reading.

The thick Woolwich sand (No. 3,) occurs also at Bexley, where (as is the case in many of the woods about Dartford) shafts 40 or 50 feet in depth have been sunk through it at an early period for the purpose of extracting the subjacent chalk, as is now done at Reading, and Plumsted brick kiln. Mr. Hasted, in his History of Kent, conjectures that many of these quarries were excavated by the Saxons, as places of retreat in times of danger. He states that some of them are 20 fathoms in depth, and that they are to be found also near Feversham, and at Fritwood on the south of Murston Passage near Milton. The explanation that is suggested by the geological position of all these places appears to be much more satisfactory.

London road about two miles east of Beaconsfield. These with other extensive beds of the same era which occur between Bulstrode and Windsor, are in almost immediate contact above the chalk, and appear to belong to the formation of plastic clay. The Windsor fire bricks and soft sandy bricks for arches, are probably also made from beds of this same formation. Mr. Warburton has been told that at Clewer near Windsor, the Thames cuts through a bed of shells which he suspects to be the same as are found at Woolwich.

We will now leave the beds of the plastic clay formation in the London basin, to trace them in the same relative position on the coast of Sussex.

A similar deposition of sand to that of Reading containing a breccia of chalk flints as its lowest stratum, (about three feet thick) was noticed by the Honourable H. G. Bennet and myself in July, 1814, between Newhaven and Beachy Head, in the cliff at Chimting Castle half a mile on the east side of Seaford. The sand here is fawn coloured passing into olive with flakes of mica almost a line in diameter, and occasionally contains irregular veins and masses of tubular concretions of iron-stone. Its greatest thickness is under 50 feet. Mr. Warburton informs me that he has seen similar concretions in the same stratum of sand at Sudbury in Suffolk, in immediate contact above the chalk. Under this sand at Chimting the breccia of the lowest bed forms an ochreous pudding stone composed of sand and chalk flints, (the latter both rolled and angular) the whole being strongly united by a ferruginous cement, and the flints covered externally with a green coating like those in the oyster bed at Reading. Specimens of this breccia have been presented to the Society by the Hon. H. G. Bennet. At Chimting Castle there is but a small insulated portion of these strata immediately incumbent on the chalk. This chalk rises suddenly to a lofty cliff on the east side of the flat ground that lies between Newhaven and Seaford, dividing the beds of the plastic clay formation at Newhaven from their outlying fragment at Chimting, with which they probably were connected before the excavation of the valley of the Ouse.

The upper surface of the chalk at Chimting, as seen in the cliffs, dips at an angle of about 20° to the west. The dip of the incumbent beds of breccia and sand is conformable with it. These last beds are soon lost in ascending the hill eastward from the Castle; first the sand ceases, and afterwards the breccia having formed a thin cap on the chalk for a short distance disappears a little below the Signal House about one mile east of Seaford. Hence the chalk extends forming a cliff to Cuckmere Haven, where on the heights composed of it on the west of the Cuckmere river, we sought in vain for the stratified sand and breccia, finding nothing but an alluvial cap of sand and gravel; and as far as the eye could judge, looking eastward from this point, there was no appearance of superior beds on any summits of the chalk which forms the entire substance of those magnificent cliffs that extend from Cuckmere Haven to Beachy Head.

At Newhaven, in the lowest part of the Castle Hill close to the mouth of the Ouse on the west side, we again found the breccia that has been described at Chimting Castle, nearly of the same thickness and in the same state and relative position between the upper surface of the chalk and the incumbent beds of sand; it differs from it only in being less firmly cemented, and appears equally identical with the oyster bed at Reading. The greater number of its flints are not much rolled.

The state of the tide, and their elevated position, prevented us from examining the hollows on the surface of the chalk in which

Mr. Webster discovered the pure alumine; we found however a large loose block containing this substance which filled cavities and veins in a mass of singular structure, composed of irregularly concentric thin layers of gypsum alternating with still thinner laminæ of ochreous iron ore. There were also small crystals of selenite in the same cavities with the alumine. The whole mass had strong marks of stalactitic origin, and was probably introduced into one of the cavities on the surface of the chalk by infiltration from the incumbent beds of marl, which abound in shells and iron pyrites, and contain all the elements from which the alumine, iron, and gypsum might be derived.

In this cliff of the Castle Hill at Newhaven the following section is presented, shewing beds of the plastic clay formation above the chalk.

Section of the Castle Hill at Newhaven, commencing from the lowest bed.

No.		Feet
1.	Chalk, containing alumine in hollows on its surface - -	50
2.	Breccia of green sand and chalk flints, the latter covered with a ferruginous crust - - - - - - - - - -	1
3.	Sand, varying from yellow to green and ash colour - -	20
4.	Series of clay beds containing coaly matter, selenites and fibrous gypsum, also leaves of plants, and sulphur-coloured clay - - - - - - - - - - - - - -	20
5.	Foliated blue clay containing cerithia, and cyclades, and a few oysters - - - - - - - - - - - - - - -	10

In this clay is a seam of iron pyrites about an inch thick with pyritical casts of cyclades and cerithia.

No.		Feet
6.	Consolidated argillaceous rock full of oysters, with a few cyclades and cerithia - - - - - - - - - - - -	5
7.	Alluvium full of broken chalk flints mixt with sand - -	10
		116

On comparing this section with those we have given in the London Basin we shall find a correspondence very striking. (See coloured sections, Pl. 13, No. 1 & 2.) On the same chalk No. 1. is the Reading Oyster bed, No. 2. which though inconsiderable in thickness seems constantly to form the next stratum above the chalk, though organic remains have been noticed in it only at Reading. No. 3, at Newhaven, is the ash coloured sand of Woolwich in diminished thickness. Nos. 4, 5, and 6, appear to be an enlarged condition of the plastic clay bed No. 7 and 8 of Woolwich, and from 7 to 11 inclusive at Loam Pit Hill.

We again observed localities of the red variety of plastic clay in a small valley at the village of Binstead, three miles west of Arundel, and again on the declivity of the hill by which the Binstead and Chichester road descends into Arundel.

These insulated portions of strata of the plastic clay formation that have been noticed at Seaford and Newhaven, and other places at the south base of the chalk hills of the South Downs of Sussex, appear to be outlying fragments at the eastern extremity of the great series of depositions above the chalk in the south of England, which Mr. Webster describes as extending from near Dorchester by the Trough of Pool and the New Forest to Portsmouth, Chichester, and the flat coast on the south-east of Arundel. (See Mr. Webster's Map, vol. ii. Geo. Trans. Pl. 10.*) Here they enter the English Channel, and just touching the coast with their outlying fragments at Newhaven and Chimting Castle, appear again on the opposite shores of France in the same relative position.

I am indebted to the kindness of M. Brongniart for the following section near Dieppe, which forms a valuable link connecting the formations above the chalk in France with those of the same era in the south of England. He has observed the following strata in the perpendicular cliff under the light-house of St. Margaret, on the west of Dieppe, counting upwards from the lowest stratum :

1. Chalk.

2. Sand and sandstone in thick beds containing concretions of the same substance.

3. Strata of plastic clay, impure and containing lignite much charged with iron pyrites, also oysters and cerithia, both in beds and irregularly disseminated.

4. Alluvium.

These strata M. Brongniart considers as identical with beds of the plastic clay formation in many other parts of France, particularly at Marly, and in the Soissonnois, where the same organic remains occupy strata similarly disposed and identical with those near Dieppe.

I shall add a few more circumstances of resemblance in the French and English formations of plastic clay.

It is noted by M. M. Cuvier and Brongniart, that in the basin of Paris the sand between the chalk and plastic clay, though very pure, is often coloured red or bluish grey. In the latter state it occurs at Woolwich, Lewisham, and Newhaven. We have already (p. 280.) stated the analogy which the Reading oyster bed bears to the brecciated bed next above the chalk at Meudon. Of the plastic clay it is also stated by the same authority that it often consists of two beds separated from each other by a stratum of sand. The lowest of these two being properly the pure plastic clay, while the upper is coarse, sandy, and blackish. The sand dividing them is also said to vary in colour like the plastic clay itself, from white, grey, and yellow, to grey mixed with red and pure red. The English beds of plastic clay and the sands attending them at Reading, Corfe Castle, and Alum Bay, exhibit analogous variations in colour and consistency; indeed at the latter place they run through almost every possible combination in the scale of colours. Between the upper plastic clay and calcaire grossier of Paris, there is also stated to be sometimes found a bed of sand of irregular thickness, which they are doubtful whether to consider as belonging to the formation of plastic clay or calcaire grossier, but are rather inclined to attribute it to the former. It contains organic remains in very few places. Is it not improbable that this bed is contemporaneous with some of the upper strata of the plastic clay formation which we find at Loam Pit Hill, at Blackheath, and in the Isle of Wight, at which last place the beds belonging to this series are accumulated to a thickness far greater than has been yet noticed in any other spot, amounting at Alum Bay, according to Mr. Webster, to 1131 feet, interposed between the chalk and London clay.

Viewing it on the great scale then we may consider this formation, which has been characterized by the title of plastic clay, as composed of an indefinite number of sand, clay, and pebble beds, irregularly alternating. Of these, the sand forms in England, the most extensive deposition, in which the clay and pebbles are interposed subordinately and at irregular intervals.

Again, the occurrence of organic remains in the different beds of this formation, is like the alternation of the strata composing it, exceedingly irregular: sometimes they occupy the clay, at other times the sand or pebbles, and very frequently are wanting in them all.

A good example of shells occurring, mixed with large pebbles, may be seen at Sundridge Park, near Bromley, in Kent, where we find an immense deposit of shells, peculiar to the plastic clay formation, accumulated confusedly in a bed of loose sand and pebbles. Of these shells some are broken and others entire, and delicately preserved. They are aslo sometimes fixed together by a calcareous cement (derived apparently from the substance of the shells themselves) forming a hard breccia with the siliceous pebbles and sand in which they are imbedded. A similar breccia was sunk into in the workings of the Redriffe tunnel.

I have from this bed at Bromley a specimen, in which five oyster shells are so affixed to the opposite sides of a large kidney-shaped pebble, that they seem to have commenced their first growth on it, and to have been attached to it through life, without injury by friction from the neighbouring pebbles. We cannot but infer then that these pebbles received their form during a long period of agitation, which was succeeded by a period of repose; in which latter they were in a state of sufficient tranquillity for the shells in question to live and die undisturbed in the midst of them.

The enormous quantity of these completely rolled and rounded chalk flint pebbles * that occur in the English plastic clay formation

* It may be observed of these pebbles occurring in the plastic clay formation, that they are never calcareous, but composed almost entirely of oval or roundish and rather flat chalk flints, completely rolled down and slightly altered, sometimes to the centre, by decomposition; which beginning from without has produced, in some cases, a number of concentric zones, disposed in agate like rings, nearly parallel to the outer surface of the pebble, and resembling an agate in colour though inferior in purity. The fact that in these pebbles we occasionally find fragments of organic remains peculiar to the chalk formation, shews that they were not formed like agates in empty cavities. And the decomposition of their iron commencing from the outer surface, is fully adequate to produce the concentric structure which they present; as may be seen in similar concentric zones resulting from the same cause in pebbles of sandstone, and many other rocks, of which the substance is compact and tolerably uniform in texture.

on the south of London, corroborate the arguments adduced by M. M. Cuvier and Brongniart, from the irregular projections and furrowed surface of the French chalk, and from the fragments of chalk forming a breccia with the plastic clay at Meudon, to prove the consolidation of the chalk to have been completed before that partial destruction of its upper strata by the force of water, to which they justly attribute these furrows and the Meudon breccia. These English beds of chalk flint pebbles (the wreck of strata thus destroyed) afford additional evidence of the immense scale on which this aqueous destruction was carried on, and confirm also the conjecture (which by them is chiefly grounded on the total difference of the organic remains in the two formations) that a long period of time has probably intervened between the deposition of the chalk and the plastic clay.

More frequently the pebbles aro clouded with tints of red and yellow, presenting an indefinite variety of beautiful modifications, and assuming the irregular arrangement of the colours in an Egyptian pebble. The finest varieties of these colours are displayed to the best advantage in polished specimens of the Hertfordshire pudding-stone, so common in cabinets and ornamental jewellery. The pebbles of this pudding-stone appear to be no other than altered chalk flints of the same era with those found at Blackheath, and differing only in the accident of their being firmly united by a strong siliceous cement. Many of the purest varieties of the Blackheath pebbles if polished, are exactly similar to those of the Hertfordshire pudding-stone.

Large blocks of a coarse variety of the same siliceous pudding-stone are not uncommon on the surface of the chalk in the south of England. I have seen them at Bradenham, near High Wycombe, at Nettlebed, at Portesham, near Abbotsbury, and in Devonshire, lying insulated on the bare chalk. They have not yet I believe been found imbedded in their native stratum, which seems to have been destroyed extensively above the English chalk, and to have been a member of that series of irregular alternations of beds of clay, sand, and gravel, either separate or mixed together, which for reasons already stated, has been designated by the appellation of the plastic clay formation.

APPENDIX.

It may not be uninteresting to insert here the following notices, illustrative of the formation of the marsh lands immediately below London, which, though not directly connected with our subject, the plastic clay, yet forms a prominent feature in the physical history of that part of the neighbourhood of the metropolis which we have been describing.

It is well known that at this time the waters of the Thames from London to the sea are upheld by dykes or sea walls. Within these dykes the river by its daily sediment of mud has so raised its bed, that even in ordinary tides the water is above the level of the meadows, as far up as Woolwich and the Isle of Dogs. This elevation of its bed is precisely analogous to what has happened near the mouths of the Po, the Rhine, and other large rivers, which have been upheld for many centuries by embankments. The following facts tend to illustrate the process that was going on before the period at which these embankments were made.

In the account given by Capt. J. Perry, about 100 years ago, of the stopping of the breach made in the sea wall at Dagenham, about twelve miles below London, that able engineer particularly describes what he calls moor log. This, he says, was composed of vegetable matter heaped together, but chiefly of brushwood, among which there appeared to be a considerable quantity of hazel trees ; hazel nuts were also found in the mass, but were easily crushed, the kernel being entirely perished. There were also trunks of other trees, of which the yews were the least decayed ; some of them measured 15 or 16 inches in diameter. There were also willows two feet and upwards in diameter; they retained a whitish colour like touchwood, and were softer than the adjacent earth or moor log. The moor log appeared at about three or four feet under the marsh ground, and differed in thickness at different parts; at Deptford it was six feet thick; at Woolwich Reach, opposite the ballast wharf, it was between seven and eight feet thick; its thickness as well as its breadth gradually increasing down the river. Beneath the moor log was a stratum of blue clay, and under this gravel and sand. Stags horns were likewise found in different places, a little above the vein of moor log.

Mr. Derham's account of the Dagenham marsh land (Phil. Trans. 1710, p. 478), affords the following particulars in addition to those given by Capt. Perry.

The stumps and roots of many trees were found in the same posture in which they grew, situated in a soil consisting of a black oozy earth, full of the roots of reeds; the tops of these stumps were so worn that it could not be ascertained whether the bodies had been cut off by the ax, or broken by natural violence. The bodies themselves lay horizontally on the surface of the oozy earth, in confusion, but a northerly direction seemed most prevalent. They appeared almost all of them to have been alder, though at first they were supposed to be yew. Over the trees lay a covering of grey mould, of the same nature with the sediment of the Thames at this day, varying in thickness from seven to twelve feet. Mr. Derham mentions the names of the following places in which he noticed traces of this subterranean forest. Dagenham, Havering, Rainham, Wennington, Purfleet, West Thorrock.

It happened a few years ago that in cutting the canal and basins in the Isle of Dogs, a subterranean forest containing hazel nuts, with hazel and other trees, was discovered to lie under the bed of indurated mud, that forms the surface of that peninsula.

These data throw much light on the natural operations that were going on, between the period of the last retreat of the diluvian waters, and that at which sea walls began to be erected against the rising waters of the Thames. The substratum of clay and gravel mentioned by Capt. Perry, formed the first surface of the valley uncovered by mud or water, and lying at a small elevation above the then existing high water level of the river. The sediments of the river gradually raised its bed, and caused its waters to spread laterally over the adjacent low lands; first converting to marsh by inundations at high tides, and at length completely burying, by its daily sediment of mud, those tracts which in the early periods of the rise of the bed of Thames, had been quite dry and covered with extensive forests. The horns of stags that inhabited them lie on the surface of the moor log, which appears to be the wreck of these ancient forests, first converted to swamps as the water began to reach their level, at length wholly destroyed by the constant inundation of the ground on which they grew, and still affording evidence of their position and extent, in the roots and trunks that lie buried on the surface and in the mass of the moor log, and over which a bed of mud has subsequently been deposited by those gradually rising waters which caused the destruction of the forest.

XVI. *On some Beds of Shell-Marle in Scotland.*

By HENRY WARBURTON, Esq. F.R.S.

VICE PRESIDENT OF THE GEOLOGICAL SOCIETY.

[Read January 21st, 1814.]

THE late researches of Messrs. Cuvier and Brongniart in the vicinity of Paris, and those of Mr. Webster in the Isle of Wight, have made known to us a new series of beds, of which the most remarkable consist almost entirely of the shells of freshwater molluscæ. An instance of analogous recent accumulations will not, I hope, be undeserving of the Society's attention.

The Rev. James Lambert, of Trinity College, Cambridge, has supplied me with most of the following particulars, which have been chiefly abstracted from the returns made to that gentleman's enquiries by some respectable land agents and proprietors in the neighbourhood of Dundee.

The beds of shell-marle are chiefly found in the shire of Angus, in the several parishes of Kerrymuir, Airlie, Forfar, Rescobie, Meigh, Newtigh, Abermo', and Lundie, lying from eight to twenty miles north-west or north-east of Dundee. They are also known in the shires of Perth and Ross, and south of the Tay in the shire of Fife near to St. Andrew's, and of Berwick near to Kelso.

The shells, which, by the kindness of Mr. Lambert, I am enabled to present to the Society, were taken from a bed of marle lying on the estate of Mr. Cleghorn, about four miles south of St. Andrew's. This bed is found in a piece of swampy ground, at the bottom of a natural hollow, in attempting to drain which the marle was discovered. It is entirely covered by moss, and also rests upon moss, of which a specimen, taken from beneath the marle, accompanies the shells. In the middle of this hollow the marle is five feet thick.

Logie lies in the parish of Kerrymuir, between Glamis and Forfar. The following succession of beds has been discovered on cutting trenches for obtaining the peat mosses. Moss, containing trees, from four to six feet thick; shell marle, from six to seven feet; blue clay; shell marle, nine inches thick; gravel or quick sand, and sometimes a third bed of marle.

These beds of marle are continuous, and extend over many acres; they are thickest in the middle, and become gradually thinner towards the edges of the bogs.

The marle of Logie, as well as that from Fifeshire above described, consists almost entirely of the shells of the Helix putris, such as are the specimens presented: myriads of this species are now found living in the brooks that flow through the bogs of Logie. Living specimens of the Mytilus cygneus, equal in dimensions to those mentioned by Montagu, and occasionally containing fine pearls, are found in the same brooks: of this shell the marle also contains fragments.

Not far from Logie, in the parish of Forfar, are the moss and loch of Resteneth, which about the year 1794 were entirely drained by a cut made into the loch of Rescobie, lying at the distance of half a mile on a lower level. Both the moss and loch contain shell marle: that in the moss is covered to the depth of five or six feet by fine black peat, that in the loch not unfrequently so. The marle does not lie in a horizontal bed, but shelves from the middle of the loch, where it is eleven feet thick, to the edges of the moss, where it does not exceed in thickness a few inches.

The marle of Resteneth consists of the shells belonging to the Helix putris (Pennant), (peregra Montagu), and the Cardium amnicum (Mont.), both which are now found living in the waters that flow through the loch. Neither of these in size much exceed a pea; yet not less than two millions of cubic feet of marle had been dug between the years 1794 and 1807 for agricultural purposes.*

Resteneth loch lies about twelve miles distant from the sea at the level of 196 feet above low water mark. It gives rise to a considerable stream, which flows into the sea about thirteen miles east of the loch, after forming in the three first miles of its course the lochs of Rescobie, Balgarvie and Balmodin, in all which shell marle is obtained by dredging with boats; in the loch of Rescobie at the depth of 25 fathoms.

Lord Duncan's loch is situated in the parish of Lundie, eight or nine miles north-west of Dundee. It covers an area of seventy acres, of which fifty have been drained, and from which shell marle is dug, as in that of Resteneth.

In all these places we have the same appearances; the marle always occupying some natural hollow or basin, which either is or has been the site of a pool of water. In Resteneth loch we have

* The shell marle in an economical point of view is of some importance. On the estate of Mr. Cleghorn, from an area of half an acre, a quantity has been raised that would have cost £2500. if procured from St. Andrew's, after being imported thither from the shire of Angus. At Resteneth it is dug with the spade, and sold to farmers at 2d. the cubic foot, from two hundred and fifty to five hundred cubic feet being laid on the English acre. That which lies immediately under the moss is reckoned the best. Some mention of the economical use of shell marle will be found in the Statistical Survey of Scotland, under the heads of several of the above mentioned parishes.

the complete history of one of these accumulations. A pool of water is peopled by myriads of little animals, with whose exuviæ it becomes gradually filled, and thus beds are raised and fitted for vegetation. Water and land plants arise and decay, and in a humid soil a peat bog is formed; perhaps (as has happened at Logie) the outlet of the water is again choaked, and the same effects renew in the same order.

The calcareous beds thus formed are, it is true, on a small scale, when compared with those of the Paris or Hampshire basins. Yet contrasting the insignificance of these little testaceous animals with the space occupied by their exuviæ, which at Lundie, for instance, is many feet deep and covers an area of seventy acres, the extent of their beds is surprising. The siliceous beds indeed, and the porcelanic limestone of the Paris basin are wanting to this recent formation, and are still problems for geologists to solve; but in respect of the quantity of shelly matter the analogy is perfect, and the imagination can readily seize the effects produced in a warm and prolific climate with animals of decuple dimensions, and with a liberal allowance of time.

Since shell marle is not common to all the Scotch lakes, it might be worth inquiry what peculiar circumstances favoured its production; whether calcareous salts are particularly abundant in the waters that yield it; and what are the rocks from which those waters spring, or which form the sides of containing basins. The water of Resteneth is said to be remarkably clear.

There is no limestone near to Logie, except in a small vein, distant therefrom two miles, at Readie in the parish of Airlie. The predominant rock about Resteneth is a sandstone of a brown, red, or whitish grey colour, which alternates with a coarse ferruginous pudding stone. Whin-dykes, and veins of barytic spar, occasionally tinged with copper, intersect this rock. From the northern edge of the loch rises a considerable hill, called Pitscanellie hill, composed entirely of grit-stone, whose different beds, alternating with a coarse breccia, furnish stones for slating, paving, mill-stones, and rubble work. From the south side of the loch rises a hill of freestone, whose summit is covered by whin. This bed of whin is of no great breadth, and extends about two miles in length, from one end of the ridge to the other. If we may guess from this description, the prevailing rock seems to be the red sandstone, so common in this island; it is in basins formed in this rock that the shell marle is found in the vicinity of Kelso.

XVII. *Geological Remarks on the Vicinity of Maestricht.*

By the Rev. W. E. HONY, Fellow of Exeter Coll. Oxford.

MEMBER OF THE GEOLOGICAL SOCIETY.

Read 16th December, 1814.

THE interest excited by the magnificent specimens which have been discovered at different times in the neighbourhood of Maestricht, induced me when in the Low Countries in the summer of the present year, to go somewhat out of my way in order to visit so celebrated a spot. I am sorry that my stay there was necessarily so short that I could take only a very hasty survey of that country. I am induced however to lay before the Society a short sketch of what I saw, because I believe that though so much has been written and said on the subject of the fossils of Maestricht, but little is known in England as to the relative situation of the strata containing them. The mountain of St. Pierre commences about a mile south from the town of Maestricht, and extends in a direction towards Liege for nearly three leagues. It is an insulated hill forming a ridge, the sides of which are for the most part very steep. The subterraneous quarries must have been worked from a very early period, and are said to extend through its whole length. The hill presents an almost perpendicular escarpment towards the Meuse, and it is in walking on this side of it that the strata are seen to the greatest advantage.

About a league from Maestricht you obtain a good section of the lower beds of the hill, and these are decidedly chalk, containing beds of flint nodules from two to three feet distant from each other. The chalk appears to contain fewer fossils than that which we have in this country, but in the nature of these fossils, and in every other respect, completely resembles it.

Above these are beds resembling the chalk in colour, but more hard and gritty to the touch.

Above these again lie a succession of beds of the calcareous freestone of which the mass of the hill is composed, and it is in these that the quarries are situated. This stone is of a yellowish colour, and so extremely soft in the quarry that it may be easily cut with a knife; it becomes however of a lighter colour and more hard by exposure to the air. Here and there is found a thin stratum completely made up of fragments of marine substances; these are chiefly species of corallines and madrepores mixed with shells. In these thin strata the remains are much less perfect than in those which contain fewer of them, and their substance is so extremely tender that it is very difficult to obtain a specimen which does not break to pieces immediately. Such parts of the rock, though of course unfit for building, are not useless, but are broken down, and in that state conveyed by the Meuse to Holland as a manure for the meadow land.

The whole of these beds from the chalk to the top of the hill are separated from each other by beds of flints, which exactly resemble those found in the chalk, presenting like them the usual appearance of having been formed on corallines, &c.

The beds of flints in the chalk and lower strata of freestone, as has been mentioned, are at a distance from each other of not more than two or three feet, but as you ascendd, the istance between them is greater, and towards the upper part of the hill is as much as eight or ten feet.

These flints frequently contain organic remains; of these the most common is the belemnite; shells also and silicified wood are not uncommon.

The height of the hill above the Meuse is I should imagine about 150 feet.

To the eye the strata appear to be perfectly horizontal. As however, I found the chalk gradually rising as I proceeded in a direction nearly south, it is probable that there may be a very slight inclination towards the north. My stay was too short to enable me to give any account of the numerous fossils of this rock. I may however mention that those which I found most common were various species of corallines and madrepores, (particularly the fungites;) belemnites; numulites; several species of echini, amongst others, a small one having the mouth in the centre of the base and vent lateral; several kinds of oysters and pectines. I was also fortunate enough to find a very beautiful baculites with turrited articulations, but this I believe is very rare. It is described in the 3d vol. of Parkinson's Organic Remains, p. 142.

The top of the hill is covered by a bed of gravel, in some places of considerable thickness, containing rolled pebbles of flint, white quartz, graywacké containing veins of quartz, and a red sandstone. I believe that this gravel rests immediately on the strata which compose the hill, and that the beds of sand which M. Faujas de St. Fond thought he perceived under the gravel are only a part of the rock in a state of decomposition.

It is rather extraordinary that this celebrated naturalist should have described the freestone rock of Maestricht as "un grès quartzeux faiblement lié par un gluten calcaire." It appears that it is almost wholly calcareous, containing little or no siliceous matter.

Geologists will of course be anxious to learn whether these beds, occupying a situation similar to that of the Paris strata, are identical with any of them. I am myself too little acquainted with the latter to form any opinion on the subject. I am inclined to think however that the Maestricht rock differs from all the beds which form the Paris basin.

It would be departing too much from common language to call it chalk; but the gradual transition of the chalk into the freestone, and the separation of the strata from each other by parallel beds of flint, seem to be sufficient reasons for including it in the chalk formation.

When nearly at the southern extremity of St. Pierre I crossed over to the right bank of the Meuse to examine a rock which rises very boldly near a little town called Visé. This rock I found to resemble the limestone of Derbyshire, containing all the fossils characteristic of that formation, and like it frequently passing into chert. The fossils most abundant are several species of anomiæ and entrochi: the latter are more particularly abundant in the chert. In some pieces I also found that species of coal which is called anthracite included in veins of calcareous spar.

In the country round Liege, distant about two leagues S.W. of this place, there are (as is well known) extensive collieries.

XVIII. *On the Parallel Roads of Glen Roy.*

By J. Mac Culloch, M.D. F.L.S.

PRESIDENT OF THE GEOLOGICAL SOCIETY,

CHEMIST TO THE ORDNANCE,
LECTURER ON CHEMISTRY AT THE ROYAL MILITARY ACADEMY,
AND GEOLOGIST TO THE TRIGONOMETRICAL SURVEY.

[Read 3d January, 1817.]

THE extraordinary and hitherto solitary phenomena which I have undertaken to describe, although long known and celebrated by the natives as the traditional works of their great ancestors, remained concealed from the world in general till Mr. Pennant published a short account of Glen Roy in an appendix to his Tour. A second description appeared in the Statistical Survey of Scotland, since which I know not that any attempt has been made to explain the origin of the Parallel Roads, although they have long been objects of curiosity to philosophical as well as to ordinary tourists. However convinced the Highlanders may have formerly been that these parallel roads, as they are called, were the works of Fingal and the heroes of his age, they have lately inclined to a different belief, and with most philosophers are willing to think that they may have been the result of the action of water. Still the matter remains disputed among the partizans of the different theories, and as the establishment of the latter opinion is attended with geological consequences of the first importance, it deserves to be investigated with the greatest care.

The appearance of the parallel roads is so extraordinary as to impress the imagination of the most unphilosophical, nay, even of the most incurious spectator. It is not therefore surprising that they should excite the admiration of the natives, in whom the progress of civilization has not yet extirpated those poetical feelings and that sense of the sublime, of which their literary relics still afford us proofs.

