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hibit ossified processes developed along the two flattened edges of the ray, which served to support the gills.

The ossified walls of the air bladder are occasionally found ; one specimen in my cabinet is nearly six inches in length by three in breadth.

LABYRINTHODONTS.

Vertebræ and other bones of labyrinthodonts recognised by L. C. Miall, Esq., as those of *Loxomma* have been found. They are rare.

THE MINERALS OF THE YORKSHIRE COAL-FIELD AS APPLIED
TO THE MODERN MANUFACTURE OF IRON. BY BENJ.
HOLGATE, ESQ.

THE large quantity of Iron, that in the form of oxides and carbonates, combined with earthy matter, is found distributed over the world, and in every Geological formation, is frequently unutilized owing to the want of means for reducing it to the metallic state. Its reduction into the state of pig, or that in which it may be cast into any required form, and its manufacture into the malleable state and steel, so that it may be worked under the hammer or drawn out by means of rollers into bars, is dependent upon the means of obtaining fuel, a large quantity being required for its manipulation, and upon a plentiful supply of substances, not fusible at high temperatures nor chemically acted upon by either the fuel or the Iron in a state of fusion. Thus the Iron-ore of Spain, though of no use in that country, is brought to England in large quantities, and mixed with the ores of this country. The oolitic and liassic ores of North Yorkshire would be less valuable were they

not contiguous to the Durham Coal-field. The supplies of coal and fire-clay obtained from this district in large quantities, make the Cleveland Iron the cheapest in the world.

The district known as the Yorkshire Coal-field (from Leeds southward) contains in its ganister beds and various fire-clays, its carbonaceous iron ores, and its excellent coals, all the materials necessary for making the best iron that can be produced; the reason of this superiority may perhaps be best explained if we first consider what is required in these substances. 1st—

FIRE-RESISTING MATERIALS.

The requisite materials for withstanding heat are various, and have to be regulated by the kind and quantity of heat used; they must be of such a nature that they may not be decomposed by, nor combine chemically with, the substances heated in the furnaces or crucibles made of them.

Thus, graphite crucibles are perhaps the best for resisting absolute heat, but when used for melting steel cause a deterioration in quality, by its chemical combination with the carbon.

It is practically impossible to melt silica, but at the same time, a furnace made of silica would be of no use, because repeated heating and cooling would crumble it into sand, though it would not melt it. Materials must therefore be found containing silica, with such a proportion of alumina and an alkaline earth, such as lime, potash, or soda, as will combine chemically and flux with it to such an extent as to prevent its crumbling down, and at the same time, not so much as to allow it to flow into a liquid.

It will be seen that these proportions will vary with almost every use to which these materials can be put. It would be useless to provide the same substances for moderate temperatures, which are absolutely necessary when high tem-

peratures must be used. But besides this, furnaces are only heated on the inside, and they must be made sufficiently thick to bear the wear and tear to which they are subjected. The bricks are bad conductors of heat, and being heated only to a little depth, the consequence is, that many fire-bricks, even those considered of good quality, become worn out, not by gradual fusion, but by breaking off to the depth penetrated by the heat. The pieces that snip off sometimes fall into the furnace at once, and at others remain semi-detached; when the heat is again increased, it gets behind the detached piece and fuses it into the form of drops; should the fused brick fall on the iron it will cause a bad forging. It has been attempted to prevent this, in the case of fire-bricks used for some of the Durham coke ovens, (which have to be heated frequently and then suddenly cooled to a certain extent, by injecting water, in order to cool the coke before it is drawn out), by making them considerably less in section (about $2\frac{3}{4}$ in. square), but of the same length as ordinary bricks. It is also sometimes attempted, instead of building furnaces with the ends of the bricks presented to the heat, to build them a double thickness, with the side of the brick presented to the heat, so as to allow the inner row of bricks to expand; but it is clear that if a single brick gives way, the flame will get behind that thickness of bricks, and will soon bring down the whole side. Fire-bricks, therefore, will be better and last longer, if they contain a substance which will conduct the heat through the brick, and make the expansion more regular, even though this substance does not improve its infusibility. This quality appears to be present in bricks containing a greater proportion of peroxide of iron than the ordinary fire-brick. The minerals to meet these wants are found in the Ganister which lies in the Lower Coal Measures, just above the Millstone Grit, both at the north and west boundaries of the

Coal-field from Leeds by Bradford, Halifax, Huddersfield, and Deepcar, and in the fire-clays which underly some of the coal seams. Some of the Millstone Grit and other stones also resist moderately high temperatures. The Ganister is a hard, siliceous sandstone; the best qualities contain about 97 per cent. of silica.

