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“Description of the Cleator Iron Ore Company’s Barytes and Umber Mines and Refining Mills in the Caldbeck Fells.”

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In the following Paper, the most improved methods of grinding and “floating” umber, and of grinding, “floating,” and bleaching sulphate of baryta, or “heavy spar,” are described in detail.

About five years ago a mining Royalty, in the Caldbeck district in Mid-Cumberland, was brought before the notice of the Cleator Iron Ore Company, and the Author received instructions to inspect and report on certain mineral veins. The Royalty, which is the property of Sir Francis Denys, Bart., is known as the Caldbeck Fells, and has been worked for lead and copper for many centuries, often with considerable success. After a careful examination of the surface of the ground, and one or two levels which were still open, the Author was able to report:—

(1.) That one drift had followed a vein of brown umber for a distance of 25 fathoms, the mineral being left in the roof, sole and fore-breast of the working.

(2.) That there were strong indications over the whole Royalty that sulphate of baryta existed in large quantities.

After receiving this report, the Company decided to drive a trial-level 4 fathoms below the sole of a drift at the north end of the Royalty, in which barytes had been found in considerable quantities. When this level cut the vein, the barytes was found to be 4 feet in thickness, and of a fairly good colour.

The uses for umber are limited; and as each trade has its own particular shades of colour, it is not easy to adapt the mineral in one form to the use of all. The manufacturers of brown-paper, who are probably the largest users of umber for staining purposes, have each their own favourite tint of paper, and for this reason the mineral is seldom used in its pure state.

The umber now being worked by the Cleator Iron Ore Company is light in colour, but it has an exceptionally high staining power, and the process of levigation separates, as far as possible, the oxides of iron and manganese from the silica and alumina with

which they are mixed. The vein is situated $\frac{1}{2}$ mile to the west of High Pike, at a point called Hare Stones, and at a level of about 1,800 feet above the sea. The mineral has been formed in a vein in a rock of the granite or hypersthenite orders, the chief constituent of which was feldspar, now decomposed and forming a mass of impure china clay. As this clay contains crystals of quartz, distributed more or less evenly throughout the mass, it has never, in all probability, been true hypersthenite; but as the nearest granite outburst is that of the Skiddaw Forest—the “Skiddaw Forest granite” of Sedgwick—its identity is difficult to determine. The Author inclines to the idea, after examining the enclosed quartz, that this china clay is the relic of a granite mass similar to that which disturbed the Skiddaw series of the Lower Silurian slates a few miles to the south. The umber has now been proved to a depth of 8 fathoms, and is from 2 to 6 feet in width. An overhead tramway has been erected to convey the mineral to the levigating works at the head of Roughtongill.

Throughout the Caldbeck Fells there are indications of manganese; and, although several places have been tried, this mineral has not been found in workable quantities, nor of a quality sufficiently rich to be of any use to chemical manufacturers.

The Cleator Iron Ore Company now decided to erect machinery on the most improved principle for grinding and levigating the umber; first, because the mineral, when washed, was considered by experts to be superior in colour and staining-power to any umber found in England; and, secondly, because the vein was so filled with crystals of quartz that the most effective separating process was considered necessary in order to free the mineral from grit, and any substance which would detract from its staining qualities.

The order for the machinery was placed in the hands of Messrs. Rushton and Bradburn, of Liverpool, and while it was being made, the wooden buildings in which it was to be placed were erected. A light over-shot water-wheel, 30 feet in diameter and 2 feet breast, was removed from Redgill, where it had been used for crushing lead ore, and after being repaired it was re-erected at Roughtongill Head.

