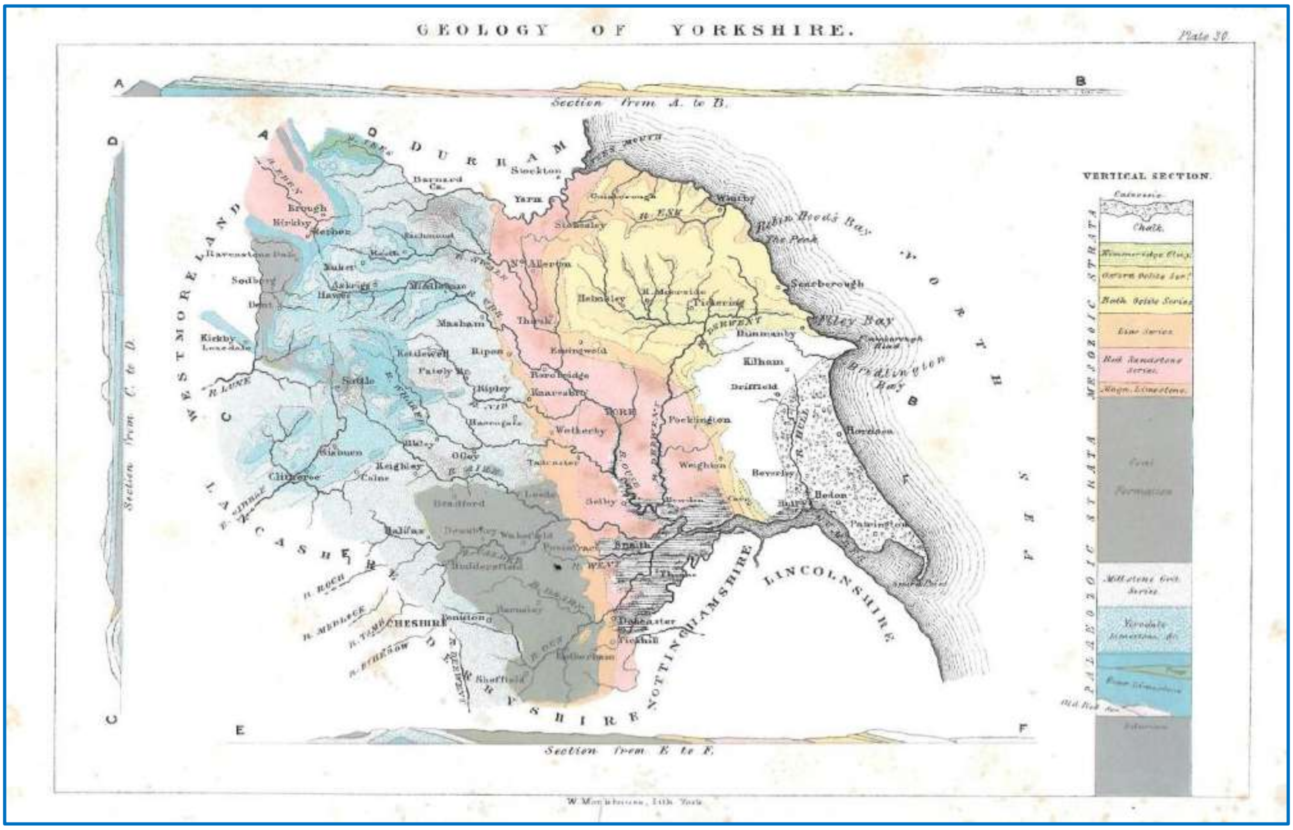
The Genesis of Geology
in
York and Beyond



HOGG 25th Anniversary Meeting

23rd-24th October 2019

Marriott Room, York Explore, Library Sq. York YO1 7DS

History Of Geology Group

Yorkshire Philosophical Society

York Museums Trust

The genesis of geology in York and beyond

HOGG 25th Anniversary Meeting

23rd – 24th October 2019

organised in association with the

Yorkshire Philosophical Society and supported by York Museums Trust

Venue: Marriott Room, York Explore, Library Square, **York YO1 7DS**

PROGRAMME

Wednesday 23rd October

10.00 Registration and coffee

10.30 Start: Welcome and Introduction (house arrangements)

10.40 – 11.20 **Keynote talk**: ***Follow the reptile: Fossil trading on the Yorkshire coast and what it tells us about science and money.***
Roger Osborne

11.20 – 11.40 ***Geological connections in the early Yorkshire Philosophical Society***
Peter Hogarth

11.40- 12.00 ***The Harrogate wells case of 1837 and a gathering of the scientific elite***
John Mather

12.00 – 12.20 ***Scripture and Science: The Dean of York's critique of Buckland and Sedgwick's riposte.***
Margaret Leonard

12.20- 12.40 ***John Phillips and the first chromolithograph geological map in Britain***
John Henry

12.40- 13.00 ***The Yorkshire Boulder Committee – an erratic affair.***
Duncan Hawley

13.00 – 14.00 Lunch

14.00 – 14.20 **HOGG AGM**

14.20 - 16.40 Afternoon 'viewing tours and discussions' : Yorkshire Museum collections
4 x 30 minute sessions + 10 minutes swap-over.

1. ***Kirkdale Cave specimens – fossils from Buckland's Reliquae Diluvianae***
   YMT Assistant Curator Stuart Ogilvy &YPS volunteers
2. ***Yorkshire Museum's William Smith map of England and Wales***
   YMT Curator Sarah King & Duncan Hawley
3. ***Mosaic Smith's map of Yorkshire + Calotype of De La Beche***
   Rod & Margaret Leonard, Project Coordinators
4. ***Yorkshire Jurassic World Exhibition***
   Self-guided tour with specially produced collector/provenance leaflet on exhibits.

19.30 **HOGG 25th Anniversary Dinner** (Optional – self-pay)
Ask Italian Restaurant, The Grand Assembly Rooms, Blake St, York YO1 8QG

Thursday 24th October

Field Day (Optional) - shared car transport

AM **Kirkdale Cave, Vale of Pickering** - visit and virtual tour of the site (inside the cave) of Buckland's main source of evidence for 'Reliquiae Diluvianae'

PM **Rosedale - The Magnetic Ironstone Conundrum –** visit to sites of ironstone discovery, exploring different geological interpretations of ironstone deposits by 'practical men'.

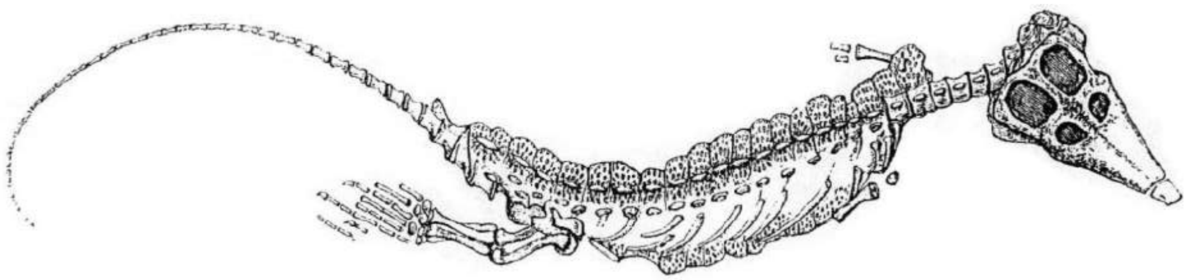
Gentlemen and players: early fossil trading on the Yorkshire coast

*Roger Osborne, High Tide Publishing, 70 High Street,
Snainton, Scarborough YO13 9AJ*

In the late eighteenth and early nineteenth centuries the status of fossils underwent a radical change. This change not only reflected humanity's shifting attitudes to the natural world, it sparked a 'goldrush' in fossil trading on the Yorkshire coast.

In 1758 two Whitby residents found a large fossil reptile and, in a significant development, reported the find to the Royal Society via the Philosophical Transactions. More fossil reptiles emerged from the alum workings, attracting attention from local naturalists. Once naturalists came together to found museums in Yorkshire and throughout Britain locals were keen to find fossils to sell to these burgeoning institutions. In 1824 a fossil teleosaur cost Whitby Museum £7, by 1841 Adam Sedgwick had to pay 200 guineas to a Whitby dealer for a plesiosaur. Other Whitby fossils ended up in York, Dublin, Harvard, Houston and Manchester.

From beautiful curiosities, fossils became objects of scientific interest and huge commercial value. The story of early fossil trading has much to tell us about how 'pure' science is often rooted in money, rivalry, ambition and status.



Teleosaurus chapmani

Roger Osborne studied geology at Manchester University before pursuing a career in printing and publishing. He was commissioning editor for academic and educational books at Macmillan then editor of popular science and medicine at Faber & Faber. Since moving to the Yorkshire coast in 1990 he has been a writer and publisher. His historical works have ranged from a history of democracy to an account of a scientific fraud, and include elements of the history of geology. He has continually sought new ways of representing the past. His books have been published around the world and translated into 10 languages.

He runs High Tide Publishing, which publishes guidebooks to the landscape, geology and fossils of the Yorkshire coast and moors.

Geological connections in the early Yorkshire Philosophical Society

Peter Hogarth, YPS

Two sequences of events converged to produce the Yorkshire Philosophical Society, the important geological collections of the Yorkshire Museum, and to stimulate interest in the geology of Yorkshire.

BUCKLAND ENTERING THE KIRKDALE CAVERN. FROM A CARICATURE BY THE REV. W. CONYBEARE.

The chance discovery in 1821, in the Kirkdale Cave, of a cache of fossil bones of hyenas and hippopotamuses was rapidly followed by an influx of learned gentlemen to the cave, and consequent dispersal of specimens into private collections. Many felt that such interesting specimens should be reassembled into a museum for public – or, at least, learned – perusal. Before the end of the year, four gentlemen of York (who, between them, possessed several hundred of the Kirkdale fossils) met and founded the Yorkshire Philosophical Society: followed shortly by the creation of the Yorkshire Museum.

The second sequence of events started with the presence in Kirkby Lonsdale of William 'Strata' Smith creator of the celebrated geological map. Smith was invited to York to give a series of geological lectures to the nascent Philosophical Society. The lectures were a success, in part because of Smith's nephew and assistant, John Phillips. Phillips was promptly recruited as Keeper of the Yorkshire Museum; he became a dominant figure in the Society and, indeed, in geology. As he put it many years later, 'educated in no College, I professed Geology in three Universities'.

The combination of the Yorkshire Museum, John Phillips, the Yorkshire Philosophical Society and connections forged with the likes of Sedgwick, Murchison, Buckland, and de la Beche, combined to put the Society at the forefront of geological studies in England.

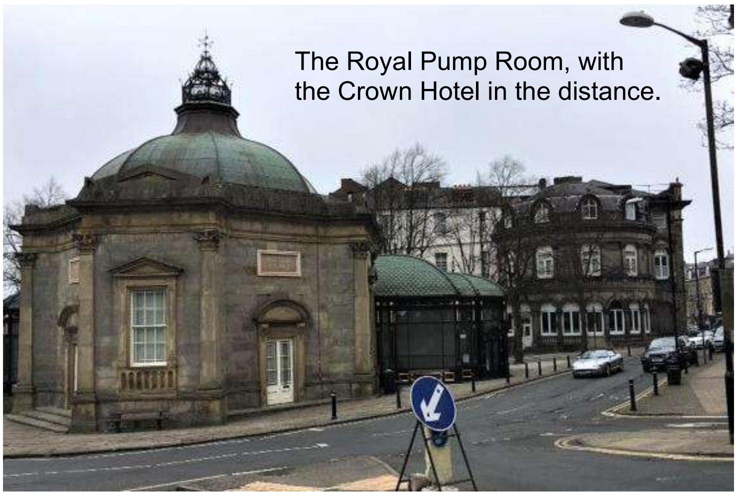
I came to the Biology Department of the then new University of York as a graduate student, and somehow stayed on, eventually retiring as Senior Lecturer in Biology. My main area of research was tropical marine biology, particularly the ecology of mangroves.

Since retirement I have been able to pursue other interests, including historical research. My involvement with the Yorkshire Philosophical Society presented the opportunity to research and write a history of the York Museum Gardens (created by the Society), and I am currently working on a number of other projects related to the Gardens, and the early history of the YPS, in preparation for out forthcoming bicentenary celebrations.

The Harrogate wells case of 1837 and a gathering of the scientific elite

John D Mather, Department of Earth Sciences, Royal Holloway University of London, Egham Surrey, TW20 0EX

On Thursday 14th March 1837, the proprietor of the Crown Hotel in Harrogate appeared before Yorkshire Spring Assizes indicted for a misdemeanour in digging a well in the immediate vicinity of the Old Sulphur Wells at Harrogate and supposedly affecting the flow to the well. The defendant pleaded not guilty. Both sides subpoenaed a distinguished group of scientific experts to support their case. Amongst these were William Smith, John Phillips and John Dalton for the prosecution and Thomas Sopwith, John Johnstone and Reid Clanny for the defence. Unfortunately, for the interested persons who attended, anticipating an intellectual treat, the two sides rapidly reached an accord, without hearing any of the experts. Following the hearing, the witnesses on both sides dined together that evening, at what Sopwith later described as one of the most pleasant dinners he had ever attended. Both Smith and Dalton gave addresses which gave their uninhibited views on the progress of the sciences of geology and chemistry respectively. The statements of the scientific experts were latter collected and published by the Harrogate antiquarian William Grainge and provide a snapshot of contemporary views on the geology and origin of the Harrogate mineral waters.

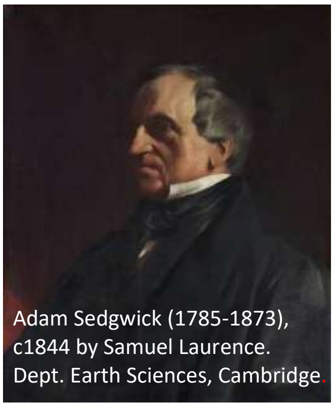

The Royal Pump Room, with the Crown Hotel in the distance.

A graduate of Liverpool University, where his Ph.D. was on Scottish metamorphic rocks, John joined what is now the British Geological Survey (BGS) in 1966. He was assigned to the Hydrogeology Unit where he was soon rewarded with a 2 year posting to the Caribbean. Research on groundwater pollution and waste disposal followed, before he was seconded to NERC headquarters for three years. He became Chief Hydrogeologist in 1986 and an Assistant Director the following year. Moving to Royal Holloway University of London in 1990, as Lyell Professor, he continued his research on groundwater and began to work on the history of hydrogeology, which he recognised as sadly neglected. A particular interest has been the pre-1900 development of ideas on the origin, prospecting for and development of groundwater supplies. Now living in Devon, he continues to write and throws functional stoneware pots in a shed in his back garden.

Scripture and Science: The Dean of York's critique of Buckland and Sedgwick's riposte

Margaret Leonard, YPS

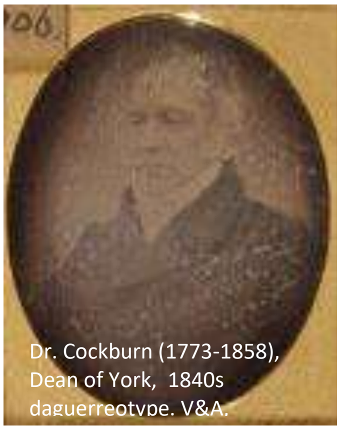
In 1844, the British Association for the Advancement of Science held its annual meeting in York for the first time since it was founded here in 1831. Now a very large gathering, the various sections held their meetings in a number of different buildings around the city. The Geological section, whose organising committee reads like a roll-call of the great and the good in 1844 Geology, met in the Hospitium, in the grounds of the Yorkshire Museum. Murchison, Sedgewick, Phillips, De la Beche were all involved, though sadly Buckland was unable to attend as his daughter had recently died.



Adam Sedgwick (1785-1873), c1844 by Samuel Laurence. Dept. Earth Sciences, Cambridge.

Papers were presented on many of the hot topics of the time. Murchison spoke on the Silurian Rocks of Scandinavia and Russia, De la Beche on the progress of the Ordnance Geological Map of England, soon to acquire its independent status as the British Geological Survey. Papers were presented relating to the search for the North West passage and the proposed Panama Canal, and many palaeontological discoveries were reported.

The conference report, compiled by Phillips, gives at least an outline of each of the above. The paper which caused the most interest, however, is represented only by its title 'The Very Rev. the Dean of York's Critical Remarks on certain Passages in Dr Buckland's Bridgewater Treatise'. The newspapers were not so coy, however, so we can learn a little of Dean Cockburn's interesting geological theory, and of Sedgewick's firm rebuttal. Consideration will also be given to the background to this outburst, and an interesting connection will be drawn with a later clash between religion and science.



Dr. Cockburn (1773-1858), Dean of York, 1840s daguerreotype. V&A.

After studying at Imperial College, I taught maths in a comprehensive school in Humberside, whilst raising our two children. In 1992, my husband's career took him to the USA, and I joined him there. After trying a number of volunteer roles, I took a post at the Baltimore Museum of Industry, eventually becoming Director of Education.

In 2002 we sold our house, bought a sailboat, and spent the next four years cruising the Eastern seaboard of the USA and the Caribbean islands, before sailing back to England in 2006, and settling in York

As members of the YPS, we became involved in commissioning the Geological Map mosaic. The research for this introduced us to the history of Geology. My current project, on the photographs taken at the 1844 conference of the British Association, has provided the opportunity to look at a cross-section of the ideas current in geology at that time.

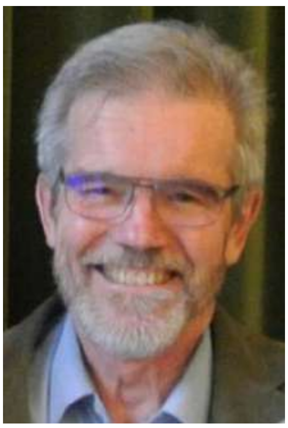
John Phillips and Lithography

John Henry, Nineteenth Century Geological Maps,
71a Oxford Gardens, London W10 5UJ john@geolmaps.com

During the nineteenth century, the process of geological map making progressed from hand-coloured engraved maps to colour lithography, or chromolithography. The remarkable career of John Phillips (1800-1874), nephew of William Smith (1769-1839), encompassed the major part of this period of geological map-making and illustration. While not a major player in the field of printed illustration and mapping, his story is a vignette of the progress in Great Britain of lithography in the 1800s.

Phillips as a teenager experimented with lithographic printing with a view to assisting his uncle and supporting himself during Smith's time in debtors' prison. As his opportunities and experience expanded in Yorkshire, he illustrated his first publication in 1829 with a hand-coloured lithographed map of the county. Decades later he published the first chromolithographed map, in a 'popular' account of the landscape and geology of Yorkshire, the first colour printed geological map in England. Late in life, his book on Mount Vesuvius included a colour lithographed map. During his career his maps illustrating published books and articles havered between hand colouring and colour printing, and between engraved and lithographed basemaps, depending upon his publishers who did not embrace colour lithography as did publishers and geological surveys in Europe and the new colonies. This interest but ambivalence is reflected in John Phillips' career.

Geological Map of the E. Part of Yorkshire, drawn by J.Phillips, 1829. The base map is lithographically printed. Courtesy of the Geological Society of London.



John was educated at the University of Waterloo, Ontario and ITC, International Institute for Aerial Survey and Earth Sciences, Enschede, Netherlands.

He worked for consulting engineers, ARUP, producing preliminary engineering geological maps from the interpretation of aerial photographs and satellite images to identify potential problems and to organise ground investigations for large construction projects in the UK and abroad for thirty years. Since retiring, he continues to consult especially where historic air photos are key to understanding difficult ground conditions. He has developed an antiquarian business dealing in historical geological maps, sections, illustrations and books. Currently, John is secretary of HOGG.

The Yorkshire Boulder Committee – an erratic affair

Duncan Hawley, 73 Marlcliffe Road, Sheffield S6 4AH duncan.hawley@gmail.com

John Phillips was the first to report on erratic boulders in Yorkshire at the 1836 British Association meeting. He wrestled with understanding how rock from Cumbria came to rest in the Vale of York. In 1840, when Louis Agassiz first proposed "perched bowlders" as evidence of past ice sheets, interest increased in the distribution of erratic boulders across northern Britain. Following Scotland's example in 1871, the BA established a Boulder Committee for England, Wales and Ireland in 1873 to record members' findings. Initial results were patchy, and the BA appealed for more observers. In 1886, the Geology section of the Yorkshire Naturalists' Union (YNU) initiated a Yorkshire Boulder Committee (YBC). The YNU was a federation of local natural history societies with a combined membership of 2,310. The YNU was a 'liberal' union that embraced middle and working classes, gentlemen and ladies, together with professional geologists in pursuit of natural history as science. The YBC gave local groups and individuals interested in geology a route to record their pursuits and gain a respected reputation. The professional geologists identified erratics and advised on their provenance and did their own field work.

Geologists at Louth, May 1896

In 1906 the YBC was re-named "The Glacial Committee" to reflect the wider interests of its members; but, from then on the search for erratics all but ceased, save for the work of the East Riding Boulder Committee which now reported as the Hull Geological Society. Reports diminished to a paragraph, the last appearing in 1936. The BA Boulder Committee ceased with the outbreak of WW1.

In 1908, J.H.Howarth, Secretary of the YBC for many years, claimed "… the whole county has been examined, and much of it again and again. … there is hardly an acre of ground, certainly not a square mile, which has not been searched for traces of glacial phenomena, by members of the Committee … . The open moors and fells, the secluded glens and wild mountain gorges, have all been hunted. Railway cuttings, trenches for waterworks, deep borings, drainage operations, brick-works, building foundations — in short, sections of all kinds (many made for the purpose) have been noted and watched with patient and persistent care."

The results of these searches were plotted in 1888 and 1892 on maps which have been lost. However, Howarth's 1908 paper 'The Ice-Borne Boulders of Yorkshire' in *The Naturalist*, included a map and detailed accounts of YBC records, classified by provenance and by petrographic type. Little used until 2005, the U. of Sheffield's BritIce glacial mapping project incorporated the YBC's records to compile regional ice streams.

The YBC was the prime example of devolved local activity contributing to geological science as envisioned by the BA when it appealed for local observers of erratics. The sheer volume of YBC records demonstrated the fruitfulness of aligning with field naturalists at a time when enthusiasm for natural history in the field was perhaps at its height. The result was a truly Yorkshire erratic affair.

Duncan was first exposed to the 'greats' of the heroic age of geology at school, then UCL where he was President of the student Greenough Club in his final year. He has enjoyed a career in education, teaching at state and independent schools, at a field centre in the Forest of Dean and at university in Swansea. He has received the Geographical Association's Awards for Excellence (2012) and for Excellence in Leading Geography (2018). He is past Chair of the Earth Science Teachers Association and current Chairperson of HOGG. Duncan works on the geology of the Old Red Sandstone and has contributed to the BGS maps for Brecon, Talgarth and Hay-on-Wye. He is involved in geo-conservation through the Sheffield Area Geology Trust. He has a particular interest in the development of early geological maps.

AFTERNOON SESSIONS
at
Yorkshire Museum

Kirkdale Cave Specimens – fossils from Buckland's *Reliquiae Diluvianae*

Stuart Ogilvy, Assistant Curator, York Museum Trust & YPS volunteers

Kirkdale Cave has a special place in British palaeontology as William Buckland's first, and classic, fossil hyena den. In 1821 bone and teeth remains were noticed being used for road repairs. They were traced back to a cave in Kirkdale, near Kirkbymoorside. The cave was excavated the following year, and the specimens became the basis of the collections of the recently formed Yorkshire Philosophical Society.

The remains came to the attention of Rev. William Buckland of Oxford University. He realized that they had come from a hyena den. He also stated that they had been there for a very long time, possibly for thousands of years. This was a radical view at the time and went against conventional clerical thinking. These controversial views were published in his book, *Reliquiae Diluvianae*. This gave rise to a debate between early geologists and the church. The argument was eventually resolved by Adam Sedgwick at a meeting held in the Hospitium in the Museum Gardens in which the Yorkshire Museum sits.

Kirkdale Cave is now recognized as one of the most important Ipswichian Interglacial sites in Britain. The fauna indicates a warm and relatively damp climate, and contains hyena, straight-tusked elephant and hippopotamus. Many of the bones are characteristically pitted giving them a "peppered" appearance. This has been caused by the bones being gnawed by the hyenas.

MS figure to accompany Buckland (1822). Account of an assemblage of fossil teeth and bones of elephant, rhinoceros, hippopotamus, bear, tiger, and hyaena, and sixteen other animals; discovered in a cave at Kirkdale, Yorkshire, in the year 1821: with a view of similar caverns in various parts of England and others on the continent, *Philosophical Transactions*. Drawn by Mary Morland. Courtesy of Royal Society archive, PT/73/9/18.

