other small plates which cannot be distinguished from the former either in size or form. These, however, possess no pores; and whether they were arranged alternately with the poriferous plates, or formed part of the base or summit of the test, it is impossible to determine in their disjointed condition. Both sets show the overlapped portion of the plate very distinctly. The plates of *Archæocidaris* are thinner than similar plates in other species of *Cidarida* constructed upon the normal plan. This feature, taken along with the overlapping characteristics of the plates, may have given more flexibility to the test, like that observed in *Calveria*. If this were the case, and the plates held loosely together in the living animal, it may help to explain how very seldom it is that we find a specimen preserved with all its parts in position.

Sections of the larger spines of *Archæocidaris*, which I have recently prepared, show that they were tubular, the hollow interior, now filled with carbonate of lime, being a quarter of the diameter of the spine. In this other characteristic it also agrees with the *Diadematis* and the other species with overlapping plates noticed in the MAGAZINE.

VII.—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.;
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(Concluded from the February Number, p. 74.)

PART II.

East Cumberland.—In the Cross Fell and Alston Moor district the Mountain Limestone is split up into numerous beds of limestone, sandstone, and shale, the thickness and character of which are well known through the local names given to each horizon by the miner, and from the writings of Messrs. Westgarth Forster, Sopwith, and Wallace.

The chief limestones in the Alston Moor district, down to the Great Whin Sill, a sheet of probably intrusive basalt, are the Little Limestone (20 feet below which are two Coal-seams, 18 and 12 inches thick respectively); the Tumblers or Great Limestone, about 70 feet thick; the Scar Limestone about 30 feet; and the Cockleshell Limestone about 18 inches, full of *Productus*; the Tyne-bottom Limestone, about 24 feet, resting on a shaly bed, which occasionally has a thin coal, which at Smither Gill I found to be turned into an impure graphite, resting on the Great Whin Sill, which at Tynehead is 110 feet, but at Providence vein on the Tees considerably thinner. Of the Alston Moor beds, about 200 feet consist of limestone, 350 of sandstone, and 520 of shale; some of the latter beds are extremely well characterized, and maintain their thickness over a large area, like the Tyne-bottom plate, only 50 feet in thickness, overlying the Tyne-bottom Limestone. There are several limestones below the Great Whin Sill, extending through some 900 feet of measures, the chief of which is the Jew and the Melmerby Scar Limestone, 124 feet in thickness.

The very remarkable fault known as the "Great Sulphur Vein"

traverses the country about W. and W.N.W. for a distance of nearly eight miles from Hard Rigg Edge, Melmerby Fell, (where it terminates against a S.W. fault) to the neighbourhood of Burnhope Seat, on the borders of Durham, where it spreads into a number of strings, which unite near Hiddenhole Mine. Following its course westwards it crosses a vein which has been worked in the Sir John's Mine. In the high level of this mine the miners, after penetrating the Sulphur Vein, which was no less than 180 feet in width, found the Sir John's vein on the opposite side, shifted 20 fathoms. This high level is driven on the north side of the Sulphur Vein, in the plate overlying the Scar Limestone, while on the south side it is in the plate under the Cockleshell Limestone, indicating a throw of more than 100 feet to the north. A little further west, the Sulphur Vein is well seen on the banks of the South Tyne, just below the Tynehead Smelt Mill, which is built on the Great Whin Sill, through which the river has cut a narrow gorge, terminating in a waterfall about 46 feet high, the base of the Whin Sill, abutting against the Sulphur Vein, which on the north side throws in the Tyne-bottom Limestone, which again forms the bed of the river.

The vein is found to be mainly made up of iron pyrites in a quartz matrix, with here and there large masses of the magnetic form—pyrrhotine, the latter was found to contain on assay small quantities of nickel and a trace of cobalt, and the former, assayed with the quartz matrix, about 40 per cent. of sulphur.

The low-level in Sir John's Mine is also driven through the Sulphur Vein, which there was found to consist of enormous masses of iron pyrites, with some copper. The latter mineral occurs in the Sir John's and in several other veins in Tynehead in the strata ranging from the top of the Scar Limestone to the top of the Tyne-bottom Limestone, but more particularly in the beds known as the Copper hazles, no less than 1600 tons of copper having been raised from the Sir John's Vein alone since 1811.

West of the Tyne the Sulphur Vein crosses the hill called Noon-stones, where it consists entirely of pure white quartz; descending the hill, it is found in Cross Gill, where it was once, I believe, worked for a short time for gold; it consists of brown-stained quartz with ordinary and magnetic iron pyrites.

Still further west it was met with in the large mine at Smitter Gill, now abandoned, where many lumps of pyrrhotine may be seen lying on the refuse heaps, with fluor and other lode stuff derived from the lead lode.

