IRONSTONE MINING IN DERBYSHIRE

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Abstract: Coal Measure ironstone mining has been much neglected by historians despite it being of major importance until replaced by Jurassic ores in the 1870s. Sources are fragmentary, but it has proved possible to assemble details of its geological occurrence, and to describe or hypothesise about methods of working, including openworking, bell-pitting, thurling, bank working and a bottom-slicing technique. Remains can still be found, especially around South Wingfield, Wingerworth, Riddings and Ripley.

INTRODUCTION

The argillaceous or clay ironstones from within the Coal Measures formed the main resource, before about 1876, for the Derbyshire iron-making industry. Derbyshire was fourth, in the early and mid 19th century, amongst English iron-working counties. Only very little amounts of iron minerals from other sources were ever worked in the County, notably haematite pockets within the limestone from around Hartington which were purchased by the Sheepbridge Iron and Coal Company, and Friden by the Butterley Company. Some also was worked around Winster, Elton, Monyash and Brassington, though it is not always clear whether this was for ironmaking or for pigment. Although some 12-15 million tons of Coal Measure ironstones were extracted in total, peaking in 1871 with nearly half a million tons, their working had practically ceased by 1900. In consequence they have not had the intensive geological study which the coals have warranted, though reserves of some 380 million tons have been suggested (probably now much reduced by indiscriminate dumping of iron-bearing material during opencasting for coal). Later geological accounts add relatively little to Smyth's account of 1856, though a few details emerge in Stokes' brief account of 1878. By specialist iron historians the technicalities of clay-ironstone mining have virtually been ignored, and amongst mining historians it falls almost unnoticed between coal and the non-ferrous metalliferous interests.

The ironstones were described by Gibson, Strahan *et al* (1920) as occurring throughout, but mainly near the bottom of the Lower Coal Measures and the bottom of the Middle Coal Measures. They occur in several forms, in thin "cracked" beds or as balls or nodules, up to 30 cm or so across. The grain size is usually very fine and the colour grey or brownish grey. Generally the layers of nodules are very thin, and occur in what were described as rows or "rakes" - around Ambergate (Blackshale Rake) there were eight thin rakes in thirty feet of shale strata. There were no beds in Derbyshire comparable to the Tankersley Ironstone in Yorkshire which was in places three or more feet thick.

Like the ironstones themselves, the methods of working have also received little attention. Areas of working are necessarily described in leases to ironmasters, but not the methods and there is similarly little about the men who worked the mines, though generally they seem to have been less well regarded and less well paid than either coalminers or ironworkers: They generally and perhaps always were paid by contract, at a price per ton. At Dale and Stanton an advertisment of 1793 required about 20 miners, at four shillings per ton, the price apparently including sinking, getting and turning (i.e. winding out) the water (Chapman 1981:30). At Butterley around 1829, they received an average of 12/- to 14/- (shillings) a week, labourers got 12/-, whilst coal miners got 15/- to 20/-, and furnacemen 17/6 to 21/- (Glover 1829 I:231). By 1883, excavation, freight and waggon hire together cost only 3/10 per ton at Stanton, so wages must have fallen considerably, presumably in response to ores which were by then being imported from outside the district (Chapman 1981:105). Something of their numbers can be determined from the census returns for 1841 and afterwards, rising from, in that year, 591 to 1428, 1427 in the next two counts, then falling to 726, 72, 24 and, in 1901 the few remaining were described as "shale miners" (Landers and Vellacott I:361). Since these figures do not easily equate to the amounts of iron ore being mined or iron being made, it is probable they are underestimates and that some, even many, colliers had a dual role.

DERBYSHIRE ARGILLACEOUS IRONSTONES

Output of Derbyshire ironstones peaked at just under half a million tons in 1873, though decline then rapidly took place with the importation by railway of the more prolific and more easily mined, Jurassic ores from Northamptonshire. Between 1870 and 1880 output fell 60%, and there was an even more dramatic fall by 1882 (150,000 to 15,000tons). Though a few thousands of tons were worked annually until the First World War, probably mainly by the Butterley Co., it was regionally insignificant.

Table 1. Output of Derbyshire iron and ironstone.

	Iron	Ironstone
1740	550 tons (Kendall 1893)	
1789	5600 tons (Pilkington 1789)	23,000 - 28,000 tons (estimate)
1796	9656 tons (Kendall 1893)	
1806	10,329 tons (Farey 1811)	41,000 - 61,500 tons (estimate)
1823	14,038	
1830	17,999	
1839	34,272	
1848	95,160	
1860		387,500 tons (Burt *et al* 1981)
1870		384,865 tons
1880		150,000 tons
1882		15,000 tons
1890		23,732 tons
1900		2,835 tons
1910		1,448 tons

Top Rake 15 feet 11½ inches

	ft	in.
"Whetstone", lean or poor measure, not got	0	1
Shale	1	6
"Single balls", lean	0	0½
Shale	1	6
"Double Chitter", lean,brown, rough, nodules	0	2
Shale	3	0
"Cheeses", good measure	0	1½
Shale	2	0
"Bearstone", capped with cone-in-cone, lean, rough texture	0	1
Shale	2	3
"Blues", upper, good, rich, flat nodules	0	1
Shale	1	3
"Blues", lower,	0	1½
Shale	2	0
"Old Man", good, nodules often thick	0	2
Shale	1	6
"Old Woman", or sheeting, good, flat nodules	0	1
Shale	12	0

Bottom Rake 21 feet 4½ inches

	ft	in.
"Smooth "Chitter", smooth, lean measure, brown and rough	0	2½
Shale	3	6
"Flampard", very rough, granular stone, lean	0	3
Shale	2	0
"Red Measure", good, cleavage planes with white coating	0	1½
Shale	3	0
"Chance Measure", lean	0	0½
Shale	1	6
"Dun Lining", lean, black, with small crystals of pyrites	0	1
Shale	1	0
"Dun Measure",good, thick black nodules	0	1
Shale	2	0
"Over Lumps", good, cracks coated with white powder	0	1
Shale	1	0
"Nether lumps", good, cracks coated with white powder	0	1
Shale	1	6
"Overbottoms", good	0	1½
Shale	1	6
"Roof Measure", good, rough and black	0	1½
Shale	1	6
"Bottom Measure", good	0	1
Shale	1	6

Coal smut, 2 feet 3 inches above the roof coal (Silkstone - Black Shale)

after Strahan, Gibson *et al*, 1920

Note: White Watson (1811 p.14-15) referred to this same horizon in somewhat different terms and details.

Table 2. Ironstones of the Black Shale Rake at Hady, Chesterfield

Between 1855 and 1914 some 8,558,000 tons of ore were mined (Burt *et al*, p.xiii) suggesting a total output of some 12-15 million tons during the life of the industry. This can be compared with the estimate of some 380 million tons reserves in 1920 (Strahan *et al*, 1920 p.47), of which about 52% was contained in the Black Shale and Striped Rakes, and about 20% in the Brown Rake, which were the major deposits previously worked.