The geological collections of the Yorkshire Museum Trust are internationally famous, with over one thousand type and figured specimens. There are over 100,000 fossil specimens with a comprehensive Yorkshire coverage with particular strength in the Carboniferous period, and the Mesozoic and Tertiary eras. The mineral collections number over 5,000 specimens and there are more than 7,500 rock specimens. The tempest Anderson photographic collection is internationally important, particularly for its vulcanological content.

The Yorkshire Philosophical Society William Smith Map

Duncan Hawley and Dr Sarah King, Yorkshire Museum.

"On one occasion, early in 1824 … Dr. Matthew Allen of York … was introduced to Mr. Smith, and … mentioned the circumstance to some members of the Yorkshire Philosophical Society, then lately formed … The consequence was an application from the President of the Society (the Rev. Wm Vernon Harcourt) to Mr. Smith to deliver a course of lectures on geology in York … New maps were coloured, and sections drawn … ". (John Phillips ,1844, *Memoirs of William Smith LLD.*, p. 107).

The William Smith map '*A Delineation of Strata of England, Wales and parts of Scotland*' that now hangs in the Yorkshire Museum was one of the 'new maps'. Several colour features on the YPS map make it an interesting variant of Smith's 'big' map. The YPS map was not assigned a 'number' and does not bear his signature under the cross section. Maps up to March 1816 were numbered and signed and four distinct series can be recognized (I to IV); maps after this date were all unnumbered and unsigned and classified as Series V. However, the YPS map differs from other known Series V maps. It has some features in common with Smith's reduced scale map issued in March 1820. Some geological boundary detail is very similar to locations on Smith's County Maps issued 1819-1824, particularly in the North of England. Coral Rag is marked on the YPS map, although in several places the geological boundary and outcrop differ from that shown on his County map of Yorkshire issued in 1821. In the northern counties (Northumberland, Durham, Westmorland), trap and basalt outcrops are featured on the map but with some boundary variations from Smith's maps for those counties, issued in 1824. However, the Cheviot Granite marked on the Northumberland county map does not feature. The geology of the Isle of Wight on the YPS map is comparable to a Smith version C, which appears on the later Series V maps issued in the 1830s. However, the version C colouring is not known from any other map known to have been issued in the 1820s.

The colour washes used on the map are of interest. In particular, many areas originally coloured green have degraded and appear as a blue shade. The most likely primary cause of this degradation is exposure to sunlight during display. However, it may also indicate a lapse in the quality of the colouring demanded by Smith on his earlier maps, although the later Series V maps are coloured to a very high standard. Lastly, some of the geology and colouring on the sheets making up the YPS map do not match; this suggests the map was not produced as an entity, but that some of the fifteen component sheets, if not all, had already been coloured.

The viewing of the YPS Smith Map at this meeting aims to explore the some of these features and explain the significance and importance of this unique Smith map by putting the features of the map in the context of its original acquisition and use.

References

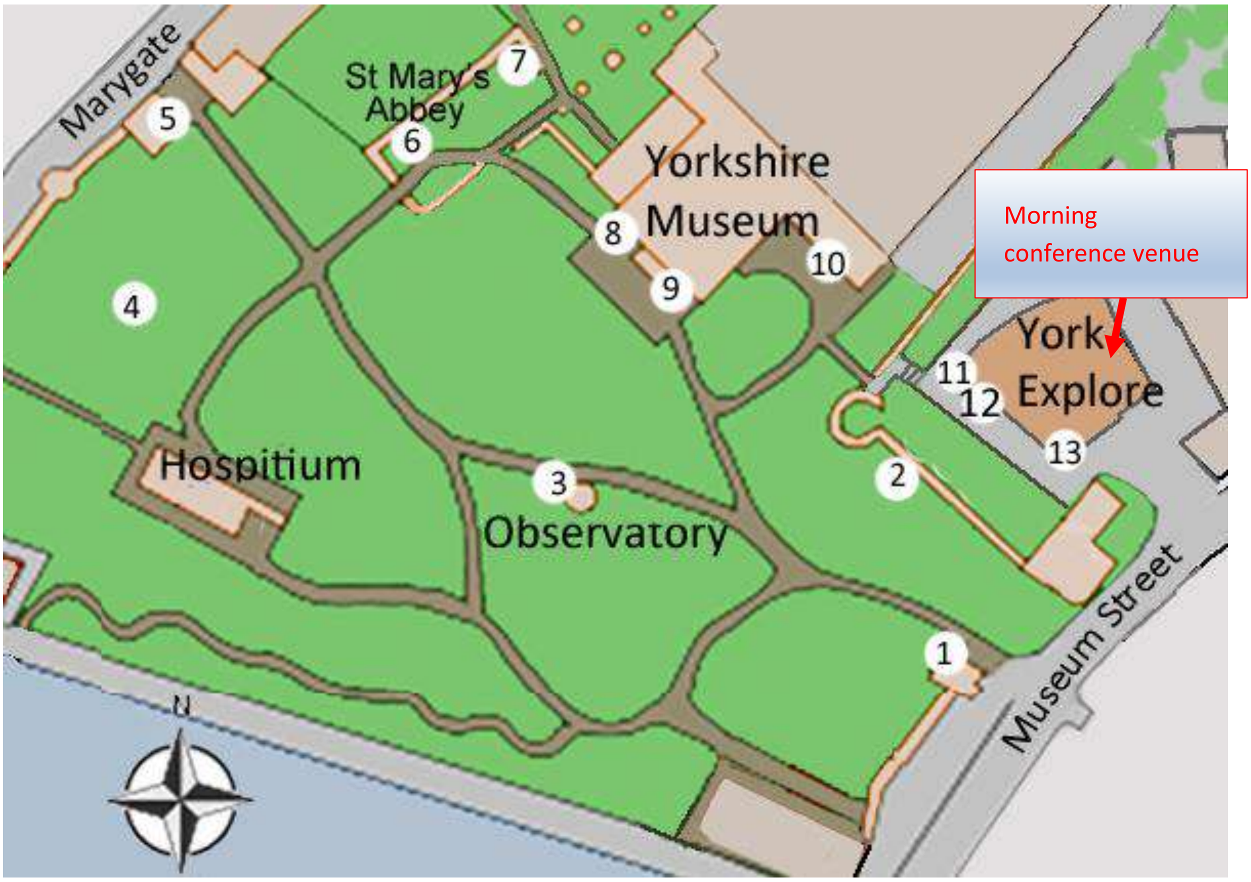
Sharpe, T. (2016). William Smith's 1815 Map. A Delineation of the Strata of England and Wales: its production, distribution, variants and survival. *Earth Sciences History*, 35 (1), 47-61.

McIntyre, R. (in press). Trap Rocks on William Smith's Maps. *Earth Sciences History.*

See back cover for an illustration of the YPS's copy of William Smith's map, *A Delineation of the Strata of England and Wales with part of Scotland*.

Calotype locations

Margaret and Rod Leonard, YPS



1. Information board
2. Henry Baines
3. Sir John Herschel
4. Sir Henry Thomas De la Beche
5. Mrs Harcourt
6. William Etty, RA
7. Photographers David Octavius Hill and Robert Adamson
8. Archbishop Edward Harcourt
9. Sir John Johnstone
10. The Baines family
11. William Scoresby
12. Charles William Peach
13. Dr Simpson

Sir Henry De la Beche (1796-1855), calotype 1843.

Geological Map Mosaic

Rod Leonard, YPS

This YPS/YMT joint project celebrated the bicentenary of William Smith's famous 1815 geological map, by installing a walk-on mosaic of the Yorkshire part of the map. The stunning artwork created by artist Janette Ireland can be admired in Museum Gardens, behind the ruins of St Mary's Abbey.

We placed boulder-size samples of the rock types identified by Smith in the surrounding flower border. Samples of the two clays, Red Marl and boulder clay, have been fired into ceramics and mounted on concrete plinths. Successive mudstone samples representing Smith's clunch clay stratum have reliably demonstrated the effect of weathering and erosion!

Mosaic strips of the pebbles, used to represent each rock type, have been placed in front of each sample, to make a link between the samples and the main mosaic. Information boards explaining the project are on the nearby pavilion, and explanatory leaflets can be obtained from the YPS. Further information can be downloaded from the YPS website.

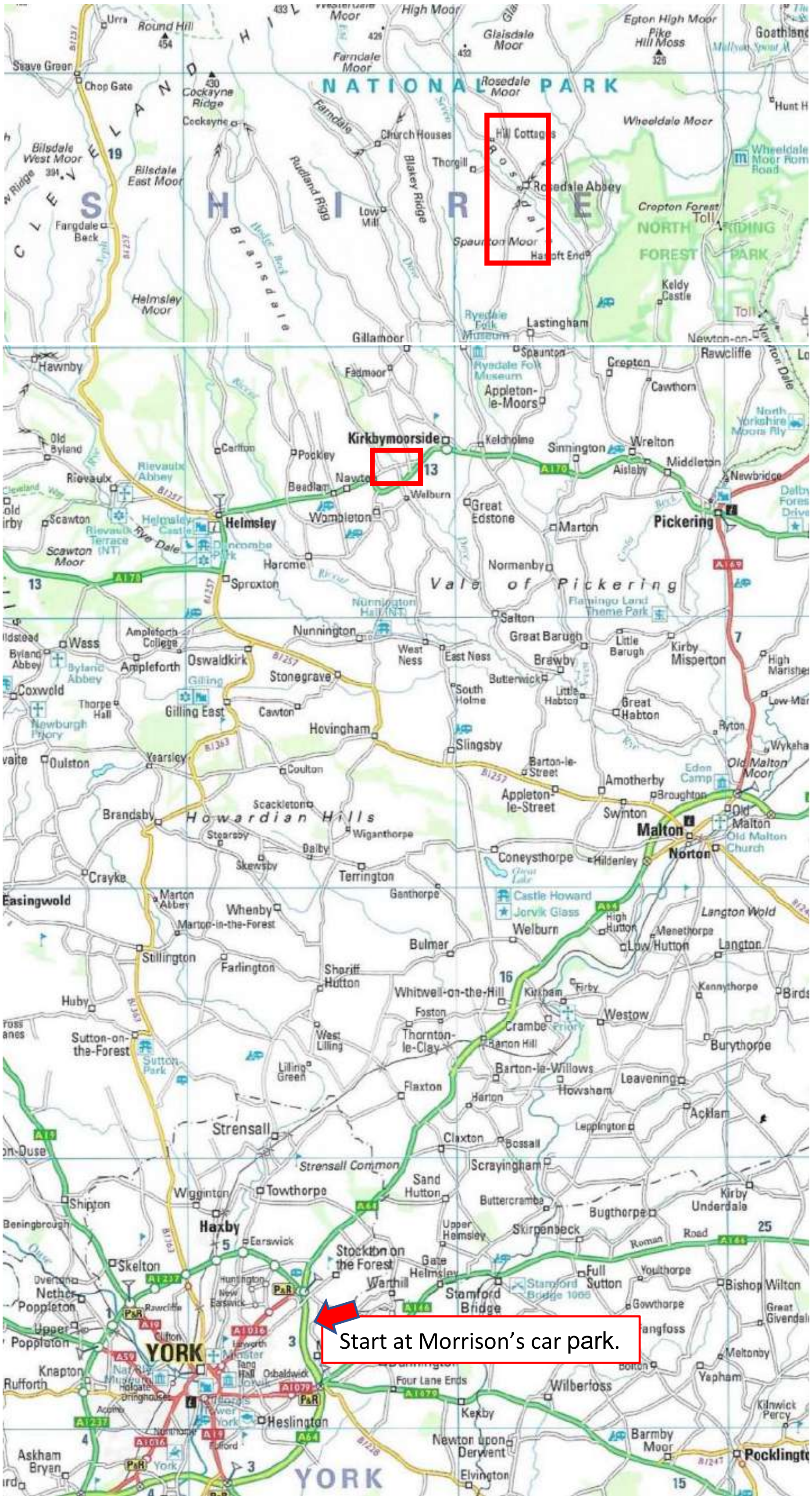
The mosaic is now one of the most popular stops for York tourist guides, and has proved an attractive educational tool and an interesting introduction to Yorkshire geology for people of all ages.

The project has also spawned and funded a number of related YPS initiatives including the formation of a YPS Geology Group; the John and Anne Phillips Prize at the University of Hull; a blue plaque for John Phillips; a headstone on John Phillips' grave; and support for HOGG and YGS events in York.

Although my wife Margaret and I had two children while I was on a student grant, I obtained a London PhD in chemical engineering. I started work as a research scientist in the pigment industry, which led to a varied career- I successively managed plant technical, process development, production, and project engineering departments. I ended up in Baltimore, Maryland as vice-president of R&D for a global chemical company. When young, Margaret & I had made a pact to retire early and do something mad. We bought a 38 ft sailing boat, taught ourselves to sail, and spent 5 years exploring the US East Coast, the Bahamas, and the Caribbean before sailing back to England. We settled in York, and I am currently the Treasurer of the YPS. With my wife, I have organised YPS study tours and worked on several fascinating projects, including the William Smith map mosaic, the Gardens Book, and the Calotype Project.

DAY 2 – FIELD EXCURSION

Separate field excursion guides will be issued for the two sites visited.



Itinerary		
Stop	**Location / Activity**	**Time**
	Leave Morrison’s carpark, Foss Islands Road, York YO31 7UR	09.30
	Arrive at St Gregory’s Minster Kirkdale YO62 7HF. Walk to Kirkdale cave	10.30
1	Kirkdale Cave - viewing and discussion	10.40
	Travel to Chimney Bank Top via Hutton-le- Hole and Loskey Beck	12.00
2	Arrive Chimney Bank Top (ngr SE 721948) – view over Rosedale – general briefing	12.30
	Walk down incline to Magnetic mines	13.00
	Arrive and View Magnetic Mines	13.30
	Arrive Chimney Bank Top (up incline) and travel to Rosedale East	14.20
3	Arrive Rosedale East (SE 708977) and Walk to Rosedale East Mines (SE 706981)	14.50
	Explore Rosedale East Drift	15.20-16.00
	Return to York	16.30
	Arrive York (Railway station)	18.00

Please arrange packed lunch, or there will be an opportunity to purchase sandwiches, etc. at Morrison’s before 09:30 departure.

YORK MEETING – Registrants*

Name	Affiliation	Field visit
Keith Adkins	YPS	
Michael Alexander	YPS	Yes
Jenny Bennett	HOGG	Yes
Malcolm Birtle	HOGG	
Jay Bosanquet	HOGG	Yes
Cynthia Burek	HOGG	
Tim Carter	HOGG	Yes
Stephen Donovan	HOGG	Yes
Chris Duffin	HOGG	Yes
Peter Ellenger	YPS	Yes
Jane Hanstock	YPS	
Duncan Hawley	HOGG	Yes
John Henry	HOGG	Yes
Peter Hogarth	YPS	
Robert Jenkinson	YPS	
Margaret Leonard	YPS	Yes
Rodney Leonard	YPS	Yes
Cherry Lewis	HOGG	Yes
John Mather	HOGG	Yes
Susan Newell	HOGG	Yes
Roger Osborne		
Martyn Pedley	HOGG	
David Ridgeway	YPS	
David Rowe	YPS	
John Saul	HOGG	
Donald Southall	HOGG	
Hilary Southall	HOGG	
Colin Speakman		
Anthony Spencer	HOGG	
Brit Spencer	HOGG	
Anne Spurgeon	HOGG	Yes
Ian Stead	HOGG	
Sheila Stead		
Paul Thornley	YPS	Yes
Richard Trounson	HOGG	Yes
Geoffrey Walton	HOGG	
Mrs I Wood	YPS	

*as of 13th October

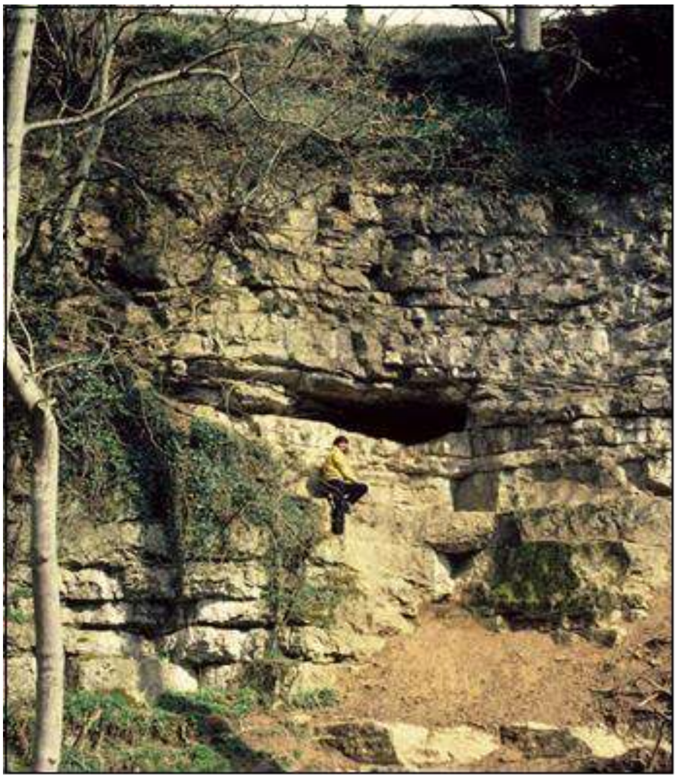
The YPS copy of William Smith's map, *A Delineation of the Strata of England and Wales with part of Scotland*. Image courtesy of York Museums Trust : http://yorkmuseumstrust.org.uk/ : CC BY-SA 4.0 Accession No. YORYM : 2004.25

The genesis of geology in York and beyond
HOGG 25th Anniversary Meeting
Thursday 24th October
Field Excursion Notes

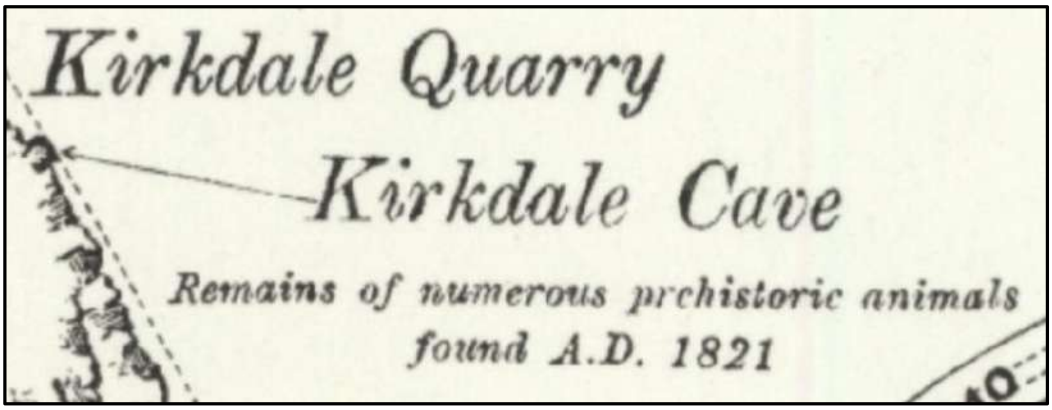
Thursday 24th October

Field Excursion Notes

KIRKDALE CAVE,
nr. Kirkbymoorside



https://maps.nls.uk/geo/explore/#zoom=18&lat=54.2622&lon=-0.9599&layers=168&b=1
O.S. Yorkshire 1:2500 – XC.1 and XC.2 – revised 1910, published 1912.



Extract from: "Records of warfare…embalmed in the everlasting hills": a History of Early Coprolite Research

MERCIAN GEOLOGIST 2009 **17** (2), 101-111

Christopher J. Duffin

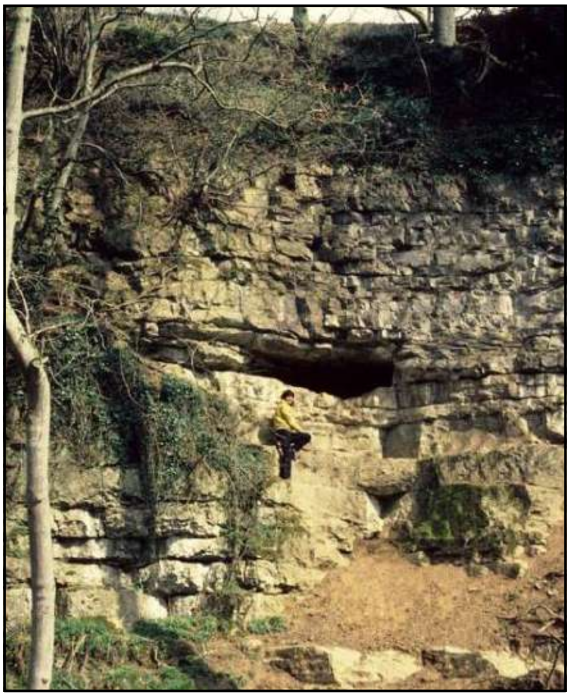
Abstract: Although 'coprolite'was introduced as a term for fossil faeces by William Buckland in 1829, specimens had been described and figured in earlier literature. John Woodward described specimens from the Chalk as fossil larch cones a century before Buckland's work, an identity later confirmed by James Parkinson in 1804. Gideon Mantell described more Chalk specimens in 1822, whilst François- Xavier de Burtin described further spiral forms from the Brussels area as fossil nuts. Buckland first identified fossil hyaena faeces from the Ipswichian cave deposits of Kirkdale in Yorkshire, and then applied his experience to specimens from the Jurassic of Lyme Regis and the Rhaetic Bone Bed of the Severn estuary area. He developed a nomenclature for the specimens that he described, the first such attempt in ichnology. A rich network of domestic and foreign colleagues and correspondents either supplied him with information and further specimens, or applied his conclusions to their own material. Buckland's coprolite research engendered good-natured ribaldry from his colleagues.

The first half of the nineteenth century was a time of radical change in thinking amongst the natural sciences in general, and in geology in particular. A cutting edge contributor to this rapid pace of conceptual change was William Buckland who worked tirelessly as a politician for science, gave many a helping hand to up and coming colleagues, developed a rich network of contacts and friends, and acted as a popular figurehead for geology. Among the many innovations for which he was at least partly responsible was the growing appreciation that the fossil record sampled a diversity of once living communities, rather than being the chaotic record of a universal deluge. It was Buckland who first recognized that in the same rocks that sported the panoply of body fossil such as shells, teeth and bones, there were also traces of the daily activities of once living organisms – footprints and faeces (Duffin, 2006). Coprolites were first identified by William Buckland, who also gave us the name, effectively making him a founder of palaeoichnology. Kirkdale Cave

William Buckland was born the eldest son of the Rev. Charles Buckland on 12t.h March 1784 at Axminster in Devon (Rupke, 1983; Duffin, 2006). In 1813, Buckland was appointed Reader in Mineralogy and then Reader in Geology in 1818. Quickly establishing himself as a popular lecturer, he illustrated his talks with the liberal use of specimens, maps and sections, holding the audience not only with the innovative approach and scientific content of his lectures, but also his rather theatrical style and sense of humour. Completing something of a 'Grand Tour' of European geology in the company of W.D. Conybeare and G.B. Greenough, he spent some time with August Goldfuss who was engaged with the careful excavation of the bone-bearing sediments in the cave floor at Gailenreuth near Muggendorf in German Franconia

"Little did the boy think, who stepped amongst the bushes, with which the mouth of the Cave was overgrown; or the woodman, when felling the oak; that he was walking on a spot, which in some future time, would interest the literary world, and draw many from the smoke of populous and polished cities and towns, and from the retired cloisters of colleges, to explore a Cavern, then unknown, and to visit a situation, which before had been comparatively unobserved! But unexpected circumstances every day unfold some mysteries, and give fresh stimulus to the energies of the human mind." (Eastmead, 1824 p4).

