# Invisible Labour in the Woodwardian Collection

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**Abstract**

As is widely known, the 'Woodwardian Collection' at the Sedgwick Museum, Cambridge, holds the nearly 10,000 rock, mineral, and fossil specimens collected by the eccentric English natural historian John Woodward between 1688 and 1728. Less widely appreciated, however, is the extent to which Woodward's collection depended on the 'invisible labour' of mineworkers, gem cutters, and other labourers. In this article, I use some of Woodward's extant field notes to reconstruct his debts to these labourers. As I argue, the taxonomic schemes for metallic ores and gems that Woodward proposed in a scientific treatise of 1728 owed more to the intellectual, as well as physical, labour of the mineworkers and gem cutters that he encountered in the field than is suggested in the treatise itself. The Woodwardian Collection is thus an ideal case study for rendering the invisible labour behind mineral collections more visible.

**Keywords:** Woodwardian Collection, invisible labour, mineral collections, mining, gem cutting

## Introduction

In early Hanoverian England, few mineral collections were as well-known as Dr John Woodward's (*c.* 1665-1728). Comprising nearly 10,000 specimens of rocks, fossils, and minerals collected by Woodward and his agents between 1688 and 1724 and bequeathed to the University of Cambridge upon the doctor's death, the Woodwardian Collection is today held at the Sedgwick Museum of Earth Sciences, Cambridge (Price 1989). Those who visit it today follow in the footsteps of such illustrious early moderns as the antiquarian Ralph Thoresby and the traveller Baron von Uffenbach (Eyles 1971: 412-3; Levine 1977: 123-4). And, like those early-modern visitors, most of today's visitors probably give little thought to the miners, quarrymen, gem cutters (also known as lapidaries), and other workers from whom Woodward procured his specimens. It is my aim here, however, to use the example of the Woodwardian Collection to argue that curators can tell richer, more interesting stories if they pay attention to the provenance of their mineral collections; further, these stories promise to be of much value to historians of the earth sciences interested in how taxonomic schemes for minerals developed.

What role, then, did miners, quarrymen, and other workers play in the assemblage and curation of mineral collections in early-modern England? And what role, if any, did they play in the development of taxonomic schemes for minerals? A familiar answer is also an obvious one: with exhausting physical labour, they extracted the specimens that were sold to the learned gentlemen naturalists who did the intellectual labour necessary to construct the mineral taxonomies. One historian tells us that '[t]raditional miner's earthlore was little tapped or refined by elite natural philosophers' (Porter 1977: 15); another tells us that the practical knowledge of miners and other labourers was too localized to be helpful for making scientific generalizations (Rudwick 2005: 33). In other words, the bodies of these workers were important, not so much their brains.

Yet recent research suggests that it is time to revise the claims of Porter and Rudwick. On the one hand, a growing literature on the artisanal knowledge of early-modern, non-British labourers, and especially miners, has shown that their 'invisible labour' played an important

role in the development of natural knowledge (Smith 2004, 2022; Anthony 2018; Bigelow 2020). On the other hand, Porter's and Rudwick's claims are grounded primarily on their reading of published texts. This is significant because, as Lydia Barnett has demonstrated in her recent survey of eighteenth-century 'elite works of natural history', gentlemen naturalists only tended to render the labour of their fossil finders visible in their published writing in order to assert their own socio-intellectual superiority. 'Substantive traces of laboring-class fossil finders', Barnett argues, 'appear to have been created primarily as a means of signalling the social status of the author-collector and not as a means of awarding credit to the original discoverer' (Barnett 2020: 250, 262).

To get a more accurate picture of the contributions that miners and other workers made to knowledge about minerals, then, I suggest that we need to turn to the private notes that naturalists made on their field excursions. These were not intended for publication, and, consequently, if they survive they may reveal more accurately the naturalist's intellectual debts to his or her social inferiors. Unfortunately, not many of these field notes are extant; fortunately, some of Dr Woodward's are.

In what follows, I will examine Woodward's *Fossils of all Kinds Digested into a Method* (1728), his influential taxonomic scheme for 'fossils' – a word that, in the early eighteenth century, referred to all things 'dug up', including minerals – in the light of his previously overlooked field notes. Half of these field notes, kept at Cambridge University Library (CUL), have long since been catalogued but have never been subjected to sustained analysis. The other half were recently discovered by the present author appended to the back of one of Woodward's unpublished treatises kept at the British Library (BL).[1] I will show: (a) that Woodward's taxonomic scheme for the metallic ores was largely derived from the practical taxonomy of the miners he interacted with in Cornwall, Cumberland, Westmorland, and Yorkshire; and (b) that his understanding of gemstones owed more to his conversations with gem cutters than is suggested in the pages of *Fossils of all Kinds*. Overall, my argument is that the practical knowledge of those who provided Woodward with his specimens played a much greater role in his classification schemes than has previously been realized, and that, accordingly, the Woodwardian Collection must be central to future discussions about how museums can communicate the importance of invisible labour to their visitors.

The article is divided into four sections. In the first section I will provide a brief overview of Woodward's life and his works, situating him in his intellectual context. Then, I will use his extant field notes to reconstruct the fieldwork he conducted in mines, establishing that, though he is best remembered for his speculative contribution to the theory-of-the-earth genre, he was also an assiduous fieldworker. The remaining two sections will focus on the taxonomies that Woodward produced for metallic ores and gems. I show that the knowledge of the workers Woodward encountered in mines and workshops played a major role in his own understanding of his specimens. I conclude with some curatorial suggestions for rendering the invisible labour behind the Woodwardian Collection more visible.