There was a close locational relationship of known early bloomery sites ("cinderhills"), the later charcoal blast furnaces, and the coke fuelled blast furnaces of the 1780s onwards with ironstone production areas. Each iron producing site appears to have openworked or mined its ore from within a very short distance. Major ironworks at the later period certainly integrated the mining of ironstone and coal with their smelting activities, and it is likely that this was always the case, though some iron ore (or stone) was sometimes "bought in".

GEOLOGY

The Derbyshire ironstone is found mainly in the form of the iron carbonate, siderite, most commonly as rows or "rakes" of nodules within black shales, but also within "blue" and "white" (dark and lighter grey?) shales, less frequently as continuous layers of ironstone rock. Usually the ore forms a sequence of thin bands of ironstone within 10-40 feet of shale, and a 10% recovery of 30% grade ore would have been considered very good indeed from such a zone. Certain horizons have septarian nodules (flattened discs with cracks in the centre radiating outwards), in which are found a range of minerals including pyrite, galena, blende (iron, lead and zinc, sulphides - which must have created severe pollution around blast furnaces). Others are associated with prolific plant or bivalve remains. Iron carbonates form isomorphs with magnesium and calcium carbonates (ankerite) and these are both common constituents, as in the "Dogtooth Rake", in which calcite scalenohedra, or its isomorphs, are common.

Analyses of the ores are not common. Percy (1864 II:211-212) gave the compositions of several, showing, simplified, that the main component was iron carbonate, with up to 1% manganese and up to and even over 1% phosphorus. Lime and magnesia were normally only a few percent, but in one specimen from Civilly Rake at Stanton, Percy's analysts found well over 20%, presumably as carbonate. Actual iron content was usually between 20-30%, sometimes a little over.

The most prolific horizon was the Black Shale Rake, which occurred just above the eponymous coal. This is found near the western margin of the coalfield from Sheffield and beyond down to around Ripley, south of which it is sometimes known as the Striped Rake. It probably had its maximum development at Hady, just east of Chesterfield. As Table 2 shows, in some 37 feet of strata, a total of some 26 inches of mineable ironstone was found. According to White Watson (1811), it was, in early times, only worked down to the "Old Man", a term which in Derbyshire lead mining usually refers to old works, or the old miner, variously, but here probably refers to his limit of working. White Watson also gives a section from this same area, but almost three times as thick, with almost three times the amount of iron ore within it. Since both sources can be considered generally reliable, this suggests the deposits were highly variable over quite small distances. Smith, Rhys and Eden (1967) describe another section, at Spitalwell Mine, with ironstone layers alternating with blue and black bind, and up to 40% iron. There were 20 layers of ironstone between a half to three inches thick, of which 10 were worked, yielding 5000 tons of 26% iron per acre.

The only other sections with comparable detail are for the Black Rake (Table 3), and Dogtooth Rake (Table 4 and below). The former occurs above the Ell Coal (i.e. not to be confused with the Black Shale Rake), at Salterwood. This is much thinner, but with hardly less ironstone within it than the Hady section above. The Black Rake occurs close to Brown Rake, also an important horizon and sometimes close enough for the two to be mined in the same pit, which accounts for the importance these two deposits had.

Percy (1864 II:228-9) described Brown Rake at Butterley as in three measures: Balls, Top Measure and Bottom Measure.

Black Rake had two: the Top and Bottom Measure.

Dogtooth Rake at Staveley: White Measure, Sugar Plum Measure, Marble Measure, Balls, Snail Horn. The third and last varieties had abundant shells. Stokes (1878:104) refers to the ore being filled with *Anthraconaia* shells. Ford (pers. comm.) notes that the "Tupton Marble", possibly from this horizon, and full of shells which he identifies as *Carbonicola*, was used as an inlay in Derbyshire Black Marble work. The term "cockleshell ironstone" has also been used. See also Table 4.

The Stanton estate was claimed as capable of producing up to 8000 or 9000 tons per acre. Uppermost was the Honeycroft Rake, which was 16 yards thick and, since no depth is mentioned, this is probably at outcrop. 43 yards below was the Stripe or Civilly Rake 6 yards thick, at 89 yards was the Green Close Rake 10 yards thick, at 105 yards depth was the Round Meadow Rake which was 4 yards thick, and at 125 below surface was the Hollyclose Rake 5 yards thick (Chapman 1981:54). The Honeycroft Rake at Stanton was, in another account, described as: Chitters, Tufty Balls, Barren Beet, Grindstone Measure, Grinders Wife, Big Balls, Bottom Flats and Brick Measures. Tufty Balls were presumably septarian, since in cracks they contained iron carbonate, calcite and sphalerite. Civilly Rake, also at Stanton, had Rachell Measure, Chance Balls, Bottom Measure, Chitters, Coal Measure (Percy 1864 II:228-9).

Dale Moor Rake at Stanton: Clunch Balls, Roof Measure Balls, Roof Measure, Over Bottom, and Bottom Balls. The first had significant vegetable remains, and there were perfect fossil fishes within the measures.

Given the general lack of descriptions, these vernacular terms are probably as near as we shall get to describe the varieties which occur: some are obvious - Rachell would probably indicate small and few, Chitters would be similar in size to the small potatoes given a similar name, though one might wonder about the contiguity of the Grinders Wife and the measure below it!

Kendall (1893:182-3) included the information in Table 5 below of the ironstone produced per acre for each of the ironstone rakes, though he did not specify the localities, nor what system of mining was necessary to produce the quantities.

Hard Rock		9-10 inches
	Brown Ironstone	4-5 inches
Black Rake	Binds with chance balls of ironstone	18 inches
	Blue ironstone	9-10 inches
Binds		4 feet

Table 3. Black Rake Ironstone at Salterwood

Ironstone	White Measure		4 inches
Bind		1 foot	6 inches
Ironstone	Sugar Balls		3 inches
Bind		1 foot	6 inches
Ironstone	Dogtooth		4 inches
Bind with ironstone balls			11 inches

Table 4. Dogtooth Rake (Stokes 1878).

WORKING THE IRONSTONES

Because of the substantial thicknesses of shale or bind in which the nodules occurred, the mining methods were often somewhat different from those used for coal, and there was a very much higher proportion of waste: there was no ironstone rake, for instance, which could be worked entirely in-seam. Three of the rakes were situated immediately above a workable thickness of coal using Kendall's (1893:179-81) strata table, which would be enormously advantageous, since waste from the ironstone measure could be, partially at least, stowed in the space left by the coal, and their joint working could make otherwise marginal thicknesses of either economic: Black Rake had 10 inches of ironstone in 5 feet 9 inches of black shale above the 26 inches thick Ell Coal; the Threequarter Rake with 8 inches of ironstone sat on the 19 inches of the Threequarter Coal; most worthwhile was the Black Shale Rake with 2 feet 3 inches of ironstone just above the 5 feet 4 inches of the Blackshale Coal, which were often worked together.