His experience in Germany was to hold Buckland in good stead when he later examined cave deposits at first hand in Yorkshire – deposits that would, indeed, "give fresh stimulus to the energies" of his mind! Quarrying of oolitic limestone was taking place near the small village of Kirkdale, a few miles away from Kirby Moorside in Yorkshire. During the summer of 1821, John Gibson (George, 1998), a manufacturing chemist, was visiting friends in the area. He noticed large blocks of limestone being used to repair the roads; scattered between them were various pieces of bone and tusk. Gibson traced the origin of the material to the small quarry by the side of Hodge Beck (SE678856), adjacent to Kirkdale Church. Believing the remains to have come from modern cattle which had either succumbed to the disease 'murrain' (probably Rinderpest), a highly infectious viral cattle plague, or had fallen into an open chasm, the quarrymen had scattered them as aggregate on the local roads. The land owners (the Welburn Estate and a local solicitor) generously gave permission for the cave contents to be fully excavated, hoping that the bones and teeth would, "fall into the hands of such persons, who would deposit them in public institutions or otherwise take care of them, to preserve the interesting memorials of this wonderful cavern" (Eastmead, 1824 p7). Keen amateur geologists, collectors and enthusiasts were happy to oblige and gathered up some of the material; local surgeon, coroner and apothecary, Thomas Harrison also discovered the cave in the autumn of 1821 (*Gentleman's Magazine*, February 1822), while George Young and his co-worker John Bird, and Rev. William Eastmead an independent minister in the village, all collected from the site. Retired colonel William Salmond reputedly funded and superintended the excavation, and executed the plan drawing of the cavern used in subsequent publications. On December 7th 1822 Salmond met with his colleagues Anthony Thorpe and James Atkinson, a retired surgeon, in an attempt to bring their various collections of Kirkdale fossils together in a suitable repository; hence the Yorkshire Philosophical Society was born. Gibson was credited with completing the bulk of the excavation and accumulating a huge collection which was shown, among others, to James Parkinson. Other material found its way into a wide range of personal collections and public institutions.



Entrance to Kirkdale Cave today.

It was Edward Legge, Bishop of Oxford, who eventually informed Buckland about the discoveries at Kirkdale. Joseph Pentland was told of the finds. The Irishman was working in the laboratory of Georges Cuvier, Parisian father of comparative anatomy who, at that time, was engaged in writing the second edition of his *Recherches sur les ossemens fossiles*. William Clift, curator of the John Hunter Collection at the Royal College of Surgeons, had also written to Cuvier, sending him some drawings of the better material from Kirkdale. Pentland wrote to Buckland on 26 November 1821, urging him to procure some specimens from Kirkdale for the French Professor. Buckland accordingly visited the cave in December 1821, and joined the team. At around 75m long, 4m high and up to 2m wide (Fig. 5), this cave was smaller and contained thinner deposits than those he had seen during his visit to Germany. Buckland's excited descriptions of the cave to his correspondents refer to a profusion of the comminuted, trampled bones and teeth of hyaenas, mixed together with a host of other species, including "Elephant, Rhinoceros, Hippopotamus, Horse, Ox, Deer, Fox and Water Rat", forming a sort of pavement over the cave floor. A full faunal list is given by Boylan (1981). Buckland went on to conclude that the assemblage represented a hyaena den, analysing breakage patterns of the bones to prove that they were from carcasses dragged into the cave and broken by feeding action. In doing so, he was the first person to conduct anything like a rigorous study of biostratinomy.

Buckland was impressed by the fact that bone debris was strewn all over the cave floor, including the deepest recesses of the cavern, and that the walls and bone fragments had been polished by the passage of the predators through the cave. His ecological explanation of the fauna as a hyaena den was not universally accepted; there was some tension between Buckland and George Young, for example. Young preferred the notion that the accumulation of bones was part of a diluvial (flood) deposit and left the excavations as a result of the difference of views.

Many did embrace Buckland's view, however, and relished the idea of antediluvian hyaenas roaming the Yorkshire countryside in search of prey. Similar hyaena dens have been described much more recently from the volcanic plateau of Al-Shaam Harrat in Jordan (Kempe et al., 2006). The Dabié Cave (Fig. 6), with its almost unbroken covering of bone scatter, gives an impression of the sight, albeit partially obscured by marly sediment and stalagmite, that must have met Buckland's eyes as he entered and excavated Kirkdale cavern (Fig. 8).

Nestling between the bones and teeth, much as on the floor of Al-Fahda Cave (also in Jordan, Fig. 9), Buckland noticed some small balls of a white material. Intrigued as to their nature and origin, he wondered if they might be fossilised faeces deposited by the hyaena (Fig. 10). He referred to them both in his letters and in print as *Album Graecum*, an old apothecarial term pertaining to dog faeces which demonstrate the property of turning white on exposure to air. Rather frighteningly, *Album Graecum* (also known as Stercus Canis Officinale) was used as an ingredient, particularly in the 16th and 17th centuries, in the treatment of colic, dysentery, scrofula, ulcers (Wootton, 1910) and especially quinsy (a peritonsillar abscess that can form as a complication of acute tonsillitis), both as a component of a poultice or plaister and (possibly worse!) a gargle. The 'drug' was obtained by feeding otherwise half starved dogs with bone fragments; the protein inside was digested and absorbed from the bone, leaving an easily blanched phosphate-rich faecal pellet which was collected with some eagerness (Burnett, 1833). The parallel drawn by Buckland between *Album Graecum* and hyaena coprolites thus becomes both appropriate and striking.

Buckland described the Kirkdale material (Buckland, 1824 p20) as having an external form that *"is that of a sphere, irregularly compressed, as in the faeces of sheep, and varying from half an inch to an inch and a half in diameter; its colour is yellowish white, its fracture is usually earthy and compact, resembling steatite, and sometimes granular; when compact, it is interspersed with small cellular cavities, and in some of the balls there are undigested minute fragments of the enamel of teeth."* Anxious to confirm his suggested interpretation, he sent some of the material to William Hyde Wollaston, the chemist, physicist and mineralogist. Wollaston showed the specimens to the Menagerie Keeper at the Exeter Exchange, who immediately noted their similarity to the droppings produced by the Spotted Hyaena (*Crocuta crocuta*).

Painting by R. Ansdell R.A., from about 1843, of William Buckland.

Caricature by W.D. Conybeare, of Buckland entering the Kirkdale hyaena den, only to find it occupied.

The analysis conducted by Wollaston "finds it [the hyaena coprolite] to be composed of the ingredients that might be expected in faecal matter derived from bones" (Buckland, 1824 p22). In his reply to Buckland, Wollaston (24 June 1822; Buckland Papers, Royal Society) wrote that "though such matters may be instructive and therefore to a certain degree interesting, it may as well for you and me not to have the reputation of too frequently and too minutely examining faecal products."

Buckland's study of Kirkdale and its fauna was initially published in the *Philosophical Transactions of the Royal Society* in 1822, and then issued as the *Reliquiae Diluvianae*, published by John Murray in 1823. The importance of the work was recognised by the Royal Society, who awarded Buckland the prestigious Copley Medal for 1822, an honour reserved for "outstanding achievements in research in any branch of science". Buckland's was the 62nd in a long sequence whose pedigree included men such as Benjamin Franklin, William Herschel, Joseph Priestley, James Cook and William Wollaston himself, and was the first such award for geology. The then President of the Society, Humphrey Davey, commented, "I do not recollect a paper read at the Royal Society which has created so much interest as yours" (letter dated 18 March 1822; Buckland Papers, Royal Society).

Shortly afterwards (1827) Buckland published a note in the *Proceedings of the Geological Society of London* of his lecture of November 17 1826 entitled "*Observations on the bones of hyaenas and other animals on the cavern of Lunel near Montpelier, and in the adjacent strata of marine formation*". Rather larger than Kirkdale, this cave contained a similar fauna to that of Yorkshire, but Buckland was astounded by the high incidence of hyaena faeces – "an extraordinary abundance of the balls of *album graecum* in the highest state of preservation". He concluded that, at Kirkdale, "a large proportion of the faecal balls of the hyaenas appear to have been trod upon and crushed at the bottom of a wet and narrow cave, whilst at Lunel they have been preserved in consequence of the greater size and dryness of the chamber in which they were deposited."

Buckland was renowned for his rather earthy sense of humour. Indeed, Charles Darwin wrote of him in his *Autobiography*, "though very good-humoured and good-natured, [Buckland] seemed to me a vulgar and almost coarse man. He was incited more by a craving for notoriety, which sometimes made him act like a buffoon, than by a love of science". He was certainly not averse to a joke at his own expense and reveled in the cartoons and doggerel which flowed from the fertile minds and pens of some of his friends. Coprolites were, of course, grist to the mill for this type of ribaldry.

Philip Bury Duncan, a stalwart of the Bath Royal Literary and Scientific Institution (Chairman 1834- 1859), for example, wrote to Buckland with some oft- quoted verses :

Approach, approach ingenuous Youth And learn this fundamental truth

The noble science of Geology

Is bottomed firmly on Coprology For ever be Hyaena's blest

Who left us the convincing test I claim a rich Coronam Auri For these
Thesauri of the Sauri

The couplet at the end links the golden crown with the 'treasures' (thesauri) of the extinct saurians, these treasures being their faeces. Duncan also delivers some lines of Latin :

Avia Pieridum peragro loca nullius ante Trita solo, coecas iuvat explorare
ferarum Speluncas, iuvat et merdas exquirere priscas Saurorum duro et vestigia
quaerere saxo

These lines are modeled on Lucretius' *De Rerum Natura 1*, lines 925-927. An English translation of the classical original reads as follows :

I wander through the pathless places of the Muses, Previously trodden by the foot of none.

I am glad to approach the virgin springs, And drink; glad, too, to pluck new
flowers

Duncan's modified version can be translated as :

I wander through the pathless places of the Muses, Previously trodden by the foot of none.

I am glad to explore the hidden caves of wild beasts, glad, too, to search out ancient turds of lizards, And to look for traces in the hard rock.

On a fold of the envelope he wrote : *"Tear off the other side for Mrs B for she must know nothing of the Bona Dea Coprologia - Cloacina Ocaeaningae"*. Even here, he is playing a coprolitic theme. The Good Goddess Coprologia is linked with the Cloacina Oceaningae or oceanic sewer, in the oblique reference to Rome's sewage system, the Cloaca Maxima, which ran into the River Tiber and thence to the sea. In a parallel with the Roman sewage system,

Mundane they might be, and a source of humour and fascination they certainly are, but who would have thought that in the excited conclusion to a careful piece of analysis by William Buckland they could also take on an air of romanticism: *"In all these various formations our Coprolites form records of warfare, waged by successive generations of inhabitants of our planet on one another: the imperishable phosphate of lime, derived from their digested skeletons, has become embalmed in the substance and foundations of the everlasting hills; and the general law of Nature which bids all to eat and be eaten in their turn, is shown to have been co-extensive with animal existence upon our globe; the*

Carnivora in each period of the world's history fulfilling their destined office,—to check excess in the progress of life, and maintain the balance of creation." (Buckland, 1835 p235).

References

Boylan, P. 1981. A new revision of the Pleistocene mammalian fauna of Kirkdale Cave, Yorkshire. *Proceedings of the Yorkshire Geological Society,* **43** (3), 253-280.

Buckland, W. 1822. Account of an assemblage of fossil teeth and bones of elephant, rhinoceros, hippopotamus, bear, tiger and hyaena, and sixteen other animals; discovered in a cave at Kirkdale, Yorkshire, in the year 1821; with a comparative view of five similar caverns in various parts of England, and others on the continent. *Philosophical Transactions of the Royal Society of London,* 112, 171-236, pls. XV-XXVI.

Buckland, W. 1824. *Reliquiae diluvianae; or, observations on the organic remains contained in caves, fissures, and diluvial gravel, and on other geological phenomena, attesting the action of an universal deluge.* 2nd edition. London: J. Murray, 303 pp.

Buckland, W. 1827. Observations on the bones of hyaenas and other animals on the cavern of Lunel near Montpelier, and in the adjacent strata of marine formation. *Proceedings of the Geological Society of London*, 1, 3-6.

Buckland, W. 1835. On the Discovery of Coprolites, or Fossil Faeces, in the Lias at Lyme Regis, and in other Formations.

Burnett, G.T. 1833. Inaugural Address. *The London Medical and Physical Journal*, 69, February 1833, 89-100.

Duffin, C.J. 2006. William Buckland (1784-1856). *Geology Today,*

22 (3), 105-109.

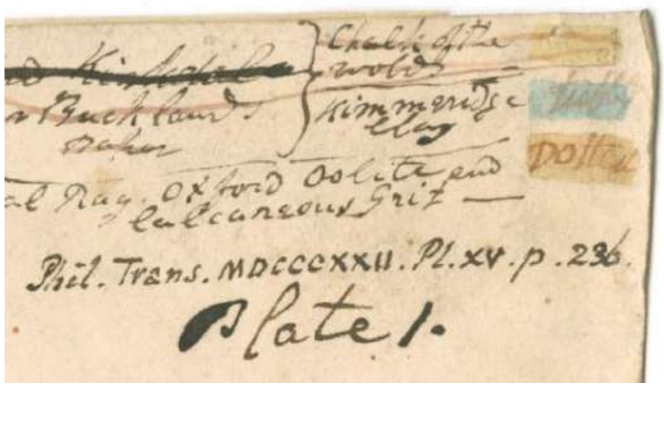
Eastmead, W. 1824. *Historia Rievallensis: Containing the History of Kirkby Moorside, and an Account of the Most Important Places in its Vicinity; Together with Brief Notices of the More Remote or Less Important Ones. To which is prefixed a dissertation on the Animal Remains.* London: Baldwin Chadock and Joy, 486 pp.

Kempe, S., Al-Malabeh, A., Döppes, D., Frehat, M., Hensch, H.-V. & Rosend, W. 2006. Hyena Caves in Jordan. *Scientific Annals,*

Wootton, A.C. 1910. *Chronicles of Pharmacy*. London: Macmillan, 2 volumes.

Draft figure of Kirkdale cave intended for William Buckland's 'Account of the assemblage of fossil teeth and bones of elephant, rhinoceros, hippopotamus, bear, tiger, and hyaena, and sixteen other animals; discovered in a cave in Kirkdale, Yorkshire, in the year 1821: with a comparative view of five similar caverns in various parts of England, and others on the continent' in *Philosophical Transaction*, 1822. Courtesy of the Royal Society archive, PT/73/9/14.

Draft coloured geological map intended for William Buckland's 'Account of the assemblage of fossil teeth and bones of elephant, rhinoceros, hippopotamus, bear, tiger, and hyaena, and sixteen other animals; discovered in a cave in Kirkdale, Yorkshire, in the year 1821: with a comparative view of five similar caverns in various parts of England, and others on the continent' in *Philosophical Transaction*, 1822. Published uncoloured. Courtesy of the Royal Society archive, PT/73/9/13.



CAVES AT KIRBY MOORSIDE.

I mentioned in my former paper, that a second cave had been discovered in the vicinity of Kirkdale, which was reported also to contain bones, and that it had been closed by Mr. Duncombe till I should come down to examine it, which I did in July last, accompanied by Sir H. Davy and Mr. Warburton. Our labour was lost as far as related to the discovery of more bones, or a second den of hyænas; but it was repaid by the confirmation which this cave afforded in all its other circumstances of my speculations on that at Kirkdale, and by the discovery of another cavity in Duncombe park containing animal remains, which throw much light on the mode in which the caves and fissures that were not inhabited as dens became filled with bones. I had also the satisfaction of demonstrating on the spot to Sir H. Davy and Mr. Warburton the actual state of many of the phenomena described in my account of Kirkdale. The cave at Kirby Moorside was intersected in working the face of a quarry of the same limestone as that at Kirkdale, at the north end of the town, and on the right side of a narrow gorge or valley called the Manor Vale, which descends from the north towards the Vale of Pickering, nearly parallel to the valley of Kirkdale, being about sixty feet broad, and bounded by slopes forty feet high, and forming one of the many smaller vallies of denudation excavated on this limestone by the diluvial waters as they subsided from the moorlands to the Vale of Pickering. A considerable portion of the right bank of this valley has been laid bare by the workings of the quarry, and on the face of it there are traces of a fissure connected with several small cavernous holes. The aperture discovered last spring is in the centre of this quarry, and near its floor; on removing the wall with which Mr. Duncombe had caused it to be closed, it was found to pass obliquely into the body of the hill, and to be intersected at a few feet from its entrance by a large fissure; this point of intersection forms, as at Kirkdale, the widest and most lofty part of the cavern, within which it diminishes into smaller vaults, which soon become impassable: the outer part of the cave when first opened was about four feet high and six broad, and its entire floor covered with an uniform mass of loamy clay, precisely similar to that on the floor of the den at Kirkdale. On digging into this loam it was found to be six feet deep for a considerable distance inwards, and to contain no bones. At its bottom there was no stalagmitic undercrust dividing it from the limestone floor, nor any repetition or alternation of a second or third bed of stalagmite in any part of its substance; its surface alone was in many parts glazed over with an extensive sheet of it oozing outwards from the side walls, and sometimes entirely crossing and forming a bridge over the loam. Above this crust some parts of the roof and sides were loaded with stalactite in its usual fantastic forms; but there were no bones of modern animals, nor traces of loam, or even of dust, upon the surface of the superficial crust of stalagmite. In all its circumstances, as far as they went, it agreed with and confirmed the history and chronology I have given of the cave at Kirkdale, excepting the two accidents of its not having been inhabited as a den, or received any stalagmite on its floor, before the introduction of the diluvial loam. The absence of bones in this cave (the mud being present) adds to the probability that it was by the instrumentality of the hyænas, and not of the diluvial waters, that the animal remains were collected in such quantities in the adjacent den at Kirkdale.

At about a mile east of Kirby Moorside, at a spot called the Back of the Parks, there are other quarries on both sides of a comb that descends rapidly into the valley of the Dove, in the face of which there occur several small caverns and vertical fissures: these fissures vary from one to six feet in breadth, and rise from the bottom of the quarry to the surface of the land, and are entirely filled with diluvial loam, of the same kind as that in the caves both here and at Kirkdale, and the Manor Vale. It was in the upper part of one of the fissures that several human skeletons were found and taken out in the year 1786, but the spot on which they occurred has been destroyed in continuing the workings of the quarry: they were probably bodies that had been interred here after a battle.

OPEN FISSURE IN DUNCOMBE PARK.

The newly discovered fissure in Duncombe Park differs from those we have been last describing in the circumstance of its being of post-diluvian origin; it contains no diluvial sediment and no pebbles, and has within it the remains of animals of existing species only, and these in a much more recent and more perfect state of preservation than the bones at Kirkdale. It is a great irregular crack or chasm, in the solid limestone rock, which forms a steep and lofty cliff on the right side of the valley of the Rye, being in that most beautiful valley of denudation which descends from Rivaulx Abbey through Duncombe

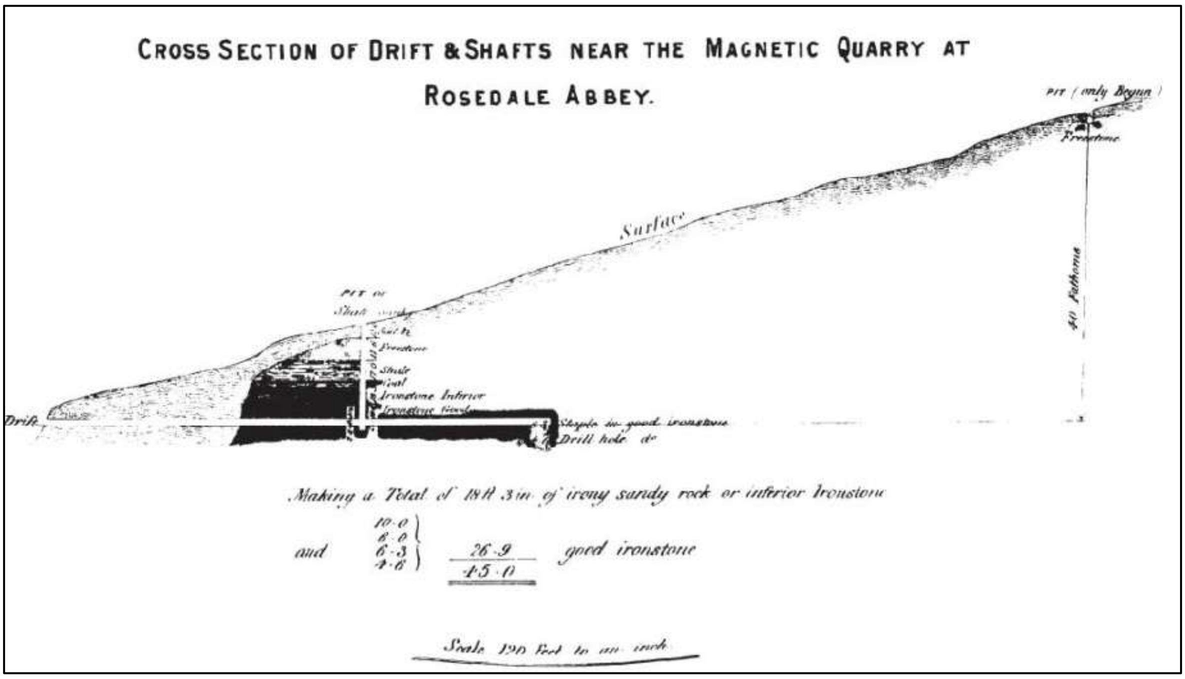
The genesis of geology in York and beyond

HOGG 25th Anniversary Meeting

Thursday 24th October

Field Excursion Notes

Rosedale - the magnetic ironstone conundrum



Rosedale – the magnetic ironstone conundrum

Afternoon

Rosedale – the magnetic ironstone conundrum

Practical Men

"The practice of geology, through the search for mines and minerals, has been much less attended to by historians than has the geology undertaken by leisured amateurs - even though practical geology was as important in the past as the oil industry is today."

Hugh Torrens (2002) *The Practice of British Geology, 1750–1850.* London: Routledge.

Introduction

At its peak in the mid 1870s-mid 1880s the ironstone industries in the area (alongside the remainder of the Cleveland Hills) provided 38% of Britain's need for iron, which equated to 20% of world demand. The area contributed to the shifting industries in North East England and the establishment of Middlesbrough as a centre of iron-making and its impact on the nation and the world beyond. Iron was in much demand - investment in construction of railways, in Britain and abroad started around 1835 and continued apace for the next three decades creating a significant demand for rails made from iron.

In 1835 ironstone was first identified and the first underground ironstone mining commenced in the Cleveland Hills ironstone mining district. Ironstone was identified in stream near tunnel works at Grosmont when building the new railway between Whitby and Pickering and was subsequently worked along the Murk Esk Valley at Beck Hole and Esk Valley, then at Kildale. In 1853 a magnetic ironstone with a significantly high iron content was discovered in Rosedale.

In 1851, 38 Blast Furnaces were operating in the North East and 13 were supplied with ironstone from the North Yorkshire Moors area. By 1863 108 Blast Furnaces with 78 supplied with ironstone from that area.

The impact of industrialisation on the landscape was in the creation of mines, the calcining kilns, construction of ironworks, the creation of mineral tramways and railways and the construction of accommodation for the increased population of the area.

It was largely through the work of 'Practical Men' that the ironstones were located and exploited.

This excursion visits two of the seminal sites of ironstone discovery and the remains of the vast industry that ensued, and explores the role of geological understanding in how the 'practical men' attempted to interpret the ironstone deposits.

It will also underline the importance of the economic imperative in advancing of geological knowledge and the vital role of 'home-front' geology during the First World War.

Rosedale
Rosedale Abbey
ROSEDALE WEST SIDE CP
Cottages
Quarry (dis)
Bell Plantation
Stone Bank
Medd's Farm
High Thorgill Farm
Thorgill
Gill Bank
Low Bell End
Bell End
Low Thorgill Farm
Sheepfolds
Quarries (dis)
Heygate Bank
Page's Plantation
Hancow Road
Shaft (dis)
Shaft
Pile of Stones
Piles of Stones
Tumulus
Ford
Thorgill Bank
Daleside Road
Hill Plantation
New Road
Heygate Farm
Moor Plantation
East Lodge
Resr
Waterhouse Well
Thorgill House
Hotel
Sch
Thorgill Crag
Quarries (dis)
Sevenford House
Hobb Farm
Pry Hills Wood
The Grange
Alder Carr Lane
Smith's Plantation
Thorgill Head
Low Farm
Hobb Crag
River Seven
Sewage Works
Cattle Grid
Jewel Mere
Grouse Butts
Newlands Farm
Gates Plantation
Yatts Farm
Pry Hills Lane
Bank Top
Shooting House Hill
Tumulus
Three Howes
Bank Farm
Sheep Dip
Mill Farm
Pile of Stones
Mine (dis)
Sheepfold
Hollins Farm
Mapping sourced from Ordnance Survey
This product includes mapping data licensed from Ordnance Survey with the permission of HMSO. © Crown copyright and/or database right 2006. All rights reserved. Licence number 100045615

Earliest geological surveys of the area

The earliest geological surveys of the area to establish the (detailed) geology were undertaken on the coast, but these were not systematic. The coast is predominantly shale clay, which was locally divided into four types, black, grey, jet and alum shales (identified by their contents). Here, ironstone was found in numerous thin clay bands of ironstone, commonly called 'dogger bands,' in North Yorkshire, and intermixed largely in the shale are 'nodules' of ironstone. Two significant seams of ironstone became known to locals – the 'main seam' (which splits the shales) and the 'top seam' which is about 40 to 50 fathoms (approx.. 240-300 ft or 75 – 90 metres) above the main seam, lying above the alum shale. However at least three other thinner 'dogger bands' were know to lay below the main seam in the black shales, and another in the sandstone that is above the top seam. The ironstone was largely picked off the shore front (as nodules or cobbles) and shipped directly to Newcastle to be smelted.