In the vicinity of Leeds, it is worked at Meanwood, and at Laister Dyke, near Bradford. Though the Meanwood is not equal to Sheffield ganister, it is so near, that the cost of carrying the Sheffield ganister to Leeds outweighs its superiority. It is full of the rootlets of the trees which have formed the coal seams, generally found overlying it; it breaks into irregular pieces, without stratification, being very hard and brittle, and it cannot be used for building purposes. It is ground for the purpose of lining cupolas for melting iron, furnaces for melting steel, and Bessemer converters. In all these it has to be often replaced, as it cracks away; but it is not suited for making crucibles for steel or glass, because it would crack away too rapidly, or fall into a powder. It is ground and mixed with fire-clay and other sandstones, to make what are called silica bricks; though these are used for very high temperatures, they can only be used where the temperature is constant and regular, and are not suitable for furnaces which are subject to great and rapid variations in temperature, as they crumble to pieces.

The bricks made from the fire-clay which is found among the Ganister measures underlying the Halifax Hard-bed coals at Shipley, near Bradford, is, perhaps, the best suited for building reverberatory furnaces; while those made from the clay found in the same measures in the neighbourhood of Huddersfield, have long held the reputation of being the best for glass furnaces, and I think would also build good iron furnaces, as they expand and contract without cracking, and do not form into drops so much as many other fire-bricks do.

These clays contain a larger proportion of peroxide of iron, than is found in the majority of the clays of the district. The clay underlying the Low Moor Better-bed Coal is of very good quality, and is made not only into fire-bricks, but into sanitary tubes, chimney pots, and terra cotta work of all kinds. To the east of Farnley it is found generally as a fire-clay; but at Farnley, Bowling, and Low Moor, it sometimes becomes a ganister.

The fire-bricks made from the Better-bed clay are those in general use in this district, and are very beautiful in appearance. They are used in building all kinds of furnaces, from the fire backs of our homes, to furnaces for making steel. Many of the sandstones of this district are well adapted for furnace building where moderate temperatures are required, and before the fire-clays became generally used, a period of quite recent date, they were largely used, and are still in some instances. The ground ganister which is sold in Sheffield, often contains a considerable amount of sandstone ground with it when not required for the highest temperature, in order to prevent its breaking down.

A rough stone from the Millstone Grit, found near Moor Allerton, Leeds, when ground into sand, makes a very good reverberatory furnace bottom, and the flag-stone in the quarry near the Armley Midland Station, has been used to a considerable extent for building the furnaces of glass-houses. Newcastle fire-stones are still offered for sale for this purpose. A sandstone which is found at Deepcar also possesses fire-resisting properties, and I have no doubt that many other sandstones, if tested, would be found to resist heat to a considerable extent. The great drawback to their general use is their want of homogeneousness, for though the stone of one part of a quarry may resist heat well, that in another part might be only an indifferent quality.

IRON.

Iron is used for its strength, but how differently various qualities of iron perform this function, everyone is not aware; thus some iron is of such a brittle nature that it will break with a slight shock, while other iron though no stronger under a pull or thrust applied gradually, will bear a heavy weight applied suddenly, and this principally constitutes the difference in the quality of iron. It is of the greatest importance, that our structures should not only be strong under regular weights or work, but that they should remain firm if this weight or work be applied suddenly.

The iron made from the ores found in the Leeds and Bradford districts, is the best in the world that can be produced in large quantities. The pig-iron is converted into wrought-iron, and used for the manufacture of crank axles for locomotives, wheels, wheel tyres, and boilers; crank axles and screw shafts and boilers for steamers, and indeed for any purpose, where the cost is not so much an object as safety, and where the result of breakage would be disastrous.

In some places, iron is made from magnetic ore directly into wrought-iron of very good quality, by melting it in small hearths with charcoal, but in this way it is only made in very small quantities, quite inadequate to supply the large demand for iron of the best quality.

In the vicinity of Leeds and Bradford, however, it is made largely, but the supply of ore must in a short time become worked out, as, although iron nodules are diffused all through the coal measures of the district, it is in such small quantities as not to be worth working.

The Ironstone worked is in three principal layers of nodules, which lie about 2 feet above the Black-bed coal, their aggregate thickness would only make a seam of about 4 or 6 inches; its value may thus be judged, for in the Cleveland

district, the ores sometimes attain a thickness of 30 feet, then again, the yield of iron in the Bradford district is only from 30 or 35 per cent.