OPENWORKING

Most of the ironstones appear to have been worked only to shallow depths, and opencast methods seem to have been in continuous use throughout the period of exploitation, leaving lines of discontinuous banks along hillsides above the outcrop, notably in areas above the Black Shale Ironstone and, in the final period of mass exploitation, around Stanton and Dale. No details as to hand-working methods of such opencasts are available, though it may be possible to determine this from archaeological survey. At Stanton by the 1850s a stationary engine was used to haul ore up from the gently inclined beds of a large quarry, with the shale being backfilled into the "vast cavity" (Smyth 1856 p.45).

Cement	1800	tons
Pinder Park	2000	
Brown	2500	
Black	2000	
Dogtooth	2000	
Nodule	1600	
Blackshale	4000-7000	
Striped	2500	
Green Close	1000	
Holly	1200	
Black or Kellands	3000	
Yew Tree	1000	
Honeycroft	6000	
Dale Moor	3000	
Civilly	4000-5000	

Table 5. Output of ironstone per acre

Table 6. Summary of information on the Derbyshire Clay Ironstones

Names	Stratigraphic position	Where Mined	Notes
Inkersall Rakes Measures Balls	Above the Top Hard Coal.	Staveley and Duckmanton	Not much used
Tanyard Rake Black Rake	Above the Ell Coal, a few feet above the Brown Rake.*	Butterley - outcrop and deep. Salterwood.	About 27% iron at Butterley,. and 2000 tons per acre.
Brown Rake Pinder Park Rake (Staveley) Buff or Cement Rake. Black Rake at Morton Colliery, Clay Cross.	Above the Ell Coal - eg. 90 feet at Renishaw, 33 feet at Morton. It is the equivalent of the Tankersley ironstone in Yorkshire, and generally occurs within 30 and 60 feet above the Deep Soft.	Bell pits west of Renishaw Park Collieries and at Staveley. Worked either side of Riddings anticline near Ripley (Butterley). Salterwood.	Nodules in 60 feet of shales and mudstones. Has about 30% iron at Butterley. Brown Rake yielded 2500 tons per acre at Butterley.
Blue Rake or Poor Rake	Above Piper and Deep Hard, below the Ell Coal.	Butterley, Poor Rake at Alfreton.	
Riddings or Spring Rake Old Man's Rake Whetstone Rake	Above Furnace (Tupton) Coal, below Piper Coal	Riddings at Alfreton, others at Butterley	
Between the Tupton and Deep Soft Coals, ironstones are found irregularly at several horizons, but there is much confusion in their nomenclature, as miners gave the same name to ironstones of similar character. Includes Brown Rake, Black Rake, Blue Rake, Whetstone Rake, Old Man's Rake, Riddings Rake. Hospital Rake at Denby may be same stratigraphically as Dogtooth Rake (Stokes 1878).			
Dogtooth Rake (the Wallis's Rake at Butterley is near the same horizon)	Above the Tupton (Furnace) or Threequarters Coal, sometimes lying on it, sometimes split from it by shale. It is 40 feet above at Chesterfield.	Morley Park. At Clay Cross at No. 2 Pit worked with the coal at a depth of 74 yards where immediately above the coal. Salterwood, Marehay.	Five courses of nodules at Clay Cross, four courses at Butterley, three courses near Ilkeston. 3 to 4 inches thick at Morley Park. Up to 2000 tons per acre at Chesterfield. Contains dog tooth calcite.
Three Quarters Balls Nodule Rake of Morley Park, and Dogtooth Rake of Butterley	Below the Tupton Coal. Six feet below at Morley park.	Butterley Morley Park	
Black Shale Rake (called Striped Rake in the south of the district).	Immediately above the Black Shale (Silkstone). Found at Butterley 36 feet above the Clod, here split from the Black Shale Coal.	North of Sheffield to Ripley, maximum between Dronfield and Clay Cross. Worked at Hady, Barlow, Glasshouse and Springwell.	63 to 96 feet thick shale/ironstone measures in Clay Cross area. Between 4000 and 7000 tons per acre. Striped Rake 2500 tons
Yew Tree Rake, Bacon Flitch Rake, Black or Kellands Rake	Above Kilburn Coal, below Black Shale. Bacon Flitch is about 70 feet above Kilburn.	Locally worked between Alfreton and Morley Park	Black Rake 3000 tons per acre at Morley Park
Green Close Rake, Holly Close Rake, Black or Ketlands Rake, Yew Tree Rake, occur in a group of measures between 37 feet below the Clod Coal and 66 feet above the Kilburn Coal, and were raised at Morley Park.			
Honeycroft Rake	Immediately below the Kilburn Coal. Striped Rake is shown as above the Clod Coal by Gibson, Pocock et al 1908)	From the Dale District to Ambergate. Kirk Hallam.	Yielded up to 6000 tons per acre, with eight courses of ironstone in about 45 feet of shale. Up to nearly 33% iron.
Civilly Rakes (also Greenclose, Round Close and Hollyclose Rakes)	Below Kilburn Coal, above thin Norton Seamand lies about 130 feet above the Alton Coal.	Opencast NE and N of Stanton - by-Dale, and W and N of Dale. Not worked elsewhere.	Five courses of nodules amidst 20 feet of shale, yielding about 4000 tons per acre.
Dale Moor or Hagg Rake	Below Kilburn Coal and below Naughton Seam.		Five courses of nodules in 60 feet of shale, yielding about 3000 tons per acre. Over 33% iron recorded.
Sources: Farey 1811; Smyth 1856; Percy 1864; Stokes 1878; Gibson, Pocock *et al* 1908; Gibson and Wedd 1913; Strahan, Gibson *et al* 1920; Smith, Rhys and Eden 1967; Frost and Smart 1979; Chapman 1981, NCB Shaft Records (held by DCC.); Geological Survey 6" Maps. * Kendall (1893:181-2) shows Black Rake below Brown Rake with 10 inches of ironstone.			

BELL-PITTING

Bell pits were extensively used - "the outcrop of the Black Shale in particular is marked by a belt of trees growing on the irregular land resulting from the collapse of bell pits" (Smith, Rhys and Eden 1967:238), and Griffin referred to their use near Heage (1959:393). Since then, however, a great part of the outcrop has been opencasted for coal. This method of mining appears to have been particularly suited to near-outcrop mining of the dispersed bands of ironstones. It was still being intensively used in the early 19th century, and was still in use at Unstone after the mid- 19th century, when it was described as only workable, such was the thickness of the measures, by opencasting or bellpits (Smyth 1856; Tomlinson II c.1852:75). It seems likely that a great many of the closely-spaced pits and shaft mounds surviving in woodland areas in considerable numbers throughout the older-worked sections of the coalfield were for ironstone rather than coal.

The term bell-pitting has generated some confusion, notably perhaps, because of its mis-use for the well-known mining at the Tankersley Ironstone outcrops in Yorkshire (part of the area of mining now used as a golf course shows the shaft mounds clearly from the M1 motorway). These are better considered as closely spaced shaft mines in which a considerable amount of horizontal movement of ironstone was required, probably using either thurling or the bank system of mining. The great virtue, and distinguishing feature, of the bell pit is that the ore can virtually be dragged direct from the workplace using the rope from the jack roll at the top of the shaft. To avoid confusion, Gould and Cranstone (1992) prefer the term shaft mound for the surface expression. However, despite their expressed doubts of the actual existence of bell pits (pers comm), the use of the method can be demonstrated and the appropriateness of the term is clear from both contemporary description, and personal observation of sections in modern opencast workings.