William Smith mapped the area on his 1815 map, denoting the formations as as Clunch Clay overlain by Iron Sand and Cornbrash. On his 1821 County map of Yorkshire the sequence is amended to 'Clunch Clay and Alum Shale', 'Sand Rock and Grit Freestone of the Moors being over the Alum Shale'. However Smith did not make any reference to ironstone or their workings.

Bird & Young 1822 & 1828 (2nd edition)
'A Geological Survey of the Yorkshire Coast: Describing its Strata and Fossils Between the Humber and the Tees, from the German Ocean to the Plain of York.'

The Rev. George Young (of Whitby) provided the first systematic description of the geology and strata (rocks and fossils) of the region "in the order in which they occur, noticing the breaks, contortions, and other phenomena which they exhibit; and stating their connection with each other, and with the strata of adjoining districts, as far as it can b e ascertained." Thus, Bird & Young subdivided North Yorkshire into the following 'formations':
Oolite,
Limestone & Calcareous Sandstone
Second Shale,
Sandstone, Shale & Coal
Aluminous strata

After stating that the ironstone holds a conspicuous place in the ironstone and sandstone division, Young states: "It appears to be partly calcareous, partly argillaceous, and has been ascertained to yield 15 per cent. of iron, being collected for an iron-foundry at Newcastle." He does on: "the beds are seldom more than 9 or 10 inches thick"

The thick, or main seam, is however pointed out in the section describing the Boulby cliffs, viz:

6. *Main bed of aluminous schistus or alum-rock, 200 feet.*
7. *Imperfect seams or fiat nodules of hard blue limestone, mixed with alum-shale, 10 feet.*
8. *Hard compact alum-shale, 30 feet.*
9. *Ironstone in beds, or rows of nodules, interstratified with the shale, 15 feet;*

Young says that estimates have been made of the proportion of iron, being "from 30 to 60 per cent.," an estimation which he remarks, "is perhaps beyond the truth"; so, that although he may be said to have faintly identified the main bed, he attributed no real commercial value to it.

Adam Sedwick 1826 On the Classification of the Strata which appear on the Yorkshire Coast; Annals of Philosophy, 11 (Article 5), May 1826

In the description of the district in question, our best geological authorities are at variance among themselves. Mr. Smith identifies the alum-shale of the Yorkshire coast with the Oxford clay and the coal formation of the moors and the limestone of the vale of Pickering, with the calcareous grit and oolite of the coral- rag formation. Mr. Greenough refers the alum-shale to the lias, the sandstone and coal formation of the moors to the great oolite, and the limestone of the vale of Pickering to the coral-rag. Mr. Conybeare is inclined to identify the formation of the moors with the inferior oolite, and the limestone of the vale of Pickering with the great oolite. A part of these discrepancies has undoubtedly arisen from the anomalous character of the strata in question ; for there is obviously great risk of error in attempting to bring into the same class distant deposits which are unconnected, and bear little resemblance to each other. Notwithstanding these difficulties, I am disposed to think, that a careful examination of a very small number of facts, in addition to those with which we are now acquainted, would enable us to determine with certainty the respective places in the series of English formations to which the strata on the Yorkshire coast are to be referred.

John Phillips 1828 'Illustrations of the Geology of Yorkshire'

Extracts from Tabular View of the Series of Yorkshire Strata to indicate the position of the ironstone beds within Formations:

" Bath oolite formation	14. Ferruginous beds, (inferior oolite of Somersetshire.)	Utmost Thickness. 60 feet.	Peak, Whitby, Boulby, the Cleveland Hills
" Lias formation	15. Upper lias shale	feet	Cliffs near Whitby, Hills near Guisbro', &c.
	16. Marlstone series	"	Cliffs near Staithes, Head of Bilsdale, Eston Nab, &c.
	17. Lower lias shale	"	Robin Hood's Bay, Boulby, Redcar."

Description - Bed No. 14 is known as the 'Top Seam' and Bed No. 16 and the Main Seam'

" Carboniferous series	Cap sandstone, nearly	50 feet.
	Sandstone traversed by ochry veins	
	Shale	4 "
	Irony stone in nodular masses and beds	
	Upper lias shale or mine	150 "
	Hard shale with layers of calcareous nodules	30 "
	Soft alum shale	20 "
	Alternations of ironstone beds and alum shale forming projecting scars	20 " "

The section at Kettleness (on the coast) indicates bed thickness:
here the 'Top Seam is recorded as 4 feet and the 'Main Seam' as 20 feet.

" Carboniferus and oolitic formation . . — " No. 14. Sub-calcareous irony sandstone, often containing shells, called *dogger* (*inferior oolite* of Somersetshire.)

" Lias formation.

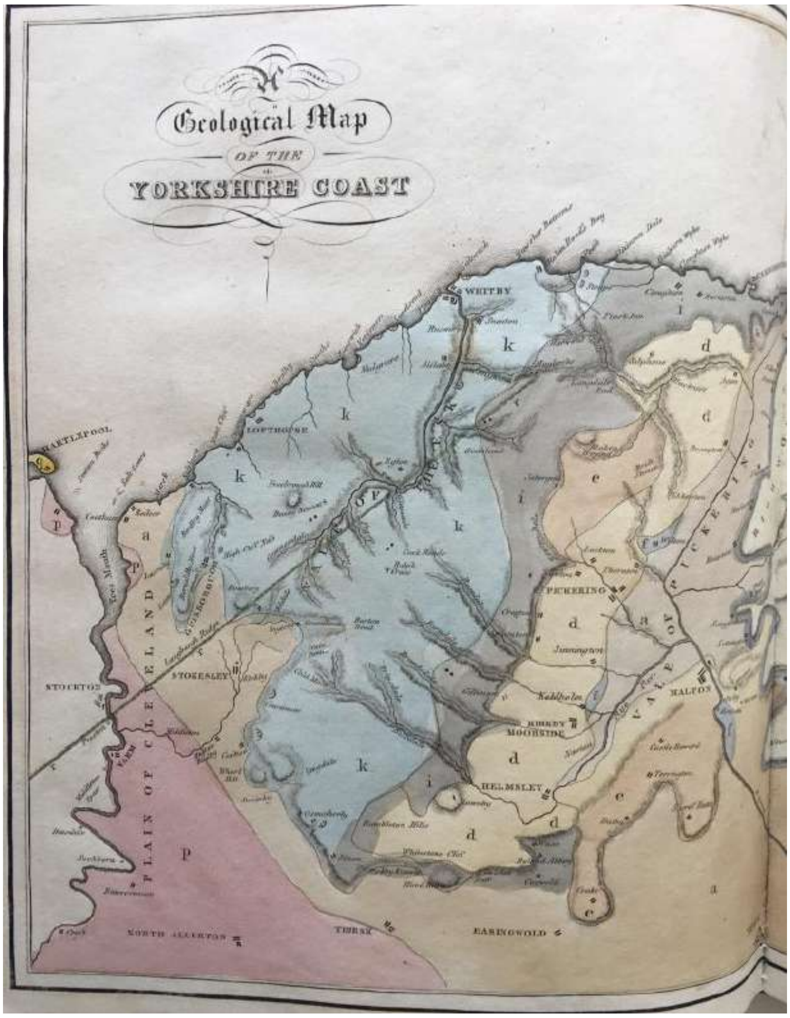
" No. 15. Upper lias shale, or alum shale, with nodules of argillaceous limestone, ammonites, belemnites, &c., (*blue marl* of Northamptonshire.)

No. 16. Ironstone and sandstone strata with terebratulæ, pectines, cardia, aviculæ, &c., (*marlstone* of Northamptonshire.)

No. 17. Lower lias shale with gryphææ, pinnæ, plagiastomæ, &c., (*lias shale* of Somersetshire.)"

Bird & Young 1822

"The ironstone holds a conspicuous place in this series, is hard and compact. It is red or ferruginous without, and extremely hard and compact. It appears to be partly calcareous, partly argillaceous, and has been ascertained to yield 15 per cent. of iron, being collected for an iron-foundry at Newcastle. The beds are seldom more than 9 or 10 inches thick; and more frequently consists of nodules, or flat intersected masses, than continuous strata. The ironstone is usually imbedded in shale, which fills up the interstices between the nodules or blocks…"

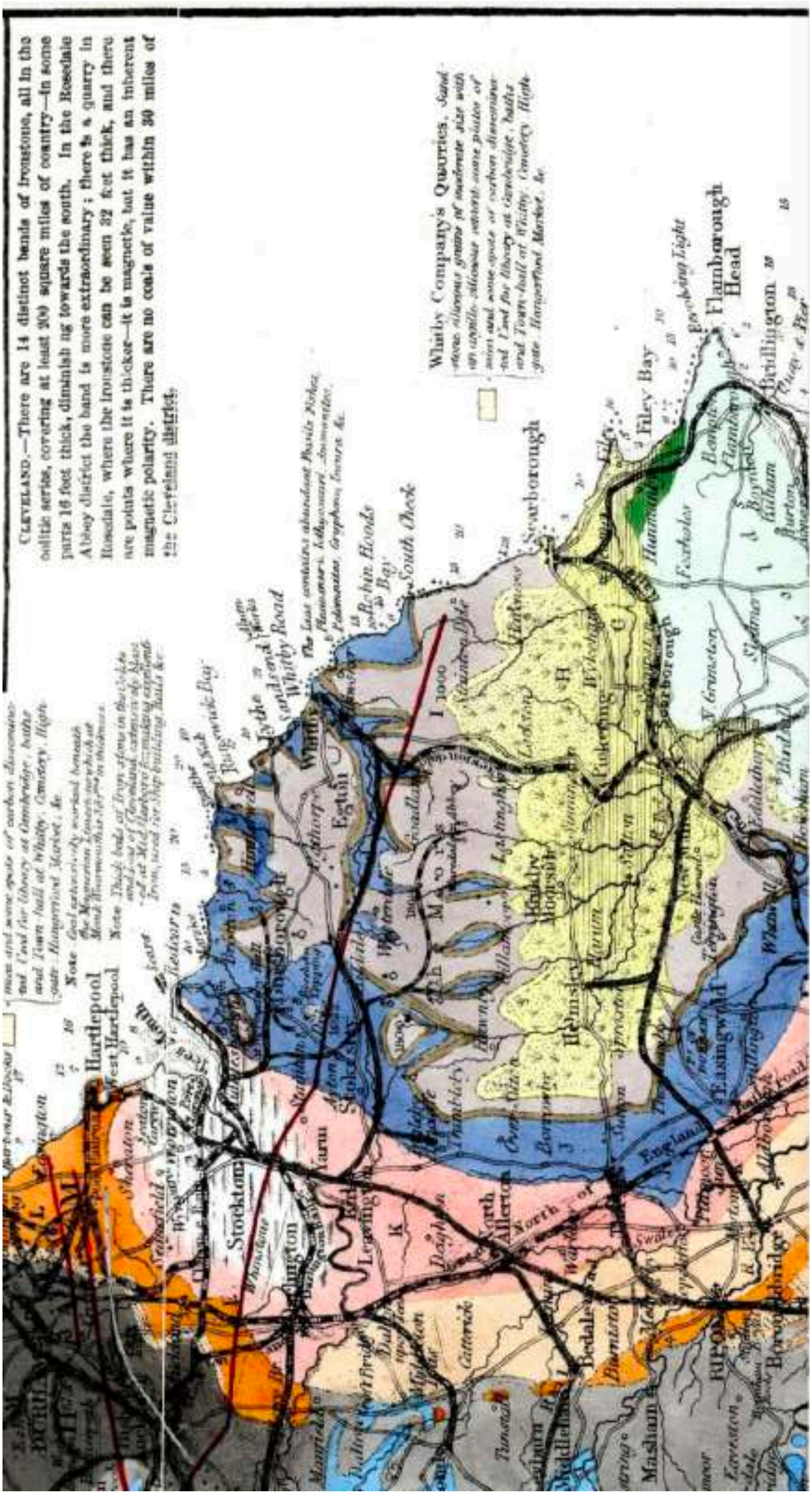


John Phillips 1828
Illustrations of the
Geology of Yorkshire

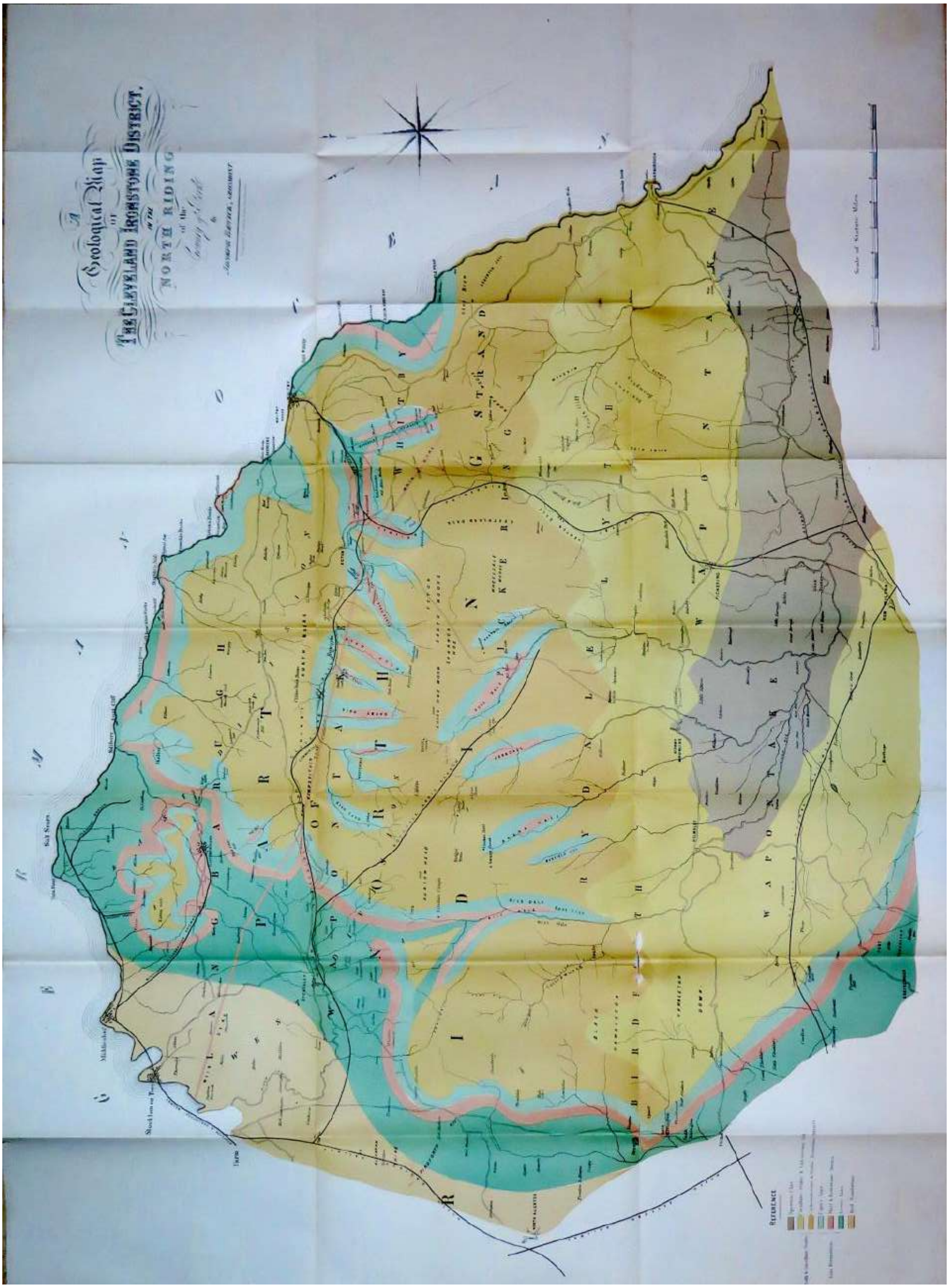
"Ironstone abounds on this coast, and has been formally shipped in large quantities to Newcastle. Inland, ironworks established by the monks informally carried on near Rivleaux Abbey and further up in Bilsdale, and in the valley of Hackness. The principal repositories of this mineral are above the grey limestone and below the upper layers or Alum Shales. **It is at present of no value except as ballast**."

Geological Map of Cleveland

by J.A. Knipe Esq. (extract from Geological Map of the North of England) in Fordyce, W. (1860)
(Courtesy of Chris Toland)



Geological Map of the Cleveland Ironstone District
by Joseph Bewick (1861)
(Courtesy of Chris Toland)



Geological Section of the Cleveland Ironstone District
by Joseph Bewick (1861)

Principal Characters

John Marley,
Mining Engineer
'Discoverer' of the Cleveland Ironstone

1823-1891

Joseph Bewick (the younger)
Agent, Grosmont Iron Mines
1816-1862

?

Nicholas Wood
Mining & Steam Locomotive Engineer
President, NEIMME
1795-1865

Discovery of the Rosedale Magnetic Ironstone

Marley (1857) recounts that around 1851 material was being sought in East Rosedale to mend the roads. Traditionally, road material was 'robbed' from small quarries of suitable material - in this case a quarry near to Hollins farm and the west side of Rosedale.

In 1853 Mr. W. Thompson, a collector and shipper of ironstone at Staithes, was in the area looking for jet, and he noticed the ironstone in the roads. It was quickly realised that the material from the west Rosedale quarry had magnetic properties and was high in iron content, so the quarry was extended and a drift driven into the hillside.

The quarry stone was however, 'unproved' as to its extent or thickness; "lying in conglomerated state, as though it were a disjointed and isolated batch, forming concentric rings on the hill end, and not uniformly stratified in any one direction" (Marley 1857) – or was it? The drift extended 100 yards with the same character and thickness as in the Quarry.

Local iron agent Joseph Bewick considered the magnetic ore might have a very different disposition and origin, linked to the Cleveland dyke. Marley also considered the ore might simply lie along a fault plane, as a small quarry about 400 feet above showed a similar conglomerated rock, although here the ironstone was non-magnetic. Marley convinced himself the upper quarry was the 'Main Seam', also found across the valley, though was open to being proved wrong in his conjecture. Nicholas Wood, President of the NIIME considered the evidence suggested the magnetic deposit a bed.

What was at stake?

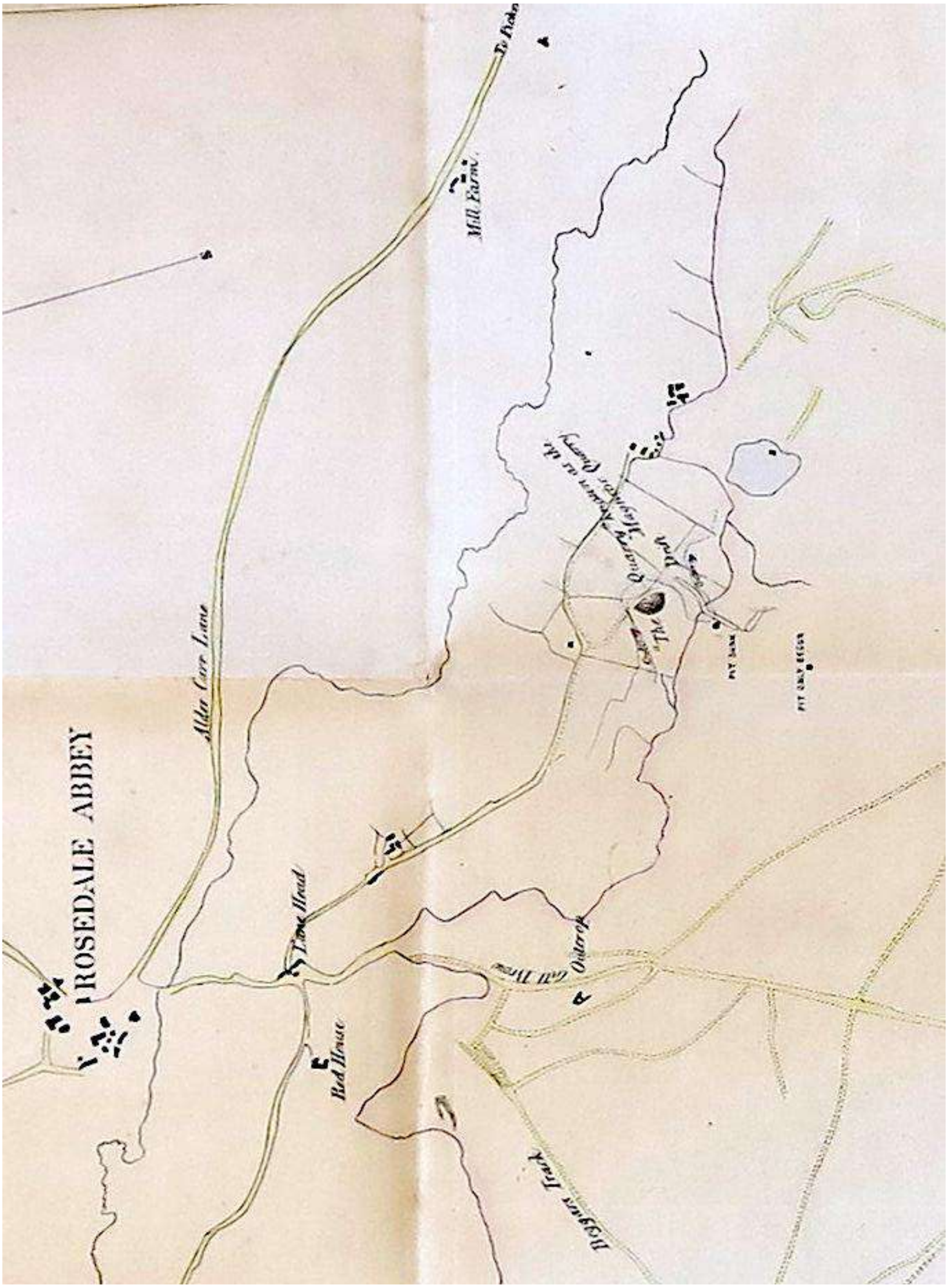
Main Seam ore proved iron content between 25 and 33% and sold at a price of about 8 shillings a ton.

Magnetic ironstone proved content between 40 and 50% iron, and would command a price of at least 10 shillings per ton.

Given the economic potential, it was of significant importance to ascertain the true position of this magnetic deposit and whether it was a continuous bed or of casual occurrence.

It was a conundrum – but could it be solved?

Location of Rosedale Magnetic Quarry' and Drift
From Marley (1857)



L

Nicolas Wood, 1869.

On the Deposit of Magnetic Ironstone in Rosedale.

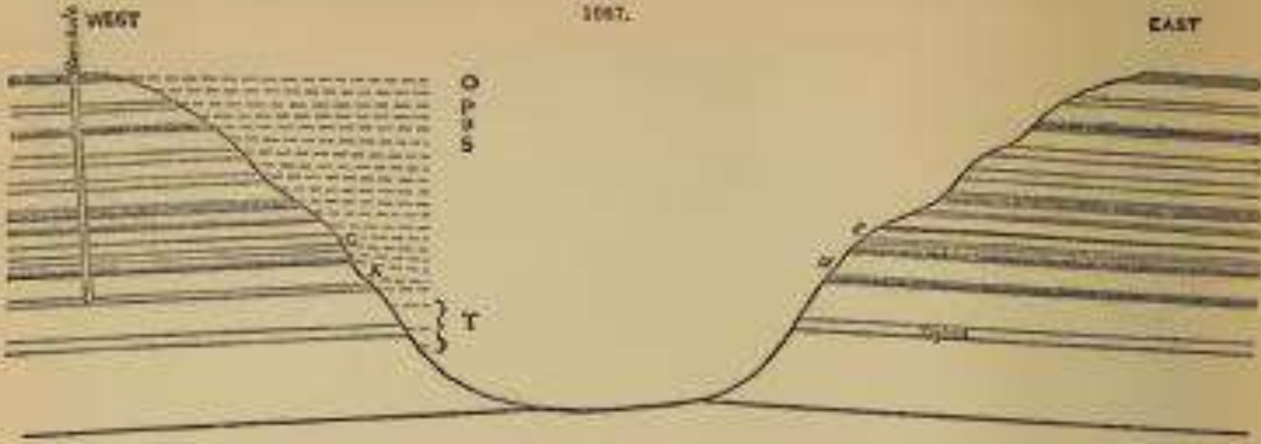
Spons' Dictionary of Engineering, **Part VIII (**Borings and Blasting), 501 - 512.