On each side of a long, hollow, deep valley, bounded by dark and lofty mountains, and at a great elevation, three strong lines are traced, parallel to each other and to the horizon, the levels of the opposite ones coinciding precisely with each other. So rarely does nature present us in her larger features with artificial forms, or with the semblance of mathematical exactness, that no conviction of the contrary can divest the spectator of the feeling that he is contemplating a work of art, a work, of which the gigantic dimensions and bold features appear to surpass the efforts of mortal powers. We cannot therefore wonder that the solitary and poetical Highlander, educated amid mountain storms and hourly conversant with the sublime appearances of Nature, should attribute to the ideal and gigantic beings of former days a work which scorning the mimic efforts of the present race, marches over the mountain and the valley, holding its undeviating course over the impassable crag, and the destroying torrent.

But it is the duty of the philosopher to investigate causes. I purpose therefore to give as ample and detailed a description as I was able to draw up, of the appearances themselves, and afterwards to examine the several modes of explanation which have been offered; stating the arguments for and against the different hypotheses as amply and as distinctly as I can, and deducing from the balance of probabilities such conclusions as the evidence appears to justify. The necessity of investigating their probable or possible origin from natural causes will, in consequence of the extent of their geographical connections, lead to rather a wide range of enquiry, not however wider than the importance of the subject will be found to justify. I have attempted to keep clear of all speculations purely hypothetical, and wherever physical evidence and analogy have entirely failed, have rather chosen to leave the question in its natural obscurity than to involve it in more profound darkness by assigning imaginary causes. To avoid any bias which the original and not sufficiently descriptive term, *Parallel roads*, might preserve in the reader's mind, I have substituted that of *Lines*, a term less exceptionable and sufficiently expressive of their appearance.*

* I think it right to remark that every precaution was taken in ascertaining both the levels and the elevations which will be referred to in the arguments hereafter to be used. Those which could not be accurately determined, on account of the nature and extent of the ground requiring a survey, have been estimated by such approximations as were attainable, and these are distinguished wherever they occur. However imperfect, they are no where so lax as to affect the arguments, even if the errors were much greater than any which could have occurred, as no undue stress is any where laid on hypothetical assumptions. The levels of the *lines* were observed by a spirit level, and the vertical distances between them were measured by the same instrument. One barometer of Ramsden's construction was applied for the measurement of the elevations; and such differences between any two altitudes as were required, were ascertained by observations repeated at very short intervals. For determining the absolute altitudes above the level of the sea, the barometric observations were compared with a register kept purposely for these experiments by Lord Gray at Kinfauns Castle, those observations, with the required corrections, being made at the same hours with instruments of similar construction. To remove still more any chance of error, the principal altitudes were deduced from a medium of nine observations taken on four different days, the greatest variations between the extremes not exceeding one twelfth of the whole. The altitude of the great Caledonian valley is known from the measurements belonging to the canal.

Notwithstanding all this care however, I can only consider these altitudes as approximations, since I am convinced from a careful comparison of barometric registers that this instrument cannot be relied on when used in this manner, as I have attempted to show in a late communication to this Society.

Before examining any of the theories which have been proposed to explain the singular appearance which this glen exhibits, I have judged it expedient to describe with as much accuracy as possible the appearances themselves, without entering on the question of causes, or prejudging in any degree the case. In thus describing it, I have preferred beginning at the source of the river, or rather at the commencement of the valley, since the rivers which form the Roy arise as mountain torrents, forming a junction in the middle of a valley of considerable magnitude.

A low hill of granite skirts the boundary between the source of the Spey and the valley of the Roy. At the foot of this hill, in a slightly elevated boggy plain, is found Loch Spey, which by a declivity for some time scarcely perceptible runs eastward through Badenoch to fall into the Moray firth. The western end of the boggy plain just mentioned stretches for a few hundred yards beyond the head of Loch Spey, and then descends by a sudden step into the upper valley of Glen Roy. This valley is of an oval form,

The principal map does not pretend to be an accurate survey. The defective nature of all the maps of Scotland hitherto constructed, as well as the smallness of their scales, prevented me from making any use of them for this purpose; but as the description would have been unintelligible without some sketch of the ground, I have given one which must however be considered merely in the light of a military reconnoissance. The sections do not pretend to be real. The transverse ones are, like the map, delineated without attention to their true proportions, and are merely intended to mark the important variations of the form of the bottom of the valley, and more particularly the points in which the *lines* and the terraces coincide. The curved longitudinal sections are equally artificial, but they assist the imagination in pursuing the wide connections of Glen Roy with the sea. The profiles of the *lines* are *deduced* from actual measurement by the spirit level.

Of the accompanying views I need only say that they are intended to elucidate several parts of the description, and to convey a slight notion of the nature of the appearances in question. The purposes of the two other maps in shewing the connections of Glen Roy with the neighbouring and with the more distant country will be obvious.

about four miles in length and one or more in breadth, being bounded on two opposite sides by high mountains. From them descend two streams which unite about the middle of the valley to form the Roy. From this junction the water flows with a moderate velocity for a space of two miles, when the glen suddenly contracts and terminates in a rocky hill of low elevation. The water, forcing its way for some distance through a narrow pass between approaching rocks, enters into a second glen, which I shall distinguish by the name of the lower Glen Roy. It is in this latter glen that the phenomenon of the *roads* is chiefly to be seen, nor on entering the upper from the lower one would it be suspected that any similar appearance existed in it. A *line* however may be observed on the left hand extending upwards from the junction which forms the Roy, along the face of a low hill towards the elevation in which Loch Spey lies. A careful examination of this *line* by the spirit level shows it to consist of a level narrow terrace, which if prolonged eastward would cut the perpendicular above Loch Spey, and if continued westward would meet the summit of the flat rock that forms the division between the higher and lower Glen Roy. It will speedily be seen that this summit is on a level with the uppermost of the *lines* in lower Glen Roy, and that the terrace which I have now described is in fact a prolongation of that *line*. It is necessary to remark that no other terrace or *line* is found in the upper valley.*

The flat rock already mentioned as forming the gorge of lower

* The map, Pl. 20, is copied from Arrowsmith's work, and contains various *lines* supposed to be seen in the adjoining vallies. I have retained them in all the places which I had no opportunity of examining, without intending to be responsible for their existence. Where they did not agree with my own observations I have without scruple omitted or altered them.

Glen Roy, or the division between the upper and lower vallies, is seen projecting at right angles to the right hand side of the glen, and then turning westward so as to form a promontory parallel to that side; having a *cul de sac* on one hand and giving passage to the river on the other. No *line* is visible on the rock itself, but from its junction with the side of the valley (as the plan will show)* the two *lines* commence, and are seen running on far along the face of the hill, the uppermost one being precisely even with the flat parts of the surface of the rock just described. It is proper here to remark that the surface of this rock rises higher in some places than that *line*, yet it is not marked by any corresponding one. The drawings accompanying this paper will render intelligible that which words alone cannot describe; and I must here premise once for all, that this minuteness of description, however superfluous it may at first sight appear, is absolutely required, as the circumstances thus dwelt on will be of essential use in investigating the cause of the appearances under discussion. It is by an attention to circumstances which at the first glance appear trivial, that abstruse truths are often discovered; and it is precisely where leading and obvious phenomena offer no clue to guide us, that a ray of light will often be thrown on the subject from appearances at first neglected. Had the greater features of Glen Roy been capable of explaining the singular phenomena which it exhibits, this paper would have perhaps been altogether superfluous, since all observers would have been agreed respecting their causes.

These level and parallel *lines* are scarcely to be seen in this place, except by looking from below upwards, a position by which they are foreshortened to the spectator's eye. They may sometimes

* Plate 18.

indeed be distinguished (but with more difficulty) if viewed in profile. In the part which I am now describing the *lines* are narrow and the declination of their surfaces from the horizontal plane is considerable, as the profiles* will show. This ground is rocky and irregular, the natural rock being visible in many places, while in the rest of the glen it is but rarely seen; and it may be remarked that wherever the natural rock comes to light these marks or *lines* are always least discernible, being of much smaller dimensions, and having a much greater conformity in their slopes to the natural slope of the hill. Whatever loose matter occurs here consists of large fragments, which have evidently descended from the hill above. That this is their origin and that they are not transported materials is plain, since they are not rounded and since they exactly resemble the natural rock, which is of a remarkable character, consisting of mica slate traversed by numerous veins of red granite; a rock which is limited to the upper part of the glen and is not found in the neighbouring hills. The natural rock projects in many parts of the *line* so as to interrupt it; or it is wanting wherever a solid mass of rock occurs in its course. As I am here only describing the appearances, I will not anticipate the arguments by asking whether the *line* has not been sometimes overwhelmed by the fall of rubbish; in many cases however its obscurity evidently arises from the refractory nature of the materials on which it is traced. Obscure marks of two similar *lines* are here and there visible on the left hand side in this place, particularly on certain projecting faces where the surface of the hill is, from its outline, evidently covered with a coat of alluvial matter. Independently of these fragments of the two principal *lines*, many short indistinct traces are to be seen at different levels from those on

* Plate 18, Profiles No. 3, 5.

which these two lie. It is here necessary to say that the two *lines* on the right now described are parallel to each other, and correspond precisely in level with the fragments of the two upper ones visible on the opposite side.

As we proceed down the glen a river is seen entering at the left hand equal in size to the Roy, and falling into it by a cascade which rushes over a rocky bed. Here a great series of terraces is found, forming a large *terreplein* at the top of this glen which I have called lower Glen Roy. These terraces are of different levels, as may be seen both in the section* and in the views that accompany this paper.† The highest of them will hereafter be proved to lie on a level with a third *line*, to be described in the course of this investigation. It falls off however by many successive stages of terraces, and numerous smaller ones are also to be seen descending down to the very bed of the river, skirting its banks and accompanying its course. The bottom of the glen is here an alluvial flat, as the above mentioned section will show. Between the two upper *lines* on the right hand an intermediate one now becomes visible for a space of about half a mile: I did not measure it, but to the eye it appears equidistant from both. At this point the two *lines* now described suddenly quit the rocky face described on the right hand, and continue their courses along the alluvial slopes of the declivities which follow; where also they acquire their greatest breadth and distinctness.

I forbear giving the breadths in all the places where I measured them, because it is not important. The profiles will show the principal varieties.‡ In detailing their measures I must remark that it would be impossible to describe the precise geographical point measured, and such often is the curvature at the entering and salient

* Sect. L, Plate 21. † Plate 14, 15. ‡ Plate 18.

angle, or at the inner and outer edge of the *line*, that no precise limit for the measure of breadth can be assigned; different modes of measurement may therefore produce differences of many feet.* It is sufficient if they agree generally, and in general sixty feet may be assumed as an average breadth: by far the largest portion of all the *lines* will be found to conform to this measurement.

Great terraces are now visible on the right. These are not precisely on the same level with that which I before mentioned as corresponding to the course of a third and lower *line*, but they do not differ materially from it.

I shall not describe the various rivers which enter the glen, the principal ones being marked in the plan, but may mention that in this upper part of the valley, both before and at the junction of Glen Turit with Glen Roy, they are generally accompanied by their own lateral terraces.

On the left hand going down the glen many marks or fragments of *lines* are seen between the principal ones; but these are short, and are remarkable for many obscurities and deficiences. In a few places there are errors of level to be seen in the *lines*. Examining these however there appears no doubt of their having been produced by partial subsidences of the whole alluvial face; and this is confirmed by the appearance of one great slide on the left, which has descended many feet, and which the imagination can readily replace. It is necessary to be cautious in examining these instances of errors of level, as the laws of perspective are apt to lead to mistake when the *lines* pass curved surfaces elevated high above the horizon.

Where the faces of the hills have been furrowed by the long continued action of descending torrents, the *lines* enter these hollows

* Plate 18, Profile No. 8.

for a certain space; and as this rule is general, it is unnecessary either to describe the spots or to mark the exceptions, but the fact itself is important. They are often ploughed across or obliterated by torrents obviously recent; and they sometimes also terminate abruptly in more ancient torrents; but still the two upper ones continue generally traceable and commonly very well marked: for the rest I must again refer to the plan.* From these appearances we can often ascertain the relative difference of age between the hollow or torrent and the *line:* and we can also in some cases distinguish that a part of one hollow is prior and a part posterior to it. It may be remarked generally that the *lines* are best marked on the straightest sides, or on those slopes which lie in a straight or a slightly curved plane, while they are most obscure where the most numerous sinuosities, torrents, irregularities, or rocky faces occur. Among the best marked are the two uppermost ones on the right hand above Glen Turit, one of those at the head of Glen Turit, and the three above Glen Fintec on the same side. About two miles below the head of lower Glen Roy, a semi-circular *cory* or hollow opens on the right, giving rise to a considerable stream and falling gradually into Glen Turit. The two upper *lines* (for as yet there are no more) enter it a little way and then disappear. On its opposite side, or that which adjoins to Glen Turit, appear three marks offering the only considerable anomaly in the whole course of these *lines.* The two uppermost, which on a superficial view seem to be the continuation of the two before described, will be found more distant from each other than these, and on applying the spirit level to them it is seen that the lowest is continuous with the upper one of Glen Roy, but that the highest is a supernumerary one, although of the same apparent dimension and form, and that it terminates

* Plate 18.

abruptly at both ends. That one which is continuous with the upper *line* of Glen Roy is prolonged into Glen Turit. Of the lower one I unfortunately neglected to remark, from the multiplicity of objects calling for attention at the same time, whether it was anomalous, or whether, as it appears to the eye, it is not continuous with the third and lowest in Glen Roy. I shall forbear pursuing their course into Glen Turit, as the description of this glen will find its proper place hereafter.

Passing over therefore the description of this glen, a great accumulated mass of terraces similar to those in the upper part of Glen Roy is seen at the junction of the two streams which issue from it, and from the small glen or cory whose name I could not discover, but which is delineated in the map.* The compound mass offers a surface of different heights, but the highest of them corresponds precisely in level with the highest terraces at the top of Glen Roy, and equally so with the lowermost *line* of the three for which Glen Roy is remarkable, and which now first appears continuously on the right side, having been some time visible, though in an imperfect state, on the left. The minor terraces which skirt the river are also visible here, and accompany it for a considerable space downwards along the bottom of the glen, which still continues to present an irregular alluvial flat; but as it is sufficiently marked in the plan and sections, I need not enter into further details respecting it.† The accompanying views‡ will also afford an additional and a much better illustration than any description could do.

Independently of these compound and minor terraces which are accumulated below the lowest *line*, there are also fragments and parts of irregular terraces in various places at a level above it, besides considerable channelled alluvia forming a sort of conoidal

* Plate 18. † Sect. K, Plate 21.—Plate 18. ‡ Plates 14, 15.

segments on the faces of the hill, and appearing to be the remains of more regular terraces furrowed and destroyed by the mountain torrents. Although the two upper *lines* are to be traced at the salient angle opposite to Glen Turit, they are interrupted and obscure to the very top of the valley. It is important to remark that the glen here takes a turn,* forming a considerable angle, the opening of Glen Turit being not far from the re-entering one. At the salient angle the lowermost *line* is first seen, as on the right side it first is found at the entrance of Glen Turit, into the wide opening of which it runs, together with the upper ones, for a very short space; the whole of them speedily disappearing on this side of that glen, while on the contrary side the upper one runs well marked until its course is suspended by the gradual rise of the bottom of the valley.

Having, at this part of Glen Roy arrived at the point where three *lines* on each side are visible, it is time to observe that there is a perfect correspondence of level between the opposite pairs wherever they are found. Numerous trials with the spirit level confirm the universality of this rule, and from this point of the glen downwards to its junction with Glen Spean, I did not observe that any one instance occurred of even the little anomalous curvatures which I have already mentioned as happening in the upper part of the valley. They are in many places entirely wanting, as the plan will show, and as will be mentioned hereafter, but whereever they are present they obey the law. It is to this circumstance they owe that aspect of parallelism from which they have derived a part of their name, but which evidently can be a parallelism only in the vertical plane. The varying slope of the hills prevents all

* Pl. 18.

parallelism in the horizontal one, and causes, as will be readily comprehended, the distance between any two approximate ones to vary exceedingly, a circumstance of importance in examining some of the speculations which have been formed relating to their cause and origin. In these circumstances it would be as useless as it would be difficult, to give the measures of their variations. It is sufficient to remark that the nearest horizontal distance between the uppermost and nearest *lines* may be taken at 150 or 160 feet, and the greatest between the two lowermost and most distant ones at 1000; an approximation sufficiently accurate for the purpose. But the vertical distances as ascertained by the spirit level are 82 feet between the uppermost and second, and 212 between the second and lowermost. I have omitted fractions in this measurement, because the irregularity of the ground is such, and the uncertainty of the true surface of the line so great, that it is impossible to determine this point to a great nicety. The slope of each *line* is likewise so considerable, and at the same time so various, that a great variation of this vertical distance would take place according to the point adopted as the station of the spirit level, and I have therefore fixed it at the middle of each *line*. I need not here call the reader's attention to the distances between the uppermost *line* and the top and bottom of the glen respectively, as these will fall more properly to be considered when the general levels of the surrounding vallies and outlets are examined.* For the same reasons the aspect and materials of the *lines* themselves will be best considered when I have described the mineralogical structure of the whole glen, and particularly that of the surfaces on which they are formed.

* As a convenient reference to the reader, I have however thought proper to tabulate in one view all the measurements relating to this subject which are in any way interesting;

Having passed Glen Turit, the three *lines* now become distinct and well marked on the right side, where the hill is covered with a thick alluvium: on the opposite side they are also distinct, although here and there slight appearances of irregularity, and supernumerary marks occur. The bottom of the glen continues to exhibit an

many of them being objects of general curiosity, even when not particularly connected with this subject.

	FEET.
Upper *line* of Glen Roy, above the Western sea at Loch Eil	1262
Ditto above the German sea	1266
Lowest *line* of ditto, above the Western sea	976
Upper *line* of ditto, above the land at Loch Oich	1180
Lowest *line* of ditto, above the same	886
Upper *line* above the second of Glen Roy	82
Second *line* above the lowest ditto	212
Upper *line* of Glen Roy, above the junction of the Roy and Spean	927
Lowest ditto, above the same place	633
Upper *line* of ditto, above the bottom of the Glen where the Roy enters it	283
Height of the bottom at that place above the lowest line	11
Upper *line* of Glen Roy above Loch Spey	63
The bottom of Glen Roy at its upper end, above its bottom at the junction of the Roy and Spean; or its declivity	644
Height from the junction of the Roy and Spean to the sea	343
Observed upper *line* of Glen Gloy, above the Western sea	1274
Difference of level between ditto and the upper line of Glen Roy	12
Height of Loch Spey above Garvamore	294
Ditto above the German sea	1203
Height of Garvamore, or fall of the Spey hence to the sea	909
Depression of the eastern barrier of Loch Laggan, below the upper line of Glen Roy	432

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

alluvial flat for about three miles from the entrance of Glen Turit downwards, and the terraces which are always found bordering this flat, gradually disappear as the bottom of the glen contracts. A few interruptions occur here and there, apparently connected with the rockiness and irregularity of the ground, and these are most remarkable on the right side; but shortly before the glen turns to the south, and until we arrive at Glen Fintec, all the three *lines* are strongly marked on both sides. On the slope of a brown hill in this place they are particularly worthy of remark, on account of their continuity, preservation, and the almost absolute equality of their dimensions, not only through the course of each individual *line*, but respectively to each other.* This is easily accounted for by the evenness both of the curvature and inclination of the plane of the hill on which they are marked, as well as by the form of its summit, which diverts the water courses in such a direction as to preserve that surface from their action. It is important to remark this equality, as it proves that the causes which produced these *lines*, have been similar and equal, and that the irregularities now to be met with are the result, not of irregularities in the action of the power by which they were produced, but of inequalities in the capacity of the ground on which these causes have acted.

At this place an elevated glen opens into Glen Roy on the right. No water enters into it from this valley, but the junction is formed by a dry plain extending for some space, which, declining gradually in the opposite direction, carries its waters towards Glen Gloy, with which it also communicates. As the bottom of this glen is, at its entrance, at a higher level than the lowermost of the *lines*, this latter is here interrupted; but the two upper ones enter it on each hand, and are continued for some way along its sides. It is

* Pl. 16.

unnecessary to pursue the course of this glen further, as it adds no illustration to the subject; but it is necessary to remark, that not only at the angles and curvatures of these lateral glens, but at the turns which the principal valley Glen Roy itself makes, the breadth and form of the *lines* is equal every where, as well below as above the curvature. The breadth of the bottom of the valley here has been for some time reduced to an angle;* and the strath, or alluvial flat, which characterized its upper part, has ceased. The hills on the left hand side descend with various curvatures and irregularities, but the three *lines* continue well marked on them as far as Glen Glastric, on the north side of which they turn up for a short space, and then disappear. Below Glen Fintec all the three are visible as far as a stream which enters the Roy nearly opposite Glen Glastric, and here the uppermost disappears. The rapid fall of the Roy has now increased the distance between the lowermost *line* and the foot of the glen, as the section will show.† A material alteration here takes place in the aspect of the sides of the glen, but most particularly on the right. A great range of deep alluvium is seen between Glen Fintec and Glen Glastric, the upper surface of which is not far below the lower *line*, bearing marks of a level once continuous, though now much interrupted.‡ This waste is owing to the action of mountain streams, which have ploughed it deeply to the very river, forming a great range of semiconoidal hillocks, similar to those which I mentioned as occurring in the upper part of the glen, but much more remarkable.

It is here necessary to notice that the alluvium at the top of the glen which covers the sides of the hills, consists of sharp fragments with a mixture of clay, a bed precisely similar to that which occurs so generally on the declivities of mountains, and which, from the

* Pl. 21. Sect. F. † Pl. 21. Sect. E. ‡ Vide Horizontal Section, E.F. Pl. 21.

unworn nature of the fragments, and their identity with the rocks above, appears evidently to have resulted from the wearing down of the summits. But the terraces themselves at the top of the glen vary in composition, and though often composed of the same sharp fragments that overspread the general declivity, they occasionally also exhibit various rolled and transported matters. The conoidal hillocks which I have just mentioned, as occurring between Glen Fintec and Glen Glastric, are of a very different composition. Numerous sections of them are to be seen, the result in some cases of a road lately made, in others of the action of water. By these they are shown to consist of deposits of fine sand, gravel, clay, and rolled stones of different sizes, disposed in a manner irregularly stratified, and in a direction more or less horizontal. The terraces and hillocks which occupy positions much inferior to this all the way along the course of the Spean to its entrance into the Lochy, are of the same materials.

I could perceive no traces of any *lines* on the left hand, from Glen Glastric downwards, for a space of about two miles. No reason for this deficiency appears, either in the form or composition of the ground. On the contrary it possesses that gentleness of slope and curvature, and that uniformity of alluvial surface on which, in the upper parts of the glen, the *lines* are always most deeply marked. Nor does it give rise to any streams to the action of which their loss and disappearance might be attributed. Were it not that a similar interruption occurs at a lower point down the glen, as well as in the other vallies connected with it, we might at first suppose that the acting cause had here terminated. It is in no respect different from many of the upper parts of the glen on which the roads are marked, except in the gentleness of its slope. Yet this is insufficient to account for the deficiency, as the appearance becomes again visible on hills below it of a slope precisely similar. It must at present therefore be regarded as one of the numerous difficulties attending this very difficult subject.

The upper *line* becomes also invisible on the right opposite to this place, and shortly after, the whole disappear on this side, though no material alteration takes place in the form or structure of the hills. About a mile before we arrive at the junction of the Roy and Spean, the valley expands, and here the lowermost line again makes its appearance, continuing its course round Meal Derig to the side of Glen Spean, where it disappears. The same *line* shortly after reappears on the right side, and from hence it can be traced with more or less difficulty as far as Teindrish, over a various surface of very slight inclination, until it finally vanishes. At Keppoch the Roy falls into the Spean issuing from Loch Laggan, and here it loses its name; while the Spean holds its course westward for a space of five or six miles till it falls into the Lochy.

On the left bank of the Spean, near the junction of the Roy, a *line* is visible which is found by the spirit level to correspond with the lowermost *line* of Glen Roy. It runs about three or four miles up the valley over a surface of moderate inclination, yet although the curvature and structure of the opposite hills which bound the Spean are similar, it is not found on the right bank. It continues to hold its course westward with more or less obscurity, from the junction of the Roy and Spean along the declivities of the high mountains Ben na 'chlianach, Scuir rinish, and Carn derig, which bound this wide valley to the south, finally disappearing opposite to Teindrish, and nearly in the same meridional direction. The valley is here of such dimensions that the opposite *lines* are about four miles asunder. Its bottom is extremely irregular, offering rather an accumulation of low hills than a valley properly so called. But in no place does the altitude of these hills rise to the level of this lowest *line*; a fact which it will be necessary to keep in mind when we enquire into the causes that have led to the formation of these *lines*. It is also necessary to remark that through this wide and irregular space there are no streams of any note, but that the whole is drained in an almost imperceptible manner into the only river which traverses it; the Spean. The opening of this valley is wider than its mean dimension, since it gradually and imperceptibly loses itself in the great valley of the Lochy, which forming a wide plain, at length terminates in the sea at Loch Eil.*

Before examining the distant connections of Glen Roy it is necessary to return to its more immediate ones; as in them alone the traces of the *lines* are marked. Having already mentioned all that was required relating to Glen Fintec and Glen Spean, it only remains to describe Glen Turit, which I deferred lest it should interrupt the more important account of Glen Roy itself.

I mentioned that towards the upper part of Glen Roy two glens entered by wide openings, bringing in two tributary streams to the Roy. One of these, of inconsiderable extent, has already been sufficiently described. The other, Glen Turit, forms a communication between Glen Roy and Glen Gloy, rising between the two and discharging its waters on both sides. Where it falls into Glen Roy it is at so high a level as to exclude the lowermost of the *lines*. Traces however of the two upper ones enter its mouth, on the right hand side of which (looking from the source of the water) they speedily and suddenly disappear. But on the left, besides a short trace of the second, a *line* is to be seen extending for the space of a mile or more on a level with the uppermost in Glen Roy, until it is cut off by the rising of the bottom of the glen.

* See Plates 19, 20.

This is among the best marked of those which are any where to be found, its breadth being not less than 70 feet and its inclination among the least of those which I measured. It is important to notice that the opposite sides of Glen Turit are very little dissimilar either in shape or composition, although they do not exhibit equal traces of the *lines* ; and it is still more essential to remark that the bottom of this glen is of solid rock and not of alluvial formation ; since in the course of the examination it will be important to remember that the operation of ordinary causes is to diminish, not to augment its elevation.

Where this solitary *line* disappears in consequence of the rise of the glen, a level space occurs without a stream, but in no long time it produces one, which running westward forms the water of Gloy and enters Loch Lochy beyond Lowbridge.

When I said that the upper *line* which is prolonged so far into this glen is stopped by the rising of its bottom, I did not intend to speak precisely: it ceases in fact for some space before, but evidently from the sliding of the face of the hill into the stream. That which it is important to note is, that if it had been prolonged it would have met the bottom of the glen, which may be considered as there forming an intermediate hill between Glen Gloy and Glen Roy, and thus interrupting the continuous level which should take place between them at the height of the upper *line*. It is this part of the fact alone which is important, and important in more views than one, as will appear when I shall attempt to investigate the cause of these *lines*. I may remark that these altitudes are not estimated, but were observed by the spirit level.

I have reason to regret that a tempestuous season prevented me from examining Glen Gloy with the same care which I had bestowed on Glen Roy. The requisite observations, attended with difficulties sufficiently perplexing in the latter case, were rendered impracticable in the former, while the nature of the past summer, 1816, and that of the preceding, 1815, not less unfavourable in the western highlands, have made it utterly impossible to renew the investigation, originally made in 1814.

From this cause I am unable to assert positively that there is an identity of level between the *lines* of Glen Roy and those which occur in Glen Gloy, although it will hereafter be seen that there is but little, if any, reason to doubt it. I shall describe the appearances as far as I was able to observe them; when the reasons for acquiescing in their common origin will appear.

On entering Glen Gloy from Lowbridge no trace of a *line* can be perceived for about three miles. The marks of three are then to be seen on the salient angle of a green hill on the left bank of the stream. As far as the eye can judge of their relative distances (for I was unable to measure them) they appear to correspond to those of Glen Roy: but the upper and lower one soon terminate, while the middle one is continued for some little way up the valley. On the right side of the stream, opposite to them, a very strongly marked *line* of considerable breadth occurs, extending up the valley for a long space beyond the reach of the eye, accompanied by an inferior one far less persistent.