## John Woodward: natural historian of the earth

John Woodward was born sometime between 1665 and 1668 in an area of Derbyshire surrounded by lead mines. He died in London in 1728, surrounded by the nearly 10,000 specimens and 2,000 books that he had amassed in his lodgings at Gresham College, where he had been professor of physick (i.e. medicine) since 1692. As his most recent biographer has claimed, Woodward was 'a many-sided character who combined sundry interests and several careers' (Levine 1977: 3). He became a fellow of the Royal Society of London for Improving Natural Knowledge in 1693, and he became a fellow of the Royal College of Physicians in 1702 (Eyles 1971: 399, 413). He practised and taught medicine, botanized, studied ancient civilizations, and collected antiquities – but above all else he conducted natural-historical fieldwork and sought to incorporate this into a theory of the earth.

In the seventeenth and eighteenth centuries, many European philosophers wrote cosmogonic theories of the earth. These theories sought to explain how the Earth was formed using mechanical principles, hypothetico-deductive reasoning and physico-theological arguments (Collier 1934; Porter 1979a). For example, René Descartes argued that the Earth

was a cooled star whose uneven topography was the result of the sun drying and cracking its surface (Ellenberger 1996: 177-83); Thomas Burnet argued that the sun's heat unleashed the Noachian Deluge which was responsible for shaping the surface of the Earth (Rossetter 2019: 15-22); and Thomas Robinson argued that the Earth was like a living organism (Porter 1977: 70). Woodward's contribution to the theory-of-the-earth genre, published over thirty years before *Fossils of all Kinds*, was his *An Essay toward a Natural History of the Earth* (1695).

Woodward criticized previous theories of the earth for not adequately dealing with two phenomena: the strata – that is, the recognizable layers of different rocks superimposed upon one another that form the Earth's surface – and 'extraneous fossils', that is, the petrified remains of animals and plants that, today, we would refer to simply as 'fossils'. In the 1690s, gentlemen naturalists like Woodward were split into two camps on the issue of extraneous fossils: men such as Martin Lister and Robert Plot believed that, like crystals, extraneous fossils grew at the sites where they were found as sports of nature, whereas Woodward was on the side of those who argued that God would not play such tricks on humankind and that they were thus the remains of once living creatures (Levine 1977: 24; Porter 1979b: 337). In his *Essay*, Woodward sought to explain the existence of strata and extraneous fossils by invoking the Noachian Deluge and a subsequent 'disruption' from the centre of the earth. His argument can be summarized in four stages as follows (Woodward 1695: 85-92):

1. God suspended gravity during the Noachian Deluge, causing all solid non-living matter to disintegrate into particles.

2. Living matter did not disintegrate into particles so, as the planet was increasingly subsumed under the flood waters, the dead remains of animals and plants gradually sunk in accordance with their specific gravities.

3. God reinstated gravity: non-living matter recomposed itself into stratified and parallel layers, mainly but not entirely in accordance with specific gravity, and the living remains were petrified within these layers.

4. Then a 'Force' from within the Earth caused the strata to take the form in which they are visible today: dislocated, irregular, and uneven.

Woodward's theory was quick to receive both support and criticism: support from naturalists like John Harris and Johann Jakob Scheuchzer, and criticism from the likes of Elias Camerarius and John Arbuthnot (Eyles 1971: 406; Porter 1977: 86-7; Levine 1977: 35-41). Woodward's critics, however, tended to overlook the salient point that the *Essay* was only intended as a '*Scheme* of a *larger Design*' (Woodward 1695: 2). Woodward died before he finished this larger design, and – as per his instructions – it was incinerated upon his death (Ward 1740: 300). But Woodward did publish three other books: *Fossils of all Kinds Digested into a Method* (1728), and the two volumes of his *An Attempt Towards a Natural History of the Fossils of England* (1728-9).

As John Pickstone (2000: 30) has argued, 'The eighteenth century was the great age of classification'. This drive to classify was characteristic of all kinds of natural inquiry, but it was particularly characteristic of eighteenth-century mineralogy (Adams 1954 [1938]: 170-208; Laudan 1987: 47-86; Oldroyd 1998; Rudwick 2005: 59-71). Woodward's *Fossils of all Kinds* was an early landmark in the long history of eighteenth-century mineral classifications: it was Woodward's attempt to create a universal taxonomic scheme for all fossils on the basis of his own specimens, specimens that were listed in the two *Fossils of England* volumes, which were essentially printed catalogues of Woodward's specimens, supplemented with information about their origin, properties, and uses. All of this is widely known. Less widely appreciated, however, is the extent to which the information contained in *Fossils of all Kinds* depended on Woodward's interactions with the workers he encountered on his fieldwork; and it is to this fieldwork that we now turn.

**Woodward's fieldwork: an overview**

Historians of the earth sciences agree: Woodward was one of the greatest field-working naturalists of his age; arguably *the* greatest (Rudwick 1976 [1972]: 82; Porter 1977: 25; Ellenberger 1999: 124). But what exactly did it mean to be a field-working naturalist in this period? It is clear from Woodward's publications that he visited more locations and collected more specimens than his contemporaries, and it is equally clear that he developed a more sophisticated system of arranging and cataloguing them. However, this is not a particularly satisfying answer because it tells us little about what Woodward actually *did* in the field – only that he went there in the first place. To develop a more detailed understanding of these methods, we can turn to the extant field notes mentioned earlier, which, curiously, have been nearly entirely overlooked by historians. The notable exception here is W.G. Burgess (2021: 775), who rightly points out that the existence of the notes disproves Woodward's claim that his collection was 'got together by the Industry of one single Man' (Woodward 1728: x). But Burgess was primarily interested in the legacy of Woodward's collection and not its assemblage, so he had no need to offer an analysis of the contents of the notes. By providing a first, but necessarily brief, exposition of the extant notes, I aim to recover in more detail what it meant to be, in the anachronistic words of one historian, 'a pioneer English field-geologist' in the decades around 1700 (Davies 1969: 76). More specifically, I argue that talking to workers encountered in the field – and taking their expertise seriously – was a central part of Woodward's fieldwork.