We give an example of boring for minerals, from the 'Transactions of the North of England Institute of Mining Engineers,' vol. vii. The paper which furnishes this example was read by the justly-celebrated Nicholas Wood; we give it and the discussion thereon, without any material alterations, to show the baseless fabric upon which the so-called science of geology is made to rest.

Nicholas Wood, President of the Institute of Mining Engineers, on the Deposit of Magnetic Ironstone in Rosedale.—In John Marley's very elaborate and very able account (says *Wood*) of the Cleveland Ironstone District, communicated to this Institute at its meeting of June, 1857, and published in vol. v. of the 'Transactions,' he states:—"The only special district to which I think necessary now to allude is the Rosedale Abbey district, the ironstone from which has attracted a large amount of attention, on account of its large percentage, immense deposit, and magnetic properties."

Marley then gives a history of the discovery of this bed of ironstone, its position in the series, as well as in the district generally, and adds all the information which had then been elicited with regard to the particular features and character of such deposit, which he illustrates by a diagram, showing the explorations which had been made by drifts and pits towards such elucidation; and he then concludes by saying:—"I have no doubt that this seam is the same as the seam at the point *A*, Fig. 1087, as also the same as that found on the east side of Rosedale, in Captain Vardon's property, of varied thickness, as well as the same seam as that at Grosmont, Fryupdale, Swanby, and Boltby, known as *the top seam* of Cleveland—the nine inches of coal in the pit sunk agreeing with *Beckhole*, near Grosmont, in particular; so that the only doubtful point is as to the portion from the outcrop at *A* to the so-called magnetic quarry; the most feasible solution being that it is a disjointed patch of the regular seam, known as the *top seam*, and not a vein, as has been said; and, with all deference to the parties who have had more opportunity for examining this district than I have, I propose leaving the *extent* of the *magnetic and extra percentage* tract as an *unsolved problem*, as it may vary from one or two acres to any indefinite extent, not being at all proved to the south."

This is a very clear and correct account (says *Wood*) of the information then existing on this deposit, Marley's opinion being that it represented the top seam, as developed at Grosmont Fryupdale, Swainby, and Boltby.



Reference:—O, Shale and ironstone rumble. P, Brown and grey sandstone. 9, Coal and shale. S, Shale and sandstone. T, Sandstone; top bed, of iron and lias respectively, not proved by the bore-hole.

A Section of the Strata at Grosmont is given by Marley as follows:—

	Ft.	In.	Ft.	In.		Ft.	In.
Sandstone	25	0			Ironstone band and shale	29	0
Ironstone, top seam	12	0			"Pecten" band, part of the Cleveland thick seam	5	10
Lias shale	92	0	} 198	0	Shale	17	4
Various strata, not identified	51	0			"Avicula" band, Cleveland seam ..	6	4
Lias shale	55	0					

Another section near Grosmont gives the top seam 11 ft. 6 in., then 187 ft. of shale and ironstone, and then the Cleveland band.

The Section at Fryupdale is as follows:—

	Ft.	In.		Ft.	In.
Freestone	55	0	"Pecten" band, Cleveland main seam	6	0
Top seam	12	0	Shale	30	0
Jet, cement, and alum rocks	202	0	"Avicula" band, Cleveland main seam	4	4
Shale	60	0			

The Section at Swainby is as follows:—

	Ft.	In.		Ft.	In.
Shale	13	0	Shale	132	6
Top seam	23	0	Cleveland main bed	9	3

And at Felix Kirk, near Boltby, the Section is:—

	Ft.	In.	Ft.	In.	
Brown, yellow, &c., gritstone			0	0	
Boltby and Rosedale iron rock			7	0	
Alum shale, or upper lias shale			116	0	
Upper band of nodular ironstone	0	7			
Thin seam of soft shale	3	0	} 4	1	Type of Eston or Cleveland main seam.
Lower band of nodular ironstone	0	6			

Section of Strata in the Hills at Swainby Mines.

	Ft.	In.	Ft.	In.	
Soil, &c.			3	0	
Freestone			21	0	Near the limekiln this is 100, with 9-in. ironstone balls in it.
Slaty coal	0	9			
Shale	1	0			
Sandstone	4	0			
Slaty coal	0	9			
			6	6	
Shale			5	0	
Coarse freestone			3	6	
Shale, with occasional nodules of ironstone			13	0	
Ironstone, good	2	0			
Ironstone	21	0			
			23	0	
Carried forward			78	0	

Section of Strata in the Hills at Seminby Mines—continued.

		Ft.	In.	Ft.	In.	Ft.	In.	
	Brought forward					78	0	
	Shale					132	6	
Not Wrought	Ironstone			2	8			
Not Wrought	Shale			1	0			
				3	8			
	Ironstone	2	5					
	Shale	1	8	5	7			
	Ironstone	1	6			9	3	Scarthnick bed or seam.
	Shale					9	3	
	Ironstone			1	3			
	Shale			0	6			
	Ironstone			1	3			
						3	0	
	Shale					16	6	
	Ironstone					1	6	
	Supposed shale, but unproved down to the level of the bottom of Crook beck					335	0	
						585	0	

Section of the Strata at Eston Nab, showing the top seam, and the main or Cleveland band, where the latter is in perfection.

		Ft.	In.	Ft.	In.	
Approximated.	Soil, and other strata unproved			50	0	
Approximated.	Freestone			60	0	
Approximated.	Shivery post, patches of jet and clay			54	0	
	Nodular ironstone	0	1			
	Shale	2	3½			
Seam called the "Top Seam."	Nodular ironstone	0	3			
Seam called the "Top Seam."	Shale	0	7			
Seam called the "Top Seam."	Nodular ironstone	0	0½			
Seam called the "Top Seam."	Shale	0	10	6	0	Measured working section.
Seam called the "Top Seam."	Nodular ironstone	0	1			
Seam called the "Top Seam."	Shale	0	6			
Seam called the "Top Seam."	Nodular ironstone	0	1			
Seam called the "Top Seam."	Shale	0	6			
Seam called the "Top Seam."	Ironstone band (varies)	0	9			
	Aggregate of ironstone, 15¼ inches.					
Approximated.	Lias shale, including jet rock at bottom			210	0	
	Ironstone band	0	2			
	Shale	2	5			
	Ironstone band	0	2			
	Shale, mixed with nodules of ironstone	1	10	10	0	Measured section.
	Ironstone band	0	3			
	Shale	1	0			
	Shale, inclining in some parts to a fire-clay nature	4	2			
	Aggregate of ironstone, 9 inches.					
Cleveland Main or Thick Bed or seam of Ironstone.	Top block, left as roof	0	11			
Cleveland Main or Thick Bed or seam of Ironstone.	Parting regular at outcrop, but not so after.					
Cleveland Main or Thick Bed or seam of Ironstone.	Second block (left as roof near outcrop)	2	3			
Cleveland Main or Thick Bed or seam of Ironstone.		3	2			
Cleveland Main or Thick Bed or seam of Ironstone.	Main parting (a good one near the outcrop, but lost farther in).					
Cleveland Main or Thick Bed or seam of Ironstone.	Main block and uniform	12	0	17	0	Measured section.
Cleveland Main or Thick Bed or seam of Ironstone.	Parting (lost after leaving outcrop).					
Cleveland Main or Thick Bed or seam of Ironstone.	Bottom block (varies)	1	10			
	Shale	7	0			
	Ironstone band (called 2-ft. band) ..	1	8	15	6	
	Shale	6	0			
	Ironstone band	0	10			
	Blue shale			36	0	
	Various beds of grey post and metal stone, &c. ..			93	6	
	Total			552	0	

The main features of the sections given by Marley as assimilating to the Rosedale bed, are,

1st. The top seam, varying from 12 to 23 ft. in thickness.
2nd. Lias shale and other strata, 132 ft. to 220 ft.
3rd. The Cleveland main band, 9 to 12 ft.

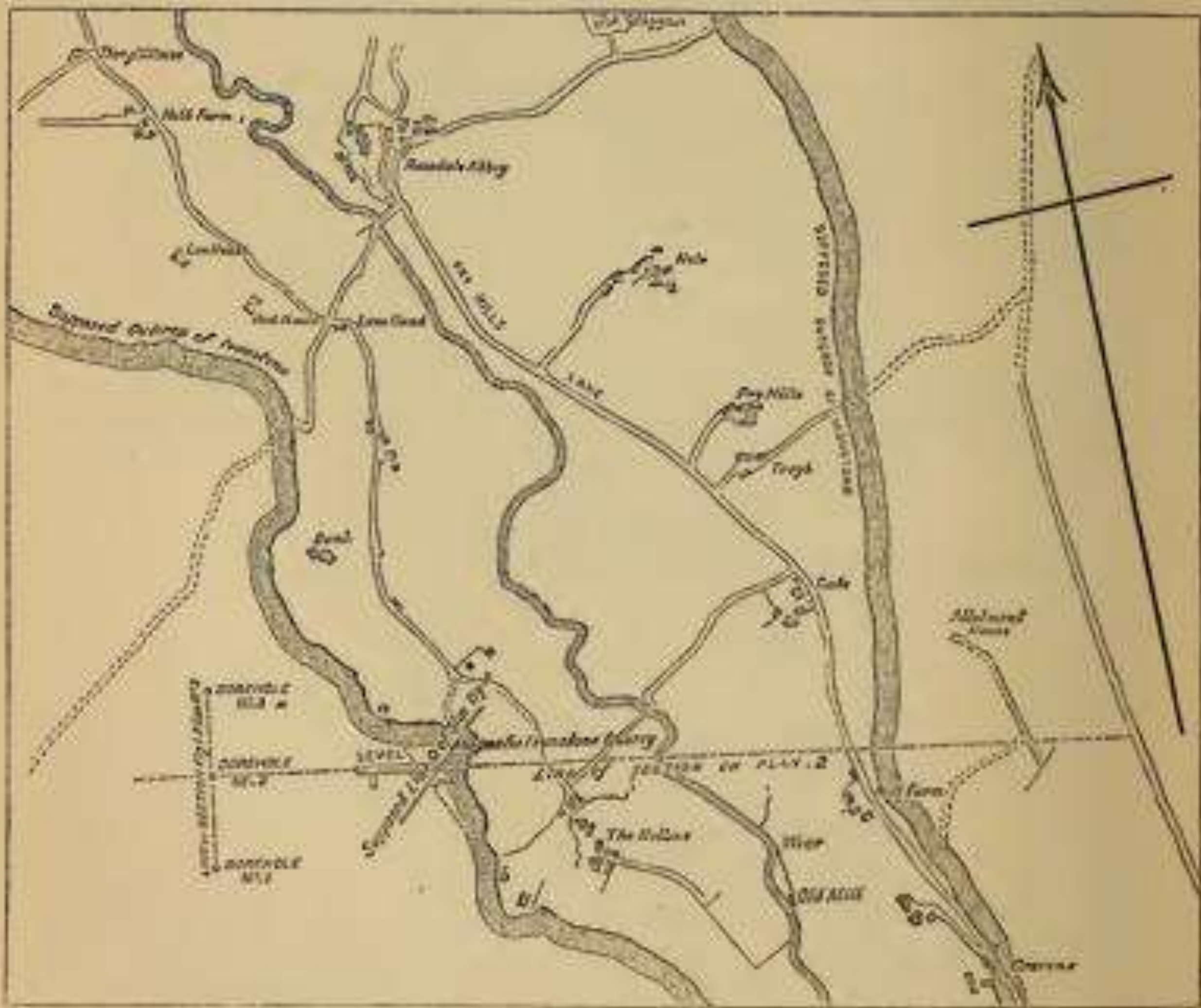
But in all these sections there are no beds of ironstone between the top seam and the Cleveland main band.

Bewick, in a paper presented (says *Wood*) to the Institute, and printed in vol. vi. of the 'Transactions,' gives drawings, and an account of the deposit of Rosedale, and concludes with these remarks,—"My object in thus troubling the members of this Institution with the foregoing remarks is twofold. First, to show that the iron ore of Rosedale, instead of being a large mineral field, as was first asserted, and still believed to be so by many, is nothing more than a volcanic dyke; and secondly, that the ironstone lately opened out in this locality is not, as it is reputed to be, the main seam now being worked in the Cleveland and Grosmont districts, but it is my opinion, if Marley will permit me to say so, the top seam."

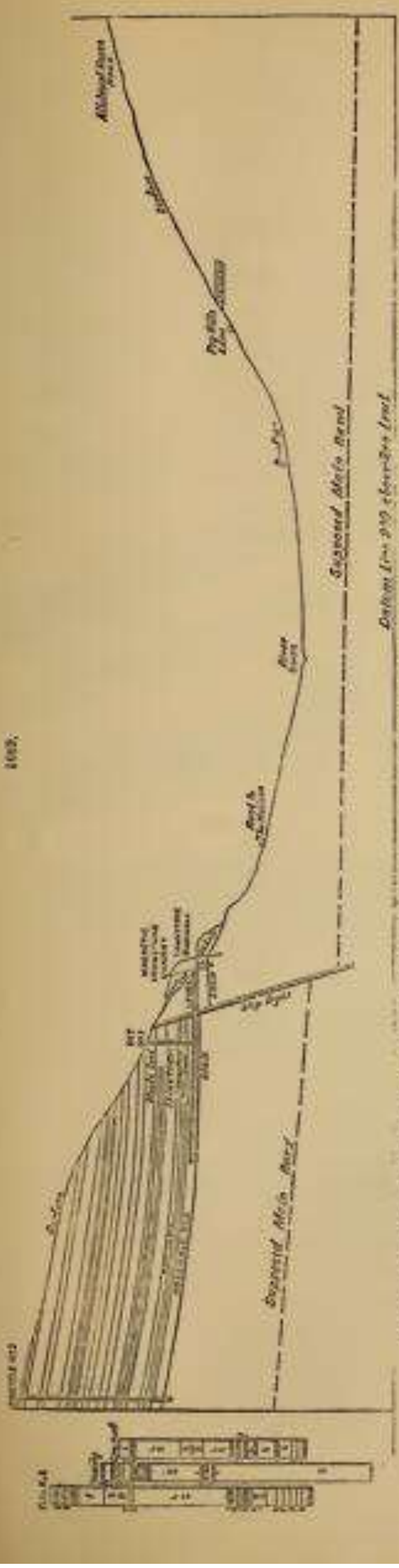
I shall now (observes *Wood*) give an account of the operations concluded by Professor Phillips and myself towards the investigation and development of this bed of ironstone.

The first discovery of this deposit of ironstone was at a quarry on the south-west side of the valley of Rosedale, about a mile south from Rosedale Abbey, and shown, Fig. 1088. When this

1088.

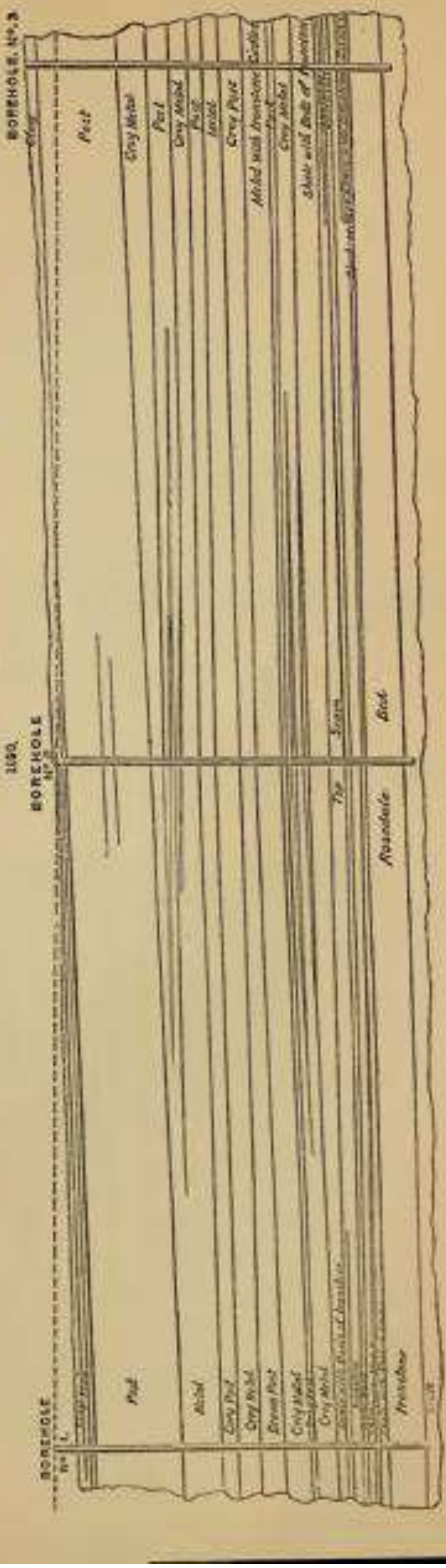


quarry was opened out it was found to consist of apparently a confused mass of ironstone boulders of an ellipsoidal structure, and of gigantic size, often 3 or 4 ft. in diameter; the central part of these boulders being generally blue, and consisting of a solid dark oolitic magnetic iron ore, with, in many cases, sandy and solid ironstone crusts around it; and, in receding from the centre, the iron ore becomes paler, alternating with dark brown purplish layers; the layer then becomes pale brown, and the magnetic quality is lost. In most cases, however, the nodules are quite solid, and a slight stratification exists, though very obscure; and in several cases, likewise, the oolitic structure is merged into compact brown iron ore. In some parts also, where exposed to the water and to the weather, the iron ore is partly washed away, and a gritty ferruginous crust remains. These great variations do not occur where the ironstone is under cover, or covered by other strata, but appears to assume those different phases in consequence of its extreme susceptibility to change by exposure to air and water; and it is somewhat remarkable that the magnetic property is



1189.

Reference to side sections:—F, Freestone. S, Shale. I, Ironstone. G, P, M, Grey post and metal. L, S, Lias shale. S, P, Shivery post. C, Coal.



1190.

strongest where the mass is thickest, and scarcely shows any magnetism in places where it is thin, or where it has little cover, and, consequently, more exposed to decomposition or change.

The great characteristic difference of composition between this ironstone and the top and main band of Cleveland is, the entire absence of shells, the structure being entirely of an oolitic character, being entirely composed of small round concretions of iron ore, cemented together with extremely thin siliceous or arenaceous films, and in its magnetic properties exhibiting polarity, and likewise in its greater richness than the ordinary ironstone of Cleveland.

This quarry has been excavated so as to form a face of 60 ft. in thickness; to which must be added 11 ft. of blue magnetic stone, 2½ ft. red ironstone, slightly magnetic, bored down below the bottom in magnetic stone, and 3 ft. of shale.

Soon after the quarry was discovered, it was thought advisable to drive a drift into the side of the hill, to ascertain the extent of this deposit, the quarry being about 600 ft. from the bottom of the valley, and about 300 ft. below the utmost level range, or plateau of moors, lying on the south-west side of the valley. This drift, together with a pit sunk upon it, is shown by a drawing in Marley's paper. Since then, it has been driven to a much greater distance, and three *bore-holes* have been put down from the surface to the Rosedale bed of ironstone.

Fig. 1088 shows the position of this drift, the distance and direction in which it has been driven into the hill, and also the position of the three bore-holes and the quarry. And Fig. 1089 also shows the section of the same drifts, and the section of the borings, together with their depths from the surface, and the beds of ironstone which they have proved. I have carried such section across the valley, for the purpose of showing the position of the ironstone band on the opposite side of the valley.

Fig. 1090 shows, on a larger scale, the strata bored through in the three bore-holes above alluded to, and the ironstone beds which they have proved; Figs. 1091 to 1093, bore-holes, Fig. 1094, facing drift, and Fig. 1095, side drift—show the thickness of the lower bed of ironstone in the several bore-holes in the face of the drift, and also in the side of the drift.

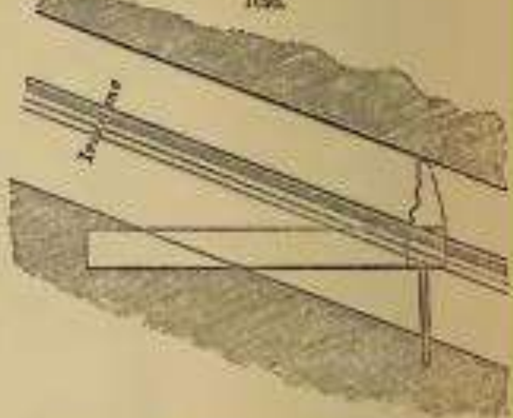
1091.

1092.

1093.

1094.

1095.



It is necessary to remark that, where the drift was first set away in the side of the hill, it met with shale, and it continued in shale for a distance of about 80 yds., when the ironstone was found. The drift continued in the ironstone for a distance of 180 yds. farther, making a total distance of 260 yds. from the face of the hill. Fig. 1089 is a section of the ironstone at the face or farthest extremity of the drift, showing an entire thickness of 32 ft. of ironstone, namely, 6 ft. 2 in. of drift, 11 ft. 9 in. above the drift, and 14 ft. below it. And, what is important to mention, the ironstone was here distinctly stratified, as shown by the lines across the section, Fig. 1094.

400 yds. in advance of the extreme end of the drift, and 660 yds. from the side of the hill, a *bore-hole*, No. 2, Fig. 1089, was put down; and at right angles to the line of this bore-hole from the drift two other bore-holes were put down from the surface, as shown, Figs. 1089, 1090, each 200 yds. distant from No. 2 bore-hole, or 400 yds. separate; and the following are sections of the strata passed through in these bore-holes.

Account of the Boring No. 1, *Fig.* 1090, *or South Bore-hole, on Rosedale Moor.*—1858.

No.		Fms.	Ft.	In.	No.		Fms.	Ft.	In.
1	Clay	0	5	0		Brought forward	39	4	9
2	Metal or shale	1	1	0	13	Ironstone, magnetic	0	5	0
3	Brown freestone water ..	12	5	6	14	Shale mixed with ironstone	1	0	9
4	Metal or shale	6	1	6	15	White post	0	2	4
5	Brown and grey post	2	0	0	16	Shale	1	1	0
6	Grey metal	3	2	0	17	Dark metal	0	3	0
7	Brown and grey post	3	4	8	18	Shale with post girdle ..	1	5	3
8	Grey metal	3	4	9			45	4	1
9	Grey post	0	5	6	19	Ironstone, magnetic	5	2	0
10	Grey metal	3	1	10	20	Inte. shale	0	1	6
		38	1	9		Total depth, fathoms ..	51	1	7
11	Ironstone, magnetic	0	4	0					
12	White shale mixed with ironstone	0	5	0					
	Carried forward	39	4	9					

Account of the Boring, the Middle Hole, or No. 2, Fig. 1090, on Rosedale Moor.—1857.

No.		Fms.	Ft.	In.
1	Freestone ramble	0	3	0
2	Metal	0	4	0
3	Brown post .. 5 2 0			
4	Grey post .. 1 3 0	12	1	0
5	Brown post .. 5 2 0			
6	Metal	5	3	0
7	Post with water	0	5	0
8	Metal	0	5	0
9	Coal	0	0	4
10	Metal	0	2	6
11	White post with water	0	3	0
12	Metal	2	1	6
13	Grey and brown post	2	3	0
14	Metal	3	2	0
15	Brown post	2	3	6
16	Metal	3	5	0
17	White post	0	4	0
18	Metal	0	5	5
	Carried forward	37	3	3
	Brought forward	37	3	3
19	White post	0	1	3
20	Metal	1	3	6
21	White post	0	3	3
22	Metal ironstone girdles	2	5	0
		42	4	3
23	Ironstone	2	1	3
24	White post mixed with whin	1	2	0
25	Metal with ironstone girdles	1	1	6
26	Black metal mixed with ironstone	0	4	0
		48	1	0
27	Ironstone	5	2	0
28	Inte. grey shale	1	1	0
	Total depth, fathoms	54	4	0

Account of the Boring, No. 3 Hole, Fig. 1090, or North Hole, on Rosedale Moor.—1858.