Being prevented from tracing this valley into Glen Roy, I attempted to examine it in the opposite direction by entering from Glen Turit. I have shewn that the *lines* of Glen Roy terminate at the head of Glen Turit, in consequence of its elevation by which their progress is at length naturally terminated. From this point which separates the head of this glen from that of Glen Gloy, since it is the common boundary of both, no *line* can be seen for a space of three or four miles; at which point one commences on the right side, which according to my information extends far towards the bottom of the glen, and is therefore continuous with that one which I examined from its mouth. The principal question with regard to this *line* is, whether it corresponds with the uppermost or with the second of Glen Roy. I attempted to determine it by the spirit level and by the barometer. The former observations were so much impeded by the weather that I am unwilling to place any reliance on them, since the vertical difference of these two *lines* being little more than 80 feet, considerable nicety would be required in carrying on the levels. From the barometric observations it appears that the difference of level between this upper *line* of Glen Gloy and that of Glen Roy is only 12 feet, a difference that may fairly be attributed to errors of observation. It is probable therefore that these two are on the same level, while there seems abundant reason to conclude, from the general similarity of proportion between the intervals of those in Glen Gloy and those in Glen Roy, that the former have originated from the same cause as the latter, and admit of the same general train of reasoning which will hereafter be applied to these. If any doubt should remain, in consequence of the want of more positive evidence, it must be remembered that the *lines* of Glen Roy have been shown to enter Glen Spean, and also to be prolonged through the common wide valley in which both these rivers terminate; that the situation of Glen Gloy is by the intervention of Glen Lochy analogous to that which Glen Roy holds to the common valley of the Spean and Roy; and that on a calculation of chances it is almost infinitely improbable, that the apparently corresponding proportions of the three *lines* of Glen Gloy are not actually corresponding, and sufficient to prove, if not a former continuity between the levels of the different vallies, at least a common cause for all.

In terminating this description I may remark, that the topographical deficiencies which may be found in it are irremediable until an accurate geographical survey of this country shall be made, but that these deficiencies can not materially affect the arguments about to follow, whatever additions they may chance to make to them.

In as far as the mineralogical structure of the country is concerned in the description of the *lines* of Glen Roy, I have already noticed the principal facts in describing the nature of the alluvia which form the surfaces of the hills. I may however proceed to say, that the natural rock is not often visible on their faces, although it may be observed in most parts of the bed of the river. I have already briefly remarked that at the upper part of the valley it consists of a hard micaceous schist traversed by veins of red granite. The same rock is continued upwards towards the source of the Spey till the granite itself appears; which forms the most elevated part, and that only, of the country between the sources of the Spey and of the Roy. But in proceeding from the head of Glen Roy to its mouth, the granite veins gradually disappear; various sorts of schist, micaceous, quartzose, and argillaceous, occurring in an irregular order and at various elevations. The beds are sometimes to be seen absolutely horizontal, and at others as completely vertical; and I need hardly say that they occupy all the intermediate angles. A similar construction extends through Glen Gloy, and along the sides of Loch Lochy, as well as the skirts of Ben Nevis.

The different opinions which have been entertained relative to the origin of these *lines*, or *Roads*, as they have most commonly been supposed, render it necessary to describe their form and materials; which the accompanying sections, with the aid of a few words, will render easily intelligible. There is no need for the pickaxe and spade to investigate this question, since the water courses have produced innumerable natural sections; recent ones may be found after every fall of rain, a circumstance in which Lochaber is by no means deficient.

The extreme breadth of these *lines* may safely be taken at seventy feet, or a little more, and their most general one lies between that and fifty. As in no instance that I have remarked do they exceed the former, so they very rarely indeed fall short of the latter dimension. The most remarkable exception to this rule has been already noticed in describing the upper part of the glen; and it may not be amiss to repeat that the *lines* are narrowest and least marked on the hardest and most rocky ground, where in fact they cannot, with any latitude of language, be called *roads*, since they are absolutely invisible to a person when standing on them. In no case is their surface level, but it lies at various angles with the horizon, from 30° and upwards to 20° and 12°.* It is probably from this cause that they are in many cases invisible where we should otherwise expect to find them; their own inclination coinciding so nearly with the general slope of the ground as to render them imperceptible from the place of the spectator.† Both the interior and exterior angles are very much rounded; ‡ and the surface, I need scarcely add, is marked by considerable inequalities, from the fall of stones, and the partial accumulation of plants and recent soil. In describing their relation to the side of the hill, they may be said to bear the resemblance of sections of parallel layers applied in succession to its face.§ In only one instance is there a slope, resembling a superior *talus*, and this is visible for perhaps half a mile ;¶ while

* Vide Profiles Pl. 18. † Prof. 1, 5. ‡ Prof. 8. § Prof. 7, ¶ Prof. 6.

in no instance did I perceive the marks of an inferior one. But the profiles now referred to, which were selected among the most remarkable ones, will represent these several circumstances better than they can be described by words.

With regard to their structure I can only say, that it does not appear to me calculated to throw light upon any system respecting their origin. When they are found on those faces of hills where the rubbish is sharp, they consist of sharp materials; where it consists of transported materials, they are formed of rounded gravel and sand. Whatever hypothesis of their formation may be adopted, it is evident that this circumstance can throw no light on it; as, whether they are the effects of nature or of art, they must have been formed in and of the materials in which they exist.

Having thus described Glen Roy itself with the *lines* for which it is distinguished, and pursued its connection with the neighbouring vallies, it is necessary to extend our views, and to trace its connection with the sea.

The glen itself opens by a wide mouth, as I before said, into the great valley which stretches between the northern and western sea, and which is the seat of the Caledonian canal. This opening is so gradual that its breadth cannot be defined, but it may be conceived to vary from five to seven miles. The whole of this space is uneven and hilly, consisting of rocky elevations and alluvial deposits. The Spean flowing through it and falling into the Lochy forms one deep section, but no other water courses are found in it, either direct or lateral; such at least as exist are of very insignificant dimensions. On applying the spirit level to a great many points through this wide space they were all found inferior to the lowest *line* of Glen Roy, with one or two trifling exceptions. The opening of Glen

Spean, as must have already been remarked, like that of Glen Roy, has the same direct and present communication by means of the Lochy with the western sea.

The opening of Glen Gloy is narrow, but its communication at Lowbridge with the long valley now described, is at a point somewhat higher in elevation than that at which Glen Spean enters, since its water falls into Loch Lochy, the source of the river of the same name.

Tracing therefore the course of this valley, into which Glen Roy and Glen Gloy open, we find it communicating with both seas. Its highest level is at Loch Oich, the point from whence the waters decline in two directions, and this elevation is ninety feet above that of the sea at Loch Eil. Besides the waters issuing from Glen Roy and Glen Gloy, it receives at various points to the south-westward of its summit level, the streams which issue from Loch Eil, Loch Arkeig, and numerous smaller glens, while on the north-eastern slope it is the receptacle of the waters of Loch Garry, Glen Morrison, Fyers, Glen Urquhart, and others of less note. Hence it appears that its upper level is inferior by 886 feet to the lowest *line* of Glen Roy, and by 1180 feet to the uppermost, the height of the upper *line* of Glen Roy being found from barometrical measurement to be 1262 feet above the level of the western sea. Examining now the glens which communicate laterally with this great valley, we shall find that they are all situated on the western side. They are Glen Morrison, Glen Urquhart, Glen Garry, the glen of Loch Arkeig, and that of Loch Eil.

From want of time for so laborious an undertaking, I am unable to describe either the disposition or the elevations of the four first of these branches, but have reason to think that they all rise at their western ends to levels higher than those of the *lines* in Glen Roy.

Fortunately it is not material with regard to the general results that must follow from considering the phenomena of Glen Roy, since these will be still nearly the same although these glens had not existed. The glen of Loch Eil however, which I have examined, requires a more detailed description, as it is probably implicated in the consequences which will follow from one of the theories that must be had recourse to in explaining the appearances of Glen Roy.

The valley of the Spean and that of the western branch of Loch Eil may be considered as opening into the great Caledonian valley by a common wide mouth; while the southern bend of Loch Eil lies in a valley comparatively narrow, formed by the skirts of Ben Nevis on one side, and the hills of Ardgowar on the other. It is necessary to keep this circumstance in mind till the probable causes of the *lines* in Glen Roy are brought under review. A valley of a dead level extends to the head of Loch Eil, which being little higher than the loch is of course elevated but a few feet above the sea, of which its water forms a branch. From the head of this loch another gentle rise conducts to the head of Loch Shiel, a fresh water lake, which occupying a narrow prolonged valley, at length descends by a gentle declivity into the sea at Loch Moidart. I cannot give the elevation of Loch Shiel, which is nearly the highest point of this level, but from an estimate formed on the ground, which at any rate cannot be so far in error as to affect the question, conclude it to be inferior to all the *lines* of Glen Roy, the lowest of these being 976 feet above Loch Eil. Water therefore, if we could now imagine it raised to the levels of the lines of Glen Roy, would run to the sea at Loch Moidart, as well as at Loch Eil, and at the Moray Firth.*

Returning to the head or eastern communication of Glen Roy,

* Pl. 19.

we find that it is divided into two glens separated by a partial rocky barrier through which the river forces its way, and that the summit of this barrier is on a level with the uppermost *line.* But in describing the upper glen I showed that it bore the marks of a *line* level with the uppermost one of lower Glen Roy, and consequently both continuous with it, and produced by a common cause. It is important to remark this fragment of a *line*, as, on the supposition of a continuous water level it removes the boundary of the water from lower Glen Roy to a point further east. But the next eastern point which forms the present boundary of the head of upper Glen Roy is the source of the Spey, and this elevation separates the great eastern declivity of the water at this point, or the valley of the Spey, from the western one, or that of the Roy. The measurements made by the spirit level, as well as the observations of the barometer, prove that the source of the Spey is 63 feet lower than the upper *line* of Glen Roy. If therefore we recur to the same supposition that water could now be accumulated to that level, it is plain that it would flow easterly into the valley of the Spey, as well as into the western outlets just enumerated.*

If we now turn to the remaining communication of Glen Roy, which is with the valley of the Spean, we shall find that this river flows with no great declivity from Loch Laggan to its junction with the Roy, a space of seven miles or thereabouts. The length of Loch Laggan is ten miles, and it is separated at its upper part from the valley of the Spey by a barrier of low rocks, and by a plain of nearly four miles in length, which conducts a sluggish stream into the Spey at a point about ten miles from its source. As on the east side of this barrier the waters are directed to the Spey, so on

* Plate 19.

the west they are directed to Loch Laggan. The barrier itself gives no rise to waters, as it consists of a narrow ledge of rocks; nor does it appear at any time to have been liable to suffer from the course of rivers. This is a species of judgment which can be formed without perhaps any great risk of error, by inspecting the positions and shapes of rocks and mountains, but it is a judgment of which the grounds can scarcely be explained by drawings or descriptions. The observation itself is of importance in examining the general theories of the appearances in Glen Roy. Circumstances prevented me from ascertaining the actual height of this barrier above the sea, and the nature of the ground does not admit of any direct levelling to it from Glen Roy, without a series of most intricate and tedious operations, which would in fact be unnecessary in examining the question. But by comparing its level with that of the Spey at the point where the before mentioned sluggish stream joins that river, and by computing the elevation of that point from Garvamore of which the height was ascertained, its altitude is readily estimated to a sufficient degree of accuracy for the present purpose.

Comparing these heights therefore it will be found that the barrier of Loch Laggan to the east is depressed 369 feet below Loch Spey and 432 feet below the uppermost *line* of Glen Roy. Supposing therefore that the water stood at the highest elevation in Glen Roy in the present state of the earth, it would run into the Spey not only by the channel of Loch Spey, but by that of Loch Laggan also.*

Such are the communications which Glen Roy has with the surrounding country, and through that with the sea. I have described them with all the minuteness in my power, as they are of the first importance in the investigation of the causes which are to

* Plate 19.

be assigned as giving rise to the *lines* of Glen Roy; and as the important geological consequences which follow the most probable of these theories, could only be deduced from a consideration of their extended connections. In thus describing them I have been in some measure compelled to anticipate some of the arguments hereafter to be adduced, however inclined to preserve the description distinct from the reasonings; and this for the purpose of laying a due stress on the facts of most importance, and of more effectually directing the attention to those on which the reasonings must hereafter be founded.

The first, and not long ago the most popular, nay the only hypothesis was that from whence these *lines* have derived their name of Parallel Roads. They were conceived to be roads made for the purposes of hunting, either by the Feinne, or by certain kings of Scotland, who were supposed to have resided at Inverlochy Castle, which is situated not many miles distant on the banks of the river Lochy. The arguments which are used to prove this opinion may be divided into two classes; tradition, and some physical appearances to be found in the *lines* themselves, combined with certain applications to the purpose of hunting, of which they are supposed capable. It is vain to inquire into the æra or history of the Fions, whether they existed at the time of Severus's expedition, or at a period prior to that, since rational antiquaries have given up the point in despair. Nor are the traditions concerning their connection with these roads, even if we admit their existence at some remote period, such as to demand any acquiescence in this conclusion. It is said that the hills of Glen Roy are named after the heroes or dogs of this favourite and poetical age; from Gaul, and Diarmid and Fillan, and the celebrated Bran. But this is a circumstance not peculiar to Glen Roy. The same names are applied to hills in Glenco, in Glen Lyon, and in many other places; while the very tombs of these heroes which occur in so many different parts of Scotland would prove that they possessed an ubiquity even after death.

Equally idle traditions are recorded concerning certain hollows now to be seen in Glen Turit, which are supposed to have been constructed for cooking their venison, and which go by the name of Coir na Fion; the kettles of Fingal. But admitting that tradition were to be received as evidence in such a case as this, it is not difficult to show that even tradition is at variance with itself. For they have been equally attributed to certain Scottish kings who are supposed to have resided in Inverlochy Castle.

The date of this building is much too modern to admit of any connection between it and the appearances in question, were they even ascertained to be roads. It is a quadrangular structure occupying an area of about 1600 yards, and like Harlech and others of the Welsh castles of Edward's time, consists of four curtains with flanking towers at the angles. The height of the curtain is from 25 to 30 feet, and that of the towers from 40 to 50. The scarp extends to a distance of 12 feet from the foot of the wall, and the whole is surrounded by a moat, once wet, 40 feet in breadth. It has two principal gates, one to the land and another which appears to have extended to the water. Sally ports and loop holes are also to be observed in the towers, some of the latter being intended to cover the sally port and others to flank the curtain. Remains of a building which seems to have been intended for a drawbridge are also visible. This construction altogether, not easily misapprehended by antiquaries, to whom the marks of age more or less distant are visible in ancient military works in more circumstances than those which I have now pointed out, shows that it cannot be referred to a very remote origin. The largest and western tower is called the Cummin's tower. The name however is not of itself sufficient to prove that this castle appertained to the Cummins, or that it was erected by that once formidable Clan, whose ancient fame and power have, like those of Fingal himself, associated its name with buildings and transactions in which it might have been no way concerned: yet its aspect would not induce us to refer to it to a date higher than that of Edward I. the period in which the power of that clan was in its greatest splendour. There is an idle tradition that it had been a seat of Bancho, head of the race of Stuarts, and that a league had been signed there by Charlemagne and Achaius about the end of the eighth century. But authentic records show that Bancho was not the ancestor of the Stuart family; nor was it possible that Bancho, had he existed, could have been a Thane of Lochaber; since that district was not at this remote period under the dominion of the kings of Scotland. The history of Achaius and his treaty with Charlemagne, so far from being merely involved in obscurity, has been shown by learned antiquaries to be a fiction.

So far do the arguments from tradition reach. Let us next enquire, tradition apart, whether there is any thing either in the physical construction, the disposition, the antiquity, or the alledged uses of these lines, which can justify the supposition that they are works of art. The magnificence of the object itself, when considered as a work of art, is such as to impose on the judgment by heating the imagination; and it is not therefore wonderful that such a notion should have been maintained with considerable pertinacity by remote highlanders, whose traditional belief in the power and splendour of their heroic ancestors, although fast expiring, is by no means entirely obliterated. But the phenomenon is of too great magnitude and importance to admit of such a solution without a more strict species of evidence; or, in defect of that evidence, of such collateral and circumstantial proofs as can be deduced from its present appearance and connections, from the probable motives in which it may have originated, and from the contrary deficiency in probability of other assigned causes. It is said that they were roads made for the purposes of hunting the deer: such are the assigned motives. Admitting them, it is necessary to examine how far this pursuit was likely to be aided by the contrivance in question. Two practices are chiefly in use in this chace. The first of these is to approach the deer while in their pasture or at rest, by such circuitous ways as to protect the hunter equally from their acute scent or their sight; a practice known by the name of deer-stalking. The other consists in driving them by a power of men or dogs, or both, in such a direction as to pass the stationed hunter, who thus shoots them in their course. Another notion has however been maintained relative to the method of hunting in this place and in those times. It has been imagined that the roads were fenced with stakes on each side, and used as a sort of decoy, into which the deer were driven, to be afterwards shot at leisure by those who were stationed without.

It is impossible to conceive that they were used as stations from whence to shoot deer at rest, since a fixed point must be unavailable in this variety of the chace, and since the exposure of the hunter himself would render the invention useless. For similar reasons they could be of no use in driving the deer, as the herds must necessarily pass in the greater number of cases so as to be out of bow shot. Although in the upper parts of the glen the distance from the lowest *line* to the bottom of the valley is trifling, yet at its lower part that distance becomes far greater than the range of an arrow. It is equally evident that it could not have been any part of the design of this work to bring the supposed roads within a limited and fixed distance, as although the vertical distance of the lines is equal, their horizontal one varies extremely according to the inclination of the ground, so that approximate *lines* which are in some cases but 100 feet asunder will in others be separated to 1000 and more.

If we consider them lastly as intended for a species of decoy it will be necessary to discover by what means the deer were to be enticed into them: the hunters who now drive the forests of Ben Gloe or Mar would smile at him who should attempt to drive a herd of deer into a fenced lane. In fact they bear no resemblance to any practicable species of decoy, and we have fortunately still preserved in the island of Rum vestiges of a real decoy used for this purpose. It appears to have consisted of two stone dikes arising high in the hills and gradually contracting in their dimensions till they terminated in a tall circular enclosure, in which the deer were at length confined and killed. It may be added finally that the great number of these *lines* as well as their proximity are also arguments against this notion.

Viewing them indeed in the most vague light as *roads*, even if we do not attempt to assign an object for them, they are either deficient in the qualities which a road requires, or they do not exhibit the marks by which it would be characterized, or lastly they are arranged in a manner so capricious as to render a motive for their disposition unfathomable.

Wherever the hill is formed of a soft alluvium they possess the greatest breadth, while, on the contrary, wherever the ground is rocky, they are scarcely to be traced. It is plain that they should, if they had been roads, have exhibited superior permanence in the most durable materials. We cannot escape this objection by saying that they have been wasted by time; since that time which has diminished the hardest should have obliterated the softest. If we examine their profiles (of which numerous representations are here given) we shall also see that they bear no resemblance to a work of art. There is no inferior *talus*, nor, except in one solitary instance which I have noticed, is there any mark of a superior one. They are stairs, if I may use such a comparison, on the face of the hill. It may be answered that the natural decay of the road would consist in the sliding down of the upper *talus* into the road, so as gradually to diminish its slope and to fill the interior angle, while a similar waste of the lower one would round the exterior or salient angle. But if we examine the final result of this double waste, we shall see that when this ultimate ratio of equality is established throughout the upper and lower *talus* and the natural slope of the hill, the road must disappear altogether, instead of maintaining, as it often does, a breadth of 70 feet upon an uniform slope of the face of the hill. There is another circumstance in their construction equally repugnant to this hypothesis. In no one instance is the surface level, or even nearly so, as the profiles will show.* The least angle which I discovered was one of 12° with the horizon, and more generally they vary from 20° to 30°. This is an effect which could not readily have taken place had they been originally level, as the permanent regularity of their surfaces shows that they have undergone very inconsiderable changes since their first formation.

Their capricious arrangement, if considered as works of art, is equally an objection to the notion of their having been intended as roads. Numerous and crowded in some places they are totally absent in others, and that even where no wasting causes appear to have existed. It may be added perhaps to these objections, that the

* Plate 18.

difficulty of maintaining a water level throughout the whole connection of this interrupted and distant set of *lines*, is such as would require a knowledge of engineering and the possession of methods which we can scarcely concede to times so rude; and that the want of bridges of communication where they are interrupted by torrents, of which no traces can be discovered and of which the knowledge could scarcely then have been in existence, must have rendered them useless as roads. Nor ought we to pass over another circumstance which I have noticed in describing them; that towards the top of the glen many marks are found precisely similar in dimension, level, and general aspect, but running through short spaces and at levels different from those of the supposed *roads*. These are alone sufficient to point out a different cause, and when considered together with the terraces which I have already shown to be continuous with one of the *lines*, they indicate some action of water as the real cause of this phenomenon. Into the different modes by which this action might have produced them I shall now proceed to enquire.

The visible and demonstrable marks of a continuous set of water levels throughout the whole of these *lines*, has very naturally given rise to the notion that they have been the result of the abovementioned cause at some distant period. The nature of this action is however by no means very easy to assign, and as the several views which may be taken of it are attended with consequences more or less difficult of explanation, and at any rate of very extraordinary importance in a geological view, it is necessary to examine into the various ways in which this agent might have produced these effects, instead of remaining content with a vague and general idea of their having originated in such a cause. Only three modes of explaining the action of water in producing these *lines* occur, and they are all derived from phenomena of which we see or imagine the causes going hand in hand with the effects. These phenomena are not uncommon in mountainous countries, and must be familiar to those who are intimate with the highlands of Scotland.

The sudden and rapid rise of a torrent when fed by the streams from the neighbouring hills, is marked by lateral devastation and ruin, wide in proportion as the materials of the hills are subject to be removed and transported by the rapid flow of the water. Clay, gravel, and stones thus transported are deposited in banks which skirt the course of the torrent at the level of its highest elevation, often continuing to mark that course to future times, till a fresh flow of water rising to a higher level destroys them or substitutes higher banks in their places. A partial deluge is but a torrent on a greater scale, and we can therefore conceive this phenomenon extended in its magnitude and consequences, but producing a similar set of appearances. This cause has been supposed to have produced the *lines* of Glen Roy.

The banks of the Spey, of the Lyon, and those of almost every river running through a flat alluvial valley in Scotland, or (to make use of an expressive Scottish term,) a strath, exhibit the appearance of terraces, at different elevations and distances from the present course of the stream, which have an abrupt edge resembling the profile of an earthen military defence. The numerous elevations which these terraces assume in any one valley, prove that the cause by which their surfaces have been levelled has acted at various successive intervals downwards; while their variously placed lateral sections equally show that the cause of their waste at the sides has acted at many different periods laterally. If we now attend to the course of a stream through an alluvial and flat valley of this nature, we find it gradually, often imperceptibly, but sometimes suddenly changing its position in consequence of partial obstructions produced by the transportation of rubbish. Thus while it is engaged in deepening its own bed it is also changing its horizontal place, undermining its bank on one side and in succession quitting it to attack some other point; while at the same time it is flattening a larger portion of the plane on which it flows than the breadth of its own water, and reducing it to one uniform broad space. Thus a terrace with a profile is formed and left at a distance from the course of the stream; while a series of such capricious changes, acting through a considerable space of time both horizontally and vertically, fills the bottoms of the straths with terraces so numerous and complicated as almost to bewilder us in attempting their explanation. Such a cause may be conceived to have produced the *lines* in Glen Roy. We must imagine the glen filled to the depth of its upper level with alluvial matter, and suppose that a wasting stream has held its course through it for a space of time so long as to remove the whole matter to its present depth, leaving the *lines* which are now marked on its sides, together with the terraces that are to be seen at its upper end, as memorials of its destroying force. This is the second hypothesis depending on the action of water which has been offered in explanation of the appearances in Glen Roy.

The third and last method of explaining these appearances by the the same agent, is founded on the form assumed by the alluvial matter which in many cases is found at the edges of a lake, and on the probable consequences which would arise from draining it. On this view it is conceived that a lake had existed at the uppermost level of Glen Roy, for so long a period as to have accumulated on its margin that alluvium which now forms the uppermost of the *lines* in question, and that, by a subsequent sinking through two successive and similar periods, the two lower ones had been formed in the same manner. As the sinking of the waters must have been the consequence of the failure of some barrier by which they had been confined, it is plain that considerable changes of the surface are requisite for the solution of the present appearances, as well on this supposition as on either of the former ones, although these changes must be of a different nature.

Each of these hypotheses is attended with considerable difficulty, and involves consequences as important in a geological view as they are unknown in our ordinary experience. Arguments enough have perhaps been brought to show that they could not have been works of art; and among the natural causes which present themselves I know not that any others can be produced but the three now mentioned. It is our duty therefore to examine the probabilities attached to each of these, and to chuse among them that whose ordinary effects offer the fewest discrepancies from the actual appearances under review. If the whole of the phenomena are still difficult of explanation under any system which we may adopt, we must have recourse to the method of dilemma, and at least reject those assigned causes which involve impossibilities. If it shall finally appear that an impossibility is attached to each, we shall be driven back to allow their origin in human art and labour; since this hypothesis involves at least no physical impossibility, though assuredly a very high degree of moral and physical improbability.

The first hypothesis which has been proposed to explain the appearances in Glen Roy is the action of a deluge, or rather of a series of large and powerful torrents. There must in fact have existed three torrents at distinct periods, as the nature and distances of the several *lines* obviously require such a series of causes. It is neither necessary nor convenient to examine the general principle on which this explanation proceeds, as it would lead into discussions foreign to the views of this paper, and as it is undoubtedly supported by a sufficient mass of evidence.

It is proper however before entering on this examination to recal to the reader the general disposition of the *lines*, and that of the vallies which they occupy. They are found commencing within a very short distance of that summit which is the common origin of the waters of the Spey and Roy, the one running to the east, the other to the west. In their progress westward they increase in number and in the perfection of their forms and markings, maintaining the same level throughout: while the bottom of the valley, now the course of the Roy, descends with a rapid declivity towards its junction with the Spean. One of these *lines* is found ascending the valley of the Spean for a few miles, and terminating in the great common valley of the Spean and Roy, at a point agreeing with that of its corresponding *line* which descends from the valley of the Roy. From Glen Roy the same *lines* are continued into Glen Turit, a valley opening into that of the Roy. Here they meet with its bottom as it rises during their level progress, but they are renewed in Glen Gloy, a valley placed in a reverse direction to Glen Turit, continuing throughout its descent in a course similar to that which they held in Glen Roy, until they disappear near its lower extremity and before its junction with the vale of the Lochy, the common exit of Glen Gloy and the conjoined vallies of the Roy and Spean.

We are now to examine the probable course of the torrent or deluge assumed to be the cause of these *lines*. It is most consonant to the present state of things to imagine that it flowed from east to west or from the source of the Roy towards its termination. If it be conceived to have flowed in the reverse direction from the west to the east, or from the present lowest level of the country to the highest one, it will be seen in the course of the argument, that many of the facts bear equally against the possibility of this supposition; to such an extent indeed as to render it quite unnecessary to enter into a formal refutation of it.

The cause of such a deluge or torrent as is here supposed, is generally assumed to be an elevation of a portion of land, elevating at the same time the superincumbent waters. I shall as far as possible simplify the phenomena, and thus give all the assistance I can to this hypothesis by supposing that with one *line* only, no other valley but Glen Roy exhibited that appearance. A single elevation of the site of Loch Spey would therefore be the only change required to produce the effect. But the fall of the country to the east, and the present course of the Spey show, that a wave produced by this cause must have equally tended to flow in the contrary direction or into the present valley of the Spey, and consequently to leave its impressions to the eastward as well as to the westward of its origin, on the supposition that the form of the surface was then similar to its present one. But no such impressions exist, although the form of the present valley of the Spey is fully as capable of receiving them as that of the Roy; and there are no reasons to suppose any material changes in the shape and disposition of that valley. No water courses either antient or recent, nor any agents are to be seen, capable of destroying these remains if they ever existed. Nor is it possible to comprehend by what means a wave produced at the present elevation of Loch Spey could have formed the first *line* which is visible in the upper Glen Roy. It is evident that the quantity of water carried by the assumed wave must have been sufficient to have filled the whole of Glen Roy for a course of twenty miles or upwards. It must have consequently stood at a considerable height above the present level of Loch Spey, the seat of the supposed elevation. Yet the first *line* is found within a few hundred yards from this spot, and at an elevation so little above it that it must necessarily have been buried far under the imagined wave; which could not produce this effect on a surface immersed deeply under it, since the universal pressure of the fluid would produce an equilibrium of actions: nay the very hypothesis supposes them to have been formed by the deposit of loose matters at the surface of a fluid in motion. If the assumed causes which this hypothesis requires are, even with all the simplification and assistance which can be given to them, scarcely reconcileable to the appearances of the country and the ordinary course of Nature, the difficulties become insurmountable when we recollect that it is requisite to adopt a series of such causes; a succession of three similar elevations at given distances of time, producing similar and equal effects under an inequality of circumstances so obvious as scarcely to require mention to those who have reflected on the appearances described in the first part of this paper. Although a more general and distant origin for the supposed diluvian wave should be assumed, the hypothesis is still subject to the difficulties now enumerated; since the obstruction to its course, formed by the elevated ground which confines Loch Spey, would equally prevent it from exerting the requisite actions on the parts beyond that obstacle.

It may appear unnecessary to adduce further arguments against this hypothesis, but as one of the objects of this paper is to point out the circumstances applicable to other enquiries of this nature, should such occur hereafter, it will not be useless to enumerate the remainder. Different cases may require different modes of investigation, and that argument which is sufficient for the present may not be universally applicable, as the peculiar objection here examined may not always exist. The investigation moreover is that of a subject but little attended to, and consequently admitting some prolixity of illustration.