The nearest railway station from which a good road exists is Mealsgate, on the Bolton branch of the Maryport and Carlisle Railway, and this being about 12 miles from Roughtongill Head, the question of the carriage of the heavy grinding mills was a serious one. The level of the umber levigating works is 1,300 feet above the sea, and the appliances at hand for moving and erecting

heavy machinery were few. Plate 7, Fig. 1, shows the way in which the machines are arranged, and the system employed in refining the mineral is as follows:—

The umber, having been brought down from the mine on the overhead tramway already referred to, is tipped into a hopper, from which it is passed into the washing-barrel, Fig. 2. This was constructed at the Company's workshops at Cleator, from the Author's design, and is used for washing the umber from stones and large crystals of quartz, which are intimately mixed with it. The shaft with which the barrel revolves is a hollow perforated tube, with a watertight gland at one end, and is driven by a belt from the end of the main shafting. The barrel, having been half-filled with crude umber, is caused to revolve, and water is forced into the middle through the perforations in the hollow shaft. The bars composing the outside of the barrel only being $\frac{1}{8}$ inch apart, all the larger stones are kept back, while the umber is washed through the spaces and falls into a trough below. The washing-barrel is placed about 8 feet above the main floor of the building. The umber and water are next carried into the bottom of the edge-runner mill, Fig. 3, which is a cylinder 5 feet in diameter and $4\frac{1}{2}$ feet in depth cast in one piece. The bottom, which is dish shaped, and has a central socket for the shaft, is also a single casting. The two cast-iron rollers, which are driven from a vertical shaft, and are 3 feet 6 inches in diameter, run on a cast-iron bed. When working, this mill is full of umber slurry, and the rollers are submerged. It will be understood that the rollers—which travel round the cylinder about fourteen times every minute—keep the slurry in a state of agitation, and cause the finest particles to "float," or rise to the surface, and to flow into a $2\frac{1}{2}$ -inch pipe, by which they are conveyed to the bottom of No. 1 drag mill, Fig. 4. The internal bed of this mill is composed of a single block of granite, and to the four arms at the bottom of the vertical shaft buhrstone blocks are loosely attached, which, as the shaft revolves, are dragged over the granite bed, covering, during one revolution, its whole area. The outside cylindrical casing of this mill is similar to that of the edge-runner mill; it is also full of umber slurry, which is agitated by the movements of the buhrstone blocks and the arms to which they are attached, and as the finer particles rise to the surface, they are conveyed to the bottom of No. 2 drag-mill, which is of the same construction as No. 1. After being again ground, the umber rises to the surface of No. 2 drag-mill, and is passed through a fine brass-wire sieve of 60 meshes to the lineal inch, in order that

small pieces of peat and heather, which have floated on the surface throughout the process, may be removed. Passing through the sieve, the umber is conveyed by covered boxes to the settling-tanks, which are composed of brickwork lined with cement, and are about 7 feet square and 5 feet deep. By means of little sluices, any one tank may be filled while the umber in those previously charged is settling. As the umber sinks, the clear water is drawn off the top by removing plugs, about 3 inches apart, from holes in the sides of the tanks. In four hours four-fifths of the water may thus be removed, leaving the umber lying in the bottom of the tanks of the consistency of gruel.

Pipes are conveyed to the bottom of each tank, and, by regulating three-way taps at the junctions, the contents of any one tank may be pumped out, and forced at a pressure of from 30 to 40 lbs. per square inch against the strong twilled calico coverings of the "plates" of the filter press. The water passing through the calico escapes from taps which are connected with the inside of each "plate," and the umber, now half-dry through pressure, remains on the outside of the calico. A bogie, or trolley on four wheels, is now run underneath the press, and the plates having been separated by loosening a powerful screw which has hitherto held them together, the cakes of umber, twenty-four in number, 2 feet square and from 1 inch to 2 inches in thickness, are loosened from the calico by means of wooden spatulas, and fall into the bogie beneath. When full, the bogie is run into the drying-stove, and the umber is placed on the shelves.

The finished mineral is of the following average composition :—

ANALYSIS OF UMBER.