No.		Fms.	Ft.	In.
1	Clay	1	1	0
2	Brown post	11	5	0
3	Grey metal	4	1	0
4	Brown post	3	3	6
5	Grey metal	2	0	0
6	Brown post	2	1	0
7	Grey metal	2	5	0
8	Brown or grey post	3	0	0
9	Grey metal ironstone girdles	4	1	0
10	Grey post	0	4	6
11	Grey metal	2	5	6
		38	3	6
12	Ironstone, magnetic	0	4	6
13	White shale, mixed with ironstone	1	1	0
	Carried forward	40	3	0
	Brought forward	40	3	0
14	Ironstone	0	3	0
15	Shale, mixed with ironstone	0	5	9
16	Gullity post	0	0	9
17	Ironstone, magnetic	0	5	6
18	Light-coloured ironstone	0	3	0
19	White post, mixed with whin	1	1	0
20	Ironstone, magnetic	0	3	0
21	Grey shale, mixed with ironstone and post girdles	1	2	6
22	Black metal	0	2	6
		47	0	0
23	Ironstone, magnetic	4	5	3
24	Inte. shale	0	4	0
	Total depth, fathoms	52	3	3

It will be seen, therefore, that for a distance of 580 yards from the pit, No. 1 on the section, Fig. 1089, to the boring No. 2 on the same section, the thickness of this bed of ironstone is nearly the same, and that this is the case likewise at the other two bore-holes, Nos. 1 and 3, at right angles to the above line of section, the respective thicknesses being as follows:—

	Ft.	In.
Drift	32	0
No. 1 bore-hole	32	0
No. 2 bore-hole	32	0
" 3 "	29	3

These borings and sections show two distinct beds of ironstone, stratified with great regularity; and they prove most conclusively that neither of them is at all like what Bewick terms "nothing more than a volcanic dyke."

It will be seen by the map of the district, Fig. 1088, that a border is traced around the edge of the valley; this is undoubtedly the outcrop of what is called the "top seam" of ironstone, as it can be traced south and east into Eskdale, and towards Grosmont and Fryupdale; and also north towards Swainby and Boltby, in which localities Marley has given sections of the top seam, and also of the Cleveland main band. Supposing this outcrop in the Rosedale valley to be the top seam, then the upper bed in the sections, Figs. 1089, 1090, is unquestionably the top seam likewise; and we there have a bed of ironstone upwards of 30 ft. thick, lying parallel to and strictly conformable with the "top seam" (and separated therefrom only by a thin bed of shale), of an entirely different character from either such top seam or the main band of Cleveland.

I have (says *Wood*) laid down on plan, Fig. 1089, a section of the strata given by Marley, at Grosmont to the south-east, and at the Swainby mines to the north; and I have added the section at Eston Nab. It should be observed, also, in corroboration of the upper bed of ironstone, Fig. 1089, being the top seam, that a bed, or rather three or four beds, of ironstone intermixed with shale occur in the brook of Rosedale and crops out in the bank, which is generally believed to be the representative of the Cleveland main band, though the ironstone is very inferior, and not workable. I have laid down on the section, Fig. 1089, the position of this bed of ironstone, which agrees pretty well with its position in the other sections, making allowance for the variation in the thickness of the lias shale as found in the several localities.

I have (observed *Wood*) likewise, in Figs. 1088, 1089, shown the position of the quarry, which appears to have slipped down below the level of the beds, as shown by the drift and borings. This appears to have been occasioned by a slip-dyke which crosses the drift near the pit, as shown on the plan, Fig. 1088. It will be seen by this plan that the drift passed through alluvial soil and shale up to near the pit, when this dyke was crossed and the ironstone cut, as shown on the plan. This dyke is supposed to run in the direction shown on the plan, crossing the drift near the pit, and throwing the strata down on the south-west side, and, consequently, the strata comprising the quarry; and it appears that the quarry itself is much broken, and has very much the appearance of a disjointed slip, the elliptical nodules being in a mass of confusion, as shown on the plan.

It has been supposed by some parties that this dyke has given the magnetic character to the ironstone; but it is well known that the character of the ore must be changed from a peroxide to a protoxide to become magnetic, which the crossing of the dyke through the strata could scarcely accomplish; and then we have the entire absence of shells in the lower bed, while the matrix of the upper bed or top seam is entirely calcareous and filled with shells. The concretionary nature of the stone, and the much greater percentage of iron produced by this deposit over that of either the top seam or the Cleveland main band, are also characteristic of this bed of ironstone; the analysis given by Marley of the Rosedale stone being upwards of 50 per cent. of metallic iron, while the top seam and main band are about 32 to 35 per cent.; and the produce of a large quantity smelted at Consett gave 55 per cent. from the calcined ore, and 45 per cent. from the raw stone.

Whatever opinion may, therefore, be formed of the cause of this deposit, we certainly have the fact that, for a width of 400 yds. and a length of 580 yds., we have a bed of ironstone highly magnetic, of an almost entirely uniform thickness, totally different in its mineralogical character from the ordinary stone of the district, and yielding in produce nearly 20 per cent. more iron in the furnace. To what extent this bed may exist beyond the extent already proved will be the subject of further investigation; but it will be a very extraordinary anomaly in geology if a bed of such uniform thickness should not extend to considerable distances. It has been stated that a similar bed has been discovered in other and distant localities; not being myself cognizant of the facts, and my information not being very precise, I abstain (says *Wood*) from giving such information at present. The importance of such discoveries are of too great interest in the district, and too valuable in a commercial point of view, to remain long unexplored, and therefore we may hope that at some future period the Institute will be favoured with an account of such deposits.

The President's paper on the Rosedale Ironstone having been read, a discussion thereon was taken.

Bewick said the magnetic ore in the quarry was a casual deposit in the shape of a dyke or vein.

Marley.—I understand, since I was at Rosedale Abbey, that which the President stated to be the top seam had been discovered in a regular stratified state on the south side of the magnetic quarry. At the last discussion we had on the subject, I admitted if that bed of ironstone had been discovered keeping on its uniform rise and dip, from the north side of the quarry to the south, I had been mistaken in supposing the magnetic seam to be the same as that of the seam then discovered on the north side of the quarry. Then, as to whether it was a vein or a bed, or whether, what I supposed at the last meeting, it was an overflowing between soft strata, similar to "flats" in lead veins, I had not an opportunity of forming an opinion, for want of the *three bore-holes*, which have now been given.

The *President.*—What you stated was quite correct. The top seam had not then been found on the south side of the quarry. It is now found on the south side as well as the north side; but I do not think we have yet discovered the magnetic stone on the south side of the quarry, except in the drifting and borings.

Marley.—When I made my examination, preparatory to reading my paper, the top seam at the point *A* on Fig. 1087, therein referred to, was lost, and no continuation was found south of the magnetic quarry; but, by competent witnesses, I have been informed it is now found south of the said magnetic quarry. But, if the magnetic stone is a bed, it is extraordinary so large an extent of country should give no trace of it, as at Grosmont and other places we have not the slightest trace of it. At Ingleby they are putting three bore-holes down, with a view of proving the existence or otherwise of the magnetic ironstone there. They are now, I believe, past the top-seam position, but have got nothing but shale yet. These borings will prove about 100 fathoms of strata. I have hitherto been of opinion that the round particles, in the specimens of magnetic ore, are oolitic shells.

The *President, N. Wood.*—No. I believe they are iron, with a siliceous matrix.

Marley.—Has one of those globules ever been analyzed by itself, and found to be pure iron?

Wood.—I do not know; but I believe there is no calcareous matter in those particles which there would be if it were shells.

Marley.—Unless it is some peculiar formation.

Wood.—Then the shell is gone, and the iron left.

Boyd.—The chemical part of the shell remains in the Cleveland stone.

Marley.—The magnetic stone is not in analogy with the Cleveland.

Wood.—It has changed its character from a peroxide to a protoxide.

Marley.—I acknowledge the magnetic stone is free from "pectens."

Bewick.—After hearing what has been stated by our President, I am bound to say our opinions are as much opposed as ever; and I shall endeavour to show you that the ironstone beds they have BORED THROUGH at Rosedale Abbey are not the same as the magnetic ore and top bed found by the side of the valley, that, in fact, the borings have not reached those deposits by several feet, and that, therefore, *they have not as yet proved anything more respecting them.* The strata they have bored through are quite above them, and you will find on looking at the table of the borings, publishion with the July discussion, that an important member of the series, which immediately overlies the top bed, is wanting. I allude to the great sandstone rock, which is seldom under 50, and sometimes met with 100 ft. thick. This rock does not appear in the borings at all.

Wood.—Yes, it does, namely:—

			Fms.	Ft.	In.	
Brown freestone ..	No. 1 bore-hole	.. ..	12	5	6	with other beds of post, mixed with shale.
Brown and grey post	" 2 "	.. ..	12	1	0	
Brown post	" 3 "	.. ..	11	5	0	

Bewick.—That is not the sandstone I allude to. That rock is found higher in the series, and belongs to the coal measures, which your *bore-holes* have gone through; but, as I have just said, they have not yet reached the other sandstone, and cannot, therefore, have touched the top bed. In this section, Fig. 1096, you have, in my opinion, a type of the ironstone you have gone through in your borings. The seams here are thin and divided, and the shale between them is interspersed with iron nodules; and, as you admit the seams are split in the last *bore-hole*, it but serves to confirm my opinion that they are one and the same. They occupy the same geological position in the series—that is, they intervene the great sandstone rock and the coal measures in the oolitic series.

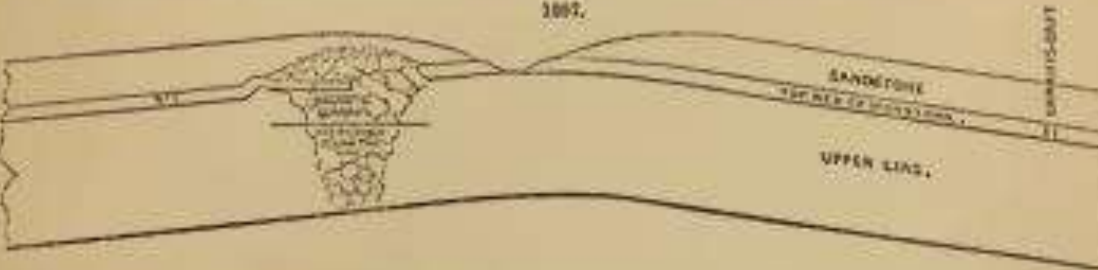
1096.

Reference:—1, 2, 3, Sandstone, shale, and coal. 4, Sandstone. 5, Upper lias. *a*, *b*, *c*, Ironstone.

Wood.—Do you purpose giving the sections for publication?

Bewick.—Yes; I intend leaving the whole of the sections with you for that purpose. The thickness of every stratum, in the diagram representing a cross-section of the vale of Rosedale, is taken from the table of the borings before referred to, in which I may here observe there is an error of 3 fathoms 2 ft. The total ought to be 48 fathoms 2 ft. instead of 51 fathoms 4 ft.; and if you take from this 1 fathom 1 ft. for the grey shale they have left off in, below the ironstone, it leaves 47 fathoms 1 ft. from the top of the bore-hole to the bottom of the ironstone. I am thus particular because I have taken a line of levels, commencing at the south drift, by the side of the hill, and terminating at the *south bore-hole*; and I find there is a difference in the height of the level, and the depth of No. 2 *bore-hole*, Fig. 1090, of 64 ft., fully corroborating what I have before stated, namely,—That the *bore-holes* have not yet reached the sandstone which overlies the top bed; and if you will allow me to explain my sections, I think they will prove to you that the ironstone they have cut through belongs to that which we call the oolitic beds, and which are found in different localities in the Grosmont district, not so thick, it is true, neither are they magnetic; but they are found, as I before stated, occupying the same geological position, and accompanied by the same description of strata. Section, Fig. 1096, is taken between Goathland Mill and Beckhole, near Grosmont, which, you will observe, contains the same alternating strata of sandstone, shale, coal, and ironstone, as you see in section, Fig. 1087, which is a transverse section of the vale of Rosedale, representing the strata they have bored through there. The ironstone beds *a* and *c*, in section, Fig. 1096, are, in my opinion, the same as those marked *a* and *c* in section, Fig. 1087. The bed *c* is very irregularly diffused throughout this portion of the oolitic district. It is found in the nodular form. In some places you find it of considerable thickness, and then, again, entirely wanting. Sometimes of good quality, but more frequently coarse and inferior, and gradually alternating with the sandstones. The bed *a* is more regular, but thinner, and of very good quality; its upper portion consists of a nodular bed averaging from 3 to 6 in.; and the lower portion a bed averaging from 12 to 18 in. in thickness. Wherever I have met with those beds, however, I have always found them so variable, both in extent and thickness,

1087.



as to afford no reasonable prospect of their paying for working. They may certainly be found different at Rosedale; but I would just observe that I consider *boring a most fallacious mode of proving ironstone deposits in strata* such as that which these borings have gone through, you are so liable to mistake a nodule for a bed, or a portion of a bed. I shall be much surprised if you do not find the section of your shaft, should you sink one, very different from the section of your *bore-hole*.

Wood.—Then it is a question of policy, in Bewick's view of the case, commercially considered, whether the borings should not be continued. With regard to the identity of the position in the series of the bed of ironstone ranging around the Rosedale valley, as shown in Fig. 1097, and also in Fig. 1087, it appears to be undoubtedly the top bed of Cleveland. All parties admit this. Then the question is, Is the bed of ironstone proved at the pit No. 1, Fig. 1089, and the bed corresponding therewith and proved in the bore-holes Nos. 1, 2, and 3, and therein designated by me as the top seam, the same bed of ironstone? Bewick thinks not, and that the borings have not yet reached this bed. I can, of course, only refer to the borings, driftings, and the section of pit No. 1, and I must add that there appears to me no doubt whatever on the subject; and the fact that, according to Bewick's plan, Fig. 1097, we have the top bed on both sides of the magnetic quarry, ranging as accurately as can be conceived with this bed in the borings, confirms this supposition, in my opinion. It is true that this bed is at a lower level at the south or left-hand drift than on the north side, but this is clearly the effect of the dyke shown in Fig. 1087, which throws down the strata in that direction. With regard to the supposed want of what Bewick calls the thick sandstone strata immediately above the top bed of ironstone, and shown on the section, Fig. 1096, to be 100 ft. thick, I have looked carefully over the sections given in Marley's paper, and I do not find in any one of them, except at Eston Nab, the extreme northern point of the district, any bed of sandstone approaching to that thickness, and there the section given is

	Ft.	In.
Freestone	60	0
Shivery post, patches of jet, and fire-clay	54	0
Top seam, exclusive of shale bands	1	3

At Rosedale Cliffs, between Staiths and Runswick Bay, we have

Freestone	26	0
Fire-clay	4	6
Freestone shale	5	5
Blue shale	0	10
Top seam, exclusive of shale bands	4	7

Still farther south, the sandstone at Wreck Hill is only 10 ft., with 2 ft. 6 in. of shale covering the top seam; and at Grosmont, Marley gives 25 ft. of sandstone, and another section at 38 ft. 6 in., which he says varies in thickness and quality. At Fryupdale, the thickness of sandstone is given at 55 ft., and at another place, namely, Swainby, the following is the section:—

	Ft.	In.	Ft.	In.	
Soil, &c.			3	0	
Freestone			24	0	Near the limekiln this is 100, with 9-inch ironstone balls in it.
Slaty coal	0	9			
Shale	1	0			
Sandstone	4	0			
Slaty coal	0	9			
	6	6			
Shale	5	0			
Coarse freestone	3	6			
Shale, with occasional nodules of ironstone	13	0			
Top seam			28	0	

Considering, therefore, that in the borings there is about 60 ft. of sandstone, there does not appear to me any substantial difference between the shale in those borings and in the other parts of the district to justify the supposition that the upper bed of ironstone is not the top seam. Bewick thinks the bore-holes have not reached the sandstone he describes. If so, he should like to ask Bewick what seam of ironstone that is in the district which has been bored to?

Bewick.—It is, in my opinion, as I have previously stated, the ironstone found in the oolitic series.

Wood.—Where does it occur in the other districts? Where do you find another similar deposit in Mr. Marley's sections?

Marley.—Dr. Verity gives a variety of ironstone seams. If you refer to my paper, you will find there are several ironstone seams lying over the seam, which we agree to be the top seam of Cleveland. Professor Phillips said that, with the exception of the classification of names, this section was practically correct.

Wood.—Do you think the ironstone which crops out all around the valley of Rosedale is the top seam?

Bewick.—I think so; I have no doubt about it.

Wood.—If we are agreed about the deposit of ironstone found cropping out around the valley of Rosedale, as shown in the different plans, then there can be no difficulty in tracing the sandstone overlying that bed to the sandstone first of all sunk through at the pit, Fig. 1089, and thence to the borings Nos. 1, 2, and 3; and these borings having passed through the upper bed of ironstone, below such sandstone, and then through the magnetic bed, there cannot be the least doubt of the geological position of these beds. With reference to the levels, there is no discrepancy whatever in that respect; there is a rise in beds in the line of the drift, and in the extension of that line to the borings, and the direction of the line between the borings seems to be nearly water-level at that part. There is not, therefore, the least discrepancy on this point. I have taken the Ordnance maps as my guide as regards the levels, and have no doubt they are correct. Whatever opinion may, therefore, be arrived at with respect to the comparison of the beds proved in the borings and in the pit, with the beds at Grosmont, &c., there appears no doubt in my mind that the mass of ironstone of the quarry is a detached portion of the thick or lower bed of ironstone, and that such bed exists *in situ* for a considerable, and, of course, at present, for an unknown extent in the locality of Rosedale.

Bewick.—If our President means by pit Fig. 1089 the air-shaft sunk on the main drift, I quite agree with him that the sandstone found in that shaft is the same as that which overlies the top seam; but, I beg to say, I entirely differ from him in supposing it to be the same as that they have gone through in the borings. I am also opposed to his opinion with reference to the direction of the dip and rise of the strata. There can be no doubt, I think, but the strata on the west side of Rosedale, *and to the south of the crown*—that is, the point from whence the strata dip in contrary directions—are dipping in a south-westerly direction, as shown in my section, Fig. 1097, and still more clearly proved by the drift commenced on the south side of the magnetic dyke, and driven in a line with the south bore-hole, running nearly west, but which has been discontinued, owing to the top seam, in which the drift was commenced, dipping so much in that direction, instead of rising, as our President supposes, as, at the distance of not many yards, to be completely under water-level. With reference to the slip-dyke or fault mentioned by that gentleman, I can only state that I have never yet been able to discover any dislocation or disturbance of the strata, other than what has been occasioned by the dyke of magnetic ore in its immediate vicinity. Then, as to the extent of the magnetic ore, all I can say is, I have paid several visits to Rosedale solely for the purpose of examining the strata in that neighbourhood, the many deep ravines which abound there affording ample opportunity for doing so, but I have never been able to trace the magnetic ore beyond the vicinity of the quarry, and every visit only serves to convince me that it is a casual deposit, in the shape of a dyke or vein. A bed, however, of 560 yds. in length, and from 30 to 32 ft. thick, cannot be identified with a casual deposit; nevertheless, I think, very probably there may be a mistake in supposing you have a solid mass of ironstone 32 ft. thick. This may have occurred from the borers having cut through nodules or irregular patches of ironstone, and also from the shale in which it is found being very hard, and of the same colour as the ironstone. From these circumstances it is an easy matter to be misled by borings.

Wood.—Whatever may have been the result of investigations on the surface, I do not think I can add any further information to that already given and shown on the plans, to prove that a thick bed of ironstone of about 32 ft. exists over a space of upwards of 560 yds. in length, and 200 yds. in width, with not the least indication of any change or termination of such deposit. It would, indeed, be a most extraordinary occurrence in the annals of boring, to suppose that occasional nodules, or irregular patches of ironstone, should have produced the result recorded in these borings. The boring through the ironstone beds was performed under the immediate inspection of *Stott*, a well-known experienced borer, who kept the specimens brought up the bore-hole; and I can add, that I examined a great many of the specimens myself with a magnet, and found them magnetic. There is not the least pretence for supposing that shale could be mistaken for ironstone. Have you seen any nodular magnetic ironstone in the Grosmont district?

Bewick.—Never. You must remember (addressing the President) that you stated at the October discussion in 1857, that Professor Phillips and yourself had discovered the magnetic ore in "two localities two miles apart," namely, at Sheriffs drift and at the Quarry; and, again, in the July discussion of last year, you stated the stone in the drift south of the dyke was magnetic, but on examining it I found this not to be the case as regards both the drifts. I believe the reason why there are so many conflicting opinions with reference to the nature and extent of the magnetic ore is owing to the difficulty there is in distinguishing the ore from the top bed—that is, in separating the igneous portions from the sedimentary: for, although they are both frequently magnetic in the immediate vicinity of the dyke, there is yet a vast difference between them. The igneous portion is harder, heavier, and more compact than the sedimentary; and the former appears to have acted upon the latter whilst in a heated condition, much in the same way as a magnet acts upon a piece of common iron, imparting to it a portion of its peculiar magnetic properties. I may here be permitted to add, that whilst I believe this ore to have been subject to a heat sufficient to evolve the different gases it contained, I yet do not think the heat has been of that intensity so as *entirely* to expel them. We need not, therefore, be surprised at *traces* of carbonic acid being found in the chemical analysis of this ore. Here is a specimen of the igneous portion, which I took from the bottom of the quarry, and, after examining it, no one can doubt, I think, of its having been subjected to heat.

Wood.—There is no doubt, as stated by Mr. Bewick, that portions of the top bed in Rosedale are occasionally magnetic, and it was this property which led to the mistake, if there are mistakes, in supposing the magnetic bed to have been discovered at Sheriffs drift, and at the drift south of the magnetic quarry. The explorations at that time had not been sufficiently extended, nor have they yet been prosecuted to such an extent as to ascertain if the magnetic bed exists in those localities. Finding part of the ironstone partaking of magnetic influence led to a supposition that this bed did exist in those localities, and the subsequent explorations have not been prosecuted to an extent to ascertain the fact either one way or the other. To *Bewick.*—From what part of the quarry did you take this specimen?

Bewick.—It is from the floor of the quarry. This (showing another specimen) is a sample of the top bed which appears to have been partially burnt, and you will at once be able to detect the difference between them. These (showing other specimens) are samples of the ironstone found in the oolitic rocks, in the neighbourhood of Grosmont, some of the nodules of which are amongst the richest of the clay or calcareous ironstones. I omitted to state that, with the exception of the first 60 ft., where the ground was so steep that I could not fix my instrument, and from which there may be some slight inaccuracies, I took my levels with a good and safe instrument, and the operation was performed in the ordinary way of back and fore sights. I find the difference between my levels and what I suppose the correct position of the top bed of ironstone, and that shown by the bore-holes, to be 64 ft.

Wood.—The question of the difference of the levels rests entirely upon the assumed inclination of the beds; a difference of level of 64 ft. in a distance of 400 yds., accords, in my opinion, with what may be supposed to be the regular inclination of the beds.

Bewick.—Yes; but in your section you connect two sandstones which have nothing to do with each other, namely, the sandstone found in the air-shaft immediately overlying the top bed, and the sandstone found in the bore-hole, between which there are several feet of *alternating strata*; and to do which you must of necessity raise your level line, and show the strata to be rising in that direction; but the drift you have driven some distance into the side of the hill, and at the same point as my line of levels, shows the strata to be *dipping in that direction.* I may mention, too, that had another bed of 32 ft. thick really been met with in the bore-hole, it must have been found along the sides of the valley, which are intersected in so many places with mountain streams, all of which have been searched by persons having a fair knowledge of the geology of the immediate neighbourhood, but without the least trace of it having been met with.

Wood.—I cannot think that there is the least doubt that the sandstone in the pit, No. 1, Fig. 1089, is the same sandstone as that proved in the borings; all the appearances on the surface, as well as the general rise and dip of the strata, prove this. Extending the line of section across the valley, it is clear there is a general rise of strata along the line of section. No doubt the strata in the drift dip towards the west, but that is no doubt influenced by the slip-dyke which crosses it. I would observe that, taking the line of section along the face of the valley in Fig. 1087, in the direction of the dotted line *a b*, and applying the inclination of the top bed of ironstone, shown Fig. 1097, to that line, and not to the curved or projecting line along the face of the hill, the position of the bed would be rising from *a* towards *b*, and it would require a slip-dyke, shown Fig. 1087, to throw the bed into its proper position along the face of the valley to the west of the magnetic quarry. On examining Fig. 1087 it will be seen that the magnetic quarry and the top bed of ironstone, as shown in Fig. 1097, project considerably to the east of the general line of the side of the valley, which, being towards the dip of the strata, shows the top bed at a lower level than if the section had been continued in a more direct line, or in the direction *a b*. Whatever conclusion, therefore, may be arrived at after all the explanations given, we have the fact of an almost horizontal bed of ironstone, and of nearly a uniform thickness, distinct in character from the ordinary beds of the district, extending over a length of 568 yds. and a width of 200 yds., which clearly proves that it is not a vein. How much greater distance it extends, must be left to future explorations to prove; but it would certainly be an extraordinary anomaly in geology for such a thickness of strata to disappear altogether in a short distance. If it extends across the valley, as shown in *Bewick's* plan, Fig. 1096, then there is no reason to suppose that it may not extend to the same distance to the north; and if, according to Bewick, the borings have not yet reached to the top bed of ironstone, then the deposit of ironstone, in the valley of Rosedale, is richer in ore than either Professor Phillips or myself has set forth. The correct extent must, however, be left to future explorers to discover. Enough has been proved to show a most extraordinary deposit of a very peculiar and rich ironstone, and well worth further investigation.