Over the whole of these moors, and at the top of the 'Melmerby Scar Limestone,' occur many poor lead lodes, since abandoned, ranging a little north of E.N.E., nearly all of which, even in the thin limestones on the escarpment under the 'Melmerby Scar,' on becoming unproductive of lead, bear brown oxide of iron. The increased value during the last two years has caused these lodes to be actively sought for. The north and south cross veins appear to be the poorest, and do not bear iron, more than lead above the Great Limestone.

South of the Sulphur Vein the Sir John's and Clargill Head Old Veins have yielded a good deal of lead in the Hiddenhole Mine; and east of Slack's Rigg, the former vein was worked in the bottom of the Scar Limestone, which, though saturated with water and much iron-stained, contains no iron-ore, which in poor lodes takes the place of the Cornish Gossans, and in those portions of the lead and copper lodes that are almost wholly unproductive of these metals, fills the whole fissure of the lode of 6, 8, and even 10 feet in width, the limonite consisting of laminated stripes of different colours, the laminae running in waving curves parallel to the sides of the lodes.

North of the Sulphur Vein, Sir John's Vein, worked at Stow Cragg, Lee House, and other Mines, has yielded considerable quantities of lead from the limestones, and copper from the sandstones, and in a portion of the lode the lead and copper are blended together. The back of the lode, both in the copper and lead portion, consists of hydrated per-oxide of iron, with veins of carbonate of lime. On the other side of the Sulphur Vein, the Sir John's and other veins parallel to it, especially High Tyne Green, Dosey, and Ladies Veins, are not very richly productive of lead or copper along a belt of country running through Bel Beaver to Tees, in a south-easterly direction, the whole lode being entirely made up of the hydrated per-oxide of iron, to the exclusion of all foreign material. The various levels driven into the hill-side, on the east side of the South Tyne and the col in which it takes its source, up to the river Tees, after passing through the lead belt, have cut into higher rocks productive only of iron. At the time these levels were driven iron-ore of this description was of little value, and heaps of it have been left around, the numbers of small shafts sunk in the course of the lodes, to extract the small portion of lead occurring here and there in the centre of the iron gangue.

The iron ore in these refuse heaps is generally light and honey-combed, with interstices in every direction; these I found, by analyses kindly communicated to me by Lieut.-Colonel A. M. Byng, to be due to the wasting away of the alumina and carbonate of lime, through the wash of rain and atmospheric action during the last 60 or 70 years. The amount of metallic iron in specimens I procured from the lodes at a considerable depth at the forebreast of the old lead levels both at Tyne Green and under the summit of Cross Fell, only averaging 33 per cent., while some of the ore from the heaps of *débris* averaged 44 per cent. of metallic iron, the iron ore being 8 feet in width, the walls containing a very large quantity of fluor: eastward on the Derwentwater estates of Greenwich Hospital, the iron is not present in this lode.

Traced eastward the iron in Sir John's and Tyne Green veins becomes rather siliceous, but parallel lodes in the adjacent manor of the Duke of Cleveland yield good brown per-oxide of iron, which is being accumulated in great heaps against the day when Middleton and Alston shall be joined by a railway.

A small W.N.W. anticlinal passes south of Bel Beaver, at John's Burn, west of Crookburn Bridge, on the Middleton road; the water

travels through a subterranean channel, the limestone dipping 5° to N.W.; two small lead lodes cross the beck, in which no iron was observable. Below the junction of John's with Crookburn, the bar of limestone is seen, resting on sandstone; the former is overlaid, a little lower down, by 30 feet of Boulder-clay, at a height of 1770 feet above the sea. Reaching and ascending the Tees, the Tees Metal Band Mine is passed, where the surface of the limestone is covered with a curious enamel of brown oxide of iron and manganese. The lode stuff in the adjacent Providence Mine is very beautiful, consisting of crystals of galena, blende, and galena, with a breccia of broken banded chert pebbles set in quartz; no iron occurs here, but the lode was rich in lead, much of which probably still remains in the mine, the miners not having been able, with the existing machinery, to contend with the water—which drains in from the Tees.

A good exposure of the Whin Sill is seen in the South Tyne, around the Tyne Head Smelting Mill, at an elevation of from 1500 to 1560 feet on both sides of the river, which has cut a narrow gorge. On the west side of the South Tyne the basalt is capped by a cliff of stiff bluish-coloured Boulder-clay about 40 feet in height, containing a great number of scratched stones and boulders, but few of great size, and, as far as I saw, none of erratic origin.

