

denudation, and such too would be the case, as Mr. Wilson suggests, where the beds presented their upturned edges to the moving ice.

The vast numbers of well-rounded and scratched stones that occur in the Drift, and of which it is in fact in many cases mainly composed, have always been a great difficulty. Much has been written of late years about the moraine profonde, as such masses of Drift are now called: but no attempt has been made, that I am aware of, to explain in a definite manner the origin of such heaps of scratched gravel; it seems to have been thought sufficient to call them moraine profonde. This term, when originally used in Switzerland, was employed, as I am informed by one who is an authority on the subject, to describe the case of an advancing glacier overriding its own terminal moraine. In such a case no doubt the glacier might so grow as to shove its terminal moraine along in front of and partially beneath it: and the matter of the moraine would be greatly altered in nature and arrangement.

Doubtless also at the commencement of the Glacial epoch the ice as it advanced would sweep before it all the loose detritus from the hill-sides and beds of river-gravel or old sea-beaches; and in this progress the stones would get scratched and further rounded. But all such heaps of detritus must have been long since swept away from the hills and deposited mostly at the outskirts of the ice-sheet; and must now be sought perhaps in the vale of York. We must seek another way to account for the masses of scratched gravel and Boulder-clay found in the very heart of the fells. When these were formed and deposited, the country must have been entirely buried in ice, as Greenland now is. There could, therefore, have been no cliffs sticking through the ice to afford boulders for the Drift; we are thus driven to suppose that such boulders were derived from beneath the ice: and I see no means by which this could have been effected save by the disintegrating power of frost, aided in cases by a happy disposition of the chief divisional planes. But however difficult to account for, and however hard to conceive, I repeat the fact is certain that there has been an enormous amount of rock disintegrated sub-glacially, so as to form gravel and coarse stony detritus over and above the grinding of the rocks superficially into fine powder or mud.

V.—ON THE OCCURRENCE OF LEAD, ZINC, AND IRON ORES, IN SOME ROCKS OF CARBONIFEROUS AGE IN THE NORTH-WEST OF ENGLAND.

By CHARLES E. DE RANCE, F.G.S.

PART I.

IN former papers I have described central Lancashire as capable of division into three plains of different elevations. The lowest being often beneath high-water mark, and always below the 25-foot Ordnance contour; the second ranging from 25 and 50 feet to 500 feet above the sea, terminating at the foot of the steep escarpment at the western edge of the Lancashire and Yorkshire moorlands forming the Pendle portion of the Pennine chain, with an average eleva-

tion of 1200 feet. Both the lower plains are much covered with drift, and the rock-surface at the sea-coast is often 50 feet below low-water mark, steadily rising in one gradual inclined plain, eastwards, or towards the Fells.

The lowest plain is covered with peat often 20 to 30 feet in thickness, resting on Cyclas and Scrobicularia Clays, which in their turn overlie the Post-glacial and marine Shirdley Hill Sand, which rising into a line of ancient Sand Dunes along the landward edge of the peat at the base of an ancient cliff of Boulder-clay bounding the second plain, in parts of which deep valleys have been entirely cut in the glacial drift, as the Ribble valley at Preston; and in other portions the Boulder-clays and interbedded sands and shingles have been re-excavated out of old Pre-glacial valleys.

Pendle range.—Between the Wigan and Blackburn coal-fields occurs a tract of elevated table-land, consisting of Millstone-grit more or less covered with peat and Boulder-clay with erratic stones, forming Anglezark, Withnell, Rivington, and other moors, with an average elevation of more than 1000 feet. This area, which has been brought up by great faults, is drained on the south by the river Douglas, which traverses the Wigan coal-field, and falls into the Ribble, whose tributary, the Darwen, receives the Roddlesworth, which drains the northern portion of the moors. This latter river, however, is in great measure absorbed by the Liverpool waterworks, and artificially carried south.

In making the "bye-wash" of one of the reservoirs for these works, near Lower Whitbank, Tockholes, on the Roddlesworth, a lode of galena was struck, ranging W. 25 N. Specimens of the ore were shown me by the lord of the manor, consisting of crystallized sulphide of lead of a bluish-grey colour, the back of the lode being quartz. The rocks in the nearest section I could find consisted of the basement-bed of the third (Millstone) Grit, dipping at 70° to the N. N. E., resting on Black Shales, containing "bullions," coated with thin seams of coal, with *Sigillaria* markings, dipping N. 30 E.