According to Pilkington,

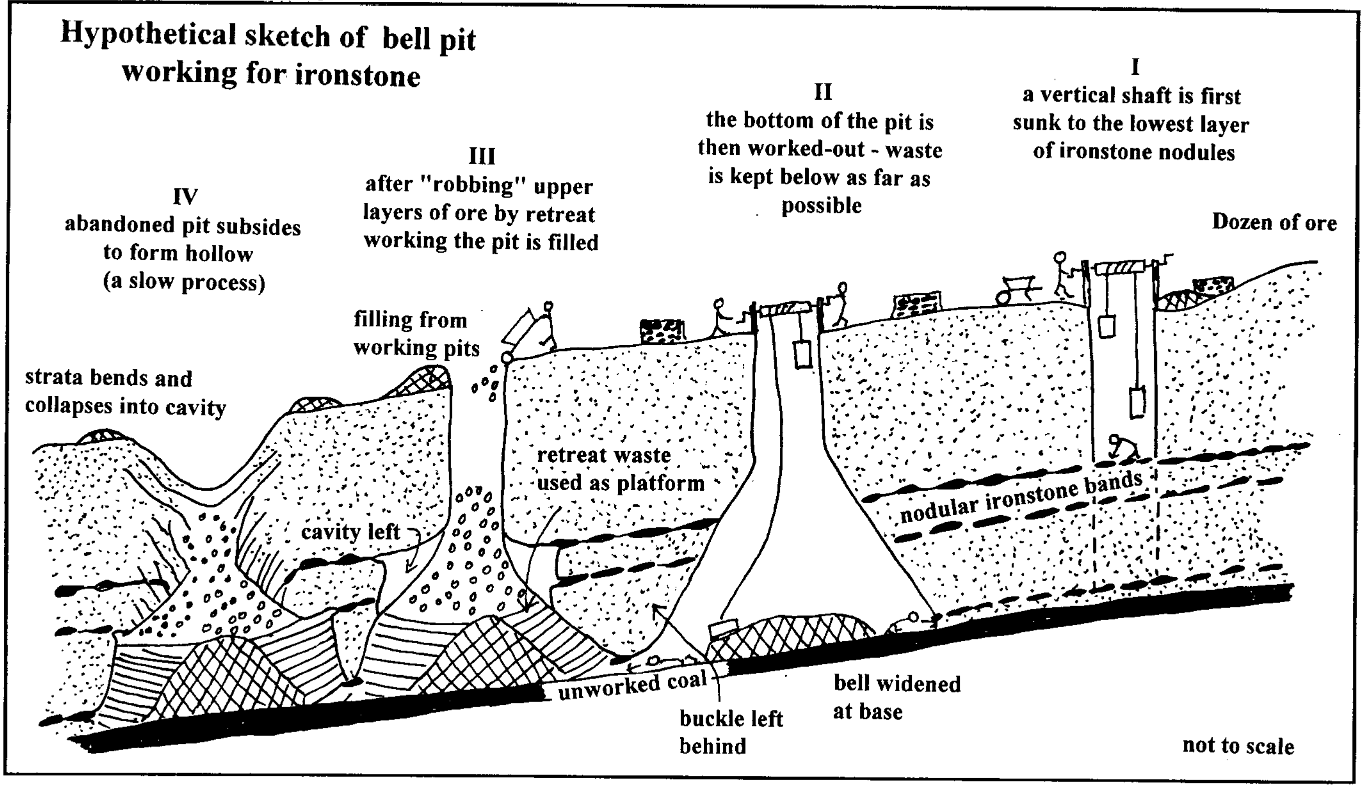
When . . . it is seen at the surface . . . (it) is taken out of the ground to a depth of eighteen or twenty yards. For this purpose a hole is made about the same size with the shaft of a coal pit. This is generally enlarged every way, as they go deeper into the earth, and at length the opening assumes the shape of a bell. It is usual not to go lower than eighteen yards. Fresh ground is then broken and another hole of the same form and depth is begun and sunk in the earth . . . soil near the surface is intermixed with the lower beds and rendered entirely useless . . and (land) receives greater injury from working mines of ironstone than with those of coal.

Pilkington went on to remark that near Wingerworth, the ore was so valuable that the land containing it was worth £100 an acre. Farey (1811) was clearly intrigued by the survival of the method:

A round pit of the usual size of a shaft is sunk, until the ironstone is reached, from three to ten yards deep, the first two or three yards being made cylindrical, and the part below it conical, in order to reach a larger surface of the stone, which being got below the shaft, and a drain laid across it for connecting with the next pit, the Workmen or Ironstone-men, begin to hollow out the Measures all round the shaft into the form of a bell (hence the name), throwing the refuse into the centre, and getting the ironstone as far as possible at all sides; which done the pit is abandoned, and another begun at a proper distance, the soil from which is tumbled into the last pit, until the stone is reached and got as before, when another pit is begun and so on; and this method of Bell-pits still continues to be used, unless when the depth becomes very considerable, or a hard Measure lays above the ironstone, which may serve as a roof in Thurling for it, or working it in short banks as coal is wrought . . . which should always be done where practicable in order to avoid the waste of ironstone in the angles or Buckles as they are called between each four adjacent pits.

Farey was always keen on ameliorating the conflict between miner and agriculturalist, where land and minerals were so frequently divorced. He considered that the drain sometimes laid at the base of such bell pits from one to the next should always be incorporated, both to drain the water from the bottoms and to prevent hollows filling with water after abandonment.

Fig.1. Sketch to show the bell pit method of mining ironstone. This varies from bell pits for coal in that the underground working finally takes a more cylindrical form. Note how the ironstone can be wound directly to surface from the workplace, this operationally distinguishing bell pits from other forms of shaft mining.