But first a brief word on the sources used is necessary. The CUL field notes are compiled into a volume called 'John Woodward's Geological Notebook', acquired by CUL from an Essex bookdealer in or around 1996.[2] The words in this title are anachronistic and inaccurate respectively: 'geology' is anachronistic because the word was not widely used in the Anglophone world until decades after Woodward's death; and 'notebook' is inaccurate because the volume is, in fact, a collection of 124 loose leaves. Some of these leaves contain excerpts from books on natural-historical topics, like Georgius Agricola's *De re Metallica*,[3] but the majority of them contain direct observations that Woodward made while in the field, especially of strata exposures in mines. Yet with the exception of some cut-and-pasted sketches, these leaves are not the original copies that Woodward made in the field in Bath, Cornwall, Derbyshire, and Gloucester, or onsite in the gem-cutting workshops he visited in London; rather, they are 'best' copies of the original notes, apparently in the hand of one John Hindle who also copied Woodward's manuscript 'A catalogue of some of my antiquities'. We can reasonably infer, then, that these field notes were particularly valuable to Woodward, and that he needed good copies of them to assist him in preparing his publications.

Frustratingly, Woodward only dated a single entry of the 'Geological Notebook', his 'Observations made on my return from Bath in Sept. 1722'.[4] CUL's attribution of the date 'circa 1720' to the volume may therefore be inaccurate, since the volume was not a unified whole and Woodward's accounts of his excursions elsewhere may actually date to an earlier period of fieldwork, perhaps even conducted before the publication of his *Essay* in 1695.

The BL field notes are a little easier to date. They were found appended to the back of a manuscript copy – written in Woodward's hand – of his unpublished treatise 'Two Discourses on Metals'. The field notes, again in Woodward's hand, relate to excursions conducted in mines and refineries in Cumberland, Durham, Northumberland, Westmorland, and Yorkshire. Once again, these appear to be best copies of previous notes, this time organized under two headings: 'Observations relating to the Natural History of Ores of Metalls' and 'Observations relateing to the Natural History of Minerals'. And again, most of the notes are undated, save for one sketch which is dated to 1704. However, another copy of Woodward's 'Two Discourses on Metals', made by his assistant John Abbadie, is also kept at the BL. Since this carries an inscription in Woodward's hand dated 13 August 1724 that reads 'These Discourses have been Wrote, now, 20 Years', it is possible that he conducted fieldwork in the mines and refineries of the aforementioned counties with the specific intention of taking notes that would help him write these two discourses, the one 'concerning Ores Mineing, & the Structure of the Earth', the other 'concerning Assaying'.[5] That would explain why the field notes found their way into the back of Woodward's manuscript, and thus we can be more confident that they

were made in the early 1700s.

These two manuscripts shed considerable light on the practical details of Woodward's fieldwork, and especially on the role of labourers in that work. There is no scope to provide a truly detailed discussion of the methods and techniques Woodward employed, or to appraise their originality and significance, in the space available here. Accordingly, I will focus on four characteristics of Woodward's fieldwork that are especially relevant to our theme of invisible labour, and the agency of the workers Woodward encountered.

First, in the field Woodward focused overwhelmingly on the strata. This might seem like an obvious focal point to modern geologists, but it was a rather novel perspective in Stuart England. Indeed, just a few decades earlier, when the influential naturalists Robert Boyle (1666a) and Robert Plot (1679) gave advice on how to write topographical natural histories, neither gave a prominent place to the strata. Woodward's field notes, however, are littered with detailed descriptions of particular strata. This description, taken in a mine of iron ore in Langron, Cumberland, is typical:

> As to the Constitution of the Earth, at the Surface is a Stratum, about 3 foot in thickness, of Common Mould, with Clay, both of a reddish Cast, haveing small Lumps of Ruble-Stone amongst it. Underneath is a Stratum of Softish gritty Stone, Grey with a Cast of Brown, also about 3 foot thick. Below that is another somewhat harder but of Stone of the same sort & Colour, & about 5 foot thick. The 4th Stratum is […] Next is a Stratum of Rubble […] Under this are two Strata more, of much the same Sort & Colour, with those above: & each about 9 foot thick.[6]

Second, Woodward's method of fieldwork was extremely physical. After touring the aforementioned mine of iron ore, for example, he scaled the Skrees mountain and took careful note of its height and inclination:

> As to the Height of the Skrees, beginning at the Lake at the foot or Bottom of that Mountain, I measured upwards to the Place where the Iron-Ore first shewd it self clear, which was 700 yards […] Standing at the Lake at the Bottom, with a Quadrant, I took the Elevation of this Mountain: & found it 45 Degrees.[7]

Moreover, though Woodward was not the first naturalist to take a keen interest in mines – Boyle (1666b), for instance, had recommended mines as particularly important sites of natural-historical exploration – he does appear to have been the first to actually mine and extract his own samples of ore: 'I dig'd in the whole Vein', he reported of his experience in a copper mine in Cornwall, 'and amongst the soft Ore, I dig'd out several Pieces of malleable flexible fine Copper'.[8] Although Woodward often referred to the fact that he had taken extended tours over England and had descended into deep mines in his publications, he never revealed the full extent of his exertions as revealed in these field notes. Such a finding corroborates Barnett's (2020: 245) claim that 'elite masculinity and scholarly self-presentation [explain why] some eighteenth-century naturalists felt that they had to publicly disavow [labouring]'.