Above the basaltic section, but below Calvert Fold, Black Shale and plates below the Scar Limestone is well seen, dipping N.E. at 12°, and then N.N.W. at 5°. Shale and plate are seen in the road near Tyne Green Mines (5° to N.W.), and at Ladies Vein the Four Fathom Limestone rests on a grit, from which a large specimen of *Sigillaria* was procured. On the slope of the Fell above, below Bel Beaver Rigg, occur thick Black Shales over the Scar Limestones, dipping S.E. at 5°, with numerous ironstone Septaria, with 38 per cent. of metallic iron.

The nodules of carbonate of iron occurring in the shales of these limestones, like the nodules of earthy iron ore in the Yoredale Shales of Lancashire, appear to have a similar origin to that adduced by Sir H. de la Beche, from the experiments of Mr. Hunt, F.R.S.,¹ to account for those in the Coal-measures, viz. that the decomposition of vegetable matter prevents the further oxidation of the proto-salts of iron, and converts the per-oxide into the proto-oxide "by taking a portion of its oxygen to form carbonic acid." The presence of *Sigillaria* in the shales of Ladies Vein, Tynehead, and the occasional fragments of ferns, prove that decomposition of vegetable matter must have gone on forming carbonic acid, which, mixing with the water, would spread over local areas, which "meeting with the proto-oxide of iron in solution," would unite with it and form a carbonate, mingling with the mud; and that impure beds either of carbonate of iron or lime would be thrown down, "according as the matter deposited from solution exceeded that thrown down from mechanical suspension," and both would form nodules when supplies of carbonates were short.

¹ Mem. Geol. Surv., vol. i. p. 186, London, 1846.

In some of the nodules, cracks radiating from the centre have been filled with galena and iron pyrites; those metals would appear to have been introduced in a soluble state after the formation of the cracks.

In the adjoining district of Weardale, in Durham, Spathic iron ores occur, in a similar manner, in lodes associated with lead and zinc ores traversing the Mountain Limestone; the higher part of these lodes are often found to be changed into brown hæmatite by the oxidation effected by air, and the percolation of water from above, which transmutation is found to descend for a considerable distance in the Spathic lodes of the Middle Devonian of North Devon and Somerset, described by Mr. Hilary Bauerman;¹ and similarly large crystals from Hüttenberg, in Carinthia, in the Museum of Practical Geology, exhibit the same change from "the elimination of carbonic acid, and the absorption of oxygen and water,"²—a like change having superficially converted crystals of iron pyrites "into brown iron ore, by the elimination of sulphur and the addition of oxygen and water."³

By a similar process, sulphide of lead and blende, exposed to the influence of waters charged with bicarbonate of lime, becomes superficially converted into carbonates, which is the case with lead left in several levels driven at the commencement of the present century in Tynehead, especially in the higher levels, water gradually losing its power of assisting the change from carbonate of iron to brown oxide, and of sulphide of lead and blende to carbonate, in proportion to the depth traversed, the oxygen probably having been taken up by the proto-oxides of iron in the shale, as suggested by Prof. Rogers, and Mr. Wallace, in his work on the Veins of Alston Moor.

In that work he describes the large quantities of carbonic acid often found in levels driven through shale in that country, and particularly the difficulty of contending with it at Long Clough Mine, Nenthead, where in making "a rise" to the surface, from the level, a seam of water charged with carbonic acid gas was met, which, when bored into from above, ran down the rise with a constant flow of water and gas. Mr. Wallace throws out the suggestion that the latter may be derived from the decomposition of overlying peat, but as it so often fills the cavern connected with the "flats" of the Great Limestone, and as I found it to occur suddenly in the main adit level of the Whitewell Mine in Yorkshire, through which there is perfect ventilation, it would appear to be more probable, that it is due to chemical change going on in the adjacent rocks, possibly the action of sour peat waters in limestone.

Many of the caverns in which occur the "flats" of this district appear to have been eaten out by the action of acidulated waters, acting along lines of joints unconnected with faults, rather than by a run of water, it being only certain beds, as the Great, Scar and Tyne-bottom Limestones that readily decompose, and form these

¹ Metallurgy of Iron, third edition, 1872, p. 80.

² Hunt and Rudler, Descriptive Guide to the Museum of Practical Geology, Third edition, p. 84.

³ *Op. cit.*, p. 24.

flats of lead, which have much in common with the great sops of red hæmatite occurring in roughly N. W. and S. E. lines in the Carboniferous Limestone of Furness.

Mr. Wallace notices the fact that there are more joints in Alston Moor in the limestones than in the sandstones, and more in them than in the shales, and that the joints cease in depth; this I found to be the case over this area, but there are certainly as many joints in the Millstone Grits east of Chorley in Lancashire (where the master joint often runs parallel to a fault) as in the limestones of Tynehead. His observations as to their ceasing in depth I have noticed to be characteristic of joints in most formations. I had opportunities of corroborating his statement that joints filled with clay, often cross 'flats,' both empty, and filled with lead, and are certainly of later origin than the formation and infilling of the flats.