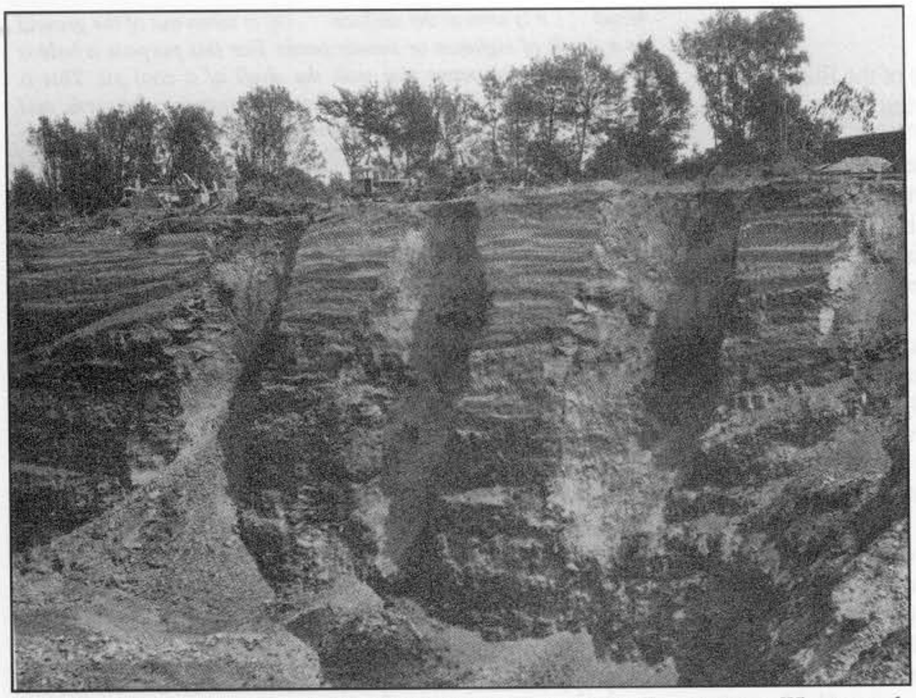
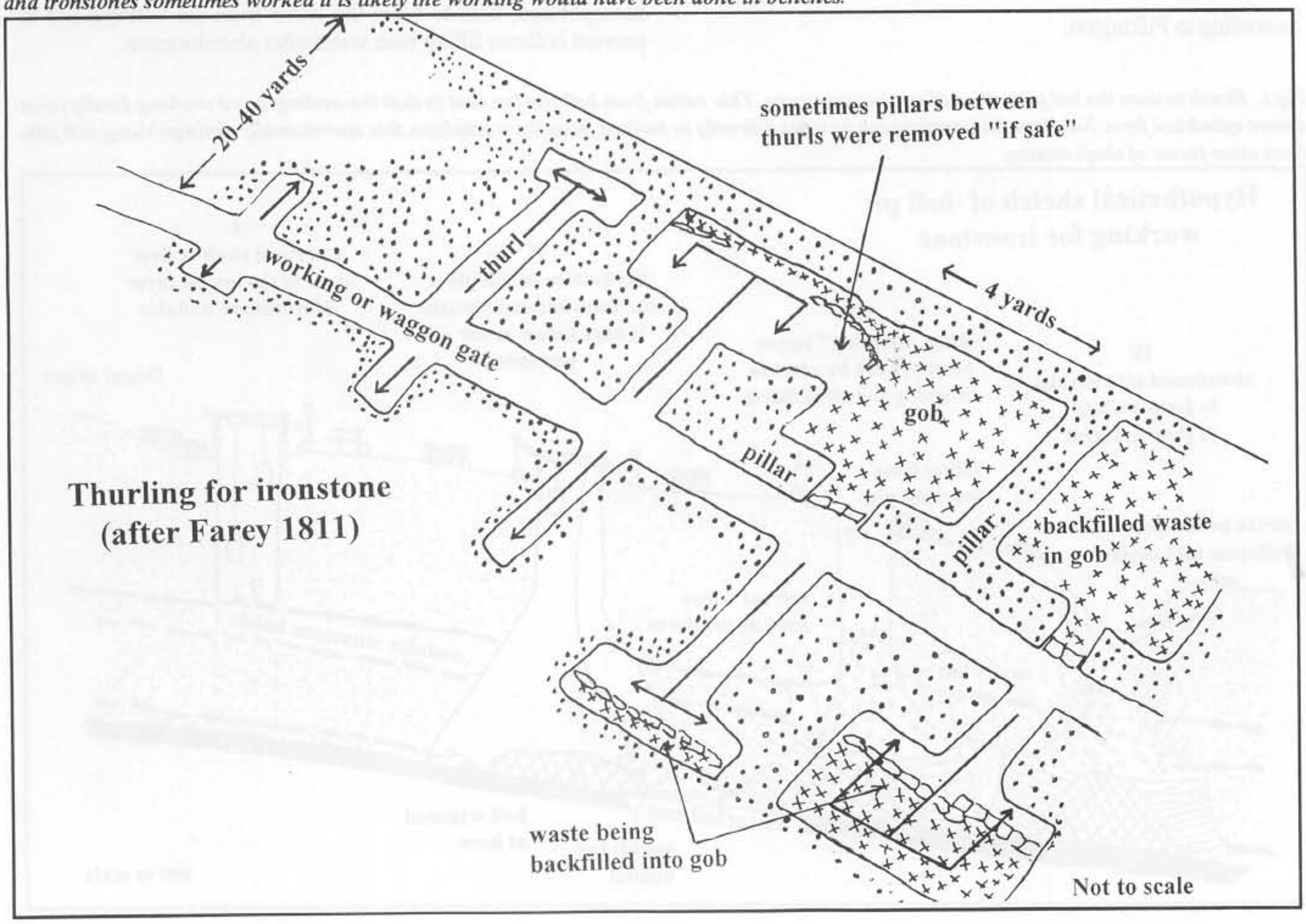


Plate 1. Bell pits exposed at Berresford Moor Opencast at Tupton near Wingerworth, Chesterfield, c.1969. The coal below had been unworked and the pits probably provided ironstone for the nearby works owned by Joseph Butler. Photo supplied by David Edwards.

These accounts may tell only part of the story. Where a vertically substantial sequence of ironstone bands was worked well below surface, it seems likely that initially the degree of belling was fairly limited, and that the bottom of the pit was the first to be considerably extended, allowing perhaps drainage and even some improvement in ventilation via the adjacent pit. The roof above would be extended to form the bell shape only as far as a reasonably smoothly curved form (perhaps better, a corbelled form) would optimise support, though use of a small amount of timbering would help considerably. The dumping of waste in the centre noted by Farey would undoubtedly have been accompanied by filling the worked-out sides at the bottom, greatly increasing stability. The pile of waste would, after the maximum bottom extent had been achieved, have provided a platform for higher ironstone bands to be worked, "on the retreat" dropping material on to the floor left below for sorting and helping stabilise the working. This would finally give a more cylindrical than bell form below the shaft section.

Filling from above would leave substantial cavities under the final lip and these, with compaction of the waste would, as time went on, leave the wide collapse hollows seen nowadays at surface. Alternatively, where the uppermost ironstone band was only a modest way below the surface, then it would be worthwhile having a wider upper section to the pit. The resultant simple cylindrical form for the whole depth of the pit would be particularly suitable for very thick sequences of ironstone/shale bands which were not stable enough

Fig. 2. Sketch to show thurling (a form of pillar and stall working) based on the description by Farey (1811). In the thick sequences of shales and ironstones sometimes worked it is likely the working would have been done in benches.



to be self-supporting overhead and would also assist in sideways support for deep (10-30 metre depth pits). This type of pit was observed during modern opencasting at Tupton some 20 years ago, whilst the layering of the infilling was compatible with the hypothesis described above.