Third, Woodward borrowed heavily from the highly localized, technical language of the mineworkers he encountered. He transposed specific, regional terminology into new regions whenever he saw a phenomenon that resembled one that he had encountered elsewhere. In this manner, he began to construct what can, anachronistically but usefully, be described as a 'geological language'. Consider his excursion to the county of Cumberland again. Here, Woodward appropriated from the miners he had previously encountered in the county of Derbyshire the term 'Belly' to describe 'large Cavityes in ye Strata, which serve for Receptacles of Ore'; and, from miners in the county of Yorkshire, he appropriated the term 'Ribbs' to describe 'Several Sorts of Ore [standing] Edgeways, & Parallel to one another'.[9]

Finally, Woodward's trust in the mineworkers he encountered was a particularly important characteristic of his fieldwork. Though historians of early-modern science have studied the notion of 'trust' in much detail, much of this research has so far focused on experiments rather than fieldwork (Shapin and Schaffer 1985; Shapin 1994). Woodward's manuscripts therefore provide a unique perspective on the role of trust in the field, as distinct from the role of trust in the laboratory. Most of the time, when Woodward referred to the expertise of mineworkers in his field notes, he corroborated their opinions with his own observations. Remarks like

'They say those Strings of Sparr allwayes goe on entire and cut the Strings of Metall […] I saw several Instances of it' were therefore common.[10] But on several occasions Woodward simply recorded the knowledge of mineworkers without corroboration, seemingly as an article of faith. A case in point is Woodward's page-long account of information obtained from an experienced Derbyshire miner:

> William Oxspring worked 7 years in a Lead Mine at Bakewell in the Peak. Twas 63 fathom deep. There were no other mines there so deep. The lead vein is near perpendicular and in some parts has water in little quantity issueing in […]. This Vein comes up to near the day. The ore is sometimes turned up by a mole. It runs from North to South: and it is crossed by other lesser veins. He has known it worked for near 2 miles to an end. Tis in some places 2 foot; in others perhaps 10 foot: in others perhaps not an inch. The oar lyes generally in Ribs, with Spar intermixt. He has sometimes observed 10 or 11 ribs standing edgwaies one by another, from an inch and half in thickness to ¼ of an inch, with spar and clay interposed. In this vein the deeper they mine the more ore, and the richer they find. As they find the vein, in some parts wider, in others stretten, mining in an horizontal direction; so do they also in sinking, or in perpendicular direction.[11]

This passage exemplifies the trust that Woodward had in the expertise of the mineworkers he encountered. He did not need to see with his own eyes the phenomena that William Oxspring described: his previous experiences had taught him that such men could be trusted to relay accurate information about the natural world. Together with the other three characteristics of Woodward's fieldwork discussed here – his emphasis on the strata, his willingness to exert himself alongside the mineworkers, and his appropriation of their language – this suggests that Woodward would have no qualms in using the knowledge of miners and other practical workers to construct his taxonomic scheme. The following sections will examine two cases where this was particularly evident.

**Mining expertise in Woodward's taxonomy of ores**

Woodward provided taxonomies for six kinds of metallic ore: gold, silver, copper, iron, tin, and lead. 'I have', he claimed, 'for some Years been carefully examining [ores] found in England, and [have] procured Samples from most other Parts of the known World' (Woodward 1728: 44). We can pass over his taxonomies for gold and silver, as these were based primarily on samples and information he had obtained from his foreign correspondents. His taxonomies for the remaining four metals, however, were based on his own experiences in various English mining districts.

Consider copper first. The only sources that Woodward referred to in his discussion of the copper ores were Pliny and Dioscorides: the former to give the Greek word for 'copper', the latter to criticize what that author wrote on the subject (Woodward 1728: 49-50). We can reasonably infer from this, then, that this taxonomy was primarily the result of his fieldwork, not his reading or correspondence. Woodward discussed three broad categories of copper ore: the common 'principal' varieties, the rarer and 'better' varieties, and 'native and pure' ore. He told his readers that the principal sorts could be judged by their colours: 'the Pale-grey, the Black, the Red, the Glossy-Purple, the Blue, the Ærugimous or Green' (Woodward 1728: 49). Here he appeared to be simply relaying the expertise of the mineworkers he had encountered in Cornwall, Cumberland, and Malham, Yorkshire on the commonness of the variously coloured ores they mined.[12]

As for the 'better' and 'pure' varieties, Woodward reported that these were often of a 'Marcasitic Yellow' colour, and that they were found 'in Form of *Threads*; of *Shrubs* in *Flakes* and *Plates*, some solid and continuous others porous; in *Grains*, *Masses*, and *Lumps*' (Woodward 1728: 49-50). It is therefore significant that his field notes for his 'Journey into Cornwall' contain references to him encountering yellow copper ore in these forms and being informed by the mineworkers that these ores were the best quality.[13] To highlight just one example, we can turn to Woodward's excursion to a copper mine in the Trewellot Cliffs. 'I got Captain John Trezas, and two Workmen, who work'd in S$^{t}$ Just Ball, & knew these Works, to

go with me down into the Works'. Supervised by the three mineworkers, Woodward then dug out a sample of ore. He reported that it was a 'fine copper', and that the mineworkers informed him that similar copper could be found elsewhere in 'Plates'.[14] Just as the list of examples of the common, 'principal' ores of copper Woodward provided in *Fossils of all Kinds* depended on the mineworkers' knowledge of their colours, the examples of the 'better' ores depended on their knowledge of the way they were deposited.

Now consider tin. Woodward was slightly more forthcoming in acknowledging the help he had received from others in his taxonomy of tin ore. He criticized previous work on the natural history of tin, particularly the work of Richard Carew (1602), before remarking:

> I have obtain'd a much fuller, more particular, and satisfying Account from some of the Gentlemen of the County, and Stewards of the Tin Mines, that have been curious, and taken Pains in making accurate Observations on the State of Things there (Woodward 1728: 54).

Even so, evidence from Woodward's field notes suggests that he received more help from the humble miners he encountered in the mines than from the landowners who gave him permission to visit them. Indeed, Woodward's taxonomic scheme for tin ore was closely related to the different ways in which the ores were found embedded in the earth. According to Woodward, only 'a very few Sparks of Metall' could be found 'in that sort of Stone that the Tinners call *Pedancarn*, and in that which they call *Growan*'. These sparks of tin were therefore of lower quality than the tin found in 'The *Tin-Veins*, or as the Miners call them, *Loads*'. 'Loads' might appear in '*Strata* of *Growan*, or that grey, *Talky*, *Slaty* Stone, that the Tinners call *Killas*, *Raze*, or *Delvin*'. Tin ore of a similar quality could also be found in the '*Shoads* or *Stream-Works*' (Woodward 1728: 53-4).