The Ironstone of South Yorkshire is also of very good quality. It is nodular, and in some places these nodules are so numerous as to form a seam, yet it retains its nodular character, and these seams are intermittent, extending only a few feet and then being absent a few feet more. It is worked at three different depths, the Black Shale Mine, about 13 yards above the Silkstone coal, is got through a depth of 5 or 6 feet; the top, or what is called the Brown Mine giving the most plentiful supply, being 9 inches thick. In the remaining height, the balls are picked out of the shale. All the ore in this working added together, would only give a solid thickness of about 1 foot.

About 62 yards above this ironstone, or 20 yards below the Parkgate coals, is the White Mine.

Twenty-five yards above the Parkgate coal is the Black Mine. On account of the great cost of getting these ores, they are fast going out of use, their place being supplied by others, such as those of Lincolnshire and Barrow, which are found in much larger quantities, and are considerably cheaper. The South Yorkshire ores are also mixed with, and improve the quality of, those above mentioned.

Iron is found associated with sulphur, phosphorus, silicon, and other substances, and occasionally with titanium. These substances are all more or less deleterious to the metal, for while phosphorus makes it *cold-short*, that is to say, brittle when cold, while it does not affect it when hot, sulphur makes it *red-short*, that is, it causes it to fly to pieces or brittle when hammered red-hot, but does not affect it when cold, and silicon renders the iron brittle and weaker in tension. There are large quantities of very rich titaniferous ores in Norway, New Zealand, and other places. These are only used to a

limited extent to mix with other kinds of iron, owing to the great hardness of the iron produced, by the presence of even a very small quantity of titanium, and hitherto the impracticability of separating them.

Iron is manufactured in two forms : as cast-iron, which is the condition produced in the blast furnace, and wrought-iron, made by decarbonizing the cast-iron, and thus rendering it malleable. In order to effect this conversion, great care is required. The pig-iron is first refined—that is, melted in an open hearth with the purest coke, derived from the Better-bed coal, or the Churwell thin coal. When in a molten state, it is run into iron troughs, and water is thrown upon it, as soon as it begins to cool. This process causes the separation of the silicon ; it is then puddled and made into stampings. The iron is so manipulated in the furnace, that nearly all the sulphur and phosphorus are eliminated. The iron is next broken up, and, according to the fracture exhibited, is made into different articles to correspond with the work which these articles have ultimately to perform. The iron is characterised by containing a very small percentage of sulphur, phosphorus, and silicon, by its great tenacity, by its ductility, and by the closeness of its grain, rendering it susceptible of a very fine polish. Its value may be judged when we consider that bar-iron of common quality may be bought at the present time at £8 10s. per ton ; whilst £23 per ton is paid for similar bars made from this ore, and locomotive cranks, made of this iron, are sold at about 1s. 1d. per lb.

COALS.

We cannot consider the uses to which coals are put, without the very important fact of enormous waste forcing itself on our attention. In the most economical mode of using them, only about $\frac{1}{10}$ of the heating power is utilised, and science has, as yet, done little towards economising their use. The

determination of the quantity of hydrogen and carbon, which are the combustible constituents of coal, has really very little to do with forming an estimate of their value, except in cases where the differences are very wide. The great use of chemistry, is in determining the quantity of sulphur and phosphorus, contained in the coals intended to be used for the manufacture of iron, with a view to rejecting all coals containing a large quantity of those substances. The uses to which coal should be put, with furnaces as at present constructed, depends in a great measure, on the rapidity with which it is intended to consume it—that is, the greater or less intensity of the fire, and whether it will coke or not, and if it will, upon the kind of coke the coal will produce; upon the ash, and the temperature at which it melts; upon the sulphur and phosphorus it may contain; and on the physical condition of the coal as to hardness, manner of cleavage, &c. According to Dr. Percy,* analysis cannot show whether a coal will coke or not; and my own opinion is, that this property, while of course it depends partially on the chemical constitution of the coal, depends also, in a great measure, upon its structure, modified by geological changes and disturbances. It appears probable, that if a good, clean coal does not coke, the whole of the coals above and below it in that locality, will be similarly influenced, other conditions being the same. I know a locality in the neighbourhood of Leeds, where the coals are considered as non-coking, and yet the same seam of coals will make good coke about three miles distant to the north-west. Coals have not only the planes of bedding, which are often somewhat irregular, but they have a vertical plane of cleavage, which is, speaking generally, in this district about north-east and south-west, but it is very variable. I think it possible, that this cleavage plane has been produced by the lateral pressure which caused the ele-

* Dr. Percy's Metallurgy, Article—Fuel, p. 308.

vation of the Pennine Range. The cleavage is often locally changed in the neighbourhood of faults, and occasionally it is without any definite direction. Now, if a piece of coal of this district, with clear, bedded planes be put on a fire, it will be found that the gas is emitted more rapidly, from the side or end in the direction of the bedding plane, than from the other, and, I believe, that the coking coals are those in which the gas has not free access to the exterior, but has to work its way through broken cleavage planes, or through long bedded planes, thus becoming condensed. It may be mentioned, in support of this, that small coals coke better than larger ones.