Peroxide of Iron	47·14
Peroxide of Manganese	11·17
Oxide of Copper	3·23
Alumina	7·66
Lime	trace
Magnesia	trace
Silica	24·70
Combined water	6·18

It is sent away in two forms—in lumps, or finely pulverized. In the former condition it is chiefly used for staining coarse brown paper; and in the latter it is sold to paint and oil-cloth manufacturers, and to the makers of the finer kinds of brown paper. In producing pulverized umber the cakes are, when thoroughly dry, pushed through a small door in the side of the stove into a room in which a conical buhrstone mill is placed. This mill is

provided with a hopper, into which the lumps are thrown, and as they pass downwards they are broken up by the screw which feeds the mill. The grinding is effected by means of a conical buhrstone, revolving at from 800 to 1,000 revolutions per minute, within a hollow cone of the same stone. A sack is placed under the outlet from the mill, and into this the umber passes in the form of fine dust. The man attending to the mill has to wear a respirator over his mouth and nose, as the dust has proved irritating to the throat and lungs. When the hand is placed in a sack of umber prepared in this way it produces the same sensation as if it was plunged into a bag of silk; and when a handful of the powder is squeezed out between the fingers, leaving little in the palm, the moisture on the hand is at once absorbed, producing an unpleasant feeling of dryness, and it is difficult to remove the stain from the finger-nails.

Seeing how well the umber machinery performed its work, the Cleator Iron Ore Company decided to proceed with the erection of plant for producing barytes in its most refined form. This was an undertaking which necessarily involved the employment of considerably more power, and the Author deemed it advisable to place the machinery about a mile lower down the Roughtongill valley, where the water-supply of a much larger drainage area of the fells could be concentrated for the purpose of driving a powerful water-wheel. At this point stood a row of miners' cottages, long disused, the walls of which were, however, in a sound condition. The contract for the grinding machinery was again let to Messrs. Rushton and Bradburn; and while it was in course of construction the buildings were adapted for its reception, and a new one erected, extending from the north end of the cottages to the fell road above (Fig. 5). The floor of this building was stepped, and a secure foundation for the heavy machines obtained in the firm deposit of boulder-clay which forms the lower part of the hillside at this point (Fig. 6). A powerful water-wheel, 36 feet in diameter, 5 feet breast, and with buckets 2 feet deep in the direction of the radius, was constructed at the Company's workshops at Cleator, from the Author's design. The bosses of the wheel are 6 feet in diameter, and are of cast iron; the segments are also of cast iron, and the arms of pitch-pine; and the buckets, which can be removed for repairs, are made of yellow-pine boards, 1 inch in thickness.

The following are the processes through which the barytes passes, from the time it leaves the mine till it is packed in casks and carted to Mealsgate station. As already stated, the mine is entered

by a level in the hillside. Unfortunately the colour of the mineral is injured by a layer of fine red clay, about $\frac{1}{4}$ inch in thickness, which lies between the barytes and the hanging cheek of the vein. The crystals are more or less broken, and the red clay washing into, and remaining between them, together with a small quantity of oxide of iron, gives a slightly pink colour to the mass, and to remove this involves considerable trouble. In certain parts of the vein the colour is also slightly impaired by the presence of oxide of manganese. On the barytes being brought from the mine, it is tipped on to an iron grating, and an adjacent stream pours a constant flow of water over it, washing out a part of the clay and other impurities above referred to. After having been picked, the barytes is carted over the fell to a depot by the roadside, shown in Fig. 6. A man is here employed in breaking the large lumps, and in washing the mineral a second time in a trough below the depot. When clean, the barytes is thrown into a wooden shoot, which conveys it to a crusher, the rollers of which break it up into pieces, none exceeding $\frac{1}{2}$ inch cube in size. At this point the mineral is again passed into a long shoot, which either conveys it to a second depot, or, as is more usual, direct to the flat-stone mill. The flat-stone mill is composed of two circular mill-stones, built of buhrstone blocks dove-tailed together in the usual way. The upper stone, which weighs 35 cwt., revolves on the lower one, which remains stationary. It was at first intended to drive the upper stone at 120 revolutions per minute, and to grind the barytes when dry. It was, however, found that the mineral contained so much moisture that it could not be dried without the employment of artificial means, and as this was impracticable, a jet of water was allowed to play between the stones, and the speed was reduced to 40 revolutions per minute. The partially-ground barytes flows from this mill in a semi-fluid condition, and is carried down a steeply-inclined trough to the bottom of No. 1 drag-mill (Figs. 4, 5, and 6). The drag-mills used in grinding the barytes are of precisely the same construction as those employed in grinding umber. An india-rubber hose-pipe, $\frac{3}{4}$ inch in diameter, conveys a constant supply of water into No. 1 drag-mill, in order that the contents may be kept in a liquid condition. The movement of the buhrstone blocks, which revolve at 18 revolutions per minute, and of the arms on the vertical shaft to which they are loosely attached, keeps the barytes and water in a constant state of agitation, and the smallest particles rise to the surface, or, as it is technically termed, "float," and are conveyed to the bottom of No. 2 drag-mill through a $2\frac{1}{2}$ -inch pipe. On