The hill-side, above the lode, dips with the beds towards the river at 7°, the lode, which appears to be in a fault, nearly corresponding in direction with the strike of the beds, running at the bottom of the valley, parallel with the stream. It is clear that under these conditions, all water falling upon the hill-slope above percolates into the porous sandstone, and will be intercepted by the fault, which, if consisting of an open fissure, would tend to be filled by any substance that the water could mechanically remove, or chemically unite with, from the grit and sandstone above.

Mr. W. Wallace, in his admirable work on Alston Moor, which I found invaluable when examining that district, gives four general laws governing the distribution of lead:—

1. That the quantity of water in circulation below the summit of a mountain, is "in inverse proportion to the depth from the surface, and in direct proportion to the distance from the watershed." Therefore, the greater the depth, the less the quantity; the further from the watershed the more the water.

2. The steeper the mountain slope, the less the water under it; the smaller the inclination, the more the water.

3. The freeness of circulation of water near the surface is directly proportional to the amount of inclination of beds, faults, joints, or veins towards the sides of a hill and *vice versé*.

4. The greater the number of veins, faults, intersecting large lodes, etc., the greater the circulation, especially when corresponding to the dip of the strata, and therefore the greater chance of the lode to which they run being ore-bearing.

Having seen the truth of these laws as applied to lead in Alston Moor, I have felt much interest in endeavouring to find out how far they appear to apply to the occurrence of other metals and of lead in other districts.

The Roddlesworth lode, being at the bottom of the valley, away from the watershed, is favourable by "Law 1."¹ The slope is rather steep, which is slightly unfavourable by "Law 2." The dip is outwards, which is strongly unfavourable by "Law 3," and there are no tributary joints, lodes, or faults, which conditions are so unfavourable, as to lead to the idea either that these laws were inoperative, or that the lode was filled with lead before the valley was formed, and when the fault held back all the water falling on the ground to the west, which, percolating into the strata, would be tolerably favourable conditions for the deposition of lead, presuming it to be present, in the rock above, in a disseminated state.

On the south-west side of the same tract of country, east of Chorley, lead ores were formerly worked in a deep valley, on the western escarpment of Anglezark Moor, between White and Black Coppice. One of these old lines of pits is a W.S.W. lode, near Coppice Stile House, in beds of the basement-bed of the Millstone-grit, its eastern extension being cut off by a fault ranging N. 30 E., nearly parallel to which runs another short lead lode. Here the slope of the ground and the beds is towards the lode.²

A little further south, at Stronstrey Bank, there are several shafts in the Kinderscout-grit, from which sulphuret of lead, blende, and copper pyrites have been procured, and in one of which carbonate of baryta was first discovered by Dr. Withering, after whom it was named.³

At several points along the same line of country are east and west faults, at Thievley, four miles S.S.E. of Burnley, and 12 miles to the N.E. of the sections at Anglezark Moor, with a northerly downthrow of 340 yards, throwing the rough rock of the Millstone-grit, and the bottom beds of the Lower Coal-measures, against higher beds of the latter, and the basement bed of the Middle Coal-measures, on the breast of a hill called Deeplay Moor, nearly 1500 feet in height, the beds dipping into the hill, at low angles. Here the slope of the

¹ "The Laws which regulate the Deposition of Lead Ore," 1861.

² These lodes are shown on the Geol. Survey of Lancashire, Six-inch Map, No. 78; they were mapped by Prof. Hull, F.R.S.

³ *Phillips' Introduction to Mineralogy, London, 1837.*

hill and fault is to the north, the lode ranging half-way across the hill, sloping down towards the Calder. The distance from the watershed is not great, nor are the other conditions very favourable; but as the works are now discontinued, the quantity of lead in the lode is probably not very great. But it is remarkable as being the highest lead-bearing horizon in the Carboniferous rocks of the district, with the exception of the Lead-mine Fault to the west at Hambledon Hill, about two miles east of Accrington, where the Arley Mine, the lowest coal of the Middle Coal-measure, is often permeated with strings of galena; and much lead occurs in the centre of the fault, which traverses the top of the hill at an elevation of 1330 feet, throwing the strata, which dip at a small angle to the south, 80 yards in the same direction.

The hill has a steep escarpment to the north, and is more or less isolated on either side, proving considerable denudation of rocks since the infilling of the fault with lode-stuff and other matter, for the fault and beds dipping from the escarpment give no gathering ground for water to pass through, and collect ore.