It is plain that a set of changes acting through a considerable space of time posterior to the present disposition of the ground had taken place before the water marks were impressed on its sides. This evidence consists in the marks of the *lines* which are traced to a certain depth on the furrows now possessed by mountain torrents, and which I have fully described in other parts of this paper. By these it is proved that the torrents existed previously to the causes which produced the *lines*, and, from what we may see of the actions of similar torrents in this or in other places, we are assured that a long period of time had elapsed between their original flow and the subsequent changes which produced the marks of the *lines* now visible in them. It is equally clear that the formation of these furrows must have been posterior, even though they had been produced in a short space of time, to the great changes, such as the breaking up either of the crust of the globe or of portions of it, which must be assigned as the cause of these deluges; and it is impossible that a series of such violent actions as would generate a deluge of this nature, could have taken place in the immediate vicinity of Glen Roy without obliterating these furrows and deranging all the signs of a previous state of repose.

The intermediate marks which are found at the upper part of the glen afford another argument against the hypothesis of a deluge. Supposing that three torrents consisting of very different quantities of water had flowed with such equable force as to have produced the three principal *lines*, we have, between the two upper ones, another so slightly marked that it must needs have resulted from a force very inferior to that which generated those below it. Yet it must have been, on this supposition, produced by a mass of water greater than that which caused these, and we can have no reason for supposing that flow attended by a less velocity. That three currents so different in depth should have been propelled with *momenta* capable of producing effects so equal, is in itself a supposition considerably improbable; but among the other more obvious difficulties attending this explanation it is unnecessary to dwell on this in particular.

The form, dimension and equality visible throughout the whole, present additional obstacles to the supposition that a deluge was the cause of these *lines*. Among the numerous difficulties which occur in attempting to solve their formation on this view, it is perhaps a trifling one, that three successive torrents should produce three deposits of alluvial matter, of which the sections should be so generally equal and similar: there are many of a more serious nature. I have shown that the deposits in the upper part of the glen in which the *lines* are traced, are of sharp materials mixed with fine clay, while at its lower part they consist of rounded matter mixed with sand and gravel. If the deposit which occupies the glen had consisted of foreign substances introduced by the flow of a torrent, it should have been formed of rounded matter throughout: in any case there should have been a similarity between the two. Nor is there any reason why it should not be equally found on hard and rocky ground as on a soft surface, since the forms and inclinations of the hills are so often alike.

It is an objection still more serious to this hypothesis, that the thickness and disposition of the alluvia should not be affected by the angular direction of the valley, and by the deviations from a direct line to which it is subject. If we conceive a current flowing through a channel of a bent or zigzag form, it is obvious that its impression on the opposed angles at the point of flexure must be different. Where the salient angle occurs it is plain that it will be more subject to the effect of the water on the side which opposes the current, than on that which declines from it. The same effect will take place at the re-entering angle, but the corresponding sides about the angle will be affected in the reverse order. If therefore the current consists of a mixed mass of earth and water, the principal deposit will be found to leeward of the salient angle, while the windward side (if we may use this metaphorical term) will remain clean. A similar effect, but in a reverse direction, will take place on the re-entering angle, which however will be more marked by the want of deposit on the side opposed to the stream, than by any accumulation on the other side that includes the angle. But if the current should have consisted of water alone, acting on a previously deposited alluvium, the effects will be of a contrary nature, since the greatest impression will, on both angles, be produced on the side that opposes the stream. Similar effects, but in a more marked degree, must take place wherever such sinuosities and furrows occur as to form a shelter to the sides from the direct action of the current. Yet we have seen that the *lines* are traced at the numerous indentations and flexures which Glen Roy exhibits, with a total disregard of this circumstance, and with a degree of equality that would have been impossible on such a supposition.

Another argument of a nature somewhat similar to this may be found in the form of the upper part of Glen Roy, already fully described, and to render it the more tangible, it is illustrated by a plan and section.* Here the form of the ground produces a complete shelter from the action of any current, which, like that supposed, must have been di-

* Pl. 18. Pl. 21. Section M. N.

rected from the east. If we even imagine it directed from the west it must have failed to make the impressions there existing on the right side, or the *cul de sac* would at least have been filled with loose materials.

In describing the openings by which Glen Turit and Glen Fintec communicate with Glen Roy, I pointed out a circumstance of which I meant to make use in this argument. I remarked that the bottom of Glen Fintec rose to such a height as to exclude the lower *line*, and that the bottom of Glen Turit was so high, at no great distance from its entrance into Glen Roy, as to exclude the whole three. With regard to the former I believe that it consists of rock, and cannot therefore have gained its present height by the deposition of alluvial matter posterior to the time at which the *lines* were formed: with regard to Glen Turit I am certain of this fact. It is plain therefore that no current could have flowed from Glen Roy through Glen Fintec at the level of the lowermost *line*, nor through Glen Turit at that of any of the three; yet the *lines* are impressed on the sides almost to the very point where they meet the elevated bottoms of these glens; an effect which, on the supposition of a current, would be impossible. The rocky nature of the bottom of Glen Turit also proves, as far as this valley is concerned, that its former was like its present state; or at any rate, that it has not been elevated by an alluvial deposit since the supposed flowing of the waters; the only supposition which could affect the validity of the argument that I have attempted to deduce from it.

It is in the next place necessary to inquire in what respect the effects of a deluge can be made to correspond with the absolutely level position which the *lines* of Glen Roy present; as I have already considered the other modifications which the action of water flowing through a channel of varying breadth and figure must receive. As the varying dimensions of the valley cannot be easily computed, it is unnecessary to examine the question with hydrostatical accuracy: a general inquiry as to the probable effects will be sufficient.

A general notion of the difference of capacity of the different parts of Glen Roy, may be acquired from comparing its vertical and lateral dimensions at its extremities; † and for the sake of simplicity I shall limit myself to this single case, although it is obvious that many more complicated considerations must enter into the account. It will also be most simple to assume the lowermost *line* as the groundwork of this investigation, as we here get a minimum ratio. This cuts the rocky bottom of the valley near its uppermost extremity.* A point therefore exists in the valley where its vertical dimension, considered from its bottom to the summit of the lowermost *line* is nothing, its breadth being in that place about half a mile. If now we examine its lower extremity, or that part of the joint valley of the Roy and Spean, where the last point of the same *line* is visible, we find it situated at a considerable height (not less than 800 feet) above the bottom of the valley, while its breadth is in this place five miles. The simple statement of this fact renders it superfluous to say that a body of water could not flow through a valley of this form, with a level surface; a condition required to produce the *line* in question. It is plain that the same objection applies to the case of the two upper ones, although with somewhat less force, according to the ratios of the several inequalities at their upper and lower extremities.

As connected with this last argument we may now ask, by what system of operations, on the same hypothesis, the *lines* were traced

† Vide Plates 18, 21, 22.

* *Vide* the tabulated admeasurements (note to page 326) where it will be seen that the bottom of the valley at its upper part is 11 feet above the lowest line.—*Vide* also, Section (6), Pl. (22).

on Glen Spean and Glen Gloy. If the solitary *line* of Glen Spean was produced by the action of a current, it is difficult to conceive that of the three separate *lines* marked in Glen Roy by one common to both glens, only a portion of the lowest, and that for a short space, should be visible in Glen Spean.

The case of Glen Gloy is still more difficult. I have shown that the head of this valley, by which it communicates with Glen Roy, is obstructed by such a rise as to exclude a free communication at this junction, of the whole of the *lines* of the latter. No current could therefore pass from Glen Roy into Glen Gloy, since its bottom, as I have also shown, is of ancient and hard rock, not a recent formation. If then there was a current common to both these vallies, the communication must have been formed by the opening of Glen Gloy through the intervention of Loch Lochy. A stream of water must therefore have run from a point where it had either a free exit, or at least a wide space in which to diffuse itself, to one whence there was no exit, and with a velocity as great in the most difficult as in the most easy circumstances, since the *lines* of Glen Gloy, wherever they exist, are at least as deeply impressed as those of Glen Roy.

The last inquiry to be made on the supposition that these *lines* are the consequences of a deluge, is, into the origin of the water which flowed through the valley, a subject on which I was compelled in some measure to enter at the beginning of this argument, but of which the whole difficulty could not be appreciated without including Loch Laggan in the investigation; a tract of which the importance could not then have been so readily understood. The views which I have formerly given of the level of this lake, and of that of Glen Spean, show that this supposed point must be removed far to the eastward, without which the waters could not have flowed through Glen Spean at the same time as they flowed through Glen Roy. This case is even more complicated than the one stated at the beginning of the argument, it being impossible that a deluge of this sudden nature and great magnitude could have taken place so as to include Loch Laggan, without changes in the surface of the earth at this place and beyond it, even greater than those which I first pointed out.

I shall not pursue the consequences of this hypothesis further. Every person's imagination can supply additional difficulties, which it would be tedious to follow to their ultimate ramifications.

The next hypothesis which has been offered in explanation of the *lines* of Glen Roy is, that they are the remains of water terraces similar to those which are of common occurrence in the alluvial straths of Scotland.

Almost all the rivers, whether of greater or smaller dimensions, that flow through these straths with small velocities, or over planes of moderate inclination, are accompanied by lateral banks lying at a distance from the actual bed of the stream. They may in fact be considered as the deserted banks of the river itself, which in forming a deeper course for its waters has at the same time changed its ground laterally, leaving its ancient bed deserted and bounded by one of the banks which formerly confined it, while the other has been undermined and carried away by its opposite lateral deviation.

The ancient bank thus assumes the form of a terrace, with a slope resembling that of a military work, and standing at that angle which the peculiar circumstances of the soil enable it to maintain. Where the action of the river has been such as to cut its way, constantly deepening, through an alluvial plain, the surfaces of these terraces will be found level, and they assume an artificial appearance. In other cases their surfaces are irregular, and often, where the river encroaches near on the original hill, are gradually blended with it until they are lost in the general slope; the river forming a second and more abrupt one in the covering of alluvium which time or more active causes have accumulated on its face.

This sketch is sufficient to give a general idea of the nature of the hypothesis I am now about to examine.

Since the opposite *lines* of Glen Roy correspond at three several stages, it is apparent that the action of the water must have consisted in cutting its way through an alluvial plain, first from the highest to the lowest of these stages, and ultimately to the present bottom of the valley, or rather to the bottoms of all the different valleys which now exhibit these appearances.

It is easy to see that no set of partial alluvia, occupying the sides of hills or the entrances of lateral torrents, could have answered the necessary conditions; as in no other case than the one previously supposed, could the river have occupied the requisite elevation. When therefore it is said that the *lines* of Glen Roy are the remains of water terraces, it ought also to be shown how these terraces were first formed. It is evident that the circumstances here assumed are the only ones capable of terminating in the present appearances.

It is a remarkable circumstance, on any supposition, that the *lines* should not only be so generally equal in breadth compared with each other, but that they should be so equal throughout such a variety of ground. But on the supposition that they are the remains of terraces, and that these terraces are the relics of a prior *terreplein* which has been subsequently removed by the action of water, it may be considered as impossible. The variety of ground over which they are extended, and the unequal action which water must have exerted on a set of terraces, the sides of which held an unequally angular direction to its current, render such a supposition untenable. It is not less an argument against this notion, that they are found entering into both the smaller and larger lateral glens and into the furrows of the hill torrents, which should have protected the terraces, had such existed in these situations, from the influence of any current or river running through the valley. The only appearance of argument on which this hypothesis rests is, that the lowest *line* of Glen Roy is found continuous with a large terrace at its upper end.* It has indeed been said that all the *lines* terminated in terraces in the same place, a mistake which the ample description that I have given at the beginning of this paper will rectify. But, admitting the whole of this postulate, the existence of terraces in the course of this valley and the coincidence of some of them with the lowest *line*, is no proof that the *lines* have been produced by the same species of action which produces terraces in the course of other rivers. Another and equally satisfactory explanation of the formation of these terraces will be given hereafter, since it is chiefly connected with the third hypothesis not yet considered, but the appearances must be briefly noticed in this place. Two sets of them are to be seen in Glen Roy. Numerous low ones of different elevations skirt the banks of the river through all that part of the valley which is marked by a flat alluvial bottom, or which has the appearance of a *strath*.† It is plain that these are the almost daily consequences of the action of the present river, and that they are in all respects similar to those terraces which are nearly the invariable companions of the rivers that flow in straths. But another and a distinct order of them is to be found at a greater elevation, which however perhaps common in their origin with the former, or rather the parents and progenitors of these smaller ones,

* Plate 15. Plate 21. Sect. L. † Pl. 14, 15. Pl. 21. Sects. K, L.

point out the immediate sources whence they were derived. They are to be observed at the places where the larger rivers enter the glen, and it is in these points only that they possess the same elevation as the lowest of the *lines*. There are no remains of any terrace at a higher elevation, or at either of the two uppermost *lines*.

Now although the action of the present water flowing in that part of the bottom of Glen Roy which has the character of a strath, does actually produce the abrupt forms of the present terraces, it does not follow that this cause has acted throughout the whole valley. It would require a stretch of imagination beyond our power, to suppose that a successive action of water should have produced three *lines*, and these only (for the exceptions are much too trifling to affect the argument) at fixed intervals, through a space so large, without leaving their intermediate marks. Had they been the result of the gradual action of water on a solid *terreplein*, the consequences must have been similar in the higher elevations to what they are in the lower ones at the present day. We now see at the upper end of the glen numerous terraces of different altitudes produced by a series of wasting actions which I have elsewhere explained. These are destined to form marks more or less permanent on its sides, and had such been the actions generating the upper *lines*, the remains of similar terraces should still be visibly intermingled with them. It is true that I have noticed some such appearances, but they admit of an easy explanation on the hypothesis next to be considered, since they will generally, if not always, be found in the vicinity of torrents which have entered the lake assumed by that hypothesis, being evidently the consequences of *deltas* or terraces, which like those at the present head of the glen and at the entrance of Glen Turit, have been worn down by the subsequent action of water, and are no further connected with the principal *lines* than the present terraces that occupy the bottom.

The chief anomaly visible, which is described as appearing at the glen that opens together with Glen Turit, is readily explained in this manner; and indeed the terraces of Glen Turit that are in contact with it offer an explanation too obvious to be overlooked.

The general equality of breadth which prevails among the *lines* is equally opposed to the notion of their being the remains of terraces; as it is impossible that such an equality should have been preserved amongst them. Nor, had the lost portions of these terraces been removed by the action of water, should they have been most completely removed from the hardest places while they were suffered to remain in the most perishable materials.

The form of the *cul de sac* in the upper part of Glen Roy, which I have adduced as an argument against the notion of a deluge, offers an equally unsurmountable one against this hypothesis. No water runs through that hollow, nor can any state of it be conceived capable of admitting its flow. Had a terrace therefore existed in this place, or had its bottom been at any time filled to the height of the two *lines* which are found marked on its right side, they must have remained to this day, since they could not have been subjected to the action of the destroying force.

I may add to these considerations, that the appearances at Glen Fintec and at the entrance of Glen Turit are equally hostile to this notion; since in both these glens there is a point of rest where no water flows, or could, under any reasonable supposition have flowed, where nevertheless the *lines* are as distinct as in any part of Glen Roy. But I must not conclude this argument without pointing out the difficulty of imagining any river running in a situation capable of effecting the required changes. I have already on so many occasions described the position of the surrounding country that it is superfluous to repeat it here. Yet I may briefly remark, that the first and highest *line* is to be seen in the upper Glen Roy within a very short distance of the source of the Spey, and at an elevation of some yards above the point whence the waters of this great river are directed eastwards. It is not easy to comprehend under what possible circumstances a river capable of exerting the actions required under this hypothesis, should have run towards the west. No river exists at present in the vicinity of this portion of the upper *line*; and even where the Roy first appears, at a place far below the position of this *line*, it is a feeble stream incapable of the powerful effects which must be assigned to it on this supposition.

In adducing these arguments against the present hypothesis, I may further remark, that I have given it every possible advantage by limiting the question to Glen Roy. It is easy to see that if Glen Spean and Glen Gloy, both bearing the marks of the water *lines*, are taken into the account, the difficulties become still more glaring.

I shall now proceed to inquire into the probabilities which attend the third and only other supposition, under which the *lines* of Glen Roy can be referred to the action of water. I am aware that difficulties of no trifling magnitude attend this supposition also; but none of them amount, or even approach, to physical impossibility. It is equally certain that no very direct proofs can be produced in favour of it, and that in defect of such there is nothing to offer but a set of analogies. But the strongest evidence is perhaps founded on the dilemma (to use the word in its vulgar sense) to which the whole question is reduced, in the review of the former hypotheses. At the same time it must have been apparent that the chief arguments which refer to this hypothesis have already been anticipated, since they were unavoidably implicated in the consideration of those which were used to invalidate the other two. Little therefore remains to be added on the subject, but I shall proceed to state the very few remaining arguments on which it must rest, and oppose to them the difficulties, and the conditions now long passed away, under which such an order of things must have existed.

The absolute water level which is found to exist between the corresponding *lines* both in Glen Roy and in those vallies which communicate with it, admits of a ready solution, on the supposition that a lake once occupied this set of vallies; nor can it be explained on any other. As a free communication, in one direction at least, still exists among them, it would even now be easy to imagine the water replaced in the same situation: the difficulty of confining it will be a subject for future consideration. If however a lake be considered the cause, it is plain that the *lines* in question were once the shores of this lake; and it equally follows that it had existed at three different elevations, and that the relative depths of these three accumulations of water may be measured by the relative vertical distances of these three *lines* from the bottom of the valley. Thus the nature of the retaining obstacles becomes more complicated, and adds materially to the difficulties that will hereafter be examined in detail.

It is necessary in the first place to recal to the reader's mind the few facts which most directly bear on this view of the case.

We have seen that the hills which bound Glen Roy have their sides covered with a coat of alluvial matter, which in some places consists of sharp substances, appearing to be merely the ruins of the summits above; while in others it is formed of rounded ones, deposited in such a manner, as to indicate a transportation from places more distant; in these the *lines* are formed. The same circumstances occur in the other vallies which communicate with the principal one.

Besides these *lines*, terraces of similar alluvial matters, with surfaces of considerable dimensions, and more or less level within themselves, are found in the lower parts of the valley, (vertically considered). These accompany the entrances of the different rivers into it, whether principal or lateral, and, being proportioned to the magnitude and power of the streams, they are most considerable at the entrances of the Roy and the water of Glen Turit. At the upper end of Glen Roy the most remarkable of these terraces coincide with the lowest *line*, with which they present a level continuously prolonged, as may be seen in the accompanying section and drawings.* In these places, they are still subject to the action of the river, from which cause they are gradually wasting away and contracting their superficial dimensions; while the lateral wanderings of the river, acting now on the alluvial plain, multiplies their number, and produces a great series of inferior ones at different levels, which skirt its course for a considerable way down the stream.

It is necessary in examining the correspondence of these phenomena with the theory of a lake, to separate these latter appearances from the former. They are plainly of posterior date, and the result of an action now daily going on, derived from the powers already noticed which rivers possess of deepening their way through alluvial plains. It is only the first class of appearances that we have here to consider, for the purpose of examining how far they agree with those which are found connected with lakes at the present day.

If we examine a lake inclosed by hills of a considerable declivity, which, being formed of solid rock, are at the same time covered with alluvial matter to a greater or less depth, we find that it is

* Pl. 21, Section L. and Pl. 15

skirted by a gravelly shore, forming an inclined plane and constituting a zone at the level of the water; of greater or less breadth according to the declivity of the hill, the quantity of alluvial matter present, and the nature of other circumstances which occasionally modify the action of these causes. Thus on entering a few feet within such a lake on a shore of moderate inclination, we plunge suddenly down, and in such a case it will be found that the soundings which succeed to the narrow zone above described, generate a section of which the line indicating the declivity is continuous with that which lies similarly above the water. Wherever rocks protrude on the face of a hill in such circumstances, the shore above described is either altogether wanting or imperfectly marked; according to the particular inclination of these rocky faces, or according to other circumstances on which it is unnecessary to dwell minutely. Where the declivity is greatest, the shore is not only narrowest, but its inclination is the greatest; and *vice versa*, it is most level and of largest dimensions where that is least. The reader who will recal to mind the particular description of Glen Roy, will recognize all these features in the present state of the *lines*; and it is scarcely to be doubted, that if the sudden drainage of such a lake as I have here described could be effected, its sides would present the appearances which occur in that valley, as far at least as all the requisite conditions were present. The conditions which have led to the uniform appearance and prolonged extent of the *lines* of Glen Roy, may be found in the general equality of the slope of the hills, their uniform and rarely interrupted faces, and the generally equal thickness and lubricity of the alluvial coat which covers them. Indeed whenever these conditions are absent we see those anomalies which on general principles we might be led to expect. It is true that I have in the description pointed out other anomalies which do not admit of explanation at present; but they do not admit it on any view of the subject, and it is not essential to the truth of any hypothesis that it should explain every fact, unless we were in possession of all the collateral and posterior circumstances which may have modified or altered the actions of the presumed cause. A few of them indeed do admit of explanation, and will be considered when the causes of the present terraces are investigated.

It is necessary to describe the manner in which the water of a lake is supposed to act in producing its shores, or in which the assumed waters must have generated the *lines* of Glen Roy. This action consists first in checking the constant and gradual descent of the alluvia of the hills. The descending matters thus losing a large portion of their weight by immersion in the water, and in winter often rendered still more buoyant by being entangled in ice, are thrown back against the face of the hill by the incessant action of the superficial waves, and are thus evenly spread against its side, producing an inclined shore, proportioned in breadth and declivity to the various circumstances already enumerated and to the length of time during which the action has been continued. This kind of levelling action is easily seen in many of the highland lakes, and is conspicuous in particular on the prevailing lee shore, wherever such a one exists. Loch Rannoch offers a striking example of it at its eastern boundary, since its situation subjects it to a very disproportionate prevalence of westerly winds, accompanied by a corresponding power in the waves which break on that margin.

It is next necessary to consider in what respect the large terraces of Glen Roy can be connected with the supposed existence of a former lake occupying that valley.

Wherever a river is found entering an existing lake, it is skirted by a shore wider than the general shores of that lake. This accumulation of matter by degrees forms a plain or a *delta* at its mouth, with a level surface; the constant action of the waves continuing to level the accumulated materials until the growth of peat or soil from the ordinary decomposition of vegetables, increases its elevation to such a degree, as to exclude the further access of the waters. Instances of such *deltas* are too common to need mention, and they are found at the entrances of all rivers whether lateral or direct; their extent and form being proportioned to the various conditions under which the different streams have entered, and which must already be too obvious to require enumeration. If a lake under such circumstances were drained, these *deltas* would be found to terminate in gradual slopes, varying according to the inclination on which they were deposited.

Let us now compare such *deltas* with the present terraces of Glen Roy; that part of its structure which appears at first sight unconnected with the previous existence and actions of a lake. Assuming the imagined lake to have stood at the level of the lowest *line*, or its third elevation, it is easy to understand that the present terraces which exist at and near that level at the upper extremity of the valley, are the *deltas* which appertained to the Roy; while the lateral ones, wherever they are found, are the remains of similar deposits accompanying the lateral streams that still exist. To explain the present abrupt declivities of these terraces we must have recourse to those actions which have succeeded to the complete drainage of the valley, and which are precisely those already noticed in a former argument, where a shifting river wanders over an alluvial strath. In consequence of the present passage of the Roy, these *deltas* have been worn down at their bases, by a succession of changes of which the marks are every where seen in the minor terraces already described, that accompany its course along the valley. Hence they have acquired their present abrupt form, and contracted their original dimensions; while in certain cases even their very remains may have disappeared, where peculiar or accidental circumstances enabled the river to act on them to the last extremity.

It will be readily asked why similar terraces are not found at the two upper *lines*, as well as at the lower one. The answer is not only easy, but tends to confirm the view of their origin here given. It must be recollected that the present state of the valley is essentially different from its condition under both the former cases. In both, the bottom of the valley, instead of being the course of a running stream, was a lake. Under such circumstances it is evident, that the effect of these waters on any *deltas* occupying such a relative position as the level which the lake last quitted, must have been to undermine and remove them had they existed to any extent; whereas, on the final drainage of the whole, they have necessarily been left in their original integrity, subject only to the gradual, corrosive, and always diminishing action of the river. But it must also be considered, that as the rapidity of the Roy and its consequent corrosive power, was much less considerable when the valley was full of water, and its fall was consequently less, a much less quantity of alluvial matter would have accumulated at its entrance during the existence of the two first lakes.

But indeed, although no conspicuous terraces are found at the level of the upper *lines*, there are sufficient indications of their former existence in many places; while in all they lie near the entrances of the torrents, and thus confirm the view which I have here given of their origin. I shall here also remark that this view explains those irregular appearances of *lines* unconnected with the principal ones, which I have, in the description, sometimes called supernumerary, and which occur here and there in positions intermediate to them.

It is easy to comprehend that these are the remains of such deltas or alluvia, undermined during the different subsidences of the lake, and remaining as indications of their former existence.

Having now compared all the appearances of Glen Roy with those which are to be found in existing lakes, and considered the probable changes which the drainage of such lakes would effect on their containing valleys, I shall proceed to point out the difficulties with which even this hypothesis is encumbered.

It has been seen in the description, that considerable deficiencies may be observed in the courses of these *lines*, as well in Glen Roy itself, as in the neighbouring glens. Some of these anomalies indeed assist in proving the probability of the hypothesis here considered: the remainder, yet unaccounted for, may perhaps be explained hereafter, when observations have been further multiplied. One short *line* only, is found in the upper valley of Glen Roy; yet all the sides exhibit a general equality of slope, form, and texture; nor is any side more than another, subject to the action of a visible wasting cause. A great deficiency of the whole of the *lines* occurs also towards the bottom of lower Glen Roy, and many partial ones in other places. Of these, some evidently arise from the rocky nature of the margin, and others may perhaps be the consequence of the coincidence between the slope of the hill and the slope of the supposed shore. But these causes will not account for them all, nor are there sufficient marks of the action of posterior waste to explain them. The anomalies of Glen Gloy and Glen Spean in particular, which I have described at length in the commencement of this paper, seem at present to baffle all explanation, and in this unsatisfactory state must the argument remain. It were well if there were no further difficulties to encounter in adopting this hypothesis, but it is necessary to enumerate them.

As I have proved in another part of this paper, that the level of the upper *line* of Glen Roy is higher than those of many vallies which would at present afford passage to the supposed waters of Glen Roy into the sea, it follows that water could not now stand at that level, unless these apertures were obstructed to at least an higher elevation. The determination of the position of these imaginary barriers, is consequently the next point to be considered; as well as that of their number, since possibly two of these openings might be closed by a single obstruction. I must therefore proceed to examine more particularly into the conditions required for the formation of such a lake as that which I have supposed to be the cause of the *lines* in Glen Roy.

I have shown that the uppermost one is of such a height, that water standing at that level would now flow out by Loch Spey and Loch Laggan, through the valley of the Spey into the eastern, and by Loch Eil, Loch Shiel, and Loch Ness, into the western sea. The two lower *lines* lying below the barriers of Loch Spey and Loch Laggan, it would, under similar circumstances, find its way through the three latter openings only. The condition of the surrounding land must therefore have so far differed at that time from its present state, that various dams or barriers must have existed in the course of these openings.

In attempting to investigate their places it is proper to commence by assuming the least difficulties, assigning no more causes than are strictly necessary to the production of the desired effect. I have shown elsewhere, that the conditions of the present barriers existing at the source of Loch Spey, and to the east of Loch Laggan, are such as to give no reason to imagine that they have once been higher. I have also shown, that by the removal of the supposed barriers to a point below Dalchully, one obstruction would have answered the purpose of confining the waters in this direction. If this were a mass of alluvial matter occupying the strath in which the junction of the Spey and Truim takes place, it is not difficult to conceive that it was gradually worn down by the action of the waters of the Spey, causing the drainage of the highest level in Glen Roy; or else after that drainage had taken place by the failure of some other barrier. The flow of the Spey and of the Roy would then follow the directions of the intermediate ground, and the present courses of these rivers, as far as they were then free, would be established. If we now turn our attention to the western side of Glen Roy, and examine the elevation and direction of the ground at its junction with the vale of the Lochy, we shall see that both Glen Roy and Glen Spean bear one common water mark or *line*, and unite into a common wide valley before they join the vale of the Lochy. The imaginary barrier must therefore be removed, at least to that part of this valley where the *lines* terminate; which is to a point beyond Teindrish. But I have shown that the form of this ground, and the gradual dilatation of the valley into that of the Lochy is such, that no barrier could have existed here without occupying the whole present valley of the Lochy. This barrier towards the sea, may therefore be removed with considerable probability to some more distant point, a probability increased by considering the circumstances which attend Glen Gloy. Although no direct continuation of level can be traced between it and Glen Roy, as there is between the latter and Glen Spean, yet I have shown that in both there are one or more *lines* at the same probable altitude, and that the condition of the upper junction of these glens is such, that the communication could not have taken place at that point. If also we suppose that Glen Gloy was dammed by a barrier of its own, independently of that which occupied the common opening of Glen Roy and Glen Spean, we multiply our difficulties without any necessity. A continuous lake must therefore be supposed to have existed among the present vallies of the Roy, the Spean, the Gloy, and Loch Lochy, independently of that portion of Strathspey which I have described above. This last connection we may for the present neglect, as well as those collateral bays or masses of water connected with the principal lake, which if restored, would also now flow to the sea. I have however so far conjectured their extent, by a glance over the surrounding country, as to have ventured on a map of them, so as to give a notion of the probable quantity and extent of water which must, under these supposed circumstances, have occupied this part of the country.* ‡

A considerable portion of Glen Lochy must therefore have formed a part of this common lake, and although we may not be able to determine its boundary in this direction, it must have extended at least to the north of the opening of Glen Gloy. But that valley opens nearly opposite to the middle of the present lake. Examining therefore its condition, we find that it is diminishing, in consequence of the increase of alluvial matter from the wasting action of the surrounding streams. As the same action of these streams must have produced the same effects in distant times, and as the permanence of the *lines* proves that the hills themselves have undergone no violent changes, the ground that includes Loch Lochy must always have been in a state of increase, not of waste, and the barrier to the north, is consequently beyond the limits of this lake. If now, we proceed northward through the great Caledonian valley, and attempt to discover the place of this supposed barrier, we get entangled in a series of similar difficulties, nor is it possible to fix on

* Vide Pl. 19.