rising to the top of No. 2 drag-mill, the barytes and water has the appearance of milk, and the grinding process is ended. The overflow from No. 2 drag-mill is conveyed by a trough to a large receiving tank, where it is kept in constant motion by means of an agitator driven from one of the countershafts. The mineral is of such great weight (specific gravity 4.3 to 4.8), that, were any of the agitators employed in the following process allowed to stand for two hours, the barytes would settle into so solid a mass at the bottom of the vats that it would be difficult to mix it again with water.

When the receiving tank is about half filled the agitator is stopped; the barytes rapidly sinks, and, as it does so, plugs are removed from the side of the tank and the clear water is drawn off. When about half the total volume of water has been removed in this way, the agitator is again set in motion, and the contents of the tank are pumped into No. 1 bleacher (Figs. 5 and 7). The bleachers (Fig. 7), are stone tanks, 6 feet square inside, and 4 feet 6 inches deep. The sides are 5 inches thick, and the bottoms 8 inches, each side being a single slab of fine-grained red sandstone. They are provided with pitch-pine agitators, as this wood withstands the action of sulphuric acid and steam better than oak or any other common wood. When No. 1 bleacher has been filled, the agitator is stopped and the barytes is allowed to settle; and as it does so the water is siphoned off the top, the object being to remove as much water as possible prior to the addition of the sulphuric acid used in the bleaching process. When charged, the bleacher contains from 25 to 30 cwt. of barytes. By means of an india-rubber hose-pipe, steam is carried to the bottom of No. 1 bleacher, and when the contents boil, 70 lbs. to 80 lbs. of sulphuric acid is poured in and thoroughly mixed with the barytes, by means of the agitator which is kept in motion. The action of the acid is to dissolve and remove all trace of the oxides of iron and manganese, which, if allowed to remain, would give the barytes a yellow colour, and render it unsuitable for many kinds of work.

After the acid and barytes have been boiled for about one hour steam is shut off, and cold water is turned into the bleacher, in order that the contents may be cooled before being run into one of the washing-vats (Fig. 8). As the vat is filled the agitator is kept in motion, and two or three hose-pipes of cold-water are at the same time turned into it. When the bleacher is empty and the washing-vat full, the agitator in the latter is stopped, and as the barytes rapidly sinks to the bottom, the acid water is run off the top by means of plug-holes in the side of the

vat. The vat is again filled with water, and the process is continued until all the acid has been removed, and the liquid does not change the colour of litmus paper. The last water having been drawn off, and the agitator set in motion, which is done by means of a clutch on the horizontal countershaft attached to the bevil pinion, there is put into the vat which is now one-third full, and contains about 30 cwt. of barytes of the consistency of cream, from six to eight table-spoonfuls of ultramarine blue, which is allowed to become thoroughly mixed. The effect of the blue is to give clearness to the white, but it must be used very sparingly, or it produces a pearly tint, which is considered objectionable when the barytes has to be used in the manufacture of white paints. The barytes is now run into a small catch-tank, and is at once pumped through a press, in every respect similar to the one already described at the umber works. The cloths, owing to the weight of the mineral, have to be very strong, and the material is specially prepared for the Company by Messrs. Rylands, of Manchester.