In a paper "on the Relative Age of the Lines of Elevation of the Carboniferous District of Lancashire and Yorkshire,"¹ Professor Hull has shown that the great series of E. N. E. anticlinal and synclinal folds exhibited in the hills of Millstone and Yoredale Grits, of the "Pendle Range," had taken place, and great denudation gone on, before the deposition of the Permian strata upon their upturned and denuded curves; and that a second system of disturbance (the Pennine), ranging nearly north and south, uplifted the Pennine Chain, dis severed the Lancashire and Yorkshire coal-fields at the close of the Permian era, which was followed long after, probably after the deposition of the Oolites, by a third system, of lines of fracture ranging N. N. W.

From the researches of Mr. J. M. Wilson, M.A.,² it appears probable, and even certain, that contortions are the inevitable results of subsidence of a curved surface, and that faults are cracks the result of the re-elevation of that curved surface, in which "the rocks have to expand, so as to fill a larger area." From which it would appear to follow that the curves of the Pendle range were the result of a subsidence taking place at the close of the Carboniferous era, accompanied by much marine denudation, produced by a sea, which on re-elevation became inland and land-locked.

The high range of Lower Carboniferous Fells which have been described as forming the eastern limit of the Lancashire coal-field northwards gradually approach nearer and nearer to the sea, the lower peat plain and the intermediate Boulder-clay terrace having been much denuded by the sea. These fells, which rise to a height of nearly 2000 feet, are a continuation of the Pendle range, and form the boundary between the counties of Lancashire and Yorkshire. The strata (as shown in the section given in fig. 1, p. 324 of Professor Hull's paper, before alluded to) of which these Fells

¹ Quart. Journ. Geol. Soc., 1863, p. 323.

² Geol. Mag., 1868, p. 207.

are composed show a series of anticlinal and synclinal rolls, the former generally corresponding to valleys and the latter to hills. From the occurrence of patches of Permian here and there upon the upturned and denuded edges of the strata of the Lancashire coal-field, of sheets of Permian sandstone indiscriminately resting on the Lower Carboniferous plains of Furness and the Vale of Eden, on the denuded edges of the Coal-measures, Carboniferous Limestone, and Lower Silurian strata in West Cumberland, it is probable that north-western England had in many districts already attained much of its present configuration in pre-Permian times, with the all-important exception of the non-existence of the Pennine chain; though from my study of the Cross Fell district it appears to me possible that the post-Permian Pennine fault coincides with the line of an older unconformity and possibly a still older pre-Permian fault, of the same general age as the Pendle curvatures.

The movement of subsidence at the close of the deposition of the Coal-measures was probably the means of producing "that excessive lateral pressure by which the older underlying strata were squeezed and forced up into the series of sharp anticlinals forming the axis of the Mendips and Ardennes,"¹ and was the means of "throwing the rock-masses into a series of great folds, ranging from east to west, across North Lancashire and Yorkshire,"² and of exposing the strata, as it gradually sank beneath the level of the breakers, to an enormous amount of marine denudation, which affected not only the Carboniferous strata of the north-west of England, but the Lower Silurian tracts of West Cumberland, where the Permian strata rest transgressively on eroded Coal-measures, Mountain Limestone, Skiddaw Slates, and "Greenslate and Porphyries."

West Riding of Yorkshire.—One of the chief of these pre-Permian axes in the Pendle district passes through Clitheroe, bringing up the Mountain Limestone in that valley, as shown in fig. 1 of Prof. Hull's paper,³ already so often alluded to, who also describes two other anticlinals, the Sykes and the Slaidburn, named by Mr. Tiddeman, of the Geological Survey, who surveyed them in detail.

The former axis has the effect of bringing it also to the surface, in the lower portion of the valleys of Sykes, Brennand, and Whitendale, drained by brook-tributaries of the Hodder, and in all of which are metalliferous lodes, which I have observed most minutely.

At Sykes I found the strata to consist of Upper Yoredale Grit (bottom beds), 240 feet. 2. "Whetstone Shales," with their siliceous seams, 100 feet. 3. Black Shales, locally called "Great Ironstone Shale," containing a band of black ferruginous compact cement stone, 160 feet. 4. Thin fine-grained grit, locally "Trough House Rock," 30 feet. 4a. Black shale, "Trough House Black Shale," 20 feet. 4b. Thin flaggy grit, "Trough House Rag" (these beds are probably the Lower Yoredale Grit), 20 feet. 5. Black shales, with thick

¹ Mr. Prestwich, F.R.S., in Anniversary Address to the Geological Society, London, 1872, p. 65.