The advantages of bell pits for ironstone mining appear to be considerable, accounting for their survival long after Farey's time: there was very little requirement to support the roof in these conditions, and the cylindrical form was an inherently strong structure; there was a reduced or no requirement for lighting or ventilation systems, whilst communication with surface was easy and immediate. The capital cost prior to production was minimal and a large number could easily be sunk simultaneously to meet output needs, with the minimum need for supervision and organisation of, presumably, a generally poorly skilled workforce. There was no need for underground haulage (an immense problem in many mines until the mid-late 19th century), and successive horizons (as many as twenty would have sometimes been necessary) can be fully exposed one after the other and sent up as separate batches. Whereas coal is found in a more or less discrete bed, the ironstones may be disseminated within a comparatively large thickness of strata, and a bell pit, despite slightly more waste of ore left behind in the buckles than in competing systems, enabled a high percentage extraction, perhaps around two thirds. They seem to have been sunk to as much as thirty metres deep. At Tupton near Chesterfield in the late 1960s and early 1970s, as noted above, the undated ironstone pits in large numbers were found in a modern opencast laid out in regular ranks and rows to a depth of over ten metres, ignoring the coal which lay immediately beneath. Similar comments have been made about bell-pitting in Yorkshire, referring to the Black Shale Ironstone (Eden *et al* 1957:68).

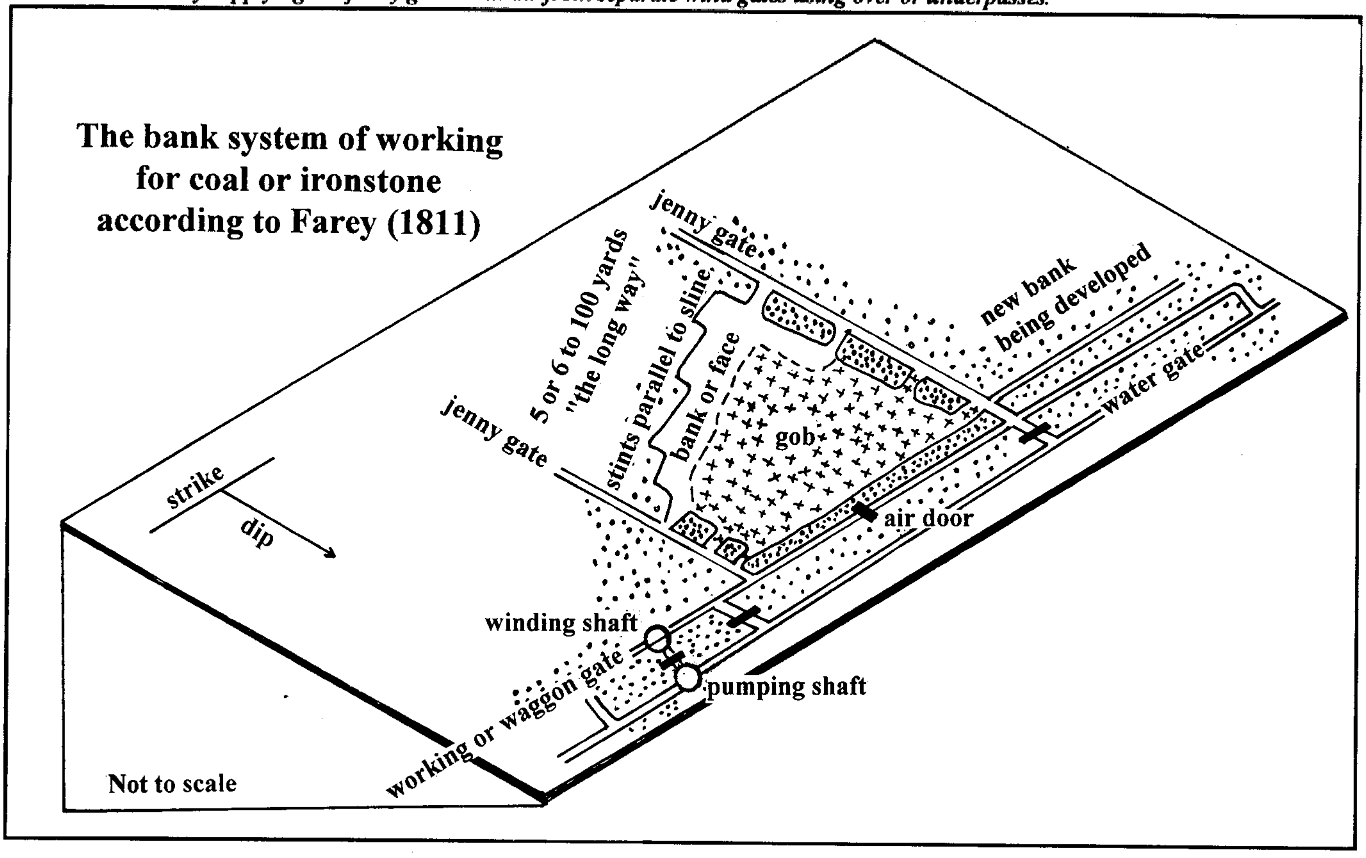
THURLING

Where the ironstone beds were deeper, then different mining methods had to be adopted. In fortunate cases the ironstone formed a thick-enough seam or at least had closely-spaced layers, had the desirable strong roof, and could be *thurled* through, as Farey described it, with pillars left to support the roof, or in a very few cases could be worked together with the coal below. The mode of thurling he described was very simple and could probably cope with a substantial thickness of strata and several "measures" of ironstone at a time. An entry 1½ yards wide was made and carried for some 25 yards from the access gate, the distance probably limited by ventilation requirements, leaving a pillar about 4½ yards wide between it and the next working. Once at the far end of the thurl, a further 2½ yards were worked from the two sides on retreat, leaving a yard thickness between completed thurls. Although he does not mention it, the huge amounts of waste shale and the needs of stability would mean that as the miners retreated, the worked-out space or gob would be packed to the roof with waste. Probably the getting was so organised that material was allowed to fall to the floor in its final position as much as possible, sorted for nodules and only the minimum amount sent out to the day. By doing this, it would also have been possible to provide a working platform to get at higher parts of the working.

WORKING "THE LONGWALL WAY" - IN BANKS

In cases where a limited thickness was extracted, then the ironstone could be worked by means of banks, a local form of the longwall system used widely in coal extraction. Banks were faces as wide as the roof would stand and, as time went on, almost certainly supported temporarily by timbering to allow greater widths and thus a very high extraction proportion. The essential feature of the bank was that it was developed between two access

Fig. 3. The bank system, a form of longwall working, according to John Farey (1811). Bt the mid- 19th century the number of air doors was much diminished by supplying the jenny gates with air from separate wind gates using over or underpasses.



(or jenny-) gates, extended as necessary to provide air, with pillars left either side of the bank between it and the gates to support the gate but with accesses through the gate-sides. As the bank advanced, new openings into the jenny-gates were made. The length, given good conditions, was probably largely limited by haulage considerations, and adjacent panels or banks advanced in echelon behind each other, adjacent panels sharing transport facilities. The face was worked by extracting the softer layer or layers first, and was "stepped" in plan, partly for convenience of adjacent stints, partly to take advantage of natural joints or cleats. Waste, of which again there was a great deal, was packed into the gob behind. By removing as many timbers as possible, the roof was allowed gradually to sag to rest on the pack. This removed dangerous levels of stress from the face, assisted in bringing down the stone once it had been holed, and also forced airflows to go across the working face. In coal mining and at least in other areas for ironstone mining, where suitable, this system probably naturally progressed into true longwall mining, in which the gateside was supported by packs, not pillars (Sawyer 1886 *passim*).