At Ashgill Mine both the veins and the flats contain oxide of iron, so that the introduction of the iron into the lodes of this district is probably of older date than the formation of the joints, the tops of which are covered near the Smelt Mill with Boulder-clay, but the clay found in the joints, like that in some lodes, appears to have been derived from the decomposition of limestone shales, or of beds like the pottery clay of Bel Beaver, associated with the thin coals, from which clay bottles and pipes were formerly made.

Ashgill Mine is remarkable for the lode being rich below the Great Limestone, though poor in that bed, which yielded in Alston Moor, according to Mr. Sopwith, F.R.S., 14,397 tons, while no other bed furnished more than 500 during three years; and which bed I believe to be the same as the 12-fathom of Yorkshire described in the early part of these notes.

The Little Limestone appears to be the highest rock in which zinc occurs in Alston Moor, descending to the base of the Great Limestone. In the Coal Sills and Little Limestone it is associated with oxide of iron, and at Guddamgill Burn this limestone is turned into a carbonate of iron, which is also the case with the Fell Top Limestone at Rampgill vein: much carbonate of iron is present in the basalt of Tyne-bottom Mines, which I found to oxidize on exposure to the air, which is again the case with strings of iron in the Whin Sill of the Tees, and the siliceous lodes in the Whin Sill of Tynehead.

Sulphate of Barytes occurs plentifully in the numerous small and poorly productive lodes intersecting, and often slightly faulting, the westward escarpments of Cross Fell: it is here associated with galena and fluor; the latter occurs plentifully in the east and west lodes, between Cross Fell and the South Tyne, but I failed to find any in the Great Sulphur Vein.

Reviewing the evidence afforded by this district, it would appear that lodes running in all directions are at times productive of iron, in all limestones, from the lowest to the highest, but that the Tyne-bottom, Scar and Great Limestones are the most productive. Lead occurs in all the limestones, from the Melmerby Scar upwards, and in many sandstones, but it is quite possible that the poorness of the lower

beds is due as much to their unfavourable position, as to the percolation of water from only cropping at the escarpment of Cross Fell. Zinc ranges from the Little Limestone down to the base of the Great Limestone. Copper from the top of the Scar to the top of the Tynebottom Limestones, especially in the copper hazles. Lastly, the greater the inward dip, the larger the supply of metal.

NOTICES OF MEMOIRS.

I.—CONTRIBUTIONS TO THE STUDY OF THE ERRANT ANNELIDES OF THE OLDER PALÆOZOIC ROCKS. By H. ALLEYNE NICHOLSON, M.D., D.Sc., M.A., Ph.D., F.R.S.E., Professor of Natural History in University College, Toronto. [Proceedings of the Royal Society, May 8th, 1873.]

IN this communication the author endeavours to elucidate the abundant and obscure organic remains which are found so commonly in the Palæozoic rocks, and especially in the Silurian strata of Britain, and which are generally known by the vague and convenient names of "Fucoids," "Annelide-burrows," and "tracks." After expressing his opinion that the first step towards the study of these obscure fossils lies in the provisional grouping and naming of the more marked forms which are already known to exist, the author proceeds to divide the remains under consideration into two great groups. In the first of these groups are those fossils which are truly the *burrows* of marine worms, as distinguished from mere trails and surface-tracks. Some of these burrows (*Scolithus*) are more or less nearly vertical in direction as regards the strata in which they are found; and they are to be looked upon as being true burrows of habitation. In this section are placed the genera *Scolithus*, *Arenicolites*, and *Histioderma*. Other burrows are of a totally different nature from the preceding, and may reasonably be compared to the burrows of the recent lobworms. These burrows run more or less horizontally as compared with the laminae of deposition, or they penetrate the strata obliquely. They are not burrows of habitation, but are wandering tunnels excavated by the worm in its search after food. The fossils of this group, therefore, as preserved to us, are not the actual burrows themselves, but the burrows filled up with the sand or mud which the worm has passed through its alimentary canal. The burrows of this kind (including many forms previously described under the names of *Chondrites*, *Palaophycus*, etc.), the author groups together under the name of *Planolites*.

The second great group of Annelide-remains comprises genuine surface-trails or "tracks," which of necessity never pass below the surface of the bed on which they occur. Some of these remains, such as *Crossopodia*, are, beyond doubt, due to the operation of marine Annelides; but it may be a matter of question whether we have in these cases the actually petrified body of the worm, or merely the track produced by the passage of the animal over the surface of the mud or sand. The author, however, gives reasons for