² Prof. Hull, F.R.S., Quart. Journ. Geol. Soc., 1868, p. 333.

³ *Op cit.*, p. 324.

ferruginous cement stone as base. 6. "Little Ironstone shale." 7. Crystalline dark warm-grey limestone, weathering red, and decomposing, locally "Red Bed Limestone," 80 feet. 7a. Dark black shale, with occasional fragments of Encrinites, "Red Bed Shale," and "Little North Shale of Brennand Mine," 25 ft. 7b. Compact limestone, seldom red ("Lower Post Limestone"), 78 ft. 8. Black calcareous shales, "Low Post Shale," with many bands of limestone, sometimes the latter predominating, which is the case at Brennand Mine, 73 ft. 9. Black chert, "Bull-star Flint," thickness variable, running off in veins, average perhaps 20 feet. 10. "Six-fathom Limestone," pale-grey colour and compact, 38 feet. 12. Thick compact limestone, fossiliferous, certain beds containing grains and crystals of lead spread throughout the mass, locally called twelve-fathom limestone. The lodes in it containing an almost unlimited quantity of barium sulphate, in fine radiating crystals, which is often associated with crystals of fluor-spar, which are sometimes colourless, and sprinkled over with crystals of lead-sulphide and copper pyrites. Large quantities of the heavy spar occur on the mine-heaps, in Losterdale brook, and on the roads, derived from this source.

The valley of Sykes roughly resembles in shape the letter \sqsupset placed on its side, in an E.N.E. direction, its long axis being the Sykes anticlinal, the various beds, from 1 to 12, ranging in concentric belts, the oldest limestone being at the bottom on the west side, the newer beds occurring above, and the Upper Yoredale Grit forming the top of the fells, on either side of the valley, which is breached on the north (W. side of the \sqsupset) by the mountain pass, called "the Trough of Bolland," and on the south (W. side of the \sqsupset) by the valley of Langden and Losterdale Brook. On the east end of the \sqsupset , the watershed at Whin Brow, between Sykes and Brennand valleys, is 1564 feet high, and is crossed by a path at 1450 feet, which descends to Brennand House, by fine cliffs of Upper Yoredale Grit, forming a combe-like hollow, surrounded by a large talus of fallen "scree."

Along the ridge above runs a fault, with an easterly downthrow of 60 feet, which has the effect of throwing the base of the Upper Yoredale Grit above the present level of the ground. It, however, reappears, and striking S.S.W. to Sykes Nab, where the grit is traversed by a small synclinal dipping S.E. at 75° , in the bank above the road, and N. 35° W. at 16° , in the quarry nearer Hareden, where an impure freestone has been worked, which can in no way compare with the beds of similar age of Longridge.¹

The basement beds of the Upper Yoredale Grit are well seen in the Trough of Bolland, where they were long ago described by Prof. Phillips in "The Geology of Yorkshire," where also may be found a section of the anticlinal in the limestone, traversed by a lode, running parallel with it.

The black shales are well seen near Turner Hill (at a height of 1274 feet by the aneroid), where the beds are rolling, and contain

¹ This fault was first made out by Mr. Hudson, who made a mineral survey of the district for the lord of the manor.

numerous carbonaceous and siliceous nodules, sulphur-partings, and the water that flows out of them is slightly impregnated with a mineral oil. The cement-stone is about four feet in thickness, and dips east of Nab House at 11° to the south-east; and on the opposite side of the valley, at Trough House, in the reverse direction.¹ The Lower Yoredale Grit occupies a narrow belt of country surrounding the various bands of limestone, &c., with the lowest and oldest at Crag Wood towards the centre; the whole series, from the Lower Yoredale Grit to the twelve-fathom limestone, forming a rough parallelogram one mile in length, and half in breadth, the long axis of which, the Sykes antilinal, runs in a direction N. 30° E.

Near Sniddle Holes, between Trough of Bolland and Whin Brow, two poor lodes occur in the shales, running E. 28° N., nearly parallel to each other, 140 feet apart. The Trough House north lode contains bisulphide of copper and iron; the south lode galena, blende, and iron and copper pyrites.² The two lodes hade towards each other, and form a small "trough fault," running with the strike of the rocks and hill-sides, with an inward dip, circumstances tending to a small circulation of water, an adverse condition for a rich lode, according to Mr. Wallace's Laws, there being no gathering for water in consequence of the slope.