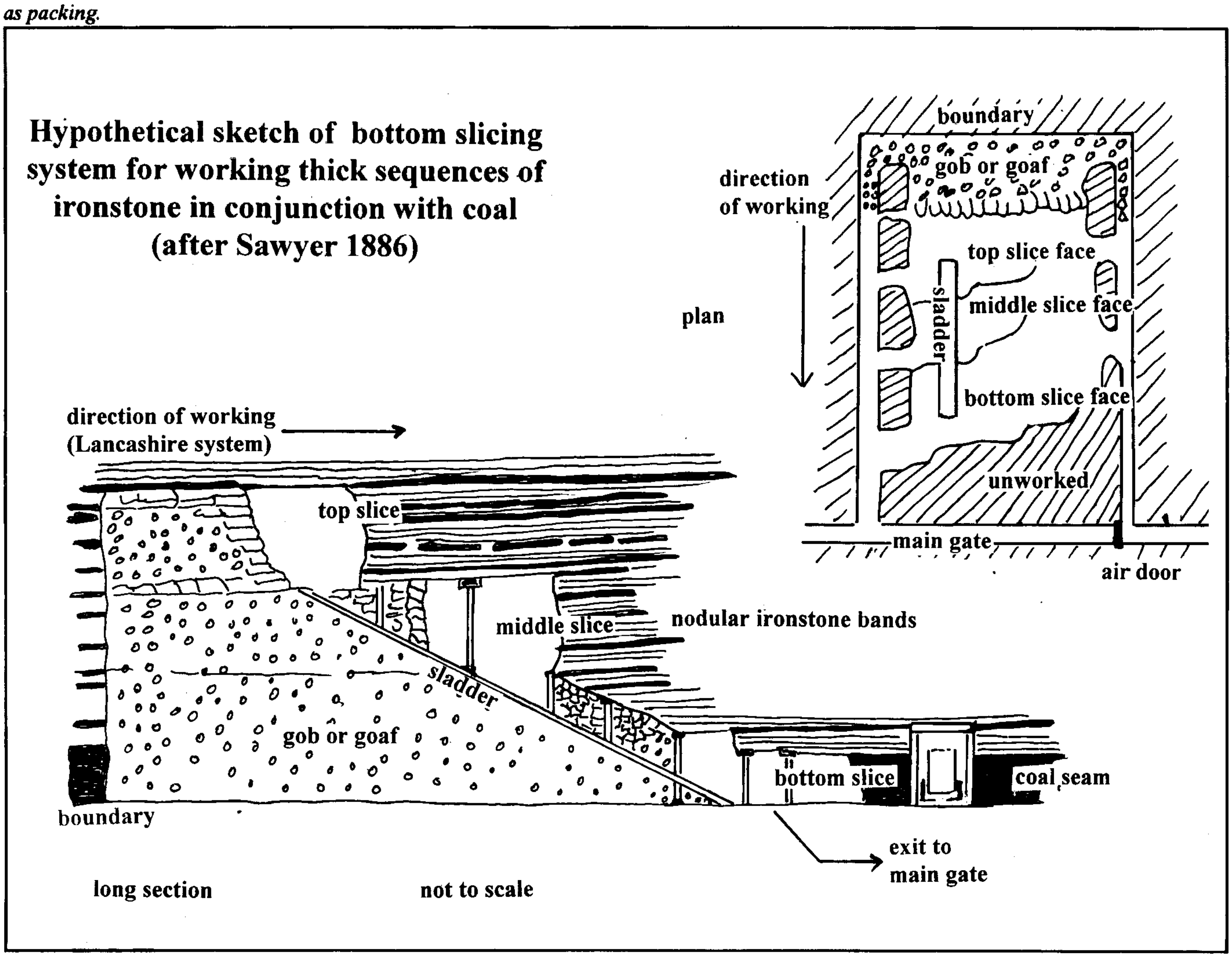
WORKING THICK SEQUENCES BY "BOTTOM SLICING"

Thick sequences, especially those in incompetent ground such as shale, are much harder to work than, for example, thin seams of coal. It is normally very wasteful to work a very thick sequence by thurling because the intervening pillar must be left very wide to avoid failure. An alternative is to devise a system of removing the material in slices, infilling cavities before opening-out another slice. There is very little information about how this was done in Derbyshire (or elsewhere either), but Sawyer (1886), writing on accidents in the North Staffordshire Coalfield provides several diagrams incidentally showing how thick ironstone/shale sequences were worked there, and the hypothetical suggestions below owe much to this source. They would be most suitable for working the Blackshale coal and ironstone.

The Blackshale Ironstone with its great thickness, certainly had special measures adopted to tackle it at depth, on a peculiar plan, as Smyth put it (1856: 43-44). A number of shafts were sunk at small distances apart, commanded by one steam engine, which by means of a large horizontal drum and chains, may be made to wind the material from above twenty shafts at once. An illustration of such an arrangement survives, following an accident in 1865 at an ironstone mine at Whittington. There the engine had both horizontal and vertical axle drums, and wound from depths of up to 200 feet from seventeen shafts simultaneously, later reduced to twelve which was thought safer (Job 1992: 233-35). Similar arrangements may possibly have been used at Butterley, where the shafts for ironstone were, near Codnor Gate for example, similarly closely spaced.

From the shaft bottoms, passages were driven to other shafts for ventilation, and from the passage sides, holes or "stalls" were opened, at the most, about seven by nine yards in area, but with a few feet of wall left between them. The lowest ironstones were

Fig. 4. A system of working thick sequences of coal, ironstone bands and shale in three lifts by bottom slicing. The bottom slice is extracted ahead of the successively higher lifts or slices. Waste and ironstone from the upper slices is passed forward via the sladder for removal or use as packing.



then extracted in the stall, and sufficient waste material left on the floor to allow the men to work the roof of the forward advancing excavation. Where strong enough the adjacent stalls were holed together. When the ground had sufficiently settled, the lower portion was then worked out (Smyth 1856:43-44). Stokes (1878:104) referred only to a kind of irregular pillar and bord working.

These somewhat limited and possibly contradictory explanations are, perhaps, better explained by the information provided by Sawyer (1886). It should be stressed there is has no direct reference to its use in Derbyshire, but it is likely that some form of comparable system was used, especially around Chesterfield and perhaps at Butterley. Whatever the width of stall or bank, which no doubt increased over time, the ground was advanced first at the base of the measures, presumably in the coal, for a convenient height, depending rather on a stable roof than the height of the miner, with almost total removal of coal and any shale waste. The roof could be either self-supporting or supported by temporary timbering. Once advanced sufficiently, a further layer or slice was worked-off above following a few yards behind the lower, rather as if on the underside of a staircase. The material as it was picked down was sorted for useful ironstone and the waste left as a step to work the second slice. Sufficient waste was passed forward, down holes left for the purpose, or down a slide or *sladder* of iron plates to the cavity behind the lower slice, there to be packed so as to provide support for the base or lip of the advancing upper excavation and protecting the miners below as they advanced still further. Thus, as for the bank system, the face was protected from excessive loading and the upper slice(s) were broken down more easily. Smyth, in writing of the need for settlement, was possibly referring to the time for this waste to pack properly, which would be partly a function of the speed of advance, and partly to the effort put into the packing: a wider face would probably allow sufficient time for this without delaying the sequence of operations.