The important point here is that Woodward's taxonomy of tin ores was organized around the larger geological structures which he had encountered in the tin mines and which, crucially, his interactions with mineworkers had helped him to recognize and understand. This much is apparent even from the text of *Fossils of all Kinds* itself. But more evidence can be found in Woodward's field notes; several pages of his 'Journey into Cornwall' contain scribbled definitions of terms like 'growan', 'killas', 'shelf', 'face', 'back', and 'floor', that were clearly obtained from mineworkers.[15] Once again, the knowledge of mineworkers underpinned Woodward's taxonomy.

Let us now turn to Woodward's taxonomy of iron ore. Once again, Woodward emphasized the visual and haptic properties of the different iron ores he had collected, and discussed them using the names that the mineworkers used (Woodward 1728: 51):

> The harder red ochreous Iron-Ores, pass by the Name of *Rudle*; the softer by the Name of *Smitt*. There is more or less of this Metall likewise incorporated with the ferruginous crustated Bodies, the ocherous *Rust-coloured-Eagle-Stone*, the *Bezoar Mineral*, the ferruginous *Geodes*, and the *Enhydros*. There is found Iron-Ore, in Form of *Ludus Helmontii*, particularly in *Monmouthshire*, where this Sort is call'd *Pin-Ore*. The rest of the Sorts are, The *smooth-grain'd Iron-Ore*, which strikes Fire, and breaks much like a Flint, but is of a ruddy Colour: The *Hæmatites*, or *Schistos*, which is of a striated or fibrous Texture, and the *Iron Stalactitæ*; several of these naturally united into one Sheaf, pass by the Name of *Brush-Ore*. The *Rhomboid-Iron-Grains*.

As with copper and tin, Woodward gave his judgement of the quality of different iron ores, revealing that the 'purer Iron Grains follow and obey the Load stone', a fact he no doubt learnt from the iron miners (Woodward 1728: 52). Although not as many of Woodward's field notes related to iron mines appear to have survived in comparison to his notes for copper and tin mines, one excursion to the Langron iron mine, Cumberland, offers us a particularly revealing glimpse of just how seriously Woodward took the natural knowledge of miners. On Woodward's account, the iron ore at Langron was found in large 'bellyes', and it was of six kinds:

> The 1. I shall take Notice of is a red clayey Matter […] 2. A brittle crumbling Ore […] 3. Stone of a rust Colour inclineing to Black […] 4. Plates of a whiteish clayey

> Matter […] 5. […] Plates of a Metallic Matter of the same Constitution with the tuberous Hæmatities […] 6. […] Bunches, or tuberous Hæmatites, of all Sizes, up to the Bigness of a Mans Head.[16]

Tellingly, Woodward went on to reveal the mineworkers' verdict on the quality of these ores. The richest – on their account, and, by extension, his – was the third kind: 'This the Workmen count the richest, & to hold the most Iron of any. They reckon the Clayey, & brittle Ore, richer then the Hæmatites […]'.[17] All this serves to underline, again, the fact that when Woodward acquired the specimens that are today held in the Woodwardian Collection, he also acquired the expertise of the mineworkers he encountered.

Woodward's taxonomy for lead provides us with an interesting comparison with what we have seen for copper, tin, and iron. The main part of the taxonomy is brief and worth quoting in full (Woodward 1728: 54-5):

> The various Names and Distinctions of this Ore, used by the Workmen, are, the *Potters* or *Blue*, the *Grey*, the *greenish Yellow*, the *Talky*, the *Stony*, the *Cavernous*, the porous Sort, call'd on *Mendip*, *Honey-Comb Lead-Ore*, the *Star-grain'd Lead-Ore*, the *striated*, or *Antimonated* Lead-Ore, the *Sparkling* or *Steel-grain'd*; this commonly yields more or less Silver, and is what *Dioscorides*, and the Naturalists after him, call *Molybdaena*: *Pliny*, *Galena*. The *White* semi-diaphanous Lead-Ore, generally fibrous, but sometimes *flaky* or *plated*. The *Ericoid*-Lead-Ore, found concreted into the Form of the *Ramose* Moss, or, as some fancy, of *Heath* or *Erica*, whence it had its Name. The *Diced* or *Cubic* Lead-Ore.

There are some similarities here with Woodward's copper, tin, and iron taxonomies: there is a focus on the colour and texture of the ores, and the mineworkers' terms are employed uncritically. Yet there are also differences. Classical authors are quoted as neutral authorities, and not simply to be criticized. There are fewer references to the way that the lead ores are found deposited in the bowels of the earth. And, unusually, there is no attempt made to compare the *qualities* of these different ores. This is interesting, given that Woodward's extant field notes reveal far fewer excursions to lead mines than to copper and tin mines. It may be the case that Woodward did visit many more lead mines and we simply do not have the evidence available to us. But his extant notes about lead mines are not as detailed as the extant notes about other metal mines. There is the page-long testimony from William Oxspring, mentioned above, and there are other scattered references to the number of, and types of ore found in, the lead mines of 'Darbyshire, Yorkshire, the Bishoprick of Durham, Northumberland' and other counties in Woodward's notes.[18] However, not one of these references referred to an excursion that Woodward had himself conducted in a mine; nor do any of them – except the Oxspring passage – refer to a conversation that Woodward had with a lead miner. It is thus tempting to think that Woodward could not offer a hierarchy of quality for lead, as he had with copper, tin, and iron, because he had not had enough conversations with miners.