The ore in the present instance must have been entirely introduced before the denudation of the Sykes valley, and must have been derived from the Upper Yoredale Grit, or higher formations.

The Trough House rock, and accompanying black shale, which contains a great quantity of sulphur, is well seen at Ram's Clough, 25 feet of grit being visible, dipping 22° at N. 40° W., and 12 feet of the black shales near the barn by the foot-bridge.

The cement-stone, lying above the Red Bed Limestone, consists of three beds of an aggregate thickness of 9 or 10 feet; it is well exposed along the course of Penny brook, near the cart-way from Nab House, where the dip is S.E. at 30° . Still higher up, where a brook branches off to the right, it is E.S.E. at 35° . A specimen I procured of this rock yielded on analysis 7 per cent. of metallic iron.

The basement beds of the Limestone shales, lying above the Bull-scar chert, are well seen in Ram's Clough, east of Sykes. Above the chert is 20 feet of Low Post shales and limestone bands, the shales being from 6 to 12 inches, the limestone from 2 to 3 inches, on which rests an earthy dark limestone, 14 inches thick, completely full of crinoid stems, on which rest 190 feet of shales and limestone bands, and Lower Post limestone.

Good sections of the limestones occur in Bracken hill, above the quarries, which are situated in the "Twelve-fathom," dipping 8° to the West. The surface of the rock in one bed is completely sprinkled

¹ As the whole of this district is now, I believe, being surveyed by my colleague, Mr. Tiddeman, I have omitted as much as possible all reference to the rocks and details of the geology, except such as have direct bearing on the distribution of ore in the lodes, to which I have there especially directed my attention.—C. E. R.

² A mass of copper pyrites was found on the opposite side of the valley, near the cement-stone bed, but it may have been brought there by glacial action.

with crystals of galena. Below this seam occurs an Encrinital band eight feet thick, resting on a Coral bed two feet thick. The lowest bed seen is often of an apparently brecciated character, the fragments being slightly dolomitized. Higher up the hill the six-fathom limestone dips 17° to the W., and a little further south the axis is reached, which passes *obliquely* across the valley, giving at first sight an appearance of a fault passing down the valley. The anticlinal arch is well seen in the quarry on the east side, a little north of which, near Cragg Wood, a small lode was once worked, running N. 60° E., with a southerly downthrow, containing blende, calamine, and copper pyrites. South of the axis by the brook the dip of the beds is S. 60° E.

A well-marked lode (fault) has been worked on both the west and the east side of the road. The "foot-wall" is particularly smooth, covered with slickenside, and hades South at 52° . On the east side of the road the lode has been driven on for a distance of 108 fathoms, commencing in a direction E. 36° N. At 13 fathoms from daylight a cross fault-lode comes in, running N. 35° W., on which a "sump" was sunk, 18 feet in depth, from which much lead was procured, but which had to be stopped in consequence of the large influx of water, the bottom being beneath the level of Losterdale Brook, draining the valley. The southern prolongation of this fault is cut off by the main lode, which is the case also with another small lode ranging N. 16° W., 80 fathoms distant from the entrance of the level; which, on the opposite side of the road, ranges W. 26° S., and has been driven westwards 69 fathoms. This productive lode is remarkable for being a strike-fault nearly coincident with the anticlinal axis.¹

Following the Sykes anticlinal to the north-east, it passes across Brennand valley, and rises a little north of Brennand House, and runs south of, and nearly parallel with, the adit-level at Brennand mine, No. 1 level of which is driven right through it. From this point it runs across "the col," or depression in the range of hills intervening between Brennand and Whitendale valleys. This col is covered with a thick deposit of peat, resting on a yellow stiff clay, containing, near the lodes, much lead and vein-stuff. In the centre is the reservoir for the mine, supplying the hydraulic pumping and hauling engines, the bottom of which was cut down to the rock, which was found to be limestone, traversed by a lode, ranging S. 20° E., proving that the limestone tract of Brennand is continuous across the col with that of Whitendale, the limestone tract at the reservoir being 100 yards in width at Brennand river; measured across the axis it is 750 yards in width, at Whitendale 600.