‡ The coloured map will explain both this circumstance and the various directions in which water raised to the upper *line* of Glen Roy would now flow to the sea. The necessary distinction will be easily made by attending to the description.

a point which shall satisfy the requisite conditions. It is not at present necessary to pursue it further in this direction; we must turn our attention to the lower end of Loch Lochy. Here we find the lake terminating in a wide alluvial plain, the recent increase of which is marked by the depth of peat on its surface; while it communicates by wide openings, as well with the sea at Fort William, as with the wide and open valley in which the western branch of Loch Eil lies. If any probable place can be selected for the barrier to the sea in this direction, it is at the narrowest part of this opening, which lies at Fort William, between the skirts of the range below Ben Nevis and the opposite hills of Ard Gowar. The aspect of the ground, the course of the waters, and the nature and disposition of the rocks, render it difficult to assign any barrier nearer to the opening of Glen Spean. But I have shown that there is another free opening to the sea, from the supposed lake of Glen Roy through Loch Shiel, and Loch Moidart. Another barrier must therefore be interposed in this direction; and thus there will be formed a large lake occupying Glen Roy to some point beyond the present source of the Spey; Glen Spean, with the whole of Loch Laggan, and Glen Gloy; the Great Caledonian Valley, from a point, of which I do not pretend to define the northern limit, to Fort William; Loch Arkeig, and a part of the valley which includes it; and finally the western valley of Loch Eil, to some undefinable point lying towards Loch Moidart and the western sea. The whole of this limit is indeed not demonstrable, but I consider that the similarity, if not the actual community of the *lines* of Glen Roy and Glen Gloy, does demonstrate that a portion or the whole of Loch Lochy was included in it. Here therefore a serious difficulty arises, although perhaps not greater than that which is afforded by the view of Glen Spean. This is the total absence of all corresponding water marks on the borders of Loch Lochy, as well as on the principal extent of the borders of Loch Laggan, and the valley of the Spean. There is a set of common features through the whole tract, the same rocks, the same slopes, the same causes of waste, yet the water marks are strongly defined through a portion of this wide space, while they are totally wanting in others. If we increase the extent of the supposed lake, we increase this difficulty, but it is already sufficiently great. It is proper to notice that this objection to the hypothesis of a lake, is equally applicable to the other two modes offered for explaining the action of water in producing these *lines*. If it is held sufficient to reject the one, it is equally valid against the other two, although it seemed superfluous to enumerate it among the more serious difficulties to which those are liable.

The complete and sudden transition from the uppermost *line* of Glen Roy to the next succeeding one, and finally to the present bottom of the valley or perfect draining of the whole, shows that the lake which occupied these vallies had subsided at three different intervals. As it is a more probable supposition that these three successive drainings took place at the same point, than at different ones, it will be most convenient to assume the present and lowest communication, namely, the real exit of the waters of the Spean and Roy, as that point. This place must be situated on the river Lochy, before its junction with the sea at Loch Eil. Here then we must imagine that a dam has subsisted, not gradually worn down by the slow corroding action of the river issuing from the lake, but by three successive failures occurring suddenly, or at least within short intervals of time. Had much time elapsed between these intervals, the several *lines* must have been more obscurely marked, or intermediate ones of smaller dimensions must have been visible. It is plain that the difficulties will be unnecessarily complicated if we consider these different drainages as having occurred at different barriers. Admitting then that the corroding action of the waters of the Spean and Roy operating on an alluvium at the exit of the Lochy, had, by destroying a portion of the barrier, discharged that portion of the lake which stood above the second *line* of Glen Roy, a vertical distance of 82 feet, we have still left standing the other barriers, of the existence of which we cannot doubt, although their place cannot be precisely assigned. By what operation then were these lowered? If by any causes of a nature similar to those which we see in daily action on the surface of the earth, it must have been by the flowing of rivers upon them. Thus the flow of the Ness and the Spey towards the sea, might have lowered the land in these directions to their present level, and thus the exit of Loch Shiel might have destroyed the barrier to the west; while the repeated failures of the supposed barrier at the mouth of the Lochy had in the mean time produced the complete drainage of Glen Roy and Glen Gloy, and with the exception of Loch Laggan, that of the Spean.

I know not that the direct arguments which have been here stated are sufficient to prove that hypothesis respecting the *lines* of Glen Roy which appears to be the best founded; or whether, combined with those indirect ones which prove the impossibility of two of the others and the high improbability of the third, they may be held sufficient to establish its truth. I have however shown, that although it still labours under unexplained difficulties, no physical impossibility is in any way opposed to its superior probability. We may therefore admit its claim for the present, at least so far as to justify us in examining the geological consequences likely to result from it.

I must in the first place remark, that the causes here assigned for the appearances in Glen Roy are attended by consequences materially affecting the notions which have, with otherwise much appearance of reason, been entertained relating to the ancient state and posterior changes of the great Caledonian valley. It is conceived by many persons that Scotland was once entirely or partially divided in this place by the sea, the highest elevation of the present land being, as we have already seen, ninety feet. By the constant descent and accumulation of alluvium from the mountains, it is supposed that the dams have been formed which now separate Loch Oich both from Loch Ness and Loch Lochy, while these lakes have been disjoined from the sea by the large alluvial plains that now extend from them at each end along the courses of the Lochy and the Ness. The operations required in constructing the Caledonian canal have ascertained the reality and extent of these alluvia, while daily observation shows that they are, in many places at least, receiving an augmentation which has a tendency at some far distant period to obliterate the lakes, and convert the whole into one prolonged strath, of which the future summit will be Loch Oich, or some point in its vicinity. If indeed we examine the changes which the lakes of Scotland are now undergoing, we shall find that they are receiving accumulations of alluvial matter at all the points where they are fed by the surrounding streams, while a comparatively small quantity of this alluvium is carried from their exits towards the sea. The result of this operation is to obliterate them, and to convert them into alluvial valleys or straths. Instances of this revolution more or less perfected are numerous, while no case of the obliteration of a lake by drainage, similar to that of Glen Roy, can be pointed out. A different series of operations must have been required for this effect, and we have to reconcile the opposite processes which at different times have been carried on in the same place; in the present case for example, in the course of the Caledonian valley. It is not however inconceivable that the causes which are now, by the accumulation of alluvium, obliterating the existing lakes, should, under some variation of ground, have heaped a barrier in the course of a valley; and generated at one period a lake which they were afterwards destined to destroy, or which, accumulating strength by confinement, while the opposed barrier was undergoing a slow waste, should suddenly break its bounds and again desert the valley which it had been previously compelled to occupy. But the difficulty of removing the other barriers, which in this case must have remained after the breaking down of that one, continue unsolved even on this supposition; and other causes, which we know not well where to seek, must be found to explain the removal of alluvia from points where they appear at present to be, on the contrary, accumulating.

This difficulty is still augmented by examining certain phenomena connected with the *lines* of Glen Roy, which seem to point to a distinct and still more distant alternation of the state of the land at those places where a free communication now exists between them and the sea. These will be found to involve a set of actions even more intricate than those by which the water was originally drained from this lake.

In describing Glen Roy I have noticed the appearances of *lines* on the sides of the small torrents which descend from the faces of the hills. They enter into these furrows to a certain depth, but are not continued throughout the whole curvature. Now if we examine the structure and position of the rocks which form the surface of the hill at any of these points, or consider the alluvium by which they are in other places covered, we shall have no hesitation in admitting, that like all similar furrows and water courses on the faces of hills, they have been formed by the action of the rivers which now occupy them, or have been scooped out by the descent of the water. But if we examine any one of these furrows we find that a portion of it, one half perhaps, and that of course the most ancient as the most superficial, bears the unwasted mark of the *lines* while the interior part, subject to a more modern destruction, exhibits no such impression. It follows therefore that the *lines* are posterior in time to one portion of the period through which the water has acted, and prior to the other. But if we now conceive the water of the lake to have stood at the height of the upper *line*, it is evident that the furrow itself could not have been formed at that level and so far below it as to admit of a regular deposit of a shore, such as I have supposed the *lines* to be, on its sides; as well as the repetition of two similar deposits occupying precisely the same portion of the furrow, at one or two lower levels. Since the descent of the torrent must have ceased at its contact with the water, that part of the furrow which, from its now bearing the mark of *lines*, is evidently of higher antiquity than the lake, could not have been then formed; nor on the two subsequent sinkings of the water can we conceive it to have been prolonged through intervals of time so precisely equal, and with actions so precisely similar, as to produce the appearances now visible. It is a more probable supposition that the water which stood at the levels of these three *lines* entered within the margin of the furrow so as to deposit its shore on all that part which was then excavated; while the bottom which now shows no mark, has been formed by the action of the same torrents since the final subsidence of the waters. Water courses therefore have existed in times more ancient than the lake, extending from the summits of the hills at least below the present lowest *line*. But as these could not have existed but in the absence of the lake, it follows that the lake itself was of a posterior formation, and that the barriers which contained it were not then in existence. We have therefore two distinct alternations of a formation, with one intermediate removal, of alluvia ; within a period subsequent to that at which the present general distribution of hill and valley were made, and therefore in times comparatively recent.

In considering the conditions requisite to the maintenance of a lake in Glen Roy, I have already been obliged to anticipate some of the observations which would more properly have been introduced in this place. They are those which relate to the position of the supposed barriers, and which necessarily therefore involve the magnitude of the original lake. But the details relating to the eastern boundary including Loch Spey and Loch Laggan require to be more particularized. It has been seen that the boundary of the lake of Glen Roy towards the east could not have been further westward than Loch Spey. In inquiring next where it is likely to have been situated, we have seen that there is a communication between the mouths of Glen Roy and Glen Spean, and that a free level would exist in the present state of things between the lowest *line* of Glen Roy and Loch Laggan, since it can be traced within a few miles of the foot of this lake. It appears therefore probable, that no barrier existed at the western end of Loch Laggan so as to dam Glen Spean immediately above the present marked *line* and between this point and the foot of that lake. This probability amounts almost to certainty, when we compare the elevation of the supposed barrier necessary for the purpose of retaining the water of the common lake of Glen Roy within the limits of the highest *line*, with the actual barrier which now bounds Loch Laggan to the east. It is evident that if the waters of Loch Laggan were now raised suddenly by any power to the height of a barrier so supposed, they would flow over their eastern boundary into the Spey, and therefore that their course westward, to which the removal of this barrier must be attributed, could not then have taken place. Independently of this consideration I showed that the difficulties of accounting for the failure of so many barriers were increased in an unnecessary degree. It is therefore perhaps a more reasonable supposition, that the barrier which dammed the lake of Glen Roy to the east, existed beyond the point at which the waters of Loch Laggan, if now elevated above their eastern boundary, would fall into the Spey; a point situated near Dalchully. Of the nature of this boundary, as well as of the causes by which it has been removed, it would be fruitless to speculate further. It is more important to point out the magnitude of the change itself.

The depression of the Spey at this point below the uppermost *line* of Glen Roy, may be estimated without material error at 400 feet or more, and the valley here puts on the form of a flat strath bounded on each hand by high rocky mountains; varying from a mile to half a mile in breadth. The necessary altitude of the obstruction may hence be readily computed, and it is equally obvious that however much during the course of the Spey to the sea the breadth of this imaginary barrier may vary, according to the position in which we place it, its altitude must be constantly increasing during the descent of a river so rapid. Variations in its supposed position will produce correspondent effects on the spaces which must have been inundated during this state of things. Thus its removal a few miles lower would cause the supposed lake to fill the valley of the Truim to a considerable height above Dalwhinnie. But it is unnecessary to pursue these consequences further in this direction. It is proper however, although we cannot assign the real causes which may have produced the breaking down of this barrier, to show that independently of the general reasons assigned for removing the boundary of the lake of Glen Roy beyond Dalchully, the two greatest elevations west of this point and between it and Glen Roy, which I have already shown to be lower than the highest *line*, bear no marks at present of having ever had a higher elevation, or of being now subject to causes of waste. Instead of this there is a plain at the elevation of Loch Spey, and a second in upper Glen Roy before the point at which the river enters this valley, amounting collectively to about a thousand yards in length, through which no water runs. This portion of the present boundary and division of the east and west rivers, so far from being in the act of waste, is gradually increased in height by the sliding alluvium of the sides of the hills which bound it, and by the formation of peat moss; an increase which is producing a visible diminution of Loch Spey, and which will, as in the case of numerous other highland lakes, at some future time, obliterate it altogether. If we examine next the nature of the present boundary at Loch Laggan, we shall find that it consists of a ridge of rock, and that it affords passage to no river. The river, on the contrary, which runs into Loch Laggan has its source at a distance, and flows in a parallel direction to it, while that which drains its eastern side into the Spey, passes it in a similarly parallel course. That all hills are subject to other causes of waste is undoubted, but this ridge affords at any rate an example of an elevation of which the wasting causes are at least trifling.

Independently of the consequences I have attempted to deduce from the supposition that an ancient lake was the cause of the *lines* in Glen Roy, other geological inferences of no small importance may be made from these phenomena, without the necessity of considering the precise nature of the action which produced them; or even with the admission that either of the two rejected hypotheses is the true one.

There can be little doubt that in any supposable case the changes themselves are of very high antiquity. Now, all the *lines* where they are on similar slopes, in similar ground, or generally in the same circumstances, present such a resemblance as to entitle us to conclude, that had the ground been uniform throughout, the whole of them would have been equal and similar. Yet lying at different heights, and consequently subject to an equal action of the descent of water, the most universally destroying of the wearing causes, they must, had those wearing causes been active, have shown very different degrees of injury. It is as inconsistent with the action of such causes, as with the ordinary calculation of chances, that an equality so great should have been preserved had they been materially subjected to these causes of destruction. We may therefore consider them as differing but little, even at this distant period, from the condition in which they were left by the subsidence of the water, or by the cessation of whichever of the supposed possible causes we choose to assume as that which produced them. The waste and destruction of hills is by no means therefore, however certain it may be, an operation of great rapidity. We are here furnished with a permanent criterion by which, within certain wide limits indeed, we can estimate it.

But this is not the only important fact pointed out by the same phenomena. We have seen that the *lines* are formed in two different sets of alluvia. The one of these is found at the upper part of the glen, and consists of sharp fragments that have been subjected to no distant transportation. They are the result of the wearing process acting on the summits of the hills, as is proved by their identity with the natural rock, by their freedom from foreign mixture, by their angular integrity, and by the quantity of fine clay that is mixed with them. This latter circumstance I would point out as in itself constituting a sufficient distinction between the transported and untransported alluvia; the last of which, independently of its rounded and heterogenous fragments, alternates with deposits of sand and gravel, and even of clay, but seldom or never exhibits the same irregular admixture of fine clay which is found in the former. The *lines* at the lower part of the glen are formed in the transported alluvium.

If we consider the first case alone, that of the untransported alluvium, we are led to enquire into the length of time required for its accumulation before the *lines* were formed in it. We see from the small changes these have undergone, that scarcely any wearing of the hills, and consequently no material deposition of rubbish has taken place since their formation, wide as that interval is. Yet the depth of this deposit being so great, while its accumulation is thus tedious, we are unavoidably carried back to an incalculable period of time previous to the existence of the *lines*, during which it must have been accumulating.

Let us now remark, that as no disturbances of the sharp alluvium, at least to a degree capable of producing the rounding of these fragments has taken place, it is plain that the waters which acted on this alluvium so as to produce the *lines*, had not been subject to violent motion. If there was no violent motion in the upper part of the glen, there could be none in the lower, since there is a continuity between these two parts. Yet these portions of the *lines* which are found in the lower part of the glen are formed in a rounded and transported alluvium of pebbles, sand, and gravel. This alluvium therefore was not thus rounded by the action of the water which produced the *lines*, since if it acted at all, it must have acted in a similar manner throughout the whole valley. We must consequently suppose that a rounded alluvium had been by previous causes accumulated in the lower part of the glen. If this took place from the action of former waters flowing through the valley, (and to what other causes can we assign it?), it must belong to an epoch prior even to the deposits of sharp matter in the upper part; as these must have been otherwise necessarily removed by that cause which deposited the rounded materials in the lower. Here therefore we are again carried back to an æra marked by the action of water, and prior even to the very distant time which appears to have been required for the tedious deposition of the sharp alluvium.

Such are the complicated views derived from a consideration of these appearances, nor is it easy to see how we can avoid the conclusions which must be drawn from them. Although some of them should have their foundation in error, there are still enough remaining to excite our industry in the observation of analogous phenomena, and to stimulate us to seek for a theory of these facts less incumbered with inexplicable results; if indeed it be possible to discover one which shall not be attended with most of the various consequences I have pointed out.

It follows yet, from a general view of these alluvia, that many of them are probably of a formation more ancient than the last great changes which produced the present state of the surface, if we consider the drainage of Glen Roy to appertain to those changes. But we are in danger of being bewildered in the views which open on us when we pursue the operations of Nature so far beyond the limits of our immediate observation.

I have thus, as distinctly as is in my power, stated the whole of the arguments, as well as the difficulties and objections which bear on this question in all the several lights in which it has yet been considered, suppressing nothing which has occurred to me as an argument even against that theory which I feel most inclined to adopt. But I must now add, that the numerous difficulties which attend it have suggested to others a different mode of explaining the nature of the obstacles by which the water was maintained at the requisite height. It has been supposed that the vallies have been always the same as they are at present found, and that the imaginary dams were no other than the waters of the ocean; or in other words, that the sea itself formed the lake, to the action of which on the sides of the hills the present levels must be attributed. It will not require many words to examine the probability of this supposition, since many of the arguments already used to refute some of the hypotheses which have been examined, are equally valid against this one. Unquestionably, numerous phenomena, too well known to require notice here, justify us in believing that the waters of the sea have in former times occupied higher levels than they do at present; although we are neither able to conjecture whether these elevations were transitory or of long duration, nor to form any rational conjecture of the causes by which they were produced. In estimating the probability of this cause as applicable to the solution of the phenomena in question, it must be recollected, that the operation of the supposed lakes in producing the *lines* has been tedious, if we may be allowed to judge from the apparently slow operations of existing lakes in producing similar shores on their margins. It must equally be remembered, that if Glen Roy was then open to the sea, and that its *lines* are to be considered as ancient sea shores, the ocean must have undergone three several depressions of level at long and apparently equal intervals of time, the last of which, it must be supposed, reduced it to its present state. On considering the elevation of the uppermost *line*, it is plain that the ocean must in this case have covered the greatest part of our island; to pass over the much larger tracts of the globe which must then also have been immersed under it. It is equally apparent, that it must also in this case have had access to innumerable vallies in Scotland precisely similar to Glen Roy in form and composition. Yet in no other instance has a similar series of effects been produced, nor can any other series of analogous phenomena proceeding from such a cause be discovered, to justify the supposition of its having been of a general nature. On the doctrine of chances this hypothesis is attended with the highest degree of improbability, while the locality of the effects strongly bespeaks a local cause, however inadequate may be the explanation already given, and however incumbered with difficulties.

Such are the objections to this hypothesis, of a general nature. The local ones appear no less decisive against it. No marine remains are found in Glen Roy, nor any indications of those deposits of calcareous sand, or of mud containing shells, which ought to be expected at the bottom of a bay where the ocean had rested so long; if even we are not entitled to suppose that solid strata of secondary rocks should have been formed in it. That such substances are found at the bottoms of the present sea lochs of Scotland, is proved by the sounding line; as well as by those banks on their shores which have accumulated by the gradual shoaling of the bottom and exclusion of the sea; and which thus permit the structure of that bottom to be fairly examined. A striking instance in point exists in Isla. In that island a deposit of sea shells is to be found in the neck of land which separates Loch-in-daal from Loch Gruinart; now covered with land alluvia and peat, and evidently a portion of the latter loch shoaled to a small part of its original dimensions. To this local objection I may add another, by barely recalling to the reader's mind that fact respecting the lake of Glen Roy which seems fully proved by the relative state of the *lines* and of the furrows of the torrents on the faces of the hills; namely, that its waters had once occupied a lower level, or that the valley had actually been dry before it was the receptacle of a lake. It is undoubtedly possible that the ocean might have had its various periods of elevation and subsidence, but the supposition is attended with difficulties at least as great as those which follow that hypothesis which attributes the confinement of the waters to solid and local obstacles.

It is time to conclude this subject. To those to whom even that theory which I have adopted shall appear unfounded, these reasonings can only be superfluous. To others whom such physical difficulties cannot appal, considering our limited knowledge of the present and former state of the globe, and of the actions and causes by which its present form has been produced or modified, their omission would have been unpardonable. To those who, in considering the *lines* of Glen Roy as works of art, are inclined to cut this knot of difficult solution, and to repose in a tacit acquiescence on motives which they are unable to appreciate, and on a state of society and manners of which history affords us no information, the whole discussion may appear unnecessary. Yet in the trust that future examinations of the earth's surface may throw future lights on this subject, and that its physical origin may be established, I shall make no other apology for the length of this paper than the extreme importance of a phenomenon which exhibits a register of revolutions in this globe of which no other similar example has yet been discovered.

XIX. *On a Shifted Vein occurring in Limestone.*

By J. Mac Culloch, m.d. f.l.s. President of the Geological Society, Chemist to the Ordnance, Lecturer on Chemistry at the Royal Military Academy, and Geologist to the Trigonometrical Survey.

[Read November 15th, 1812.]

THE shifting of veins on a small scale is much more common than the larger phenomena of this nature, which are nevertheless of frequent occurrence wherever veins exist. These larger dislocations are known to arise either from the lateral motion or subsidence of the containing parts, the sides of the line of fracture sometimes remaining in contact, and being at others separated by a vein of another description, too well known among miners to need any comment here. I know not why mineralogists have sometimes imagined that such appearances were in the smaller examples fallacious, and were contemporaneous with the formation of the containing stone. The vein represented in the accompanying drawings is at any rate too remarkable to admit of such an explanation, and its character is sufficiently decided to establish a general rule in favour of all similar appearances.

The rock in which this shifted vein is contained is a secondary limestone, and was brought from Ireland. The specimen, which formed a mill-stone of six feet in diameter, belongs to the Royal Powder Works at Waltham Abbey.

The inspection of the drawing will show more readily than any description, that the vein consists of a series of separate fragments, having somewhat of a general parallelism, with a correspondence at any two neighbouring extremities, such, as to render it a matter past doubt that they have once formed a continuous line.* To displace such a vein into its present position must have required a series of slides or shifts, each advancing by nearly a similar space beyond the one preceding it. But this sort of *echellon* movement will be very visible in an outline or diagram in which I have attempted to replace the vein in its original position, and also to trace the *alignement* on which each part must have moved to its present place.

The deficiency of parallelism occurring in this diagram arises from my having intentionally left the replaced ends at a small distance, that their correspondence might be more visible.

There is now no appearance of slide or fissure, or discontinuity of any sort in the mass, but the texture of the whole is uniform and continuous. As the specimen has been completely and highly polished, there can be no doubt respecting the accuracy of this observation. It may afford matter for speculation to inquire in what condition the rock must have been to have undergone this change. It has probably consisted originally of a series of thin strata, which having been at some subsequent period fissured at an angle, have admitted the infiltration of the white carbonat of lime which now constitutes the vein in question. That it was perfectly hard at the time of this change the angularity of the fragments shows. The same solution which filled the vein has probably joined the laminæ, and cemented the whole once more into a solid mass, although the junctions are no longer visible.

* Pl. 26. *Fig.* 1, 2.

What the situation of the present vein is with respect to the horizon I have no means of knowing, nor is it a matter of much moment, as it is tolerably evident that the strata which are now visible on the surface of the earth do not always lie in the positions in which they were formed. There can be no question that slides of this nature are of different æras, as we may often observe a succession of them in which the first has been shifted by a subsequent one. Whether those represented in the present drawings are referable to one or to different periods, there is no appearance to decide, though their uniformity would lead us to suppose that they were all produced by a single cause and at one time.

Some unnecessary doubts appear to have been entertained by geologists respecting the formation of those smaller veins which have their origin and termination in the rock where they are found, and which have no communication from without. While one party has denied their posterior origin to the rock in which they are contained, and asserted that they were of "contemporaneous formation" with the containing parts, another has had recourse to an igneous hypothesis for the purpose of solving a difficulty of which the explanation appears abundantly simple. It is universally known that many rocks contain much water in a state of intimate mixture, or perhaps combination, which they are subject to lose on drying or by exposure to the air. From this cause they contract and form fissures. Similar fissures occur from the ordinary subsidences and fractures of parts either ill supported or subjected to external violence. Such cavities being formed the process of infiltration commences. The water existing in the rock percolates into the cavities, sometimes forming crystals, and sometimes filling the cavity with a solid mass of the matter which it held in solution. When silica exists in the rock, veins of quartz are thus formed; when lime, calcareous spar.

The solution of these earths in water is unquestionably more perfect in nature and the solutions more saturated than those which we can produce in our laboratories. Doubtless there is a state of division which renders them thus easily soluble, and which is perfectly analogous to that state which these earths, and notoriously silica, are subject to even in our little experiments. The gradual formation of quartz veins is too slow perhaps to be witnessed, but it may be conjectured from the various states in which they are seen, sometimes forming a detached and distinct crystallization, at others a solid mass, and visible more particularly in the schistose rocks. In limestone, the progress being more rapid, is more obvious. In the marble beds of Glen Tilt admirable examples of this process are to be seen. Fissures are here of common occurrence in the exposed layers. If we examine these, the thinner parts are found filled with a solid mass of crystallized carbonat of lime. Towards the center, where the fissure is wider, crystals are seen approaching into contact, while further on, the walls of the crack are lined with the first efflorescence of carbonat of lime, an efflorescence destined at no long period to cement and reunite the whole. Water charged with carbonat of lime is also found in the cavities when a successful fracture of them can be obtained.

This then is the secretion by which these veins are filled up, and it offers a demonstration of which the several steps are as perfect as if we actually saw them succeeding each other. There is no reason to doubt that the stalactitical chalcedonies of the trap rocks are produced in a similar manner, and that many at least of the onyx pebbles owe their origin to a similar cause. There is equally little difficulty in explaining by the same process the supposed obscure septaria; where the contraction of the softer parts of the compound mass has left cavities defining those obscurely columnar forms which clay acquires on drying, and where the calcareous earth, resident in the mass itself, or in the surrounding beds, has been gradually brought into solution by water, and deposited wherever it could find a cavity in which to crystallize.

In the diagrams Nos. 3 & 4,* I have supposed a section of the rock containing the vein, for the purpose of exhibiting the number and extent of the slides which must have occurred to produce its present position. Where similar appearances are observed on a large scale, it will be apparent how much the form of the containing rock must change to admit of the motion of the included vein, and how the subsidence of a mountain must have followed the sliding of a large vein; from which slide also the quantity of subsidence may be easily estimated.

* Pl. 26.

XX. *Explanation of a Supplementary Plate to the Paper on Vegetable Remains preserved in Chalcedony, printed in the Second Volume of the Transactions of the Geological Society.*

By J. Mac Culloch, m.d. f.l.s. President of the Geological Society, Chemist to the Ordnance, Lecturer on Chemistry at the Royal Military Academy, and Geologist to the Trigonometrical Survey.

[Read 19th May, 1815.]

Fig. 1.* THIS figure is given for the purpose of explaining the mode in which the fibrous disposition of chlorite is effected. The crystallized arrangement which is here so visible is generally observed in those chlorite fibres which occur in transparent quartz. I have never observed it in chalcedony, yet there is little doubt that a similar disposition is equally the cause of the fibrous appearance so common in the specimens which have been figured in the former plates, the chief differences consisting in the smaller size and less perfect crystallization of the chlorite scales.

Fig. 2. The crystals of chlorite magnified.

Fig. 3. Although in the former plates I figured some specimens which I imagined to be confervæ, I had not then procured any example in which that regularity of structure, which is so conspicuous in some of the plants of this family, could be observed. The present figure exhibits that regularity in a striking manner.

Fig. 4. This figure affords a second example of that regular ramification which botanists will immediately recognize as characterizing many of the plants of this tribe; although for the reasons already assigned in the paper, it will be fruitless to attempt to discover the species.

* Pl. 27.

XXI. *On a peculiar Disposition of the Colouring Matters in a Schistose Rock.*

By J. Mac Culloch, m. d. f.l.s. President of the Geological Society, Chemist to the Ordnance, Lecturer on Chemistry at the Royal Military Academy, and Geologist to the Trigonometrical Survey.

[Read 6th December, 1812.]

THE rock which this drawing represents is well known in the country where it occurs by the popular name of *Killas*; and as the reasonings to be founded on it will not be affected by the use or omission of more scientific terms, I shall not wait to determine under which of these names it ought to be ranked.

It is to be observed at the back of the Gun wharf at Plymouth dock, where it has been cut to a smooth face to make room for the Ordnance department in that yard.