Bewick.—There is a section of the cross drift, shown in Fig. 1089, driven at right angles from the main drift to prove the breadth of the dyke, and which, at the distance of 16 yds., cuts the shale, and apparently touches the top seam at the same time. At the distance of 6 yds. the stone in this drift ceases to be magnetic. It is, therefore, incomprehensible to me how it can again become so at the distance of 200 yds. from this point. Of course, you have a right to infer from the information that reached you that such is the case. Still I would strongly recommend that the borings should be continued to prove whether the sandstone be below you or not, to ascertain which could not fail to give great satisfaction to all concerned; the cost would not be great, as the bottom of your borings must be near the top of that rock.

Wood.—The cross drift was not sufficiently extended to the west to prove the dyke, but as there was a considerable rise of the strata in that direction, no doubt such an inclination has been occasioned by the proximity of the dyke, shown on the plans, Figs. 1087, 1088. All the facts show that the slip-dyke has been a dislocation subsequent to the formation and consolidation of the various beds affected by it; and consequently such dyke could not, we can scarcely conceive, have any influence on the character of the ironstone bed itself, especially as it is not contended, I believe, that such dykes are either of a basaltic or mineral character, there being no appearance, in my judgment, to justify such a conclusion.

ON THE MAGNETIC IRONSTONE OF ROSEDALE ABBEY, CLEVELAND.

By JOHN MARLEY.

As the subject of the Cleveland Ironstone has an important bearing on iron making generally, it is hoped that some details respecting its more remarkable features may be of interest to a meeting such as the present held in the city of Glasgow, the centre of a large iron producing district.

The writer would, therefore, call attention to the extraordinary deposit of magnetic ironstone in Rosedale Abbey, now locally known as "Rosedale West." As the whole of the Cleveland ironstone district has become too large for dealing with in any single paper, it is thought that a full description of the results of the explorings of the last eleven years, showing the actual extent and position of such ironstone, will be acceptable to the profession as well as the public.

The author had the opportunity, during the month of June last, of visiting and examining this wonderful deposit of ironstone. In Part VIII. of Spon's Dictionary of Engineering, published in 1869, under the head of Boring and Blasting (page 501), the paper of our first President, the late N. Wood, on this Rosedale Ironstone, with the discussion thereon,* is given as an example of boring for minerals, and quoted nearly verbatim to show "the baseless fabric on which the so-called science of geology is made to rest."

The author felt induced to bring this subject before the present meeting thinking it a good opportunity of giving correct details of this magnetic ironstone, and at the same time of doing justice to the late N. Wood and the late J. Bewick, both of whom took a prominent part in the discussion quoted in Spon's Dictionary, the editor of which, it is understood, will be glad of the occasion afforded to place the real facts before the public, as to the extent and peculiarities of this deposit, in such a way as will show that, if the late President and Mr. Bewick

* Vol. VII. of Transactions of North of England Institute of Mining Engineers, February, 1859.

had before them correct data on which to form their judgment (using a quotation of the editor), the "so-called science of geology" would not have been in jeopardy, since it is now proved it was the borings alone that were visionary.

If any one wishes for further details as to the discovery, application, or geological formation of the Cleveland ironstone generally, as also on this Rosedale District, he is referred to the author's paper in June, 1857,* to Mr. Bewick's† and Mr. Wood's papers, read in Newcastle in 1857 and 1859, to Mr. T. Allison's paper, read in August, 1869, before the South Wales Institute of Engineers, and to Mr. W. Cockburn's paper, read at Middlesbro' before the Cleveland Institute of Engineers in 1869, as well as to the published work of Mr. Bewick on Cleveland ironstone in 1860.

In the paper of 1857, the Rosedale ore was alluded to on account of its large per centage of iron, the size of the deposit, and magnetic properties of the stone, and although iron had been made there 600 years ago, it was not until modern time, in 1834, and in 1853, that it again received attention, although previously, in 1851, a large quantity was worked for making and repairing roads.

In 1857, the quarry was unproved as to extent and thickness, the stone being in a conglomerate state, apparently not stratified, lying neither vertically nor horizontally, and allusion was made to the cheek or slip running parallel to the drift; attention was also called to the want of an exploring drift behind the quarry to prove the ironstone.

When making his examination in 1857, the writer had no doubt but that "Sheriff's Drift" seam, about 13 feet thick, was the top seam of the lias formation, now known as "the seam of the district," and the same seam as that at point A on the plan accompanying the paper of 1857, and also probably the same seam as that found at or adjoining the quarry. These suppositions, together with the fact that the top seam actually overlies the magnetic stone at the quarry forming the roof of the magnetic stone in drifting, have since been ascertained to be correct; the per centage of iron and quality, however, are very different.

Whether the writer was correct in his view as to the magnetic stone forming, or ever having formed part of, or ever having derived its high per centage of metal from the top seam, is still an unsettled question; on the other hand, it cannot now be called either a "vein" or a "bed."

* Vol. V. of Transactions of North of England Institute of Mining Engineers, June, 1857.

† Vol. VI., Do., December, 1857.

It was stated in 1857, that the extent was an unsolved problem, left to others to prove, but the boundaries of the formation are now given in this paper.

The stone, although attracted by the magnet before calcining, will only (with some very rare exceptions) attract iron itself; the best parts contain 49 to 50 per cent. of metallic iron; whereas the best parts of the main seam of Cleveland ironstone, at present in use, can only be said to yield 33 per cent., down to as low as 28 per cent.; the top seam of "Rosedale East" being said to be equal to about 35 per cent. and upwards, although the same seam, in the same valley, is found to yield in some places not more than 20 per cent.

The author gives, 1st, the following quotations from his own paper of 1857:—

"The only special district to which I think necessary now to allude is the Rosedale Abbey District, the ironstone from which has attracted a large amount of attention on account of the large per centage, immense deposit, and magnetic properties.*

"I have no doubt that this seam is the same as the seam at point A on the plan No. 6, as also the same as that found on the east side of Rosedale, in Captain Vardon's property, of varied thickness, as well as the same seam as that at Grosmont, Fryupdale, Swainby, and Boltby, known as the top seam of Cleveland, the 9 inches of coal in the pit sunk agreeing with Beckhole, near Grosmont, in particular, so that the only doubtful point is as to the portion from the outcrop at A to the so-called magnetic quarry, the most feasible solution being that it is a disjointed patch of the regular seam, known as the top seam, and not a vein, as has been said; and with all due deference to the parties who have had more opportunity for examining this district than I have, I propose leaving the extent of the magnetic and extra per centage tract as an unsolved problem, as it may vary from one or two acres to any indefinite extent, not being at all proved, to the south." †

2nd.—Mr. Bewick says, in his paper of December, 1857:—

"My object in thus troubling the members of this Institution with the foregoing remarks is twofold. First, to show that the iron ore of Rosedale, instead of being a large mineral field as was first asserted, and still believed to be so by many, is nothing more than a volcanic dyke; and, secondly, that the ironstone lately opened out in this locality is not as it is reported to be, the main seam now being worked in Cleveland and Grosmont districts, but is, in my opinion, if Mr. Marley will permit me to say so, the top seam." ‡

"The proofs afforded me are, first, its vertical or unstratified formation; secondly, from its containing no organic remains whatever; and thirdly, from its

* Vol. V., p. 207. † Vol. V., p. 208. ‡ Vol. VI., p. 19.

being highly susceptible to magnetic influence, as well as exhibiting the appearance of its having been in a state of incandescence." *

"I would just observe that I consider boring a most fallacious mode of proving ironstone deposits in strata, such as that which these borings have gone through; you are so liable to mistake a nodule for a bed or a portion of a bed. I shall be much surprised if you do not find the section of your shaft, should you sink one, very different from the section of your borehole." †

3rd.—From the late Mr. Wood's paper, the writer has embodied, on the plans and sections here given, sufficient of his plan No. 1, and of the cross section as are necessary, to illustrate and show the extent of drifts in 1859, and the position of the borings. Mr. Wood says:—

"When this quarry was opened out, it was found to consist of apparently a confused mass of ironstone boulders of ellipsoidal structure, and of gigantic size, often 3 or 4 feet in diameter, the central part of these boulders being generally blue, and consisting of a solid dark oolitic magnetic iron ore, with, in many cases, sandy and solid ironstone crusts around it, and in receding from the centre the iron ore becomes paler, alternating with dark brown purplish layers; the layer then becomes pale brown, and the magnetic quality is lost. In most cases, however, the nodules are quite solid, and a slight stratification exists, though very obscure, and in several cases likewise the oolitic structure is merged into compact brown iron ore. In some parts also, where exposed to the water and to the weather, the iron ore is partly washed away, and a gritty ferruginous crust remains. These great variations do not occur where the ironstone is under cover, or covered by other strata, but appear to assume those different phases in consequence of its extreme susceptibility to change by exposure to air and water; and it is somewhat remarkable that the magnetic property is strongest where the mass is thickest, and scarcely shows any magnetism in places where it is thin, or where it has little cover, and, consequently, more exposed to decomposition or change.

"The great characteristic difference of composition between this ironstone and the top and main band of Cleveland is the entire absence of shells, the structure being entirely of an oolitic character, being entirely composed of small round concretions of iron ore cemented together with extremely thin silicious or arenaceous films, and in its magnetic properties exhibiting polarity, and likewise in its greater richness than the ordinary ironstone of Cleveland." ‡

"The boring through the ironstone beds was performed under the immediate inspection of Mr. Stott, a well-known experienced borer, who kept the specimens brought up the borehole, and I can add, that I examined a great many of the specimens myself with a magnet, and found them magnetic. There is not the least pretence of supposing that shale could be mistaken for ironstone. §

"Whatever opinion may, therefore, be arrived at with respect to the comparison of the beds proved in the borings, and in the pit with the beds at Grosmont, &c., there appears no doubt in my mind that the mass of ironstone of the quarry is a

* Vol. VI., p. 16. † Vol. VII., p. 97. ‡ Vol. VII., p. 89. § Vol. VII., p. 100.

detached portion of the thick or lower bed of ironstone, and that such bed exists *in sitû* for a considerable, and of course at present, for an unknown, extent in the locality of Rosedale.*

"If it extends across the valley, as shown in Mr. Bewick's plan, No. 5, then there is no reason to suppose that it may not extend to the same distance to the north; and if, according to Mr. Bewick, the borings have not yet reached to the top bed of ironstone, then the deposit of ironstone in the valley of Rosedale is richer in ore than either Professor Philips or myself have set forth." †

4th.—Mr. T. Allison says:—

"This is the most singular deposit of iron ore in Cleveland, or even in England, inasmuch as its deposition does not appear to have been governed by any known law, we must, therefore, confess our ignorance, and call it the act of one of nature's *unknown bye-laws*."

Having given these quotations, the writer refers to the workings at "Rosedale West," Plate No. XXXIII., which show the extent of each trough to be about 5 to 6 acres, or only about one-fifth of the superficial area originally expected from the borings alleged to be proved, and the two troughs to be only about 150 yards in greatest width, instead of two miles as stated, the greatest depth being about 32 yards.

Two longitudinal sections of each trough, with several cross sections, are also given, Plates XXXIV. to XXXVI., and also a general isometrical drawing, Plate No. XXXVII., of the two troughs is added, by way of showing the relative position of such cross sections, from which a better idea will be obtained of the relative positions and extent of each deposit; it will be remarked that although they do not touch as stated by Mr. Allison, they very nearly do so. The sides of the two troughs are irregular and shelvy.

It will be seen from the quotations given, that the late Mr. Wood, naturally inferring that the drifts and three borings had sufficiently proved the extent of magnetic ore, never doubted their accuracy; but from the information since obtained, it is seen that had his original advice been adopted when 300 yards in, to drive 100 yards of cross cuts north and south, the extent would soon have been at once definitely proved, and future errors prevented.

The drifts, however, on getting to the distance of 400 yards, came on a shale cheek in front, then 300 yards distant from No. 2 boring; this cheek had also been proved on each side of the troughs, and on following it up it was found to be the termination of the magnetic ore

* Vol. VII., p. 99.

† Vol. VII., p. 103.

to the west, and simultaneously with such termination a slip dyke riser to the west was found, as shown in the longitudinal section of Kitching's deposit, but as some details of this may be interesting, a sketch is given, Plate No. XXXVI., taken at the end of Garbutt's deposit, and attention is invited to the isolated patch of magnetic ore on the top of the dyke, having water washed pebbles between it and the top seam of the district, similar pebbles and shells having also been found in other parts of these two deposits lying between the top seam and the magnetic stone, as also occasionally on the side of the shale cheeks.

The slip dyke at the quarry, frequently named by both the late N. Wood and Mr. Bewick, the writer thinks is nothing more than a land-slip of the hill side, very prevalent in the district.

Having proved this termination of magnetic ore, by entering only on the top seam of the district, a drift of about 300 yards was with all speed continued up to No. 2 borehole, hoping that on reaching such borehole two magnetic beds would be got instead of the one lost, but it was shown on putting a staple up (having such borehole within its area) to the position of the alleged 13 feet of magnetic ironstone, that only ordinary common shale in sitû was found, and on sinking this staple down to the alleged 32 feet of magnetic ore, nothing was found but the regular top seam of the district containing from 20 to 26 per cent. of iron, with the sandstone and shale usually found with it, and which top seam at the quarry is generally about 11 to 12 feet in thickness.

The regular dip of the strata is 1 in 23 to the south.

It will be as well here for the writer to say that it is not his intention to show how these two magnetic beds or specimens of magnetic ore got into the borehole, they were no doubt *artificial deposits*, and he leaves this part of the subject by stating that neither the late Mr. Wood, Mr. Philips, nor the late Mr. Stott had any idea of the error. Again, it may be said that a part of this paper should show how the deposit of magnetic ore got into these troughs, or how such troughs themselves were formed, these points, however, are left to the more learned, and to such as are well versed in the science of geology. The No. 2 borehole having been thus proved incorrect, it was not thought worth the cost of driving to Nos. 1 and 3.

Borings were also made at the Ingleby Mines to find the magnetic deposit, but without success.

The troughs alluded to are nearly due east and west, and some importance has been attached to this circumstance in endeavouring to explain their magnetic quality. It has also been thought to indicate the action of icebergs, but however caused, it is clear they can no longer be called either one or two beds of regular strata, and as to being veins, not the slightest fissure of any kind has ever yet been found at the bottom of the two troughs, although diligently sought for.

Notwithstanding these deposits were much smaller than was originally expected, the present owners have, since they took possession in July, 1864, vended about half a million tons of magnetic ore from "Rosedale West," besides which, in the previous three-and-a-quarter years, viz.: from April, 1861, about a quarter of a million tons were sent away, and there is still a considerable quantity to work, although from its situation and shape, only a small quantity per annum can now be got.

The above named quantities are exclusive of stone that is not magnetic, or from inferior parts of the troughs, or from the top seam of the district. Fortunately at "Rosedale East," this seam has been found to be of extra richness, which has caused a large traffic and kept the public railway fully utilized.

The PRESIDENT remarked, that having had frequent opportunities of examining these remarkable deposits, he could confirm many of Mr. Marley's remarks. The theory of their volcanic origin was now quite exploded, and their structure was now admitted to be stratified, and to contain distinct traces of fossil flora, which would not have been the case had they been subject to plutonic action. He did not think there were any similar deposits in England, although, as Mr. Marley had remarked, present observation had been entirely confined to the west end of the valley of Rosedale. But he hoped, in the interest of the proprietors, other deposits of a similarly valuable nature might yet be found.

Mr. I. L. BELL, of Newcastle-on-Tyne, remarked that it had always appeared to him, on the discovery of these singular beds, that, from a strictly geological point of view, deposits which were come upon so suddenly, and which were of such unexpected thickness, might be found to take off in a correspondingly sudden manner; and he never could endorse the sanguine views of those gentlemen alluded to by Mr. Marley. He knew that at the time it was expected the magnetic stone would be found on the other side of the valley, *i.e.*, to the east, where the "top seam" was very clearly marked; but this proved not to be the case. Between the face of the hill, where it appeared in the great cliff, and the adjoining valley in a westerly direction, it had totally dis-appeared—nor was there the slightest trace of the so-called magnetic stone in the "top seam." With regard to the character of the deposit, its thickness might on first examination lead to the supposition of its being unstratified; but the circumstance to which the President alluded proves the contrary to be the case. All the analyses that he had seen indicated the presence of carbonaceous matter, and, he thought, some water not mechanically combined (which would not so much affect the question) but in a state of hydration; and these circumstances precluded the idea of volcanic action.

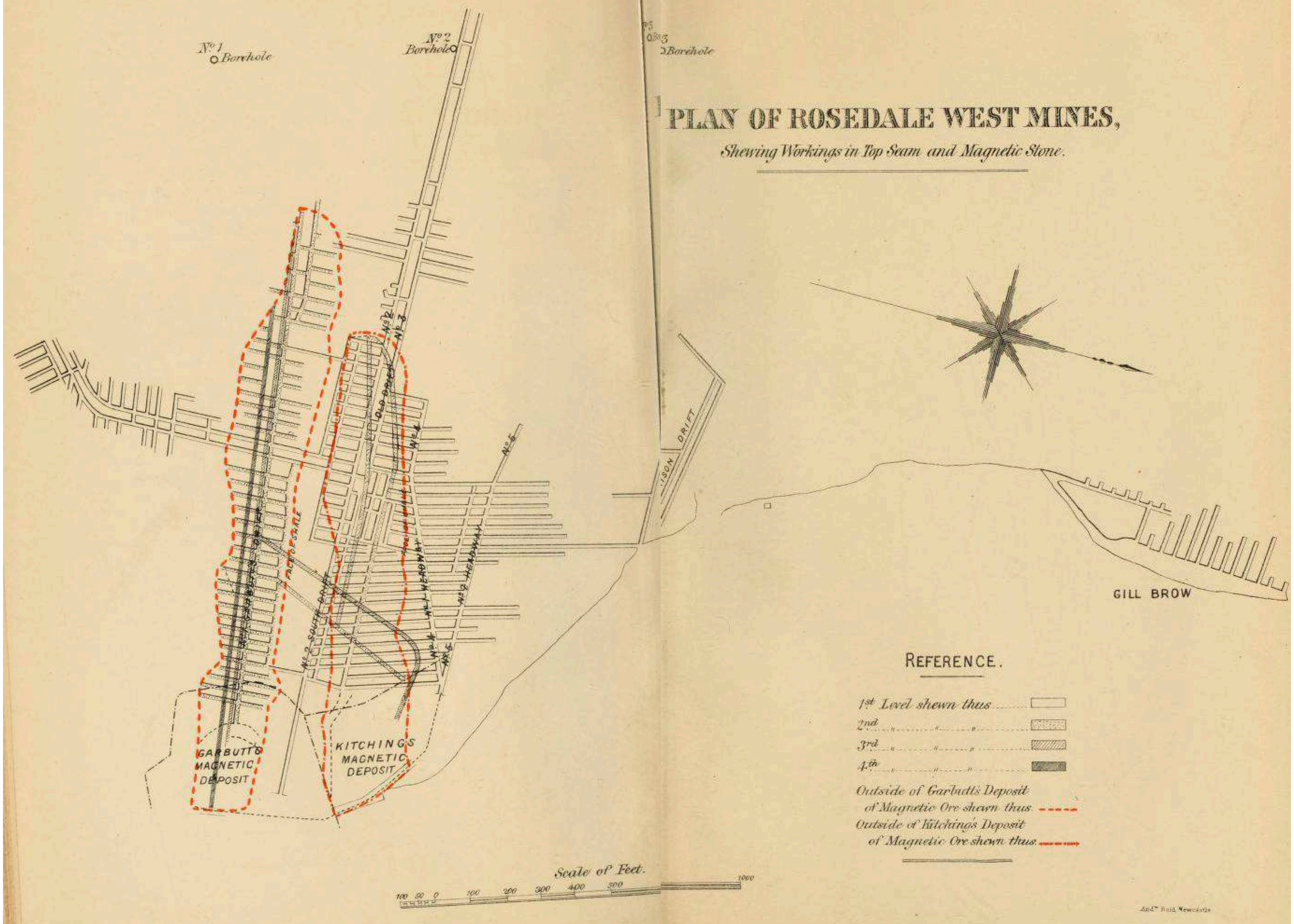
On the motion of the PRESIDENT, a vote of thanks was awarded to Mr. Marley for his valuable paper.

Mr. J. B. SIMPSON then read the following paper "On the Duty of Cornish and other Pumping Engines":—

(THE MAGNETIC IRONSTONE OF ROSEDALE ABBEY CLEVELAND.)

PLAN OF ROSEDALE WEST MINES,

Shewing Workings in Top Seam and Magnetic Stone.

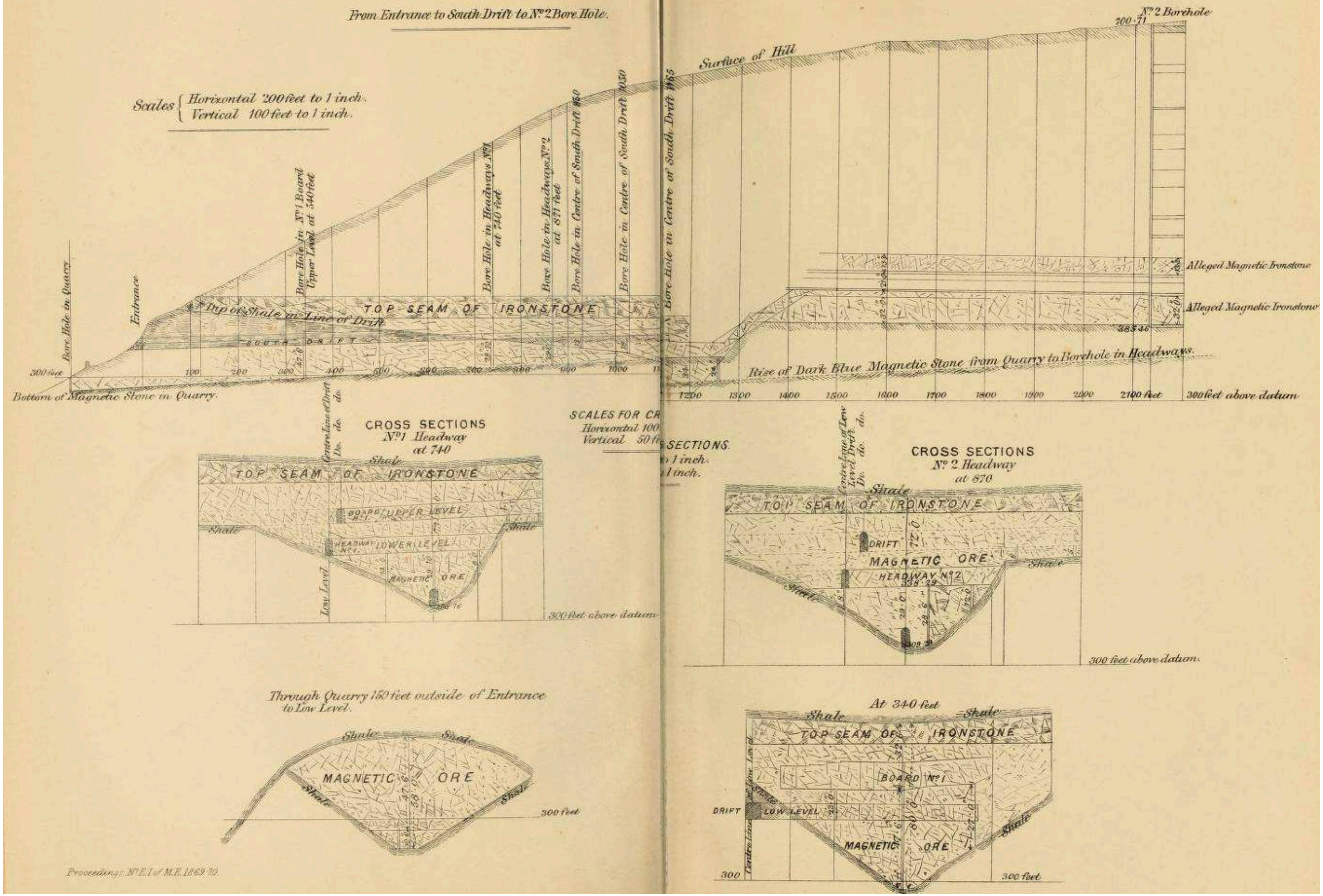


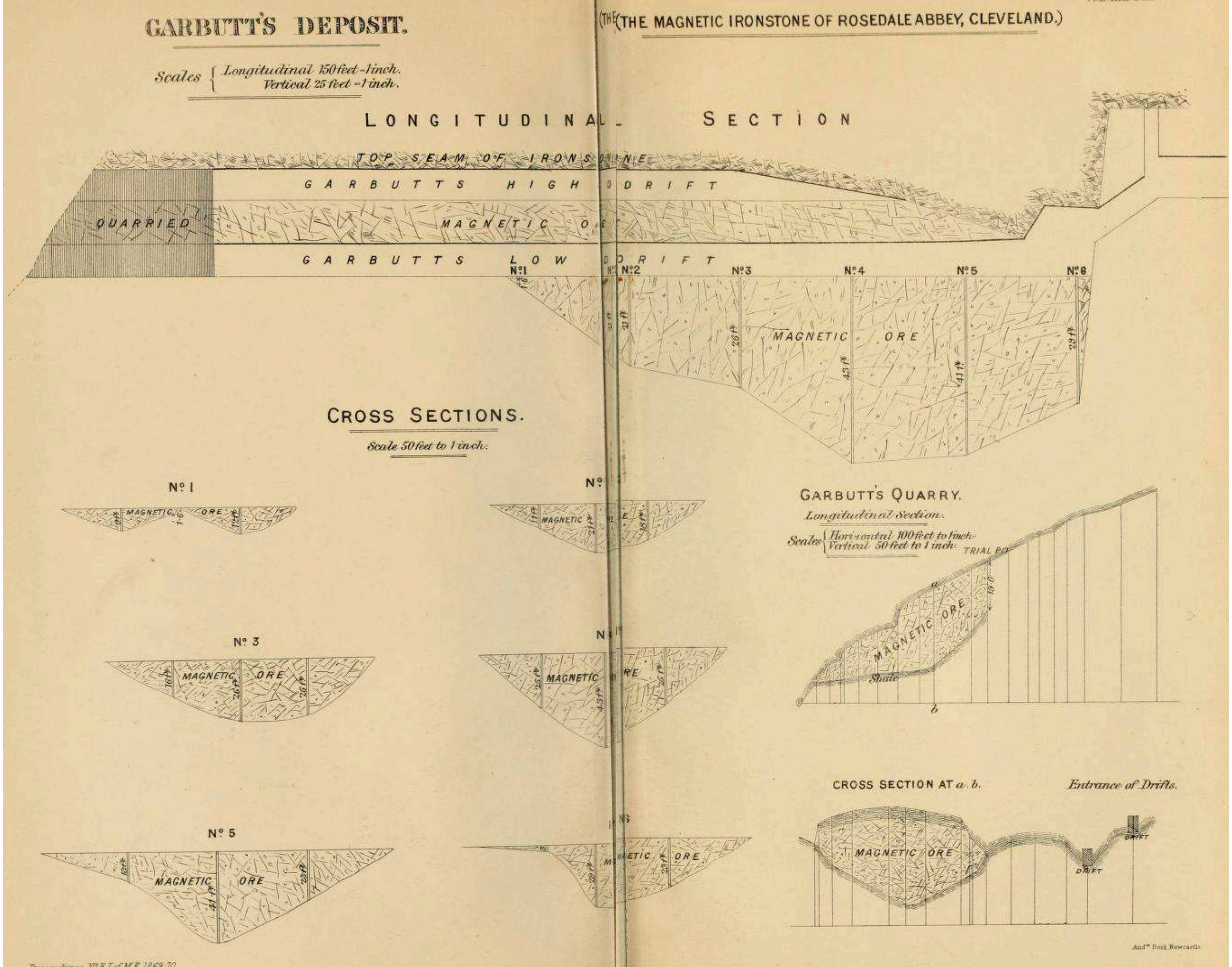
KITCHING'S DEPOSIT.