The south side of the col is bounded by Middle Knoll, at the top of which the Yoredale Grit has been quarried.

The Limestone tract of Brennand and Whitendale may be therefore compared to an elliptical boss, of which the major axis is the Sykes anticlinal, and the minor (which is more the result of the

¹ These sections were visited and viewed with much interest by the late Sir Roderick Murchison, who was of opinion that the valley is due to a fault running along it.

form of the ground than an actual roll of the strata), a line running with the Brennand Lode across the mine. This lode has a direction W. N. W., and is a downthrow of seven yards to the N. E. It is worked for lead in the mine (of the Whitewell Mining Company), which consists of an engine-shaft and air-levels, from the fifth of which an adit-level, half a mile in length, connects the mine with the lower part of the valley. The hade or inclination of the lode is on an average 55° from the horizontal; but I found it in some parts of the mine, in soft shale, to be 38° , and in hard limestone to be as high as 84° , being especially steep between levels 4 and 5. Level 1 is carried right through the axis, the bed commencing and ending in the Red Bed Limestone, with a boss of lower shaly limestone in the centre. Up to the present time the lode has only been worked on the western side of the axis, the western end of the levels being driven up to the "Bolland Shales," passing through shaley limestones, lower post limestones, and very productive red-beds, with an intercalated unproductive shale-bed in its upper part, locally called "Little North Shale." The shift of this shale in the various levels enabled me to calculate the throw of the fault.

When the lode passes through shale-beds it is much squeezed, and indeed almost invisible; with shale on one "cheek," and limestone on the other, the lode is invariably poor. With limestone to limestone, the lode is well defined, filled with lead and other foreign matter, often with spaces or hollows (locally called "loughs"), the sides of which are covered in No. 5 South, with brilliant crystals of carbonate of lime, facing towards the hollow, resting on a "foot-wall" of iron-pyrites, beautifully indented with slickenside. The beds here are dark and compact, occasionally iron-stained, and contain both in levels 5 and 6 a great quantity of blende in large masses. With Red Bed Limestone on both cheeks the lode is productive of galena, as much as five tons having been taken from one spot. The Chert beds which are productive of lead at Sykes have not yet been reached in this mine. The limestones associated with the cherts on this horizon appear to a great extent peculiar to the district, and unlike the 12-fathom limestone which persists through West Yorkshire, (uppermost of the "Scar" and "Cam" limestones, "Main" limestone, 82 feet of Swaledale),¹ into Alston Moor, on the Cumberland and Durham borders.

The Red Bed Limestone is seen in Swine Clough, on the west side of the valley, and is there traversed by a lode which slightly faults the rocks, and runs under the barn, where it throws out a copious spring of water, and probably continues across the river in an

¹ In Swaledale, above the Main limestone, is the main chert, black beds, plate, red beds (15 feet), plate, and 60 feet of white grit. The grits and the cherts are lead-bearing, and the white grit is spoken of by Professor Phillips (Geology of Yorkshire) as the probable equivalent to the "Bearing Grit" of Nidderdale, and the fire-stone of Alston Moor. In Stonesdale the corresponding beds are known as the Lower Chert series, containing more plate than limestone, throughout the whole of northern Yorkshire, one or more horizons of Chert occur above the 12-fathom limestone. In Northern Yorkshire and Westmoreland, and in Cumberland, shale is called "plate," and sandstone "hazel," solid compact beds of limestone or sandstone "posts."

E. N. E. direction to the west of Blue Scar, where it joins, or rather becomes the Whitendale lode. The top of the Red Bed Limestone in Swine Clough is 850 feet above the sea; 70 feet above it was found a mass of lead, with Red Bed Limestone attached, which may have been lifted and left there by glacial action; for a little further south of the Clough I found a rounded and scratched trap pebble, at a height of 755 feet above the sea. The limestone at the Swine Clough lode dips N. 10 W. at 35°.

In the river between the footbridge and the lime-pits a small anticlinal roll striking N. 15 E. occurs; but further up the bank near Far Pasture Clough the dip is normal, being N. 60 W. at 70°, which is also found in the "Hush levels."¹ These were driven, I believe, at the end of the last century, by "the Old Men"; they are very low, and were entirely cut with the pick, no drill-made hole, or other trace of powder being apparent, nor is there any sign of a lode; the levels branch in a tree-like form from the entrance, one of the branches extending over Brennand Level.²

Higher up on the hill, towards the top, between Brennand valley and Whitendale, lead was found in Hush-water Syke, and still higher up, at a place called "The Calf-hole," very large lumps of lead were taken out many years ago. This was probably a pocket of ore, and not a regular vein.