On inspecting the drawing, it will be seen that the fissure of the killas is perpendicular to the horizon. The general colour of the mass is a faint brown red, and a number of dove-coloured stripes of unequal thickness may be seen traversing it in very irregular curved lines, but bearing a sort of parallelism or relation to each other. To say that it resembles strongly a piece of marble paper, will be a comparison as illustrative as it is familiar.

If we pursue the same familiar analogy we may be led to explain the method by which the mass of killas acquired this peculiar disposition of its colouring matters.

It is well known that the operation of marbling, either in oil or water, is produced by partially mixing together two or more

* Pl. 28. Fig. 2.

coloured fluids of considerable density or tenacity: should the layers of the several fluids have been straight, the curved and wavy appearance is given by producing short and partial disturbances in different parts of the compound. There can be very little question that this rock must have been coloured by a similar operation while in a semifluid state, for on no other hypothesis can the peculiar distribution of the two coloured substances through the whole mass be explained. The continuity of the lines of colour precludes all possibility of a succession of deposited layers, otherwise than in those very lines, and affords at the same time a proof, if any were wanting, that the fissile property of this killas has not been the result of stratification. The whole must in fact be considered as formed either of one deposit, of a semifluid red mud, coloured afterwards by a mixture of blue mud, or of successive layers of red and blue mud. In this state the application of external disturbing force has produced the peculiar contortion here exhibited. It is evident that the theory of softening used to explain the contortion of rocks, is in this case insufficient: a species of fluidity is requisite, otherwise the elongation and narrowing of the blue lines, could not have taken place.

Having established the necessity of consolidation from a fluid state, it remains to ascertain by what powers both the fluidity and the consolidation were effected. There is no difficulty in supposing that the requisite state could exist in a mere mixture of clay and water at the ordinary temperature: but when we consider the large proportion of water requisite to maintain that state in a given quantity of clay, it is difficult to conceive how the disposition of its parts could have been preserved during the great contraction which it must have undergone in the act of consolidation.

XXII. *Memoranda relative to the Porphyritic Veins, &c. of St. Agnes, in Cornwall.*

By The Rev. J. J. CONYBEARE,

MEMBER OF THE GEOLOGICAL SOCIETY.

[Read December 3rd, 1813.]

I HAVE drawn up the following remarks on the rocks in the vicinity of St. Agnes, in Cornwall, almost wholly from the notes of my friend and fellow-traveller, Mr. Buckland, an accident having prevented my accompanying him to the most interesting spot mentioned in them.

It is well known that a considerable mining district takes its name from this small town, which is situated on the coast about eleven miles north-east of Truro. The lodes are principally worked for tin, though copper is occasionally raised. The prevailing rock is killas, and the nearest point at which granite has been noticed is in the Gwennap cluster of mines about six miles distant. Having observed in the walls of the neighbourhood several specimens of those porphyritic and granitic rocks, which are distinguished in the country by the name of elvans, we were induced to enquire more particularly into their Geological relations, and the frequency of small promontories on the coast afforded us a favourable opportunity of ascertaining their position in several spots.

Between St. Agnes and Cligga point, (a considerable headland about four miles to the east of it) no less than five of these promontories occur, each of which is traversed by a dyke of elvan, running nearly due east and west, and varying in a manner apparently capricious, both as to its thickness and inclination. The appearance of these dykes will be best understood by reference to the annexed drawings,* which are faithfully copied from sketches made on the spot by Mr. Buckland; nor can I describe their general character better than in the language of that gentleman. "The elvans all along this coast occur in beds and veins of every possible thickness, from forty feet to half an inch, sometimes overlying, but more frequently traversing the killas in various directions, under such circumstances as are apparently irreconcileable with any other theory than that which supposes them to be of contemporaneous formation with the rock containing them, the result of some play of affinities which allowed a part of the mass to assume a crystalline texture, while its coarser and more abundant portions were left to arrange themselves in the slaty or tortuous form which characterizes the killas." These elvans are for the greater part of porphyritic structure, the base being in most instances a very minute aggregation of quartz, pale chlorite, and possibly some felspar: the first of these is usually the predominant ingredient, the imbedded substances are felspar, quartz occasionally crystallized in small double hexagonal pyramids, and chlorite in small patches. In one quarry, a little to the west of St. Agnes, we found the same variety of elvan passing (by the addition of tourmalin, and the decrease or loss of all its ingredients excepting the quartz) into a rock much resembling that of Roche, in the same county. At Cligga Point itself besides the elvan, we observed a small formation of what would probably be considered by the Wernerian school, as the newer granite, incumbent upon the schist at an angle of at least 80 degrees. Its singular stratification will best be understood from

* Pl. 23.

the drawing annexed.* It has been much worked for tin, which is disseminated through its mass in veins apparently contemporaneous.† The killas which is traversed and covered by these more crystalline rocks, has, for the most part, the characters usually ascribed to clay slate, and its strata occasionally present singular curvatures; in many places it passes into chlorite slate, and in the immediate neighbourhood of these dykes it usually presents either a highly crystalline form of that rock, or such an intermixture of it with quartz and felspar as might fairly be esteemed a variety of gneiss. This change of appearance has it is well known been attributed by the most able advocates of the Huttonian theory to the action of the injected mass, while yet in a state of fluidity. To us, the aspect of the rock at the point of contact did not, (either in this or any other instance of the same phenomenon, which fell under our notice), appear to be such as we could conceive to have resulted from that process.

We were in almost every instance strongly tempted to regard the elvans as of contemporaneous formation with the schistose rock which they traverse. We are conscious however that our observations were neither sufficiently accurate or extensive to warrant the advancing any thing like a decided opinion upon this curious subject.

* Pl. 23. Fig. 1.

† I have thrown into a Note the description of three specimens from different points of this headland.

1st. Small grained granite with earthy felspar, containing imbedded crystals of flesh-coloured felspar.

2d. The same, but with little mica, and the felspar somewhat less earthy.

3d. A granite composed of middling sized grains of white vitreous quartz, light flesh-coloured felspar, and a comparatively small quantity of dark brown mica.

These, with several other specimens from the same quarter, are deposited in the cabinets of the Society.

XXIII. *On the Stream Works of Pentowan.*

By EDWARD SMITH, Esq.

[Read June 3rd, 1814.]

WHEN, a little time back on a mining excursion in the district of St. Austle, my avocation for the first time called me to visit a stream-work in that neighbourhood, I was so struck with what I saw, that I employed a second day from morning to evening in a most scrupulous examination of one of the works, from a wish of communicating my observations to the Geological Society.

The works that I visited are called the upper and lower Pentowan Stream Works, and are situated on the river which flows from Hensbarrow Hill by St. Austle, and enters the sea about three miles and a half south of that town, and at about the same distance north of Chappel Point, after a course of somewhat more than eight miles. I calculate the elevation of Hensbarrow Hill at 900 or 1000 feet above the sea; from thence to St. Austle the descent of the ground being very rapid the river is precipitated over many considerable rocks, and during the rainy season may be considered as a succession of cascades. In the dry season there is but little water, but after sudden rains the rise is both rapid and dangerous. Small rounded pebbles are found all the way in this part of its bed. From St. Austle to the sea the descent of the land is very gentle, and the hills running north and south on each side of the river seem to direct its course. In some places these approach very near together, in others they widen, and leave a greater expanse of plain. The whole of these levels from within half a mile of St. Austle to the sea having been found rich in deposits of tin, have at various times been turned over, and great quantities of ore have thus been obtained: they are all at this time enclosed and cultivated. At the mouth of the river the shore is flat on both sides to some distance; at half a mile to the east begin the high cliffs that extend to Black Bear point.

The Upper Pentowan work lies about one mile north of the beginning of the sea-beach, and about one mile and a quarter north of the sea, the valley being there about half a mile wide.

The following is the section of the Strata which I observed in the Upper Pentowan Stream Work.

		Depth from surface	
		Feet	Inches
Stratum 1.	Soil with trees growing thereon	3	3
2.	Deposit of mud mixed with small gravel, waving thus ∽∽∽	20	23
3.	Small grained spar and killas	3	26
4.	Growan (or decomposed granite), spar, killas, &c. similar to those which are now found on Hensbarrow and other neighbouring Hills	5	31
5.	Gravel, at the bottom of which are oak trees and branches, of great size	5	36
6.	Tin ground	5	41
7.	Clay, in which were the roots of a vast oak tree, which seemed to remain in the very position in which it grew. I was told that the trunk had been cut away for fire-wood, and that various trees had been found. Three feet above this level and at no great distance from the root was the end of a branch of oak of great size projecting from the wall of the work. The part visible was about 4 feet long and 3 feet in diameter. It is not improbable that at a greater depth a second mineral deposit may be found, as has been known to occur elsewhere under a bed of clay.		

The lower Pentowan work lies three quarters of a mile south of the upper, and about half a mile north of the sea. The plain is more contracted here than at the upper work, and the river flows immediately west of the excavation, and nearly on a level with the upper part of it. The excavation measures from north to south about 400 feet, from east to west about 250, and is $54\frac{1}{2}$ feet deep. In form it resembles an amphitheatre, being cut into deep *stopes* (as the miners term them) by which their work is upheld. The miner's object is to come at a deposit of tin five feet thick at the bottom of the pit, and as he works forward he throws behind him the waste matter. Water is conveyed from the river by a wooden trough into an insulated mass of the lower stratum, in which the tin is washed.

The following is the Section of the Strata at the Lower Work.

		Depth from surface Feet.	Inches
Stratum 1.	Soil with trees growing in great luxuriance, some very old, and gravel towards the bottom	3	3
2.	Fine peat. At the bottom are roots of trees, fallen trunks with ivy attached to them, and sticks impregnated with salt. In this stratum also are found sea laver and rushes	12	15
3.	Sea mud, which when dry resembles fine grey sand. At the top are masses of leaves compressed flat, whose characters are still to be distinguished. Under the leaves are cockle shells, well preserved. These as the stratum deepens become more decayed. At 4 feet from the bottom of this stratum, and at 31 feet from the surface have been found many bones of animals, viz. the horns of two deer, very large and of equal size; two human skulls, one belonging to a child, the grinders not having yet shot through the jaw; the shoulder and thigh bone of some large animal; and the vertebræ of some smaller animals. At the bottom is a bed of very small shells in great abundance, 1 foot thick, and then a thin layer of small shells in a very decayed state	20	35

			Depth from surface Feet	Inches
Stratum	4.	Sea mud, with large oyster shells and cockles	4	39
	5.	Vegetable substances, with flat compressed leaves, and a few rotten shells	$6\frac{1}{2}$	$45\frac{1}{2}$
	6.	Vegetable substances, without shells; containing rushes, fallen trees, flat compressed leaves, roots covered with moss and compressed to an oval form, wings of coleopterous insects	1	$46\frac{1}{2}$
		The trees in 2, 5, and 6, are so numerous, that the miners collect from them great stacks of fire-wood.		
	7.	At the top are found moss, sticks, hazle nuts. Beneath are small stones of killas, growan, and other pebbles, which are known by the miners to have belonged to the neighbouring hills, so far distant as Hensbarrow . .	3	$49\frac{1}{2}$
	8.	Rough tin ground, containing the lighter and poorer stones	2	$51\frac{1}{2}$
	9.	Rough tin ground, containing rich tin stones, some of great size and weight. Mixed with these are rounded pebbles of quartz, and other stones, and a yellow ferruginous clay	3	$54\frac{1}{2}$
	10.	Solid killas rock, on which all the preceding alluvia were deposited. The level of this does not differ much from that of low water mark.		

In addition to these observations I have not many remarks to offer. The lower work is much richer in metallic produce than the upper, owing probably to the valley being narrower at the former place, which confined the mineral matter within a smaller space, and prevented it from being dispersed in the plain. The stones at the upper work were much the largest, as might be expected from its greater proximity to the hills. Among the tin-stones of both works are found such as agree with the ores of particular lodes, that traverse the several hills all the way up to Hensbarrow hill, and the old miners had themselves made these distinctions, and rendered them perfectly clear to me. Thus, I think, I may venture to say, that the tin stones have been washed down from the neighbouring hills into the Pentowan valley.

The chief difference to be observed in the strata of the two Pentowan Stream Works, is the want of marine matter in those of the upper. In the lower Stream Work I have described the killas rock, upon which are deposited 5 feet of tin ground, 10½ feet of vegetable matter, 24 feet of sea mud, and 3 feet of soil, on a level with which flows the river 54½ feet above the solid rock.

The following notice and sections have also been transmitted to the Society.

British antiquities (celts, spear's heads, &c.) have been discovered in the Stream Works at the depth of 20, 30, and 40 feet, from whence it appears probable that the greatest part of the accumulation of soil has taken place at a comparatively modern period.

An accurate representation and description of the Stream Work at Porth in the parish of St. Blazey, of this county, have been presented to the public by Philip Rashleigh, Esq. in the second part of his Description of British Minerals, published in the year 1802.

Section of the Pentowan Stream Work in 1807.

Strata.		Feet.	Inc.
No. 1.	Micaceous sandy clay, interspersed with stones and gravel . . .	9	—
2.	Peat, intermixed with roots and leaves	7	—
3.	Sand, in which are found branches and trunks of trees	8	—
4.	Finer sand with shells, in which bones, horns, &c. are found ..	12	—
	N. B. The horns are chiefly those of *cattle* and *stags*; a joint of the vertebra of a *whale*, and a *human skull* were likewise found in this stratum, the former is now in the possession of the Rev. John Rogers, of Mawnan, in this county.		
5.	Coarse gravel	2	—
6.	Closer sand mixed with clay, with decayed leaves, almost forming peat towards the bottom	12	—
7.	Loose stones and gravel	1	—
8.	Tin Ground.		

Carnon Stream Work, 1807.

Strata.		Feet.	In.
No. 1.	Mud and sand	7	—
2.	Granite gravel intermixed with small pieces resembling charcoal; and a few shells	4	—
3.	Fine gravel, mud and shells	12	—
	About this depth are several irregular strata of oysters, about 4 or 5 feet in thickness, extending irregularly to within 4 or 5 feet of the tin ground.		
4.	Closer mud intermixed with shells	19	—
	In this stratum have been found several branches and trunks of trees, some of which had evident marks of being cut with an axe or other sharp instrument. *Horns* and *bones of stags*, likewise *human skulls*.		
5.	Tin Ground, varying in depth from 1 to 6 feet.		

Tregoney Stream Work, 1807.

Strata.		Feet.	In.
No. 1.	Granite gravel with layers of mud	11	6
2.	Black mud with a few shells	15	—
	N.B. In this stratum were found a cow's horn, 3 inches ¾ diameter, and 1 foot 1 inch in circumference; and several stags horns.		
3.	Tin Ground; average depth 2 feet.		

XXIV. *Observations respecting the Limestone of Plymouth, extracted from two Letters, dated September* 26, 1814, *and January* 19, 1815. *addressed to* Henry Warburton, Esq. *Secretary.*

By the Rev. RICHARD HENNAH, Junr.

CHAPLAIN TO THE FORCES AT PLYMOUTH.

Citadel, Plymouth.

SINCE the date of my letter of the 8th of August last, in which I mentioned that organic remains were found in our limestone at Mill Bay quarry, various shells and fossils have been discovered in our limestone at other places. The limestone between the Tamar and Plym rivers, extends over a tract above three miles in length; its strata run nearly parallel to one another from north-west to south-east, dipping towards the south-west, this being also the position of nearly all the stratified rocks in the neighbourhood. The westernmost point at which shells have hitherto been found is the Dock Yard. A few weeks ago some workmen found petrified bivalve shells imbedded in the solid rock, twenty feet below the surface, while removing the remains of a small mount called Bunker's Hill, which had been left when the Dock Yard was excavated. I have since visited the spot myself, and found several specimens in situ.

Further to the eastward organic remains have been noticed, on Stonehouse Hill, both above and below the road at the entrance of

Stonehouse, and in other parts of the hill near Mill Bay. Some of the specimens of shells and madrepores, which I now send, are from a part of Stonehouse Hill, a little to the west of the quarry at Mill Bay. They were broken from detached stones lying in undisturbed ground considerably below the surface, and agreeing in appearance with the solid rock. The quarry at Mill Bay lies about a mile and a half east of the Dock Yard. The specimens from this quarry were also broken from detached masses of rock found at different depths.

Still further to the east, under the citadel, at the east end of the Hoe, I have found many well-defined shells belonging chiefly to the genus Turbo, some in detached masses, some imbedded in the solid rock; but the substance of the shell in these specimens is so altered, as to exhibit the colour and texture of the surrounding matter Lastly, in a quarry at Cat-down, I have obtained shells or rather fragments of shells, as well as madrepores, but in small quantity, and not so perfect as elsewhere. It has hitherto been a point in dispute whether the limestone at Plymouth does or does not contain organic remains; but I hope that the specimens which I now send the Society will be considered as deciding the question; it must be admitted at the same time, that the instances where shells occur are by no means frequent, and that they are not then found in any quantity. I send herewith a tooth, which, together with many others, and the head and bones of a large animal, was found in the Breakwater quarries at Oreston, at the bottom of a cave or hollow in the limestone rock. It was sent by Mr. Whidbey to Sir Joseph Banks.

I take this opportunity of observing, that on the eastern side of the Sound, under Statten Heights, and nearly in a line with the great national work the Breakwater, there occurs a remarkable interruption in the natural position of the strata. The rock consists not of limestone but of a hard ironstone, which is used for paving. There is a sudden cleft or fissure which divides it from top to bottom, and the strata, instead of preserving their usual inclination from north to south, meet the eye in all directions, horizontal, perpendicular, and inclining one after the other, until they describe the radii of a large circle.

It may be worth mentioning, that from the western point of the hill called the Hoe, to the eastern, and at other places near it, I have remarked on the side of the cliff, about fifteen or eighteen feet above highwater mark, a stratum two or three feet in thickness, composed of sand and waterworn pebbles cemented together, and appearing to have been at some remote period the original beach.

XXV. *Description of the Paramoudra, a singular fossil body that is found in the Chalk of the North of Ireland; with some general Observations upon Flints in Chalk, tending to illustrate the History of their formation.*

By the Rev. WILLIAM BUCKLAND, B. D.

MEMBER OF THE GEOLOGICAL SOCIETY,

AND PROFESSOR OF MINERALOGY IN THE UNIVERSITY OF OXFORD.

[Read 15th March, 1816.]

AMONG the organic remains of the chalk in the North of Ireland, are large siliceous bodies of a very peculiar character, which I believe have not hitherto been described, and of which the annexed drawing, copied from a sketch I made of them as they appeared four years ago in some chalk pits near Moira, will give a more correct idea than can be conveyed by any description.*

These singular fossils are found in many of the chalk pits from Moira to Belfast and Larne, (see the Map, pl. 8, vol. 3, of the Geol. Trans.) but are most numerous at Moira. They are known at Belfast by the name of Paramoudra, a word which I could trace to no authentic source, but shall adopt because I find it thus appropriated. They have, I believe, never yet been found in the chalk of England, except at Whitlingham near to Norwich, and at some other places in the same neighbourhood, from whence there is a good specimen in the collection of the Geological Society, equal in size to the largest I have seen in Ireland, being about two feet long

* Plate 24, No. 1, 2, 3, 4, 5, 6.

and one foot in diameter. Through the kindness of my learned friend Dr. Bruce of Belfast, a still more perfect specimen from Moira has been deposited in the Ashmolean Museum at Oxford.*

The usual forms of these bodies are modifications of those drawn, more or less elongated or compressed. No two of them are to be found exactly alike in all their proportions. Their length commonly varies from one to two feet, their thickness from six to twelve inches. Their substance in all cases is flint. The termination of these siliceous bodies is distinct, and the separation of the flint from its matrix of chalk always clear and decided. Their outer covering has the appearance of a thin epidermis, smooth externally, and whiter than the mass of flint inclosed, which is usually of a dark grey colour. The whiteness of this crust is probably derived from an admixture of lime with the silex, as usually happens in the exterior part of common chalk flints.

In all cases these bodies seem to have had a central aperture passing into and generally through their long diameter. The breadth of this aperture varies in different specimens, from half an inch or less to four or five inches, but is tolerably uniform in each individual. It is usually largest in the elongated varieties; small, and sometimes almost extinct in those of a more compressed form. These cavities are always filled with chalk, of the same nature with the matrix in which the flints are imbedded; they appear to have been filled when the chalk was in a fluid state, and could accommodate itself to all the cavities of the organic body. The upper extremity of this central cavity or pipe is generally terminated by folding itself outwards, so as to form a kind of lip or scroll by its junction with the outer circumference, which is inflected inwards. The lower extremity of the siliceous body is usually con-

* Pl. 24. No. 2.

tracted, terminating in a root or peduncle abruptly truncated, thick and solid on one side of the central tube, but usually open on the other, to allow the passage of water to the interior (see Pl. 24, No. 2.) This peduncle bears marks of separation by violence from the point of attachment on which it grew, and which seems not to have been the chalk in which it is now imbedded: the lower portion of the peduncle from which it was torn off has, I believe, been never yet discovered.

The position of the Paramoudræ in their matrix is irregular; (see Pl. 24. No. 1.) sometimes they lie horizontally, at other times are inclined or erect; they are generally insulated, and altogether unconnected with the thin stratra of siliceous nodules which occur in the same chalk pit with them. They often lie across these strata without producing any effect on them, or being themselves affected by them. Sometimes the extremities of two specimens are found in contact; but this seems to be the result of accidental juxta-position, not of any original connexion of the animal bodies.*

The animal history of these fossils is involved in much obscurity, as they display no traces of internal organization sufficient to develope the habits and character of the original bodies, whose external features are so distinctly preserved. The central aperture or pipe was calculated to allow water to have access to the interior of the animal, as is the case in many hollow spunges, that have large single tubes passing into their center, and usually closed at

* I mention this because an idea used to prevail at Belfast that they are occasionally found linked together in a kind of chain. For my acquaintance with this fact and many others relating to the history of the Paramoudra, I beg to acknowledge my obligations to my kind friend Dr. M'Donnel of Belfast, to whose ardent love of science, and ex-extensive knowledge of the natural history of the north of Ireland, I am indebted for much valuable information on the Geology of that district.

their lower extremity. It is possible the Paramoudra, having a tube with two apertures, may have possessed a character intermediate between a gigantic spunge and an ascidia. I have broken very many of these fossils in search of internal organization, and in one case only found the appearance represented in Pl. 24. No. 7, and there magnified beyond its natural size. It presents a small cluster of hexagonal cells about $\frac{1}{30}$ of an inch in diameter. The substance of the septa dividing the cells does not exceed in thickness that of the finest paper, and appears to be silex much iron-shot; the cells are filled with silex of the same colour with the mass that envelopes them, and display no traces of radii or fibres traversing their interior. This small cluster of cells was decidedly inclosed in the body, and within the crust of a Paramoudra, extending inwards, not an inch from the epidermis. As this is the only specimen in which I have seen or heard of such traces, I think it more probable that they are a fragment of some extraneous body, that was accidentally attached to, and at length inclosed within the substance of the Paramoudra, than that the traces of an organization so distinct and decided, if it had ever existed generally, should have been so totally destroyed in every other specimen that has been examined, as to leave only the outward form to guide us in our conjectures as to the character and habits of the original animal.

The mineral history of the Paramoudra seems intimately connected with that of many other spungiform bodies which we find in chalk flints. In all these cases the organic bodies thus preserved, appear to have been lodged in the matter of the rock, while it was in the state of a compound, unconsolidated, pulpy fluid; and before *that* separation of its siliceous from its calcareous ingredients, which has given origin to the flinty nodules in chalk, and to beds and nodules of chert in other limestone rocks. The present shape of many chalk flints being that of organic bodies, demonstrates the latter to have existed before the consolidation of the former; for the fidelity with which the silex has often copied the organization, and even the accidents and irregularities of the bodies enveloped, is so accurate, that it is impossible to attribute the form of the flint to any other cause than that of the body on which it was deposited. Sometimes the organization is so delicately retained, that it seems not to have undergone the smallest derangement before the siliceous cast was taken; and the model is thus permanently preserved. In other cases the minute fibres and tubes of the animal are not expressed by the silex which has filled the spaces which they occupied, yet the external form represents with faithful accuracy that of the body which afforded to the silex its mould or nucleus. This appears to have been the case in a remarkable degree in the instance of the Irish Paramoudra.

Before the consolidation of the original compound fluid which is now hardened and separated into beds and nodules of flint and chalk, a variety of organic bodies being dispersed through its mass would afford a number of nuclei, to which, in separating itself from the chalk, the silex seems to have had a tendency to attach itself. Hence the insulated nodules that occur irregularly in the chalk, out of the line of the flinty strata, do I believe very frequently bear traces of an organic nucleus; so also in many cases do those that occupy the flinty strata. But the greater number of these latter, though their form be usually that of nodules separated from each other by an intervening portion of chalk, yet indicate no traces that refer them to organic origin, and are sometimes extended into thin, continuous tabular masses.*

* It happens occasionally that very narrow fissures, traversing the chalk and cutting two or three of its siliceous strata, are filled with tabular plates of black flint. Such

The organic bodies that afforded nuclei to these nascent flints, appear to have been dispersed pretty uniformly through the original compound mass which is now divided into beds of chalk and flints, but it is not easy to determine what cause it was that regulated the distances at which the beds of flint have been disposed, or to say why we sometimes find organic bodies preserved in flint, at other times enveloped and filled only by pure chalk. The solution of the latter question may be, that different genera of organic remains afforded centers that attracted the silex with unequal force, and that this will in some degree explain the phenomenon so common in the chalk formation, that bodies allied to the genus spunge and alcyonium, are most frequently preserved in flint and chalcedony, whilst shells and other bodies, which in their natural state were more calcareous, generally have their form retained by chalk or calcareous spar.

In cases of many of these silicified spunges and alcyonia (of which there is in the Ashmolean Museum at Oxford, an extensive collection, from Henley and Stokenchurch, in Oxfordshire) the outer crust being composed of flint in its common state, represents rudely the outline of the body inclosed. But the internal structure retains traces of all its tubes and fibres, most delicately preserved in

fissures are rather rare, and were probably of high antiquity, nearly contemporaneous with the consolidation of the rock they traverse, and before the separation of its siliceous from its calcareous portions had been fully and finally completed. I have given in the drawing (Pl. 24, No. 8) an example of these veins, from a chalk pit on the south side of the London road, at the western extremity of Hurley Bottom, at the first ascent of the hill towards Henley, and about four miles east of that town; here the lower termination of the veins is covered by rubbish. A similar appearance may be seen near Brighton, at Rottingdean, where both the lower and upper terminations of the siliceous veins are distinctly laid open by a vertical section of the cliff. I have not seen the spot, but copy the section in Pl. 24, No. 9, from a drawing and description of it that were lately sent to me. The lines represent beds and veins of plated flint; the dots express siliceous nodules.

a reddish chalcedony. The introduction of this chalcedony appears to have been subsequent to the first incasing of the body by the coarse siliceous crust, and contemporaneous with the gradual decay of the animal matter inclosed, the particles of chalcedony being successively introduced into the space vacated by the animal particles as they successively perished, till the result was an entire substitution of chalcedony bearing the form of the organization of the animal.*

* Although in the present compact state of the matter of flint it is not easy, though possible, to force a fluid slowly through its pores, it is probable that before its consolidation was complete it was permeable to a fluid whose particles were finer than its own, and that the particles of chalcedony, whilst yet in a fluid state, being finer than those of common flint, did thus pass through the outer crust to the inner station they now occupy, where they also allowed a passage through their own interstices to the still purer siliceous matter which is often crystallized in the form of quartz in the centre of the chalcedony, and so intirely surrounded by it, that it could have had no access to its present place, except through the substance of the chalcedony and flint inclosing it.

Perhaps the same illustration may be offered, to explain the formation of quartz crystals in the centre of many agates, as well as of their concentric chalcedonic zones, the substance of which appears often to increase in purity in proportion to its distance from the outer circumference. I allude particularly to those agates in which there are no traces of any funnel through which the matter of the concentric zones could have been introduced; and to those chalcedonic geodes in the basalt of the Giant's Causeway, in which also no sign of a funnel can be discovered, but the component laminæ are disposed in parallel lines, crossing horizontally the cavity in which they are contained, and sometimes filling only the lower region of it. In such cases, the upper and void portion of the cavity is lined with an uniform thin film or arch of mammillated chalcedony, so exactly conformable to the irregularities of the hollow within which it is deposited, that we can only suppose it to have been introduced by a slow and uniform infiltration through every pore of the cavity that is now lined by it, and which, had the process been continued further, might intirely have filled it up.

This seems indeed to have happened in the case of those solid geodes, of which the lower part is composed of parallel flat plates of chalcedony, and the upper part made up of curved zones of the same substance concentric with each other, and bearing the form of the arch that overhangs the horizontal laminæ of the lower region.

Those geodes in which the cavity of the upper region is open, and merely lined by a thin vaulting of chalcedony, are known at the Giant's Causeway by the appellation of Box Agates, and Dr. MacDonnel has assured me, that in countless instances, when he has broken the laminated geodes from their matrix, with a view to examine the position of their parallel plates, they lie always horizontally.

It is probable that in cases where the body perished rapidly, there was not time for this process of gradual substitution, and that flinty matter of nearly the same coarse quality with the outer crust, was introduced hastily into the void spaces that were left unoccupied by the rapid decay of the animal nucleus. This coarser process is that which appears to have taken place in a vast plurality of instances, amongst which we must reckon that of the Irish Paramoudra, whose history has led us to the present discussion on chalk flints, among which they attain a size unusually gigantic, and often a weight of nearly two hundred pounds.