When the filter-press is full, the safety-valve, which is loaded to 40 lbs. per square inch, rises. The pressure is then discontinued, and the cakes of barytes, now of the consistency of putty, are removed to one of the drying-stoves. Each of these rooms is heated by about 600 feet of 2½-inch steam-piping, and the normal temperature is 100° Fahrenheit. When the contents of one of the stoves are dry, the steam is shut off, and the doors at either end are thrown open; 40-gallon paraffin-casks, which have been thoroughly cleaned, are rolled in, and, having been lined with paper, are filled with barytes, which is well beaten down with wooden rammers. Each cask contains about 10 cwt.

The composition is as follows:—

ANALYSIS OF BARYTES.

Sulphate of Baryta	96·29
Silica	2·60
Lime and Alumina	0·10
Oxide of Iron.	0·01

It will have been noted, that large quantities of water are necessary at all parts of the grinding and bleaching processes. In the latter it will easily be understood that this water must be very pure; that is to say, as free from sand and vegetable matter as possible. Clear as the mountain streams of the Caldbeck Fells at first sight appear to be, they in reality carry with them large quantities of fine sand, and during floods, which at these high levels are frequent, a considerable amount of peat-moss also, and

if these were allowed to remain in the water, the barytes would, for the finest work, be rendered useless. The water-supply is obtained from the troughing, which conveys the water to the water-wheel; and the Author adopted the following plan for removing the impurities named:—The troughing is placed at a level of about 22 feet above the floor of the building. To the side of the troughing, about 3 inches from the bottom, is fixed a pipe, 2 inches in diameter. This pipe conveys the water to the bottom of a column of 9-inch cast-iron pipes 25 feet in height, the bottom-length of which is 12 inches, and the upper part 9 inches, in diameter. At the bottom of the column is fixed a sludge-cock, and at the top of the 12-inch piece the column is intercepted by a sheet of brass-wire gauze, of 1,600 meshes to the square inch. The supply of water is drawn from a few feet from the top of the column. It will be understood that all the water used in the washing process has to rise to a height of 20 feet in a 9-inch column of pipes, and that it is checked in its flow by having to pass upwards through fine wire-gauze; it is therefore quite free from sand and peat. By opening the sludge-cock the pressure of water above thoroughly cleans the meshes of the gauze. It may also be mentioned that a board, 4 inches deep, is placed across the bottom of the troughing immediately in front of the outlet-pipe, and that this catches a considerable quantity of sand, a portion of which would otherwise find its way down the pipe to the water column.

It would be difficult to say which part of the process demands the greatest care and attention. The speed of the machines, the quantity of vitriol, and the length of time the boiling is continued, are all of importance, and the art of obtaining invariably the same shade of white and the same degree of fineness is necessary to commercial success.

The Author is indebted to his pupil, Mr. J. J. G. Howes, for the preparation of the accompanying ten drawings, from which Plate 7 has been produced.

Fig. 1.
U M B E R W O R K S .

P L A N .

Fig. 2.

Fig. 3.
E D G E - R U N N E R M I L L .

S E C T I O N S H E W I N G R O L L E R S .

S E C T I O N T H R O U G H A . B .

Scale for Figs 3 & 4 - 3/8 inch = 1 Foot.
Inches 0 1 2 3 4 5 6 7 8 Feet.

Fig. 4.
D R A G - M I L L .

S E C T I O N .

P L A N B E L O W A . B .

B A R Y T E S A N D U M B E R M I L L S .

Fig. 5.

P L A N .

Fig. 6.

Fig. 7.

B A R Y T E S B L E A C H I N G T A N K S .

P L A N .

Scale for Figs 7 & 8 - 3/8 inch = 1 Foot.
Inches 0 1 2 3 4 5 6 7 8 9 Feet.

Fig. 8.

P L A T E 7 .

B A R Y T E S W A S H I N G V A T S .

P L A N .