The lowest limestone seen in Brennand and Whitendale rivers is the 'Lower Post.' Several small lodes occur in it at Whitendale, running E. 10 S., and N. 15 W. The Whitendale great lode³ being in the Red Bed limestone, dipping E. 10 S. at 55°, near the entrance, the lode ranges in a general direction W.S.W., hading south at 78°, at 87° in the middle, and at 70° at the end, which is 76 yards from the entrance.

This lode runs nearly parallel with the axis, about 100 yards south of it, with the strata dipping from the axis to the lode, consisting of Red Bed Limestone, which is considered a good rock for lead. Nevertheless, though the conditions here are rather favourable for the deposition of lead, from the tolerably free circulation of water, very little occurred in the lode, as far as the level is driven on it, though it contains a very large quantity of blende; the centre of the lode being, it is said, composed of a width of four or five feet of it.

This ore does not pay to work in the valleys, owing to the distance from a railway. Calamine, however, was worked many years ago, on the west bank of the Hodder, opposite Whitewell, on the slope of the hills, in a series of shallow shafts, excavated in rolling mountain limestone beds, which, from the information I have received from those who remember the work being carried on, appear to have been sunk on "sops" or pockets of metal, and not on any regular

¹ A "Hush," in the north-west of England, is a deep trench dug on a hill-side, to find lodes.

² A plan of these curious old workings was made for me by Mr. Hoyle, of the Whitewell Mining Company.

³ The following magnetic dialling, taken for me by Mr. Hoyle, is curious as showing short and comparatively sharp turns, in this lode-fault:—From entrance N.W. 72°, 23ft. 3in.; N.W. 83°, 55ft.; S.W. 81°, 80ft.; West, 23ft. 5in.; N.W. 85°, 45ft. 3in.

lode. In the whole of the district, where the carbonate of zinc has occurred, it has been as a surface metal, while the sulphuret is more often found in depth. Both ores of zinc are found in shaley-limestone and shales, in which lead would hardly ever occur.

At Brennand, the chief lead lode crosses the anticlinal, nearly at right angles, while the Whitendale zinc lode runs nearly parallel to it. There is reason to believe that the latter is the same lode that is lead-bearing at Swine Clough, on the opposite side of Brennand river. If so, it must either cross, or terminate the southern prolongation of Brennand lode, the latter being most probable, as no trace of the fault can be found on the face of Mellor Knoll. The Whitendale lode is probably newer than that of Brennand, the magnetic east and west lode being older than the magnetic north and south lode.

The surface of the ground, at the bottom of the col between Brennand and Whitendale valleys, consisted of the uppermost beds of limestone, the overlying shales having been denuded, and carried away down to the level of the limestone. As the lodes traversing these upper limestones are highly productive of lead, it would appear probable that the ore was introduced before the denudation of the col, when the upward prolongation of the faults, in the shales, were still open fissures.

To sum up the general results derived from an examination of the Sykes, Brennand, and Whitendale lodes, those running across the anticlinal axis are productive of lead; those with the strike of the beds of zinc, and at Sykes of lead and baryta, the quantity of ore being determined more by the nature of the matrix than by the distance from the watershed and from the surface.

(To be continued).

VI.—EARTHQUAKES.

By H. P. MALET, Esq.

THERE have been several Earthquakes lately, and they are still attributed to volcanic action. As the *Quarterly Review* of 1st January, 1869, tells us, the most popular notion regarding these phenomena "*is the hypothesis of contraction of the mass of this globe by radiation of heat into space.*" If we examine this sentence by geological reasoning, confining ourselves to those things, and actions, which are visible, and tangible, we find two causes of objection to it. We ask, whence is the heat to radiate into space? and where is the mass capable of contraction? There are certain laws which rule atoms, and worlds; we have only to understand these laws, and their effects, to enable us to comprehend every phenomena upon earth; man has not been able to do this, but has sought interpretations from his own imagination, till he has been led into innumerable difficulties. Man has been trying to find out an imaginary self-existing fire in the centre of this globe for more than 2000 years without success, he does not like to give it up, as it is a very convenient, and irresponsible agent; so at this present moment the Underground Committee of the British Association are ex-