With respect to the general history of flinty nodules in chalk, whether insulated irregularly or disposed at certain distances in horizontal lines, I must observe that they seem to have originated from causes not dissimilar to those which have produced both nodules and horizontal beds of chert in the calcareous strata of many other secondary formations; e. g. in the freestone of Portland, in the mountain lime of Mells in the Mendip hills, and in the oolitic limestone near Pickering in Yorkshire, and near Poligny, on the north-west edge of the Jura mountains; at which latter place are extensive strata of chert disposed altogether in small nodules resembling chalk flints, as to their shape, size, and position, and without any organic nuclei. The chief difference appears to be, that in the case of the chalk formation, the nodular arrangement of the siliceous strata very much predominates, and in the other cases the siliceous strata, though occasionally nodular (as at Poligny), yet most frequently are disposed in continuous or nearly continuous flat masses; though even these sometimes pass into imperfectly lenticular and tuberous concretions. The existence of insulated siliceous concretions irregularly disseminated through limestone, is common to almost all calcareous strata in which there is any admixture of silex; and both these concretions and the flinty strata appear to have originated during the fluid state of the matrix in which we find them imbedded, and to have proceeded with it through a nearly contemporaneous process of consolidation; the separation of the siliceous from the calcareous ingredients having been modified by attractions which drew to certain centres the particles of the siliceous nodules as they were in the act of separation from the original compound mass, and the distances of the siliceous strata having probably been regulated by the intervals of precipitation of the matter from which they were derived, each new mass as it was discharged forming a bed of pulpy fluid at the bottom of the then existing ocean, which being more recent than the bed produced by the last preceding precipitate, would rest on it as a foundation similar in substance to itself, but of which the consolidation was sufficiently advanced to prevent the ingredients of the last deposit from penetrating or disturbing the productions of that which preceded it.

The result of a succession of such deposits as are here supposed would be the accumulation of a formation of homogeneous strata, each containing in a fossil state such organic remains as happened to be entangled in the successive precipitates. The identity of these remains in that immense succession of beds which constitutes the mass of the chalk formation, is consistent with the identity of the matrix containing them; there being no reason to believe in any change of circumstances in the then existing condition of our globe, from the commencement to the completion of the deposition of the beds of chalk, since we find no admixture of sand or pebbles (the wreck of older strata), nor any symptom of interruption or irregularity in the processes from which has resulted that enormous mass of strata which usually attains a thickness exceeding 500 feet in most parts of the English chalk formation.

With respect to the stratified arrangement of argillaceous geodes and concretions, we have abundant examples of it in the horizontal beds of septaria found in the Sheppy clay, in the Kimmeridge clay, the lias, and indeed almost all secondary argillaceous strata; and we have beds of lenticular concretions both siliceous and calcareous, equally abundant in many of our sandy strata, e. g. in the green sand of the Isle of Wight, in the Stonesfield sand near Woodstock, and the sand of the inferior oolite near Bath.

As to such of these concretions (whether insulated or disposed in strata) to which no extraneous nucleus can be discovered, it is not easy to say what determined their centres of attraction. But it does not appear possible that they could have been formed by infiltration into pre-existing cavities, like the irregularly disseminated geodes of the trap rocks; since this hypothesis in the case of chalk would imply the anomaly of there having once existed, extending uniformly over many hundred square miles, as many strata of air bubbles as there are of flint alternating with the chalk; and of which air holes not one was left empty or partially filled up;* whilst on the other hand many of the nodules could not have been formed in such air holes, as they entirely derive their shape from some extraneous bodies affording a nucleus to the silex that has incrusted them.

* It is important to distinguish between cavities in the chalk itself, and those within the body or shell of the siliceous concretions contained in chalk; and whilst I contend that in the latter case the cavity of the flint has been sometimes filled in a manner analogous to the infiltration of geodes in the trap rocks (see Note, . 419) yet the presence of the organic body, to the decay of which alone these last named cavities in the flints are indebted for their existence, proves that there was no cavity antecedent to that decay, and that the silex was originally deposited in the form of a mould round the organic body from which it derives its shape.

Again; the absence in chalk flints of that arrangement of the silex in concentric or parallel plates, which geodes of an agate-like origin would possess, adds weight to the arguments that have been offered against the existence of any identity in the manner of formation of agates and chalk flints.

XXVI. *Notice of Fossil Shells in the Slate of Tintagel.*

By the Rev. J. J. CONYBEARE,

MEMBER OF THE GEOLOGICAL SOCIETY.

Read 3d December, 1813.

THE large specimen of slate, bearing the impressions of several shells, which accompanies this note, was procured by Mr. Buckland and myself at the slate quarries of Tintagel, on the north coast of Cornwall. As it has not hitherto been remarked that any traces of organic remains existed in the schistose rocks of that county, we thought that it might not be deemed unworthy of a place in the collection of the Society.

The quarries which produced it are situated close to the sea, at the distance of about six miles to the north-west of Camelford. They are worked upon a very large scale, and are celebrated for the excellent quality of the roofing slate which they afford. The nearest point at which granite occurs must be as much as seven miles distant: we were therefore not surprised at the total absence of those large granitic and porphyritic dykes which, whether they are connected with or independent of that primitive rock, are certainly of much more frequent occurrence in its vicinity than elsewhere. The veins produce quartz, rock crystals of great transparency and beauty, calcareous spar, chlorite, and in some instances adularia. I know not whether this variety of felspar has been found elsewhere in Cornwall: we searched in vain for the octohedral ore of titanium (anatase) which from the character of the slate, and its accompanying minerals, we thought ourselves not unlikely to discover. The rock has not been ascertained as yet to contain any metalliferous veins: we observed one minute bunch of yellow copper ore imbedded in the slate itself. The strata are at this spot much freer from curvatures and other contorsions than they are along the coast to the eastward of it.

The slate of Snowdon bears the impression of shells resembling those contained in the present specimen. At Tintagel they are certainly of very rare occurrence: though we spent some hours in the quarry, we could not find any further traces of them.

Figures of the shells from Tintagel will be found at Plate 25. f. 1. The lower figure represents a specimen of fossil shells from Snowdon, presented to the Geological Society by the Woodwardian Professor.

XXVII. *Notice of some peculiarities observed in the Gravel of Litchfield.*

BY A. AIKIN, ESQ.

MEMBER OF THE GEOLOGICAL SOCIETY.

SECRETARY TO THE SOCIETY FOR THE ENCOURAGEMENT OF ARTS, MANUFACTURES, AND COMMERCE.

[Read 15th March, 1816.]

THE red sand or gravel (for it may be called by either name) which overspreads the country in the neighbourhood of Litchfield, has presented to me some remarkable appearances; a short notice of which may perhaps without impropriety be offered to the Geological Society.

The principal ingredient in this alluvial mass is quartz, in small roundish grains, mixed rather copiously with scales of silvery mica, and tinged of a brownish red colour by oxid of iron. In some places no other substances than those just enumerated make their appearance, and the soil is a loose incoherent driving sand. More generally however the grains are slightly cemented together by a little red clay, and rounded pebbles of various sizes and qualities are interspersed. I am unacquainted with the thickness of this bed, but excavations to the depth of about thirty feet have been formed in it by the side of the road to Birmingham, about two miles from Litchfield. At this place the pebbles are so abundant as to compose a considerable proportion of the entire mass, and it is here that the appearances, which are the subject of the present notice, may be most conveniently observed.

The pebbles of granite, of syenite, and of greenstone, are in a state of greater or less decomposition, but present nothing very remarkable, those of schist are usually soft and rotten, have evidently swelled since the period of their having been deposited here, in consequence of which their laminæ have parted from each other, and the interval is not unfrequently filled by calcareous spar, which is occasionally prolonged in the form of thin veins to the distance of a few inches into the sand. The outer surface of the schist is but little changed, but on breaking it, the interior is often found to be little else than a black powder.

The pebbles of quartz, which are numerous, appear to have undergone no change whatever.

The pebbles of limestone are the most abundant of all, and have undergone considerable change. The madrepores and other coralloidal bodies of which the limestone is principally composed, resist the solvent action of the water which percolates through the sand much better than the compact calcareous matter that is interposed between them does; the same is the case with the slender veins of calcareous spar by which the limestone is traversed; hence in those pebbles in which the process of disintegration is only moderately advanced, the surface presents a corroded spungy appearance, the prominent parts being composed of decaying madrepores and veins of calcareous spar, while the interior of the mass is still compact limestone. In other instances, where the decay has proceeded still further, the whole of the interstitial matter is gone, and the madrepores themselves are reduced to a very tender friable mass.

But the substances which have undergone the greatest change are chalcedony and hornstone or chert.

Of the former variety the most abundant is the common nodular agate, or Scotch pebble. In these the central nucleus and other parts composed of pure quartz are unaltered, the flesh-coloured zones, consisting of silex and red oxid of iron, have become more or less adherent to the tongue, have nearly lost their lustre, and have had their hardness much impaired; while the milk-white zones which in the perfect state of the substance were of pure chalcedony, are in every instance reduced to an opake white earth, yielding generally to the nail, and strongly adherent to the tongue. Many of these nodules cannot be removed from the sand in which they are imbedded, being reduced to a soft smooth pulp, and some even of those specimens, which are now before the Society, might in their moist state be crushed between the fingers with the greatest ease.

Of hornstone I met with several varieties. One exhibits alternate bands of a smoky brown colour and white, with a glimmering lustre, shewing it to approximate to the nature of quartz; yet even in this the white bands are reduced more or less to an earthy consistence.

Another variety is the entrochital hornstone, and this appears to have suffered little if any change.

A third variety is the compact nodular hornstone, of a dull greyish white colour, and often intermixed with chalcedony. The external part of this, to a considerable depth, is reduced to a white earth; the interior is more solid, but even where the chert is but little changed the chalcedony in contact with it is totally disintegrated.

The fourth variety, and the most remark le of any, appears to have been a madrepore agate, in which the organic part was converted into quartz, while the matter which connected the tubes was chalcedony or hornstone. In this state being subjected to the same violent friction as the other materials of the gravel, it assumed the common figure of a rolled pebble. It has however since that period been subjected to the solvent action of water under some particular modification, by which nearly the whole interstitial matter (with the exception of a few flakes here and there of quartzy chalcedony) has been removed, while the quartz moulded within the tubes of madrepore and representing most perfectly the external form of the zoophyte, alone remains.

The only difference that chemical analysis has detected between quartz and chalcedony, is that the former is silex with perhaps one or two per cent. of water, while the latter contains, besides, about two per cent. of alumine and lime; but this difference appears by no means sufficient to account for the absolute permanence of the one, and the readiness with which the other suffers decomposition under the same circumstances. The moisture contained in the bed is primarily rain water, and it is not easy to see what active agent it can become charged with in draining into the interior of the mass, except carbonic acid or carbonate of lime: any of the stronger acids, such as the sulphuric, resulting from the decomposition of pyrites, would immediately be neutralized by the calcareous matter in which the whole bed abounds. Alternations of moisture and dryness, of heat and cold, to which the decomposition of the exposed surfaces of rocks is so generally attributed, could have little or no influence in this case; since the state of moisture and of temperature at the depth of twenty feet or more in a bed of gravel cannot be supposed to undergo much change.

May I take the liberty of recommending to the well known activity of the members of this Society an examination into the circumstances on which the phenomena mentioned above depend, and which appear to be not a little important both in a chemical and geological point of view?

XXVIII. *Analysis of one hundred parts of a dark Bituminous Limestone, from the Parish of Whiteford in Flintshire, North Wales.*

By EDWARD DANIEL CLARKE, LL.D.

PROFESSOR OF MINERALOGY IN THE UNIVERSITY OF CAMBRIDGE,

MEMBER OF THE ROYAL ACADEMY OF SCIENCES AT BERLIN,

AND HONORARY MEMBER OF THE GEOLOGICAL SOCIETY.

[Read 21st June, 1816.]

THE superiority which has been observed in the architecture of the ancient *Greeks* and *Romans*, may in some measure be ascribed to the materials used in the construction of their edifices. This remark is especially applicable to the works of the *Romans*; because a very principal part of the materials of their architecture consisted of substances that were in their nature artificial. Their *aqueducts*, *walls*, and *foundations*, often consisted of *bricks* and *mortar*; and in the making of *mortar*, by the judicious use of the *pulvis Puteolanus*, a *cement* was prepared which had the property of becoming indurated under water, in such a remarkable manner, that, in many instances, it acquired a greater degree of hardness than the substances themselves exhibit, which this *cement* was intended to hold together. To this property are owing the specimens of *polished mortar*, which exist in the cabinets of antiquaries, derived from ruins upon the coast of *Baia*, of *Putéoli*, and of *Naples*, and wherever else the *pulvis Puteolanus* was used in the fabrication of mortar, which has subsequently been exposed to the action of water. "*Puteolanus pulvis*," says SENECA,* "*si aquam attigit, Saxum est.*"—It was a property so well known to the ancients, that the ashes of *Putéoli* were exported to very distant parts of the Roman Empire, to be used in the preparation of *mortar* for all public works, such as moles, bridges, and ramparts, situate in rivers, lakes, or in bays, and upon the borders of the sea.† The excavations carried on in search of it, caused the spacious caverns and extensive subterraneous galleries, afterwards used as catacombs, in the neighbourhood of *Naples* and of *Rome*; ‡ and the same arenaceous substance has sometimes been brought even into *Great Britain*, to be used in the fabrication of *mortar*, both in ancient and in modern times. It may therefore be considered as a discovery of some importance, that we possess, in this country, a species of *limestone* which, when used for purposes of extracting *lime*, and in the preparation of *mortar*, is capable of communicating to the cement all the properties of the *pulvis Puteolanus.*

This species of *limestone* is found in *North Wales*, in the parish of *Whiteford*, in *Flintshire.* Some specimens of it were sent to me by my friend *David Pennant*, Esq. son of the celebrated naturalist of the same name. Its *specific gravity*, estimated in pump water, at a temperature of 50° of Farenheit, equals 2.670. It is of a dark brown colour, and, when breathed upon, it exhales an earthy odour, denoting the presence of *iron* oxide, in combination with *alumine*; but its colour is owing to *bitumen*, rather than to *iron*, as will appear by the following analysis, undertaken at the request of Mr. *Pennant*, for ascertaining the chemical constituents of this *limestone*.

* *Natur. Quæst.* Lib. 3. Cap. 20. See also *Pliny. Hist. Nat.* Lib. 35. Cap. 13.

† The *pulvis Puteolanus* was also used by the ancients in constructing the streets of *Rome*, and in all the great roads of the empire. See *Winkelmann, Hist. de l'Art*, tom. 2, p. 553.

‡ Winkelmann, Observ. sur L'Architect. des Anciens, &c. ubi supra.

1. One hundred grains being placed upon red hot iron for the expulsion of the *water of absorption*, were thereby diminished $\frac{5}{20}$ of a grain.

2. The remainder being reduced to powder in a porcelain mortar and exposed to diluted muriatic acid until all effervescence ceased, there remained an insoluble residue of the original dark colour of the limestone, which when carefully washed and dried, weighed 10 grains; allowing therefore for the weight of the *carbonic acid* and *lime*, after the expulsion of the water of absorption, 89¾ grains.

3. The supernatant acid used in this experiment being decanted, and neutralized by the addition of an alkali, yielded no precipitate of *iron* to the tincture of galls; but the prussiate of potass threw down a blue precipitate upon which however no reliance can be placed; as it is well known that the prussiate of potass is not a satisfactory test of the presence of *iron* when this metal exists in an inconsiderable portion.

4. The ten grains of dark brown powder mentioned in No. 2, being collected, washed and dried, were exposed to the heat of a flame of a candle urged by the common blow-pipe, when combustion instantly ensued, accompanied by a lambent flame, which continued during some seconds, the powder thereby losing its colour and becoming white; attended also by a loss of weight, amounting to $\frac{2}{5}$ of a grain. Hence it is manifest that the colour is owing to *bitumen*.

5. To ascertain the proportion of *alumine* (which from its chemical combination with *silex* remained insoluble in the muriatic acid) a plan recommended by Mr. *Holme* was adopted. One hundred other grains of the same limestone were calcined in a platinum crucible, and the loss of weight owing to the expulsion of the *carbonic acid* was found to equal 40 $\frac{1}{10}$ grains.

6. The calcined residue being placed in muriatic acid, a solution now took place both of the *lime* and of the *alumine*, and there remained at the bottom of the vessel only an insoluble portion of pure *silex*, in the form of a white powder, which when carefully washed and dried weighed $\frac{3}{5}$ of a grain. Deducting therefore this weight of the *silex*, from the weight of the *silex* and *alumine*, which remained in No. 4, after the combustion of the *bitumen*, the weight of the *alumine* is ascertained; which of course equals 8 $\frac{8}{10}$ grains.

From all the preceding observations, it is therefore evident that the constituents of this LIMESTONE are as follow:

Lime	49.	65
Carbonic acid	40.	10
Alumine	8.	80
Silex	—	60
Bitumen	—	60
Water	—	25
	100.	. .

And the valuable property of the *mortar* prepared from this *limestone*, is owing to the presence and proportion of *alumine*; and to its property of rapidly absorbing water.

XXIX. *Barometrical Measurements.*

By WILLIAM ALLEN, F.R.S.

MEMBER OF THE GEOLOGICAL SOCIETY,

[Read 19th November, 1812.]

THE following measurements were made with a single Barometer of the construction proposed by Sir Henry Englefield, and have been calculated according to the formula recommended by him in his memoir on the subject, which is inserted in the 14th volume of Nicholson's Journal. I shall give in detail the observations made upon Snowdon; and of the other measurements I shall mention only the results.

Snowdon.

Observ.	Hour		September 8th, 1806.	Therm.	Barom.
1	A.M.	9 0	Goat Inn, Beddgelert	61	29.69
2	——	10 25	Llyn Cader	61	29.162
3	P.M.	1 25	Summit of Snowdon	50	26.164
4	——	4 0	Llyn Cwellyn	56	29.30
5	——	4 45	Llyn Cader	57	29.12
6	——	6 0	High water-mark at Pont-aber-glas-Llyn	55	29.78
7	——	6 30	Goat Inn at Beddgelert	53	29.6

It appears from observations 1 & 7 that the Barometer had fallen at Beddgelert in $9\frac{1}{2}$ hours 0.09 inches, and from observations 2 & 5 that it had fallen at Llyn Cader in $6\frac{1}{4}$ hours 0.042 inches. The descent of the mercury may therefore be estimated at about 0.008 inches an hour, for which due correction has been made in each observation on calculating the measurements.

	Feet.
From Observations 6 and 7, the height of Beddgelert Inn above high water-mark	= 162.7
From Observations 1 & 4, the height of Llyn Cwellyn above Beddgelert	= 314.2
. . . . above the Sea . .	= 476.9

	From Obs. 1 & 2.	From Obs. 1 & 5.	mean,
The height of Llyn Cader above Beddgelert . . .	489.3	480.2	484.7 feet
. . . . above the Sea	652.	642.9	647.4

	From Obs. 1 & 3.	From Obs. 3 & 7.	mean
The height of Snowdon above Beddgelert . . .	3457.5	3409.	3433.2 feet
. . . . above the Sea	3620.2	3571.7	3595.9

In the following measurements only one observation was made at the lower station, unless the contrary is stated.

Cader Idris.

The height of the highest Peak above Dollgellau 2879
The height of the highest of the three Heads above Dollgellau . . . 2840

Ingleborough.

The height of Ingleborough above the Bay-horse Inn, Ingleton . . . 1881
Ingleton is 90 feet below Settle; the height of Settle has been accurately taken, and is stated at 621 above the sea; therefore the height of Ingleton above the sea is 531
and the height of Ingleborough above the sea is 2412

Whernside.

The height of Whernside above Ingleton 1930
. . . . above the sea 2461

Pen-y gant.

The height of Pen-y gant above Settle 1858
. . . . above the sea 2479

Shap Fells.

The height of the highest point in the road between Kendal and Shap above Kendal 1187

Helvellyn.

From two observations made the same day at Paterdale.—Day rainy.—The Barometer varied .194 in 5 hours.—The Inn at Paterdale is 24 feet above Ullswater.

The height of Grisdale brow above Ullswater	988
. . . . . . of Red Tarn	1935
. . . . . . of the top of Helvellyn	2686

Saddleback.

Threlkeld, where the first observation was made, is 235 feet above the level of Keswick Lake, which is 228 feet above the sea.

	above Keswick Lake.	above the Sea
The height of Saddleback—the Pummel . . .	2615 feet	2843 feet
the Crupper . . .	2561	2789

Skiddaw.

The Oak Inn at Keswick, where the first observation was made, is 28 feet above the lake, which is 228 feet above the sea.

	above Keswick Lake.	above the Sea
The height of Latrigg	330 feet	558 feet
. . . . . . of Half-way stone	1408	1636
. . . . . . of the summit of Skiddaw	2789	3017

Barometrical Measurements.

By SAMUEL WOODS, Esq.

MEMBER OF THE GEOLOGICAL SOCIETY.

IN the following measurements only one observation was made at the lower station, unless the contrary is stated. They are calculated according to the formula of Sir Henry Englefield.

	Feet
Branch of the Mendip hills just above and eastward of Cross; the point appears to the eye to be one of the highest in the Mendip range. Height above Cross	670

	Heights above the sea Feet
Dunkerry Beacon, one of the highest points of Exmoor, near Minehead. Weather cloudy, with light rains. From two observations, one at Porlock Quay, the other at Minehead Quay, the Barometer had fallen 0.14 inches in 5 hours	1784
Top of Brendon hills in the road between Minehead and Dulverton	1210
North hill above Minehead	1000
Highest point in the road between Barnstaple and Ilfracombe	900
Linton Church-yard, in the North of Devonshire	428
Exmoor, about 4 miles south of Linton; one of the highest points on the Devonshire side of Exmoor.	1608
Hill called Hangman, near Comb-Martin	1093
Hill about 1 mile east of the Hangman	1168
Yester, near Okehampton, one of the highest points of Dartmoor, above the Inn at Okehampton, 1561 feet	2077
The height of the Inn at Okehampton	516

Hastings, Sussex.

General Roy's station near the Windmill on Fairlight Common	588
East Cliff	190
Hill above the East Cliff	313
Castle Hill	180
Castle Cliff	135

Dover.

Western height	382
Shakespear's Cliff	310
Summit of Castle-hill, beyond the turnpike	390

Dorking, Surry.

	Heights above the bed of the Mole. Feet
Box-hill . . . about	300
Headley Church, and the highest part of the wood on Mickleham Downs	466
Norbury park	292
Bench beyond the summit of the park	320
Leith hill tower	805
Beech Trees on the south side of Headley Common	585

XXX. *Notice concerning the Shropshire Witherite.*

By ARTHUR AIKIN, Esq.

MEMBER OF THE GEOLOGICAL SOCIETY,

AND SECRETARY TO THE SOCIETY FOR THE

ENCOURAGEMENT OF ARTS MANUFACTURES AND COMMERCE.

[Read 6th December, 1811.]

THE Witherite or native carbonate of barytes, still continues to be one of the rarer productions of the mineral kingdom. The only thoroughly ascertained locality of this substance, according to Professor Jameson, (System of Mineralogy, I. 575,) is Anglesark in the county of Lancaster, where it was first discovered by Mr. James Watt. It is here found in veins traversing the independent coal formation, and accompanied by blende, galena, calamine and heavy-spar. To this locality however may be added, on the authority of Klaproth, (Analytical Essays, I. 389,) a mine near Neuberg in Upper Stiria, where this mineral occurs in a bed of spathose iron ore.

The mine at Anglesark is, I understand, abandoned : it may therefore be a matter of some interest to the members of the Geological Society, to state that my researches during the last summer in pursuance of my mineralogical survey of Shropshire, have made me acquainted with a mine, within the bounds of that county, in which witherite occurs very abundantly.

The most hilly district of Shropshire extends from the borders of Montgomeryshire to the town of Church Stretton, having the broad valley of the Severn for its northern boundary, and stretching as far south as the parallel of Bishopscastle. The general elevation of this tract above the Severn varies from 800 to above 1500 feet. It is completely intersected by two strait and simple vallies, the direction of which is about north-east and south-west, and several smaller ones parallel to the larger descend from the interior towards the north and south. The principal rock which presents itself is greywakke-slate, in beds which run north by east and south by west, rising at an angle of about 50° east by south. The colour of the rock where it has not undergone decomposition, is bluish or greyish black, probably from a mixture of carbon, for by exposure to the air it passes to a pale yellowish-grey, with a few spots of oxide of iron. Its cross fracture is dull, but its longitudinal fracture presents numerous small spangles of mica. The upper beds, or rather the superficial parts of many of the beds, are in the state of shale, that is, they are shattery, soft, and more or less decomposed. No true veins ever occur in this shale, and even veins of considerable size and regularity in the compact part of the rock, terminate almost immediately on coming in contact with the looser part.

It is in this compact greywakke-slate, and chiefly on the western side of one of the highest hills called the Stiperstones, that the principal lead mines of the county occur. Of these, that which is called the Snailbach mine, is the most important for its metallic produce, and is the only one in which witherite has hitherto been found.

The mine consists of one principal vein, with several strings proceeding from it. Its course is nearly east and west, descending at a high angle to the south : its greatest depth is about 180 yards, and there are no signs of its approaching to a termination : its general thickness is 10 or 12 feet, but in one particular part amounts to more than 30 feet. Cavities, or locks as the miners call them, are frequently met with of all sizes, from that of a walnut to that of a small room: many of the lesser cavities are filled with petroleum, the others are lined with crystals of heavy-spar, calcareous spar, and quartz, having their bottoms or floors covered with aggregated masses of the above crystals, with crystals and potatoe-shaped pieces of galena, with carbonate of lead, and with a black powder which is principally pulverulent galena. In some parts there is a saalbande or *sticking* of grey clay an inch or two in thickness, and here the vein is the least productive; in other parts the rock is hardened by an infiltration of quartz, and these are uniformly found to be the most productive. There is no regularity in the arrangement of the contents of the vein, but generally the galena occupies the sides, and the sparry veinstones the centre. Riders, or ribs of rock inclosed within the vein occur, but not frequently. The ore is for the most part foliated galena and striated galena, called by the miners *pot ore* and *steel ore*: iron pyrites is the next in quantity, and lastly blende, this latter being for the most part so intimately mixed with the galena as to be scarcely visible. The veinstones are calcareous spar, often approaching to schiefer spar, and foliated heavy-spar (called here *water spar*, because from the looseness of its aggregation most of the water drains through it into the mine.) Quartz is more rarely met with; and in the lower part of the mine, where the vein is very thick and sparry, the witherite is found in irregular masses, weighing from 40 lbs. to 2 or 3 cwt., imbedded in heavy spar. The name given to this substance by the miners is *yellow spar*, not that this is its real colour by day-light, but its transparency is so considerable that if a lighted candle be placed behind a mass of it the whole will glow with a yellowish light, a circumstance by which the miners distinguish it from heavy-spar; this latter from the looseness of its texture being in large masses quite opake. The colour of the witherite is white with the slightest possible, if any, tinge of yellow: its fracture is broad striated approaching to strait-foliated: it is for the most part massive. I have seen only a single specimen that presented any indications of a regular crystalline form. In other particulars it agrees with the usual descriptions of this substance.

The Anglesark witherite has been analysed by Klaproth, and besides carbonate of barytes appears to contain above two per cent. of carbonate of strontites, and a scarcely appreciable quantity of oxide of copper. The Stirian witherite, on examination by the same chemist, appears to be a pure carbonate of barytes. The presence of carbonate of strontites being a circumstance of some interest, I was induced to examine the Shropshire Witherite for the purpose of ascertaining whether in this particular it agreed with that from Lancashire.

For this purpose 200 grains were dissolved in muriatic acid, and left behind 1.8 gr. of a white powder which was sulphate of barytes.

The muriatic solution being supersaturated with ammonia was evaporated to dryness and ignited till the muriate of ammonia was driven off: the residue was redissolved in water, but left behind 1.5 gr. of a brown sediment, which on digestion with sulphuric acid was separated into 1. gr. of silex insoluble in the acid, and 0.5 gr. of alumine coloured by oxide of iron, soluble in the acid, and which deposited crystals of alum on the addition of sulphate of potash.

The purified muriatic solution was brought to the crystallizing point, and the muriate of barytes which fell down was removed: the mother-liquor was mixed with alcohol and heated, the fluid (after standing a minute to clear) was poured off, and on cooling deposited long needled crystals of muriate of strontites. Water was then added, the crystals were redissolved, and carbonate of ammonia was poured in till it occasioned no further precipitate. The carbonate of strontites thus obtained weighed on ignition 2.2 gr. and being redissolved in muriatic acid and mixed with alcohol communicated to the flame of this last the red colour characteristic of strontites.

The muriate of barytes was in like manner decomposed at a boiling heat by carbonate of ammonia, and the carbonate of barytes thus obtained weighed, after edulcoration and ignition, 192.6 gr.

Hence 100 parts of this witherite contain

96.3	carbonate of barytes
1.1	——— of strontites
0.9	sulphate of barytes
0.5	silex
0.25	alumine and oxide of iron
99.05	
0.95	loss

XXXI. *Extracts from the Minute Book of the Geological Society.*

1810, *February* 2.