In the accompanying diagrams, the sequence is shown worked in three slices, but there is no reason why more or less should not be used, depending on the total thickness and the presence of good roof beds. As it would have been highly advantageous in terms of stability and ventilation to work by the "Lancashire system", and as it is specifically mentioned by Sawyer in respect of thick sequence working, this has been included. The Lancashire system involves mining on the retreat, first driving the gates to the boundary of the property, then working back from this furthest extent of the extraction area towards the main gates or roadways. Waste material totally infilled the worked-out area, the gob or goaf.

PROCESSING OF THE IRONSTONE

This clearly begins at the working face with the separation of ironstone and waste, with as much waste as possible left in the workings, though much waste (much more than for coal extraction) had to be brought to surface too. It is perhaps this large volume of waste and the considerably higher density of the ironstone compared with other materials in the Coal Measures that required the many closely spaced shafts which are characteristic. Underground the transport systems were much as those for coal: sledges were used by men and boys to move loads down the dip, or wheeled vehicles were manipulated using jiggers (braked gravity-winches), with small horses, asses and donkeys to move waggons in the main roadways or gates.

On bringing to surface, the ironstone had a considerable quantity of clayey matter adhering. Consequently it was stacked into piles near the shaft mouth for a considerable time to weather - probably over a winter to let frost and rain remove the clay. The stones were then picked out by young children (1842 Employment of Children Report). According to Farey (1811 I:395), the ironstone was stacked and sold in "dozens", a rectangular pile about 22 inches high (which would let frost and water enter), a yard wide and three yards long, each pile containing about four and a half tons. A bell-pit (he described them as about 30 feet deep) provided some 12 to 16 dozens, 55-72 tons of ironstone.

After weathering, the ironstone was calcined to remove water and to reduce carbonates to oxide (Pilkington suggested sulphur was burned off too), with a reduction in weight of some 25-30% as a result.. In many cases this was done by heaping and burning with layers of coal slack and since suitable coal was often available at the iron pit, then possibly calcining was often done at the pit itself. The "usual method" was described as placing a layer of coal six to eight inches thick on levelled ground, on top of which evenly sized piecs of ironstone were placed about two feet deep. The top was then levelled by filling in with smaller pieces and a further two inches of small coals placed. Further ironstone was then placed to form a wedge shaped heap and the whole covered with more small coal. The completed heap was about seven feet high and 15-20 feet long. Lighted coals placed at the windward end were used to ignite the pile through which the fire progressed slowly. The result after cooling was a heap of porous ore suitable for the furnace, the whole process taking about a month (Tomlinson's Cyclopaedia II c.1852:76).

In other cases the ironstone was conveyed to a kiln, like a limekiln, at the ironworks and calcined there: such kilns are shown on the 1st Edition OS 1:2500 maps at Riddings Ironworks (at approximately SK 433530), for example. The use of heaps appears to have had one advantage over the kiln: in the latter the ore was broken to a higher degree and since calcined ore below a pea size could not be fed into the blast furnace, there was a higher degree of waste by use of the kiln. The waste was used for garden paths (Farey 1811 I:401).

WHAT REMAINS?

It is fairly certain that substantial evidence is there to be examined in many modern open-cast exploitations, though a very great deal has gone, since the ironstone generally occurred in close proximity to coal and both ironstone working and recent opencasting preferred shallow depths. The bellpits seen by the writer at Tupton noted here and a brief mention of what appear to have been bellpits for both iron and coal near Denby (Griffin 1969) are the only recently reported comments on ironstone mining in Derbyshire.

However there are substantial remains still available at surface. Perhaps the best and most accessible of these is at Carr Wood, Ripley. Here the hollows of bellpits can be seen within the trees and thorny scrub resulting from the working of the Balls Ironstone, which occurs just above the Top Hard coal, which was worked from about 1792 to about 1830. Close by is the route of the tramway which took the ironstone and coal down to the nearby Butterley Ironworks, where the furnace bank and remains of two furnaces are extant. There are bellpits too, again probably from ironstone working, in the woods east of South Wingfield Manor (SK 384548 - permission for access must be obtained from Wingfield Manor Farm). Roy Paulson (pers. comm.) recently recovered a fine example of an ironstone nodule from nearby, which is now in the Peak District Mining Museum.

Butterley and Riddings have extensive remains. Remains of bellpits and closely-spaced shaft mines are visible alongside the Cromford Canal near the former Codnor Park Ironworks, some partially overwhelmed by the huge and spectacular slagbanks of the ironworks (SK 443508). More are found in other wooded areas in the locality (e.g. SK 442502). Possible traces of openworking are visible at Ormonde Fields, near Codnor Castle (SK 432499) and the traces of narrow gauge tramways in that area probaly relate to ironstone mining also - the 1842 Report suggests most at shallow depth. Many bellpits are also reported in woodland areas near Wingerworth. Farey reported enormous heaps of shale waste from the ironstone pits and mines and very good examples of these, mostly of a mid-late 19th century date, can be seen in Riddings (SK 432524) and at Butterley alongside the former railway system (Forty Horse Pit - SK 415516; High Holborne Pit - SK 421504). He commented on the fact that oak trees flourished on such tips and that they should be encouraged since little else would grow. The luxuriant tree growth at both places on the old pits suggests he had a good point. It may be that the presence of lime and magnesia in the iron ores has resulted in a much less acid and more beneficial soil-environment for such growth.

Very often, however, it is not possible to separate ironstone from colliery remains, since both were mined in the same locations. This is especially true of the railways routes, of both small and standard gauge in the Butterly area and in Codnor Park (see Lindsey 1965), though some of the extensive remains of narrow-gauge tramways at Riddings can be followed directly to the calcining kiln site.

CONCLUSIONS

A surprising amount of information is available about the techniques of ironstone mining despite its general neglect by historians of the iron industry. Even so it is fragmentary, and it is necessary to hypothesise on methods of working from the fragmentary information so far investigated.

Further progress in determining clay ironstone mining features is most likely to come from observation of opencast workings and, where possible, by selective excavation around pit or shaft sites. Mining engineers and geologists are the most likely people to help here and it is possible that some may already have photographs of features in opencast sections etc. If so please let me see them (indeed since the writer gave a preliminary talk on this subject at Chesterfield, David Edwards has done just that). There is scope too in documentary sources, though many deal very sparsely with the actual technicalities. Perhaps the most likely are in accident reports where brief details are often noted even in early reports, whilst once the Mines' Inspectorate had jurisdiction, the reports were often very detailed with drawings of the accident scene. For an important industry the clay ironstones have been much neglected: hopefully this account will stimulate more activity, if only to prove some hypotheses expressed here are wrong.

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