The operation of coking is a simple one. The coals are thrown into a fire-brick oven of considerable thickness, previously heated to redness; the heat from the oven gradually communicates itself to the coal, roasting it, so to speak, without the admixture of atmospheric air, and slowly driving off the hydrogen and volatile parts of the coal, and leaving the carbon or coke in a solid and often hard condition. When used in this condition it makes no smoke, and the introduction of a blast or strong current of air, makes it burn with a very intense heat. In this form it is used for melting iron, steel, brass, etc., and, indeed, any purpose where intense heat is required in the body of fire. Coals that will not coke by this process, are called non-coking, yet by reducing a coal that is considered a non-coking one to a fine powder and heating it slowly, I have obtained a fair coke.

Nearly the whole of the coals of the West Riding will make coke of some kind. That made from the Better-bed and the Churwell Thin coals is very hard and good, and contains such a small quantity of sulphur, that it is exclusively used for the manufacture of the best Yorkshire iron. Indeed, the demand for this coke is greater than the supply, and the Better-bed coal cannot be bought, being all consumed by the proprietors of the collieries and ironworks. I am informed

that the Churwell Thin in the neighbourhood of Tong, where it is known as the Shertcliffe Little coal, contains too much sulphur. The Black-bed coal makes a hard coke, which may be used for any purpose where the amount of sulphur is of little importance.

The Beeston bed, which is the Churwell Thick and Thin coals joined, makes a coke which is used for malting purposes.

The Middleton Main, in some places, will make a coke which is used for malting purposes, and might be used for iron smelting if necessary.

The Haigh Moor coal, so far as my experience goes, will not coke, but from its appearance in some districts, it may be possible to coke it. These cokes are quite as hard as some of the Durham cokes used for blast furnaces, but the coals are worth more for other purposes than coking. The coke, however, used in the foundries in the neighbourhood of Leeds is made in the County of Durham. A first-class quality is made at Brancepeth, near Bishop Auckland. It is much harder, and will bear a greater burden—that is, will melt a larger quantity of iron by weight, for the same weight of coke, than that made in the Leeds district. The top and bottom of the Barnsley, Parkgate, and Silkstone coals are all made into coke, some of which, when washed and picked, are as good as the best Durham; and the whole of the South Yorkshire coke is of good quality, and is used in the blast furnaces, and for steel melting, &c.

Another property, which regulates the uses to which coals may be put, is the *Ash* and its melting point.

But even if a coal yields a considerable amount of ash, if the ash drops between the fire bars in a dry state, thus, leaving the grate open so that the air has free access through it, it will give better results than a coal, containing a larger proportion of hydrogen and carbon, but yielding an ash which runs and blocks up the fire bars.

The hardness plays an important part in the use of coals. All coals used for a reverberatory furnace should be hard. A soft coal will not produce the long flame necessary to fill the body of the furnace, and though the heat will be intense in the midst of the fuel, it will be local. The best coals for these purposes, in the northern part of the coal field, are derived from the Better-bed, which is almost entirely free from sulphur, and is moderately hard. The Beeston-bed to the south-east of Leeds, is about the same hardness as the Better-bed, but not so free from sulphur, and the Middleton-bed coals, from the little seam, have been long used for making best iron. But the best of all for hardness and long powerful flame, for keeping clear in the fire bars, and for giving a good yield of iron, is the hard coal from South Yorkshire, which I consider to be the type of what furnace coals, for making iron, should be. The Barnsley hards are used in Leeds for making the best Yorkshire iron, and the hards of the Parkgate seam are sufficiently hard to be used raw for blast furnaces. The Silkstone hard coal is used almost exclusively for domestic purposes.

Although the seams of the northern part of the Coal-field are not so hard, and do not yield so much iron as those of South Yorkshire, they are much harder than the Durham coals used in the Cleveland district. The latter fall away into small if exposed. On the whole, we may congratulate ourselves on having coals which cannot be surpassed, on the possession of large quantities of the best ganister, fire-clays, and fire-stones, and also of ironstone, which cannot be equalled for strength and durability.