AN Extract of a letter from Dr. Macdonell, of Belfast, to Mr. Horner, was read, in which an account is given of a stratum of submarine peat and timber in Belfast Lough, situated under the level of ordinary tides, but generally left bare at ebb tides. Nuts are numerous in it, both on the east and west sides of the harbour. On the east side, where calcareous rocks exist, the nuts are filled with calcareous spar, but on the west side, where the rocks are schistose, they are empty. Some of them are perfectly filled, others only partially so, yet the shell appears quite entire, and unchanged by any petrifactive process, although when put into acids some effervescence takes place. Dr. Hutton alledges that no infiltration can happen in circumstances similar to that in which these nuts are placed, for they are immersed in a bed of peat four or five feet thick, and this covered by a deposit of sand, shells, and blue clay, and the whole kept moist and all evaporation prevented by being covered three-fourths of the day by the tide.

1811, *January* 18.

An extract of a letter from Dr. MacDonnell, of Belfast, to Mr. Horner, was read, giving an account of some granite veins in slate, in the Mourne mountains.

In some part of these mountains, which are situated at the southern extremity of the county of Down, grey granite forms the summit of the mountain, and primitive slate the sides. The contacts are as sharp as possible, without the least of one rock graduating into the other, and in all cases the granite is continued from the great mass in veins through the slate, but never the contrary.* Masses of slate often occur, like islands floating in, and surrounded by the granite of the veins. Mr. Playfair, who was with Dr. Mac Donnell, remarked that the schist, which lies upon and near the granite, has a much greater number of fissures than that which is a mile distant. The granite veins generally terminate in fine threads.

1811, *November* 1.

A letter from George Cumberland, Esq. of Bristol, was read, giving an account of a trap rock that had been discovered at Micklewood, in Gloucestershire. It occurs to the east of the road going from Bristol, within two miles of Frampton, on an estate belonging to Lord Berkeley, and is known by the name of the *Old Rock.* The mass rises perpendicularly to the height of about 30 feet, is less than 300 yards wide, and extends in the other direction about a quarter of a mile. The same rock is found again to the north-east of the first mentioned place, dipping to the east beneath the surface.

The Micklewood rock has an amygdaloidal character, containing plain or striped chalcedonies, and numerous fungiform or irregularly cylindrical masses, composed of iron spar. Those masses are often found two feet in length; the chalcedonies vary from one to twenty inches in diameter, and are nearly all of the same shape, convex above, and concave beneath.

* Pl. 28, Fig. 1.

1811, *November* 1.

An extract of a letter from Dr. Murray, of Harrogate, to Mr. Sowerby, was read, mentioning that sulphate of strontian had been found in limestone on the banks of the Nidd, near Knaresborough.

1812, *March* 6.

A notice by Arthur Aikin, Esq. was read, on a green waxy substance found in the alluvial soil near Stockport, in Cheshire.

In 1811 a specimen from the abovementioned place was communicated to the Society by Dr. Henry. On a chemical examination Mr. Pepys found it to be a combination of resin and oil mixed with a quantity of brown quartzy sand. Its colour was bluish green, and was at first supposed to be occasioned by copper, but no metallic matter except iron was discovered in it. From its composition, and the small depth at which it was found, it was not supposed to be a natural product, but Mr. Aikin is inclined to doubt this conclusion, having met with, in the Dictionnaire d'Histoire Naturelle, under the article *Sabliere*, an account by M. Patrin, of the discovery of a similar substance at the foot of the hill of Menil Montant, near Paris. It there occurs in sand, accompanied by fresh water shells.

1812, *June* 19.

A notice by C. Mackintosh, Esq. on the aluminous strata at Campsie was read.

The coal formation which the Scottish aluminous strata accompany, may perhaps be traced and identi ed in four distinct points of this particular district of Scotland, namely, Campsie in Stirlingshire, Kilpatrick in Dumbartonshire, and Hurlet and Houston, in

Renfrewshire. The strata of the four places vary indeed in thickness, but their position and alternation may be considered the same. A sketch of the Campsie strata is subjoined, as descriptive of the whole.

After passing through the soil and one foot of limestone, alternating strata of Bituminous Schistus and ironstone occur, till we arrive at the immediate vicinity of the aluminous materials; which are,

Limestone	4 feet
Aluminous schistus, which consists of (what the miners call) the gentle slate, and the diamond slate . . .	2
Coal, of the caking quality of the Newcastle, which contains the slaty and the nodular pyrites	4
Fire Clay of excellent quality	1

The coal has been extensively excavated for a long series of years, from mines of which the temperature is seldom under 60° Fahr. frequently as high as 80°, in places excluded from any direct current of air. The circulation of this warm air has ripened the hard slate into various qualities, and these contain proportions of alum and copperas, which vary according to the time of their exposure, the recent slates abounding in copperas, those longer exposed, in aluminous matter.

1815, *April* 7.

A notice was communicated by Leonard Horner, Esq. respecting the rocks of the Isle of Tino, in the Archipelago.

The highest part of Tino is one long ridge of limestone, which affords excellent marble, that is sent for grave-stones to Smyrna and Constantinople. In the garden of an Italian convent there is a beautiful vein of asbestos running through serpentine, which passes into a kind of verde antique. It is stratified and dips westward about 65°. Here are many rich veins of lead, which generally occur in large veins of quartz in sandstone. The schistus of this island, on the side opposite to Andros, is well calculated for slates; that opposite Miconi is very micaceous.

1815, *November* 3.

Dr. Traill presented to the Society some magnetic iron sand, mixed with much iserine, accompanied with a letter, of which the following is an extract.

" I send you a bag filled with magnetic iron sand, mixed with much iserine, which I discovered more than two years ago in the hundred of Wirral, in Cheshire. It occurs on the shores of the Mersey, opposite to Liverpool, at Seacome Ferry. After heavy rains it oozes out of a deep bank of clay; but I strongly suspect that its matrix is the coarse reddish brown sandstone of the country, which, near Seacome, contains many quartzy nodules."

In a subsequent letter (dated 26th October, 1816) Dr. Traill says, " After the heavy rains of this summer, I have traced the magnetic iron sand and iserine for several miles along the coast. They are washed out of a bed of cohering sand that lies below the clay, and may be considered as entering largely into the Geological composition of that part of Cheshire."

1815, *December* 15.

A Letter from the Rev. Archdeacon Barnes was read, dated Bombay, March 31, 1815. In this letter Mr. Barnes communicates, on the authority of Mr. Copeland, Assistant Surgeon to the European force in the Guzerat, some particulars relative to the carnelians of Cambay.

These are all procured from the neighbourhood of Broach, by sinking pits during the dry season in the channels of torrents. The nodules which are thus found lie intermixed with other rolled pebbles, and weigh from a few ounces to two or three pounds. Their colour when recent is blackish olive passing into grey. The preparation which they undergo is, first, exposure to the sun for several weeks, and then calcination. This latter process is performed by packing the stones in earthen pots, and covering them with a layer five or six inches thick of dried goat's dung; fire is then applied to the mass, and in twelve hours time the pots are sufficiently cool to be removed. The stones which they contain are now examined, and are found to be some of them red, others pink, and others nearly colourless, the difference in their respective tints depending in part on the original quantity of colouring matter, and in part, perhaps, in the difference in the heat to which they have been exposed.

1816, *January* 5.

A communication from J. Taylor, Esq. Member of the Geological Society, on some remarkable appearances in coak, was read.

The coak in question is produced from two varieties of Newcastle coal, known in the market by the name of Tanfield moor and Pontop. The coal is charred in an oven of brickwork, of very simple construction, each charge being sufficient to cover the floor to the thickness of 18 or 20 inches. The combustion begins at the surface and proceeds gradually downwards. When all the bituminous matter has been driven off, the mouth of the oven is opened for the purpose of drawing the charge, at which period the coak presents the appearance of a glowing pavement rifted into perpendicular columnar masses, the bases of which rest on the floor of the oven. Adherent to the sides of these rifts are occasionally found concretions of a rather flat and small botryoidal external figure of an iron black colour, and highly metallic lustre, resembling grey manganese, or black hematitic iron ore.

Intermixed with these are small arborescent tufts, about a quarter of an inch in length, adherent by their base to the mass of coak, each branch of which, when examined by the microscope, appears composed of minute botryoidal shoots.

A LIST OF DONATIONS

TO THE LIBRARY,

TO THE

COLLECTION OF MAPS, PLANS, SECTIONS, AND MODELS;

AND TO THE

CABINET OF MINERALS,

BELONGING TO THE

GEOLOGICAL SOCIETY,

From the Close of the Ninth Session in June, 1816,

to the Close of the Tenth Session in June, 1817.

TOGETHER WITH THE DATES AT WHICH THEY WERE RESPECTIVELY MADE,

AND THE

NAMES OF THE DONORS.

I. *Donations to the Library.*

1816.	BOOKS.	DONORS.
June 1.	A Description of the principal picturesque Beauties, Antiquities, and Geological Phœnomena, of the Isle of Wight, by Sir H.C. Englefield, Bart. with additional Observations on the Strata of the Island, and their continuation in the adjacent parts of Dorsetshire; by Thomas Webster, Esq.	Sir H. C. Englefield, Bart. Memb. G. Soc.
Aug. 2.	Histoire Naturelle de diverses substances minerales siliceuses passées a l'etat de Pechsteins, ou pierres de poix, par M. Faujas de Saint Fond. Paris, 1816, 4t°	The Author.
	Annals of Philosophy for August, 1816, by Dr. Thomson.	The Editor.
Sept. 1.	Annals of Philosophy for September, 1816, by Dr. Thomson.	The Editor.
	Journal de Physique for March, April, May, and June, 1816.	Robt. Ferguson, Esq. Memb. G. Soc.
Oct. 25.	Annals of Philosophy for October and November, by Dr. Thomson	The Editor.

1816.	BOOKS.	DONORS.
Oct. 25.	Notices sur des Plantes Fossiles, renfermées dans un Schiste marneux des environs de Chaumerac et de Roche-Sauve, department de l'Ardèche par M. Faujas de Saint Fond.	The Author.
Nov. 8.	Nos. 10 to 25 of the Mineral Conchology, of Great Britain, by James Sowerby, Esq. Memb. G.S.	The Author.
9.	Two Extracts from the Bibliotheque Britannique De la matière première des Laves, & Refutation de l'Hypothèse d'un Auteur anonyme sur la formation des Vallées, by J. André de Luc.	The Author.
14.	Essai sur le Departement de l'Aude, adressé au Ministre de l'Interieur, par C. I. Barante, Prefet de Genève. 1 vol. 8v°	G. B. Greenough, Esq. Memb. G. Soc.
	Mineralogie Sicilienne, docimastique et metallurgique, par l'Auteur de la Lythologie Sicilienne, Turin, 1780. 1 vol. 8v°	. . . .
	Voyage Mineralogique fait en Hongrie et en Transilvanie, par M. de Born. Paris, 1790. 1 vol. 8°	. . . .
	A Treatise on the external, chemical, and physical characters of Minerals, by R. Jameson, Hon. Member of the Geological Society. Edin. 1816. 1 vol. 8v° Accompanied by a set of illustrative Models.	N. J. Larkin, Esq. Memb. G. Soc.
15.	Mineralogie Homerique, ou essai sur les Mineraux dont il est fait mention dans les Poèmes d'Homerè par A. L. Millin, Membre de l'Instiut royal de France, &c. Paris, 1816, 2d edit. 1 vol. 8v°	Charles Stokes, Esq. Sec. G. Soc.
	Theophrastus's History of Stones, with an English Version and Notes, 2d edit. by Sir John Hill. Lond. 1774. 1 vol. 8v°	. . . .
	A General Account of the Rivers of note in Great Britain, by Henry Skrine, Esq. LL.B.	. . . .
16.	Outlines of Mineralogy and Geology.——	The Author.
	An Elementary Introduction to the knowledge of Mineralogy. By William Phillips, M.G.S.	. . . .
28.	Annals of Philosophy, for December, 1816. By Dr. Thomson.	The Editor.
29.	Annals of Philosophy by Dr. Thomson, for July.	. . . .
Dec. 5.	Considerations sur les montagnes volcaniques, par M. Collini, Directeur du Cabinet d'Histoire Naturelle, de S.A.S.E. Palatine et de Baviere, Manheim, 1781, 1 vol. 4t°	G. B. Greenough, Esq. Memb. G. Soc.
	Mineralogisch geographische und andere vermischte Rachrichten von den Ultaischen Gebirgen Russisch Ranserlichen Untheils von H. 'M. Renovans. Reval. 1788, 1 vol. 4t°	. . . .
	Physikalisch-Metallurgische Abhandlungen über die Gebirge und Bergwerke in Ungarn von Johann Jakop Ferber, Prof. in Mitau. Berlin, und Stettin, 1780, 1 vol. 8°	. . . .

1816.	BOOKS.	DONORS.
Dec. 5.	Voyage Mineralogique Philosophique et Historique en Toscane, par le Docteur Jean Targioni Tozetti. Paris, 1792, 2 vols. 8v°	G. B. Greenough, Esq. Memb. G. Soc.
	Journal de Physique for July and Aug. 1816.	Robert Ferguson, Esq. Memb. G. Soc.
6.	Tableau Synoptique d'Oreognosie, ou connoissance des montagnes ou roches donné par M. Tondi, dans son dernier cours particulier en 1811.	The Author.
	Memoria Mineralogica sulla montagna e sui contorni di S. Gottardo di Ermenegildo Pini.	The Author.
	Bibliotheca Italiana ossia Giornale di Letteratura, Scienze ed arti compilato de Una Società di Litterati, tomo. 1. Milano, 1816.	The Editors.
17.	Journal of Science and the Arts, edited at the Royal Institution of Great Britain. Nos. 1, 2, & 3.	The Royal Institution of Great Britain.
18.	Der Granit des Riesengebirges und di ihn umgebenden Gebirgs-Familien, eine geognostische Skizze von Karl von Raumer Bergrath und Professor in Breslau.	G. B. Greenough, Esq. Memb. G. Soc.
	Breislak mineralogische Reise durch aneu Theil des Kirchenstaats.	. . . .
	Journal de Physique for September, 1816.	Robert Ferguson, Esq. Memb. G. Soc.
	Handbuch zur Chemischen Analyse der Mineral Corper von W. U. Lampadius, Professor der chimie und des huttenwesens an der Freybergen Bergacademie.	Alexander Henderson, M.D. Memb. G. Soc.
20.	Report on the Tavistock Canal.	John Taylor, Esq. Memb. G. Soc.
	Description of Greenland, by the Chevalier Charles Louis Giesecké.	Henry Heuland, Esq. Memb. G. Soc.
24.	Catalogue des 4 Collections de M. le Marquis de Drée.	M. le Marquis de Drée.
31.	Annals of Philosophy for January 1817, by Dr. Thomson.	The Editor.
	Journal of Science and the Arts, edited at the Royal Institution of Great Britain. No. 4.	The Royal Institution of Great Britain.
1817.		
Jan. 1.	Meterological Table for 1816, extracted from the Register kept at Kinfauns Castle, N. Britain.	J. MacCulloch, M.D. Pres. G. Soc.
27.	Memoire sur la possibilité de faire vivre des mollusques fluviatiles dans les eaux salées, et des mollusques marins dans les eaux douces, considerée sous le rapport de la Geologie. Par F. S. Beudant.	The Author.
	La Siderotechnie, ou l'art de traiter les Minerais de fer pour en obtenir de la fonte du fer ou de l'acier, par J. H. Hassenfratz, Inspecteur Divisionaire au Corps Imperial des Mines. 4 vols. 4t°	The Conseil des Mines.
	Transactions of the Linnean Society of London. vols. 9, 10, & 11.	The Linnean Society.

1817.	BOOKS.	DONORS.
Jan. 31.	Annals of Philosophy for February, 1817, by Dr. Thomson.	The Editor.
Feb. 7.	Journal de Physique for Oct. 1816.	Robert Ferguson, Esq. Memb. G. Soc.
	Natural History of Fossils, by Emanuel Mendes da Costa. Lond. 1757, 4to	Dr. Wright of Litchfield.
	Sciagraphia Lithologica curiosa, seu lapidum figuratorum nomenclator, a Joh. Jac. Scheuchzero, M.D. Math. Prof. Tigurino, &c. Auctus & Illustratus a Jac. Theod. Klein. Gedani, 1740, 4to	. . . .
	A Delineation of the Strata of Derbyshire, designed from a Tablet composed of the Specimens of each stratum, with an explanatory account, by White Watson, F.L.S Sheffield, 1811, 4to	. . . .
	Journal de Physique for Nov. & Dec. 1816.	Robert Ferguson, Esq. Memb. G. Soc.
31.	Annals of Philosophy for March, 1817, by Dr. Thomson.	The Editor.
March 19.	Outlines of Geology; being the Substance of a Course of Lectures delivered in the Theatre of the Royal Institution in the year 1816, by W. T. Brande, Esq. Memb. G.S.	The Author.
	Observations on an astringent vegetable substance from China, by W. T. Brande, Esq. Memb. G.S.	The Author.
	Bersuch einer Unleitung zur Geologischen Renntnik der Mineralien von D. H. F. Lint.	G. B. Greenough, Esq. Memb. G. Soc.
	Das Fichtelgebirge nach vielen Reisen auf dem selben beschrieben von J. Th. B. Helfrecht. 2 vols.	. . . .
	Mineralogische berg-und huttenmannische Reisenbemerkungen vorzuglich in Hessen, Thuringen am Rheine und im Seyn-Altenkirchner Gebiethe gesammelt von Dr. Johann Ludwig Jordan.	. . . .
	Histoire Naturelle de la Suisse dans l'ancien monde, traduite de l'Allemand de Mr. A. S. Grouner.	. . . .
	Gedanken uber Die Bildung des Basalts und die vormahlige Beschaffenheit der Gebirge in Deutschland, von A. F. von Veltheim.	. . . .
	Bersuch einer mineralogischen Beschreibung des Uralischen Erzgebirges von Bened. Fr. Joh. Hermann. 2 vols.	. . . .
	Johann Gottlieb Kern vom Schneetensteine oder dem Sachsischen Topasfelsen von Ignatz edlen von Born.	. . . .
	Considerations generales sur les vestiges fossiles vegetaux du sol des environs de Paris, par M. Hericart de Thury.	M. Hericart de Montplaisir.
30.	Annals of Philosophy for April, 1817, by Dr. Thomson.	The Editor.

1817.	BOOKS.	DONORS.
March 30	Journal of Science and the Arts, edited at the Royal Institution of Great Britain, No. 5.	The Royal Institution of Great Britain.
	Le Regne Animal distribué d'apres son organization pour servir de base a l'Histoire Naturelle des Animaux et d'Introduction a l'Anatomie comparée par M. le Ch. Cuvier, Conseiller d'Etat ordinaire, Secretaire perpetuel de l'Academie des Sciences de l'Institut Royal, &c. Paris, 1817, 4 vols. 8vo	Charles Stokes, Esq. Sec. G. Soc.
	Histoire Naturelle des Animaux sans vertèbres, par M. le Chevalier de Lamarck, Membre de l'Institut Royal de France, &c. Paris, 1815, 3 vols. 8vo	. . . .
	Memoire sur les Fossiles des environs de Paris, par Lamarck, 4to	. . . .
	Dictionaire Allemande-Francais contenant les termes propres a l'exploitation des Mines a la Metalurgie & a la Mineralogie, par J. B. Beurard, Paris, 1809, 8vo	. . . .
	Elementary Treatise on Mineralogy and Geology, by Parker Cleaveland, Prof. of Mathm. and Nat. Phil. &c. in Bowden College. Boston, 1816, 8vo	William Vaughan, Esq.
May 2.	Annals of Philosophy for May, 1817, by Dr. Thomson.	The Editor.
	Memoire sur le vases murrhins qu'on apportaient jadis en Egypte, et sur ceux qui s'y fabriquaient, par M. de Roziere.	The Author.
	Description Mineralogique de la valée de Qosseyr, par M. de Roziere.	The Author.
	De l'Ibis Egyptien, par M. de Roziere.	The Author.
	De la Geographie comparée et de l'ancien etat des cotes de la mer rouge, par M. de Roziere.	The Author.
	An Account of the Life and Writings of Baron Guyton de Morveau, F.R.S. Member of the Institute of France, &c. by A. B. Granville, M.D. &c.	The Author.
31.	Journal de Physique for January, 1817.	Robert Ferguson, Esq. Memb. G. Soc.
	Annals of Philosophy for June, 1817, by Dr. Thomson.	The Editor.

II. *Donations to the Collections of Maps, Sections, &c.*

1816.	MAPS, &c.	
Sept. 24.	Engraving of Fossil Bones in the Museo Valsamachi.	Le Conte Demetrius Valsamachi.
Oct. 25.	Ordnance Map of Dorsetshire.	Col. Mudge, Hon. Memb. G. Soc.
	Geological Map of the vicinity of Nice.	Capt. Marryat, R.N. Memb. G. Soc.
Dec. 6.	Proof of the Outline of the Ordnance Survey of Dorsetshire	Col. Mudge, Hon. Memb. G. Soc.
11.	Ordnance Survey of Sussex.	. . . .

1816.	MAPS, &c.	DONORS.
Dec. 11.	Vue occidentale de la Fortresse de Konigstein en Saxe.	G. B. Greenough, Esq. Memb. G. Soc.
	Nordliche Ansicht des Schlesischen Riesengebirges.	. . . .
1817.		
March 19	Five Drawings of Fossil Alcyonia.	Miss Benett.
May 2.	Andrews Map of England and Wales, 1786.	Sir H. C. Englefield, Bart. Memb. G. Soc.

III. *Donations to the Cabinet of Minerals.*

1816.	SPECIMENS.	
July 20.	Fossil wood from the Ferruginous Sand near Sandy, Bedfordshire.	Rev. Mr. Gorham, Fel. Queen's Col. Camb.
	Specimens of Flint from the Chalk at Guildford, with a recent sponge resembling it in general form.	C. Stokes, Esq. Sec. Geol. Society.
Aug. 1.	Fossil Organic Remains from the Chalk.	. . . .
	Specimen of the Brunswick encrinus.	G. B. Greenough, Esq. Rev. William Conybeare, & Rev. William Buckland.
Sept. 1.	Specimens accompanying a Paper by Mr. Anstice.	Mr. Anstice.
	Specimens from Guadaloupe.	Rev. Mr. Guilding, Memb. G. Soc.
	Specimens of Simple Minerals.	J. Mawe, Esq.
23.	Fossil Bones from Walton and Fossils from Sheppey.	Henry Warburton, Esq. V.P. G. Soc.
24.	Specimens of Ammonites in Portland stone.	Joseph Gawen, Esq.
Oct. 7.	Chromat of Iron from America.	Henry Warburton, Esq. V. P. Geol. Soc.
24.	Specimens from North America.	T. W. Webster, Esq.
	Specimens of Lyas and its Fossils from the cliffs on the Severn.	Henry Warburton, Esq. V.P. Geol. Soc.
	Fossils of the Chalk.	. . . .
	Specimens of Simple Minerals.	Johann Rohatsch, M.D.
25.	Specimens and Organic Remains from the vicinity of Nice.	Capt. Marryat, R.N. Memb. G. Soc.
	Organic Remains from the Lyas near Charmouth.	Charles Stokes, Esq. Sec. G. Soc.
Nov. 6.	Specimens of Bath Oolite, from Farleigh Down, near Bath.	Henry Warburton, Esq. V.P. G. Soc.
8.	Organic Remains from the Tagus.	James Sowerby, Esq. Memb. G. Soc.
9.	Specimens from Montreal, in North America, collected by the Earl of Selkirk.	John MacCulloch, M.D. Pres. G. Soc.
14.	Specimens of Pitchstone, Pearlstone, and Sulphat of Strontian on Trap, from the Euganean hills.	G. B. Greenough, Esq. Memb. G. Soc.
15.	Specimens of Kimmeridge Coal Money.	W. H. Wollaston, M.D. Memb. G. Soc.
Dec. 6.	Specimen of Fossil Pentacrinus.	Sir H. C. Englefield, Bart. Memb. G. Soc.
11.	Specimens from Italy, and from the Volcanic district on the Rhine.	G. B. Greenough, Esq. Memb. G. Soc.
	Specimens from Auvergne.	Edmond W. Rundell, Esq. Memb. G. Soc.

1816.	SPECIMENS.	DONORS.
Dec. 6.	Four Specimens of Fossil Fish from Monte Bolca Veronese.	Capt. Marryat, R.N. Memb. G. Soc.
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	Five series of Specimens from the Isles of Skye and Rasay, of Gneiss, Siliceous Schist, Actinolite, and Sandstone.	John MacCulloch, M.D. Pres. G. Soc.
1817.		
Jan. 1.	Specimens of Curl Stone from Monmouthshire.	John Norris, Esq. Memb. G. Soc.
	Specimens of Oolite from the Cotswold hills.	David Ricardo, Esq. Memb. G. Soc.
	Specimen of Steatitical Limestone from Skye.	John MacCulloch, M.D. Pres. G. Soc.
	Specimen of Sulphat of Soda with Magnesia, from Calatoyad in Arragon.	M. Leman, For. Memb. G. Soc.
	A series of Hypersthene Rock from Skye and Ardnamurchan.	John MacCulloch, M.D. Pres. G. Soc.
7.	Specimens from Scotland.	. . . .
	Specimen of crystallized Tourmaline with Appatite, from Devonshire.	J. Mawe, Esq.
16.	Specimens of Simple Minerals.	Sig. Chierici.
17.	Specimens collected in Syria by Mr. Buckingham.	Mr. Babington.
	Specimen of arsenical Cobalt and native Silver from Wilsworthy.	G. B. Greenough, Esq. Memb. G. Soc.
31.	Specimens of Arseniate of Copper.	Charles Stokes, Esq. Sec. G. Soc.
Feb. 7.	Specimens of Garnet from Fahlun, and Gadolinite in the matrix from Ytterby in Sweden.	Wm. Macmichael, M.D. Memb. G. Soc.
	Specimens of the rock at the bottom of the fall of Niagara.	Sir Henry Englefield, Bart. Memb. G. Soc.
	Specimens of red and green Tourmaline from New England.	A. Aikin, Esq. Memb. G. Soc.
	Specimens from Scotland.	John MacCulloch, M.D. Pres. G. Soc.
20.	Fossil Organic Remains from Germany.	G. B. Greenough, Esq. Memb. G. Soc. The Rev. Wm. Buckland, Memb. G. Soc. and The Rev. Wm. Conybeare, Memb. G. Soc.
	Specimens of Slate from Angers, and six Trilobites from Grenaudiere.	Hon. H. G. Bennet, V.P. G. Soc.
	Specimens of the rock in which the Cave and Sculpture of Elephanta is formed.	Dr. Wright of Litchfield.
Mar. 7.	Specimens from Scotland.	John MacCulloch, M.D. Memb. G. Soc.
	Specimens from Torre del Greco of Substances that have been altered by being buried under the lava from the eruption of Vesuvius on the 15th June, 1794.	Hon. H. G. Bennet, V.P. G. Soc.
	Specimens from the neighbourhood of Kremnitz in Hungary, and Specimens from the country between Vienna and Venice.	G. B. Greenough, Esq. Memb. G. Soc.

1817.	SPECIMENS.	DONORS.
Mar. 21.	Specimens from Scotland.	John MacCulloch, M.D. Pres. G. Soc.
	Specimens of the Green Sand stratum from Boxham, one mile east of Warminster.	Miss Benett.
	Slab of Serpentine and primitive Marble, from near the town of Milford in the State of Connecticut, North America.	William Vaughan, Esq. Memb. G. Soc.
April 18.	Casts from Bivalves from the sand at Chobham.	Charles Stokes, Esq. Sec. G. Soc.
	Specimens of Ferruginous Sandstone impregnated with bitumen from Chilly Sussex.	G. B. Greenough, Esq. Memb. G. Soc.
	Series of Specimens of Slate from Dunkeld, and a series of Mica Slate from Perthshire.	John MacCulloch, M.D. Pres. G. Soc.
	Specimens of Grauwakke with impressions of shells from Devonshire.	Rev. William Honey, Memb. G. Soc.
	Specimens found on the Strathmore estate, Parish of Eassie, Forfarshire.	John Adam, MD.
	Fossils from the Ferruginous Sand, Parham Park, Sussex.	G. B. Greenough, Esq. Mem. G. Soc.
May 2.	Specimens from the Isle of Man and Rasay.	John MacCulloch, M.D. Pres. G. Soc.
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	Specimens from Syria and Egypt.	M. de Roziere.
11.	Specimens of Arenaceo-calcareous Stalactite from Delvine, Perthshire.	John MacCulloch, M.D. Pres. G. Soc.
	Recent Shells.	Miss Benett.
	Specimens from the Alps.	Dr. Jurin, of Geneva.
June 6.	Specimens from the Basin of Paris.	Ashhurst Majendie, Esq. Memb. G. Soc.
	Specimens from the Basin of Paris.	E. W. Rundell, Esq. Memb. G. Soc.
	Fossils from the Stonesfield Slate.	Henry Warburton, Esq. V.P. G. Soc.
	Fossils from the Stonesfield Slate.	Hon. H. G. Bennet, V.P. G. Soc.
20.	Specimens from Devonshire.	Thomas Meade, Esq.
	Specimens of Pyrophysalite and other simple Minerals from Sweden.	M. Swedenstierna.

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