Woodward was not the first naturalist to benefit from a conversation with a miner. In fact, it is clear that Boyle (1666b) expected the other fellows of the Royal Society to consult with miners in order to find the answers to his list of queries about mines, and it is clear, too, that the other fellows were happy to oblige. A case in point can be found in one fellow's account of the Mendip lead mines, 'procured from some very experienc'd Mine-men' (Glanvill 1668: 767). Boyle's mining queries must be seen as one part of the Royal Society's wider 'history of the trades programme', an effort to appropriate the knowledge of practitioners involved in the arts and trades in the decades before 1700 (Ochs 1985). Another important group of practitioners for the fellows' designs were gem cutters; indeed, Michael Bycroft (2021: 41-6) has recently shown that Boyle's conversations with such workers played an important role in his understanding of the efficacy of matter in motion. And as we shall see, Woodward also profited intellectually from his conversations with gem cutters, albeit in a different way.

## Gem-cutting expertise in Woodward's taxonomy of gems

There was a crucial difference between Woodward's acquisition of metal ores and his acquisition

of gems: like pure gold and silver, gems are much harder to find in the British Isles than the ores of copper, tin, lead, and iron. Consequently, Woodward personally acquired very few gems in the field. As his catalogues make clear, he purchased most of his gem specimens from merchants or lapidaries in London, where there developed a thriving market for gems in the second half of the seventeenth century (Ogden 2018: 191; Sabel 2019: 102; Bycroft 2021: 40).

In Woodward's taxonomy, gems belonged to one of the three groups that together comprised the class of 'Stones'. More specifically, they were stones 'That [were] in some Degree pellucid and transparent'. Since Woodward claimed that there was '*so much Darkness and Confusion*' in the literature on gems, he began his taxonomy of them with a five-page explanation of '*The natural* Constitution *of* [Gemms]' – this was the only such explanation in the entirety of *Fossils of All Kinds*, testifying to the perceived complexity of the subject.

In brief, Woodward argued that '*The Basis, or prime* constituent *Matter*' of all gems was a crystal-like or 'Adamantine *Matter*' that was '*diaphanous* [i.e. light]' and '*pellucid* [i.e. translucent]'. Yet the crystal- or adamantine-like matter was, Woodward claimed, often incorporated with '*metallic Matter*'. This increased the specific gravity of the gems, and altered their 'Diaphaneity', 'Hardness', 'Form', and '*Tincture, or* Colour' by degrees, 'in Proportion to the Quantity of the additional Metal'. As a result, Woodward argued that '*there* [could] *be no fix'd and unerring* Test *or* Standard*, whereby the* Kinds *and* Names *of these Bodies* [could] *be constantly ascertain'd*'. In turn, this explained – according to Woodward – '*the* Difference *and* Confusion that [was found] *among the* Writers of Gemms', since these writers were often describing considerably different *varieties* of the same *kind* of gem (Woodward 1728: 23-7).

Having explained the confusion, Woodward offered a solution: a taxonomy of gems organized around a twofold division between 'Those which are tinged with some Colour' and 'Those which are perfectly clear, diaphanous, and without any Colour at all' (Woodward 1728: 28, 30). He acknowledged that this division '[did] *not hold so universally*', and that there were several '*Deviations*'. For example, he noted that '*There* [were] Diamonds *tinged with* Yellow: *Others with* Red, Blue, or Green […]' (Woodward 1728: 34). Seemingly, then, Woodward chose to organize his taxonomy around colour because it was the least-worst option – not because it was ideal.

Woodward listed thirteen gems that were 'tinged with some Colour', including topaz, garnet, and emerald, and just three that were 'diaphanous, and without any Colour at all', namely crystal, 'The WHITE-SAPPHIRE', and diamond (Woodward 1728: 28-32). In his discussion of these gems, Woodward relied more heavily on textual authorities than he did at any other point in *Fossils of all Kinds*; references to other texts in his discussions of earths, the other stones, salts, bitumens, minerals, and metals were far more fleeting. He drew upon the ancients Theophrastus and Pliny; the antiquary S.P. Buonazotti; the Renaissance naturalists Conrad Gesner, Georgius Agricola, Ulisse Aldrovandi, and Anselmus Boetius de Boodt; and his colleague in the Royal Society of London, Martin Lister. Most of Woodward's discussion was taken up by either pointing out instances where different authorities were describing the same kind of gem but attributed it a different name, or by suggesting entirely new names. Here, Woodward's claim that topaz was 'the Chrysolithus *of the* Ancients', and his claim that what the lapidaries called 'Rock Crystal' was the same kind of gem as '*the* Iris *of* Pliny, Agricola *and Dr.* Lister' were characteristic (Woodward 1728: 28, 30-1). In stark contrast to his discussion of the metallic ores, Woodward referred only once to his own field excursions in his discussion of gems: '*I have observ'd* [crystals] *in greatest Plenty about* Bristol, *chiefly in the Neighbourhood of* Kings-Weston *in* Gloucestershire' (Woodward 1728: 32).

If one read only *Fossils of all Kinds*, then, they might quite reasonably infer that Woodward's understanding of gems owed far more to his library than to the lapidaries he interacted with and from whom he procured his gems. However, according to a catalogue of Woodward's books drawn up after his death, Woodward owned a copy of one 'Traité des Pierres precieuses, par Robert de Berquen *à Paris 1669*' (Cooper 1728: 20). Robert de Berquen was both a Parisian gem cutter and an author who had argued in an earlier work of 1661 that hardness – not colour – should be the crucial criterion for classifying gems (Bycroft 2018: 523). Perhaps Woodward's reading of Berquen prompted him to visit gem-cutting workshops. For, preserved in Woodward's so-called 'Geological Notebook', is a draft treatise entitled 'Gemms, or Pretious Stones, rang'd according to their Difference in Hardness; beginning with

the Softest'.[19] Here we find much more revealing evidence of Woodward's intellectual debts to gem cutters. Indeed, Woodward began the draft treatise by explicitly acknowledging that he would be drawing on the expertise of gem cutters:

> Before I enter upon the particular Detail of these Bodyes, I ought to intimate that the Measures & Proportions of the Force & Shelf used in cutting of them cannot be adjusted with such certainty that the comparative Hardness of them can ever be determin'd with a mathematical strictness. I have gone as far as I could towards it by conferring with the best & most judicious Workmen we have: & have fixt the standard here all along assign'd in the best & justest manner I could, upon their Accounts carefully conferrd together; & with that I must content my self.[20]

Woodward's scale of hardness was thus based on 'the Time & Labour in cutting'.[21] This makes the 'Gemms' manuscript an important and overlooked episode in the history of the development of hardness scales. It would be a digression to discuss this history at length here. Suffice it to say that Woodward's scale anticipated the scales developed by Bengt Andersson Quist, Abraham Gottlob Werner, and Friedrich Mohs by several decades (Todhunter 1893: 582-92; Schuh 2007: 105-9; Newcomb 2009: 12-7; Bycroft 2022: 517-22). And since Woodward was so explicit about his debt to gem cutters, his previously overlooked 'Gemms' manuscript offers a striking corroboration of Bycroft's (2022) argument that hardness scales emerged from the haptic knowledge of gem cutters.

Woodward's survey of gems began with 'Turcois', the softest of gems, and, thirty-five gems later, finished with 'The Diamond'.[22] The entry for diamond was longer than the other entries, as it discussed different varieties of diamond and the impact water had on them. In other respects, however, it was characteristic, and is worth quoting to appreciate the extent to which Woodward drew on the knowledge of gem cutters:

> The Diamond cuts the Saphire [i.e. the second hardest gem in Woodward's list] freely. As near as Judgment can be made by comparing of Labour, it is about 90 or 100 times as hard as the Saphire. A certain Lapidary workt constantly 30 Days in peirceing a Diamond: & his Drill had scarcely, with all that Time, & Pains, enterd 1/60$^{th}$ of an Inch in Depth. Diamonds differ somewhat in Hardness from one another: so much that the Lapidary can perceive it in cutting them. The Yellow, Green, Red & Blue Diamonds, are of the same Hardness with ye White. Of the Diaphanous, those of the deeper Waters are rather harder than those of the paler. The Diamond discovers a Grain in its Texture & will Splitt with it.[23]

Woodward's entries for the other gems were similar. He noted, for example: that 'Crystall is above twice as hard as the Turcois: I mean it requires above twice the Time & Labour in cutting [than] that does'; that 'Lapiz Lazuli takes up full twice the Labour to cut it that Marble does'; and that 'The Oriental Topaz is about Six times as hard as the Agat'.[24] Clearly, Woodward necessarily had to rely upon, and trust, the information that the cutters gave him concerning the time it took to cut different gems. A true Baconian, Woodward might well have been convinced that, in his own words, '*Observations* are the only sure *Grounds* whereon to build a lasting and substantial *Philosophy*' – but he did not have the time to spend days cutting, or observing the cutting of, gems (Woodward 1695: 1). Instead, he trusted the haptic knowledge of the cutters to such an extent that he constructed a taxonomic scheme for gems organized around their experiential understanding of 'hardness'.

Having examined 'Gemms', let us return to *Fossils* with a fresh perspective. Of course, Woodward's emphasis on colour still jumps out of the pages. But on closer inspection, and with 'Gemms' in mind, several traces of gem-cutting expertise, usually buried in Woodward's footnotes, now appear more noticeable, as if they have been newly cut and polished. The most striking example is that Woodward appears to acknowledge that the entire category of gems was borrowed from gem cutters: '*The Stones which follow in this third Article, are those which the Lapidaries usually call* Gemms' (Woodward 1728: 23). Similarly, he later employed the more specific categories that jewellers used to identify specific kinds of gems, such as 'The HYACINTHUS, or Jacinth of the Jewellers' (Woodward 1728: 28). And in addition to appropriating the categories of the cutters and the jewellers, he seemingly appropriated

their knowledge about hardness. Woodward claimed that variations in the amount of metallic impurities found in gems led to variations in their hardness (Woodward 1728: 24); that a crystal could always be identified by '*its Hardness, which* [is] *ever the same*' (Woodward 1728: 30); that '*The white Crystalline Sapphire, is so called because 'tis of full as great Specific Hardness as the Blue, but colourless, and clear as Crystal*' (Woodward 1728: 32); that the hardness of diamonds made them '*more durable and lasting, and therefore much more valuable than any other Stone*' (Woodward 1728: 32-3); and that transparent stones and similar stones tinged with some colour could be equally hard, so that '*the oriental* Sapphire, Topaz, Amethyst, Emerald, and Ruby, *are all of the same Hardness*' (Woodward 1728: 33).

In light of the 'Gemms' manuscript, then, it is highly probable that the references to hardness within *Fossils* owe something to Woodward's interactions with cutters in their workshops. But it is undeniable that several key details from the manuscript are missing from the published book. The ranking of individual gemstones by hardness is missing, as are the numbers that Woodward attached to this ranking. A simple explanation could be that 'Gemms' was written after *Fossils*, but this seems very unlikely. Around 1700, Woodward had read a 'Discourse upon Pretious Stones' to the Royal Society, suggesting that he had already visited gem-cutting workshops by that point, or even that the paper he read aloud *was* the 'Gemms' manuscript, which had simply been recorded under a different name in the minute books of the Royal Society (Levine 1977: 84). Further, since *Fossils* only went to press the year Woodward died, this suggests that he had little opportunity, and perhaps little inclination, to return to gem-cutting workshops and begin yet another treatise on gems. It is therefore highly likely that Woodward wrote 'Gemms' before *Fossils*, and chose to omit certain details included in 'Gemms' from *Fossils*. Why?