(THE MAGNETIC IRONSTONE OF ROSEDALE ABBEY, CLEVELAND.)

LONGITUDINAL SECTION.

From Entrance to South Drift to Nº 2 Bore Hole.



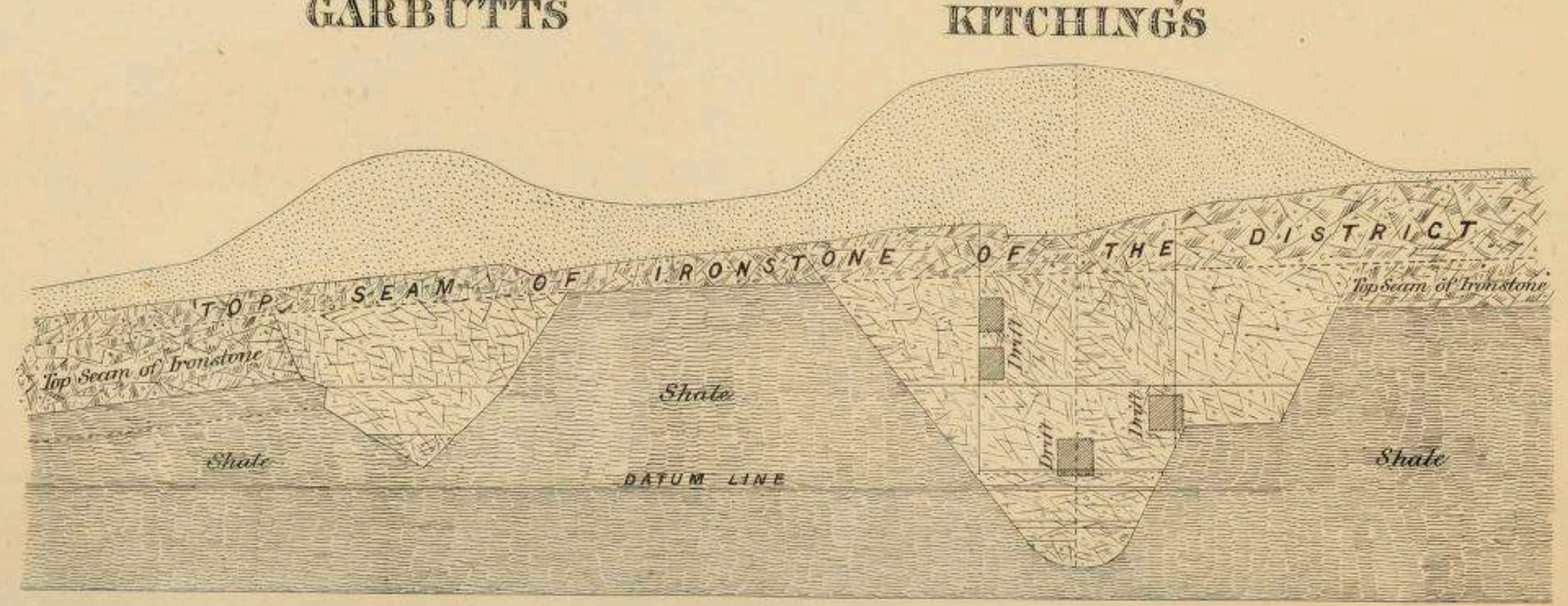


Andʷ Reid Newcastle

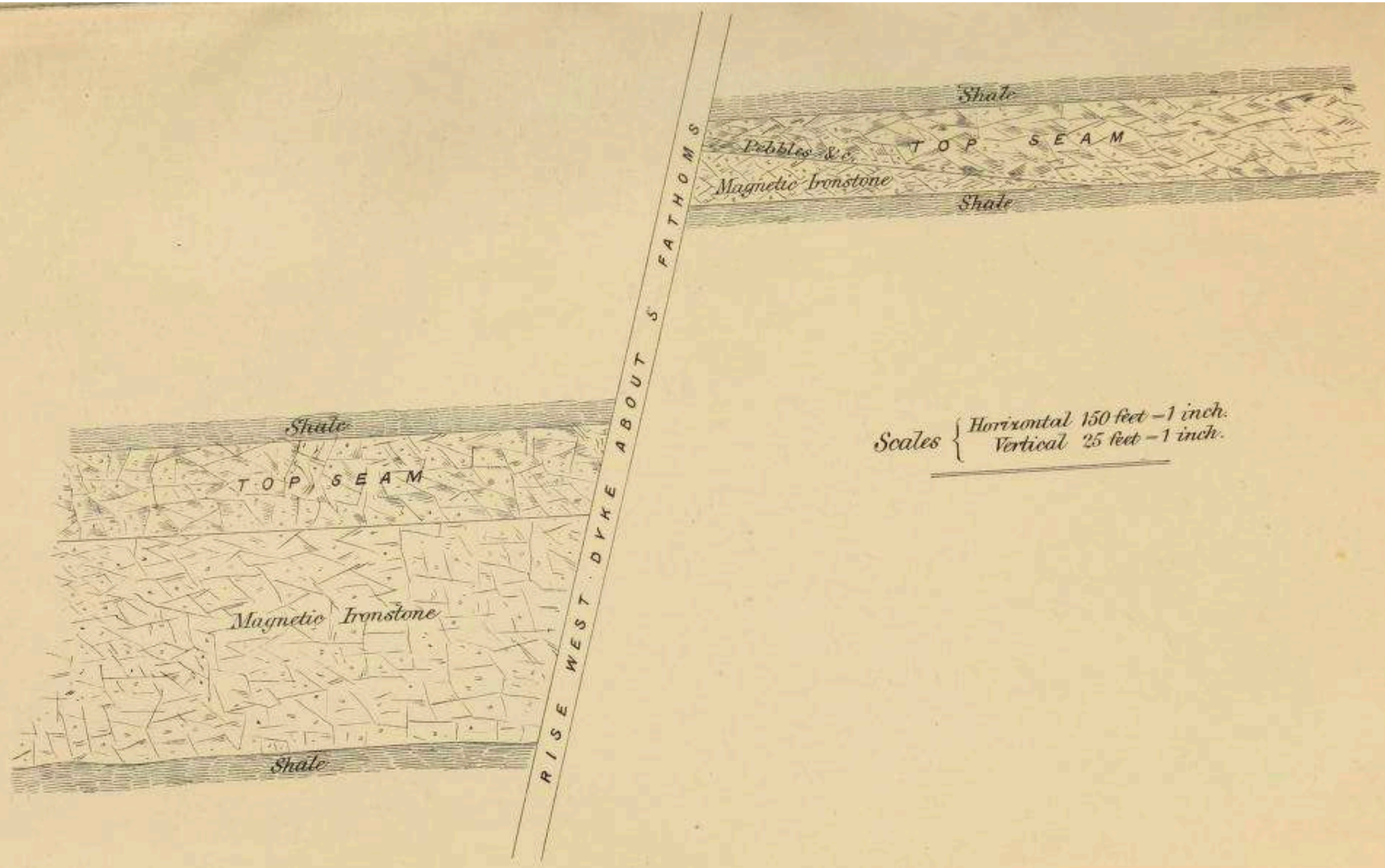
(THE MAGNETIC IRONSTONE OF ROSEDALE ABBEY, CLEVELAND.)

CROSS SECTION OF QUARRIES.

Scales { *Horizontal 150 feet – 1 inch.* / *Vertical 25 feet – 1 inch.* }



Position of the Top Seam of Ironstone and West Dyke in conjunction with the West

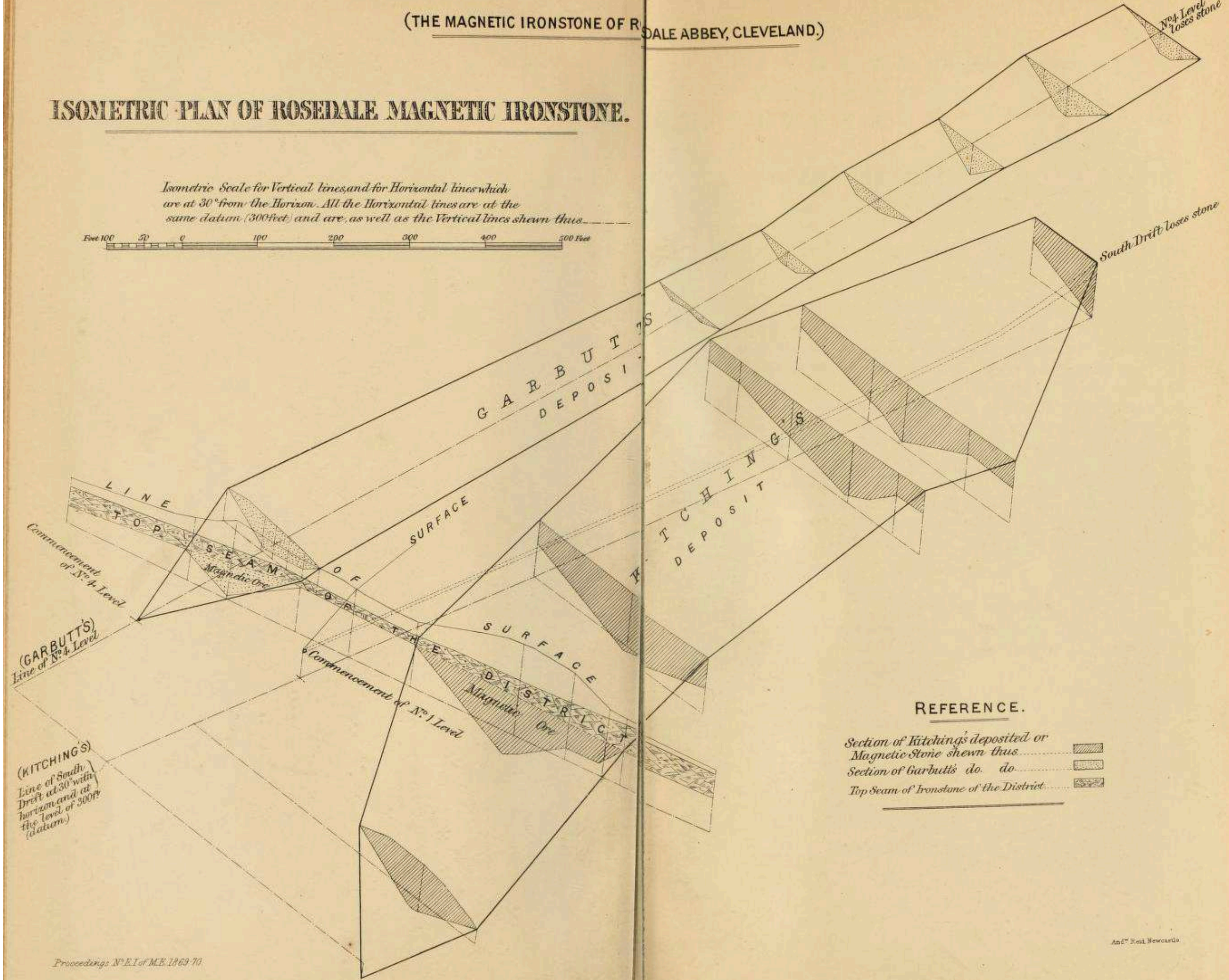


Andw Reid Newcastle

(THE MAGNETIC IRONSTONE OF ROSEDALE ABBEY, CLEVELAND.)

ISOMETRIC PLAN OF ROSEDALE MAGNETIC IRONSTONE.

Isometric Scale for Vertical lines, and for Horizontal lines which are at 30° from the Horizon. All the Horizontal lines are at the same datum (300 feet) and are, as well as the Vertical lines shewn thus ———



And^w Reid Newcastle

Current geological interpretation of the Rosedale Magnetic Ironstone deposit.

Locally, in the Rosedale area [SE 729 946], the Whitby Mudstone was deeply eroded into a series of shallow 'boat-shaped' depressions, about 500 m long by 30 m wide (Marley 1870). The depressions were filled with a distinctive Dogger lithofacies, a 'magnetite' ironstone (now shown to be a form of ferric, chronstedtite spinel; Hemingway 1974) overlain by ferruginous sandstone (Fox-Strangways et al. 1885; Rastall & Hemingway 1949). The iron ore probably represents a condensed, remanié deposit of early Opalinum Zone times that was preserved locally in shallow depressions on the pre-Dogger sea-floor.

Source: Powell (2010) Jurassic sedimentation in the Cleveland Basin: A review. *Proceedings-Yorkshire Geological Society* **58** (1), 21-72

Rosedale East Mines

From Fearnsides (1917)

TABLE SHOWING BRITISH OUTPUT OF IRON ORE, 1915.

Compiled from Statistics published by the Home Office, Mines, and Quarries General Report, Part III., issued 1917.

By Counties.

County.	Quantity of Iron Ore.	Quantity of Pig-iron obtainable.	Difference.*	
	Tons.	Tons.	1914.	1913.
York	4,831,465	1,446,413	–	–
Northampton	2,517,150	813,143	+	–
Lincoln	3,149,079	809,666	+	+
Cumberland	1,323,408	697,965	+	–
Stafford	703,231	211,071	–	–
Leicester	685,137	188,705	–	–
Lancaster	333,086	178,522	–	–
Ayr	136,996	41,099	–	–
Oxford and Rutland	140,520	38,377	–	–
Glamorgan	67,381	33,542	+	+
Lanark	68,101	20,430	–	–
Renfrew and Inverness	56,206	16,862	–	–
Antrim	39,326	15,273	–	–
Linlithgow	48,014	14,404	+	+
Stirling	41,352	12,406	–	–
Carnarvon	23,318	9,327	+	+
Wiltshire	19,486	5,846	+	+
Edinburgh	16,373	4,912	–	–
Durham	10,729	3,862	+	+
Monmouth	7,778	2,334	–	–
Gloucester	6,182	2,143	+	–
Fife	7,031	2,109	+	+
Warwick	4,338	1,314	–	–
Salop	3,560	1,068	+	+
Kent	2,458	738	+	+
Worcester	1,468	440	–	–
Dumbarton	1,168	350	–	–
Devon	40	21	–	+
Derby	31	9	–	–
Total home output	14,235,012	4,567,351	–	–
Foreign ores imported	6,197,155	4,151,051	+	–
"Purple ore"	677,600			
Total	21,109,767	8,724,402		
Less quantity exported	1,684	842		
Available for furnaces	21,108,083	8,723,560	–	–

In 1914 there were other mines at work in Worcester, Somerset, Londonderry, Brecon and Derby. In 1913 mines were also worked in Denbigh and Merioneth.

* The signs + and – indicate respectively an increase or decrease of output in 1915 as compared with the two previous years.

William G. Fearnsides (1917) THE SHORTAGE OF THE SUPPLY OF NON-PHOSPHORIC IRON ORE. Lecture I *Journal of the Royal Society of Arts* **65**, No. 3384, 743-754

AVAILABLE HOME SUPPLIES OF IRON ORE.

Output of Home Ironfields

During this, the first of the two discourses which I am to devote to the subject of iron ore, I propose to deal more particularly with the known supplies of iron ore and shall take as my key the quantitative data set out in the home office output returns in the chief inspector of mines report the latest published years. In the table we have, by counties, the tonnage of iron or worked in the British Isles during the year 1915. We shall consider items in this table in the order of the weights of pig-iron which the ores wrought in the various counties might yield when smelted.

York - *Cleveland*. -First amongst the counties as a producer of iron ore stands the shire of the broad acres, which, by reason of the productivity of the Cleveland district, has maintained the premier position in this respect for more than 50 years. The working of the Cleveland Main Seam which forms the topmost bed of the S*pinatus* zone of the Middle Lias, only began about 1850, but by 1856 the tonnage report exceeded 1 million tons a year, and in 1876 the years output had grown to more than 6 million tons. The maximum productivity of the Cleveland district was obtained in the early 80s, with 6,000,756 055 tons in 1883, since which date until 1915 yearly output has never fallen below 5 million tons, so that the total tonnage one has passed 300,000,000 t. The all bed at its thickest (about 17 feet) in the district where it was first opened up at its outcrop near Eston Nab. Down dip and along the outcrop and sickness varies somewhat irregularly, but on the average it becomes thinner in an easterly and southerly direction. Over a total area computed at about 350 square miles there is said to be an average of more than 6ft of workable ore. South of a line joining Robin Hood's Bay to Thirsk, inconvenient partings of hard shale come in the middle of the ore, and subdivide seem so that all in the district south of Kildale the seam is so split that the working of it is unprofitable. Some five and 20 mines employing nearly 10,000 men are now at work in the Northern district, and it is very probable that in these mines the winning of the all reserves already proved and opened up could find employment for almost twice the number of men who are now engaged, and that with such additional skilled labour the output of the minds could be proportionally increased.

Underlying the Main Seam, and separated from it by a hard shell it varies from little more than a parting to a rock mask several feet thick, occurs the *Pecten* seam, which is of greatest economic interest in southern Cleveland about Grosmont and Rosedale, where the Main Seam is so split up by partings has to be unworkable. This Pac10 seem there is in thickness from about 2'6" to to 4'6" feet six inches adding quality is not inferior to the Main Seam. About a score of feet below the a group of beds known as the *Avicula Seam*, also of good quality that of irregular thickness, underlies the whole of the Cleveland district, and has been exploited at a few localities.

In addition to the ironstones of the Middle Lias series, the basal bed of the overlying by Bajocian Series known as the Cleveland Top Seam or Dogger Ironstone, has on occasion been worked along the valley of the Esk. In former days this seam proved specially valuable in the Rosedale mines where it was known as quote the "seam of the district." Generally, however, it's all is to siliceous to be much in a request among Cleveland ironmasters. The circumstance that the quality improves and the thickness increases southwards, just, where the other seams are dying out, suggests that by boring further to the south and east valuable reserves of workable or maybe discovered beneath the cover of new rocks within the district drained by the River Derwent.

As mined, Cleveland or is generally blue or green-grey oolitic rock, in which the carbonate of iron occurs as oolitic grains. In the analyses silica is shown to fall at least 8%, and on occasion up to about 20% of the Rock, but the bases, more especially lime and alumina, are also present in such proportion that the or is almost self-fluxing. The sulphur percentage is not high, averaging about 0.1; but phosphorus is moderately abundant, and if the pig-irons which Cleveland or yields when smelted with Durham coke are to be made into steel, the ”basic” process is needed for its refining. It is worthy of note that the famous Thomas and Gilchrist basic process, which is the basis of all the modern German practice of steelmaking from pig-irons smelted from Lorraine ores was invented and perfected at Middlesborough between 1877 and 1881 for the purpose of converting Cleveland pig-iron into steel. In Great Britain the process has been taken up much more slowly than on the continent partly because our engineers are conservative in their practices and have been very suspicious of the reliability of any except acid steel, and partly because in this prejudice they were encouraged by ironmasters write vested interests both in the plant required carrying on the acid process and in the minds from which haematite or is wrote. In recent years, however, it has been generally recognised that the best-grade haematite or is becoming scarcer, under fresher impulse has advice being given to the basic steel industry of the Cleveland district; and at the present time the guy made from phosphoric Cleveland ores almost without admixture is being converted directly into steel on a very considerable scale. The average iron content of Cleveland ores is about 30%, and, seeing that the average value of the ore at mine was in 1915 only five shillings and four pence per ton it seems probable that Cleveland is one of the districts to exclamation may look for an increase in production of cheap iron or in this time of need. It may be noted that between 1912 and 1913 the output of all from Cleveland was increased by 852,000,360 tons. In 1910 Professor Louis estimated the available ore reserves of Cleveland at 3,000,000,000 tonnes.

Additional to the 4,746,293 tons of ore produced by mines in Cleveland, a further 51,321 was obtained from open quarries working the outcrop of the Cleveland main seem and there is also the item 23,851 tons of or noted as wrought from mines which are also working coal in the west Yorkshire coalfield.

References

Bewick, Joseph 1861. *Geological Treatise on the District of Cleveland, in North Yorkshire, Its Ferruginous Deposits, Lias, and Oolites; With Some Observations on Ironstone Mining*. London: John Weale.

Fearnsides, W.G. (1917). The shortage of the supply of non-phosphoric iron ore. Lecture I *Journal of the Royal Society of Arts* **65**, No. 3384, 743-754.

Marley, J. 1871. On the Magnetic Ironstone of Rosedale Abbey. *Transactions of the North of England Institute of Mining and Mechanical Engineers*. **19**, 193-199.

Phillips, J. 1828. *Illustrations of the Geology of Yorkshire*. York.

Sedgwick, A., 1826. On the Classification of the Strata which appear on the Yorkshire Coast. *Annals of Philosophy*, **11** (Article 5), May 1826

Wood, N. 1869. On the Deposit of Magnetic Ironstone in Rosedale. *Spons' Dictionary of Engineering* **Part VIII (**Borings and Blasting), 501 - 512.

Young, G & Bird, 1822. '*A Geological Survey of the Yorkshire Coast: Describing its Strata and Fossils Between the Humber and the Tees, from the German Ocean to the Plain of York*.' Whitby.

Young, T.P. (1994) The Blea Wyke Sandstone Formation (Jurassic, Toarcian) of Rosedale, North Yorkshire, UK. Pr*oceedings of the Yorkshire Geological Society*, **50** (2), 129-142