The answer is probably related to the points that Woodward himself raised early on in his discussion of gems in *Fossils*: the fact that gemstones were very complicated substances. This meant that they had to be approached from different angles, depending on precisely what the naturalist wanted to achieve. The cutters' understanding of hardness clearly helped Woodward to *rank* gem species and to sub-divide them, one of his main aims in 'Gemms'. Yet their understanding did not appear to help him *define* species of gem, his main purpose in *Fossils.* He was not the only one to face this difficulty. Indeed, as Michael Bycroft (2019: 150-1; 2022: 508-10) has shown, hardness did not become *the* crucial criterion in scholarly – as distinct from artisanal – gem classification schemes until after the mid-eighteenth century, as exemplified in the works of Louis-Jean-Marie Daubenton (1753), Louis Dutens (1782), Matharin-Jacques Brisson (1787), and René-Just Haüy (1801). Thus, Woodward's selective use of the category of hardness in his gemmological work is perhaps best seen as another reminder of the broader problems faced by those who sought to classify gems in the early eighteenth century.

## Conclusion

In this article I have shown that John Woodward's understanding of metallic ores, gems, and possibly other specimens in his collection owed more to the knowledge and expertise – or the invisible labour – of mineworkers and lapidaries than his published writings suggest. What, then, is the curator to do with this story?

From a display perspective it is obviously desirable that the invisible labour of the mineworkers and gem cutters be rendered more visible to visitors. But there are challenges in communicating this in a display. For, to this very day, Woodward's specimens remain preserved in the original four cabinets that he himself placed them in – and we gain much by keeping the specimens organized as Woodward himself had done. Accordingly, a better option might be to have display boards with historical information about the way that Woodward acquired his specimens. Better still, there is a real opportunity here for an interactive visual display that would allow visitors to learn about the role of invisible labour in the assemblage of mineral collections in an engaging way. In fact, a pilot project run by the Sedgwick Museum's Dan Pemberton and the digital media company Surface Impression in 2016, using a subset of 300 specimens from the Woodwardian Collection, did create an exploratory digital cabinet. Although the overall evaluation of this pilot was positive, it was ultimately unsustainable.[25]

Ideally, if more funding could be obtained, a newer, broader interactive display could allow visitors to see all of Woodward's specimens arranged in a variety of different ways, such as the date he collected them, their geographic origin, and the types of people (e.g. miners and quarrymen) he acquired them from. Further, the display could highlight where Woodward's specimens appear in his writings and provide information about the intellectual invisible labour he appropriated to understand them.

Much recent work in museum studies has rightly emphasized that natural-history and mineralogical displays have, historically, elided the dark histories of colonialism and enforced labour that were ultimately central to their existence (Das and Lowe 2018; Gelsthorpe 2021; Hearth and Robbins 2022). I have focused on the domestic invisible labour Woodward appropriated in this article, because it was domestic miners and gem cutters that were rendered visible in his extant field notes. However, if a digital rebuild of the Woodwardian Collection could be funded, this would be the ideal opportunity to explore the colonial side of the story in more detail. Woodward depended on non-European labour indirectly, since many of the precious stones that he saw cut in London were mined outside Europe. Further research on Woodward's catalogues, collection, and correspondence would be desirable to determine the extent to which he benefitted from enslaved labour. And since the Sedgwick Museum is popular with the general public and academics alike, it is the ideal place to educate visitors on the often unrecognized centrality of invisible labour and colonialism in the development of museum collections. W.G. Burgess (2021: 765) has argued convincingly that Woodward himself wanted his collection to serve as his 'meaningful intellectual progeny'. Perhaps it is time to make the Woodwardian Collection serve a more useful purpose.

**Notes**

[1] The unpublished treatise is Woodward's 'Two Discourses on Metals', Add MS 25095. The field notes are found between ff. 60-97v.

[2] This is all the information available from the CUL's register-book, and I am grateful to CUL's John Wells for passing this on.

[3] John Woodward, 'Mineralia aliquot Germanica apud G. Agricolam' in 'John Woodward's Geological Notebook', Cambridge University Library, Add. 9386/11.

[4] John Woodward, 'Observations made in my Return from Bath in Sept. 1722' in 'John Woodward's Geological Notebook', Cambridge University Library, Add. 9386/14.

[5] John Woodward, Copy of 'Two Discourses on Metals', British Library, MS 25096: ff. 1, 6, 8.

[6] John Woodward, 'Two Discourses on Metals', British Library, Add. MS 25095: f. 76.

[7] Woodward, 'Two Discourses on Metals', British Library, Add. MS 25095: f. 80v.

[8] John Woodward, 'Journey into Cornwall' in 'John Woodward's Geological Notebook', Cambridge University Library, Add. 9386/1: 24.

[9] Woodward, 'Two Discourses on Metals', British Library, Add. MS 25095: ff. 76v, 80.

[10] Woodward, 'Journey into Cornwall', Cambridge University Library, Add. 9386/1: 4.

[11] John Woodward, 'Of a Lead-Mine at Bakewell in ye Peak' in 'John Woodward's Geological Notebook', Cambridge University Library, Add. 9386/7.

[12] Woodward, 'Two Discourses on Metals', British Library, Add MS 25095: ff. 60-4, 83v-84.

[13] Woodward, 'Journey into Cornwall', Cambridge University Library, Add. 9386/1: 13-4, 22-3.

[14] Woodward, 'Journey into Cornwall', Cambridge University Library, Add. 9386/1: 24.

[15] Woodward, 'Journey into Cornwall', Cambridge University Library, Add. 9386/1: 12, 15, 16-7, 22, 25.

[16] Woodward, 'Two Discourses on Metals', British Library, Add MS 25095: ff. 77-77v.

[17] Woodward, 'Two Discourses on Metals', British Library, Add MS 25095: f. 77v.

[18] Woodward, 'Two Discourses on Metals', British Library, Add MS 25095: ff. 60-60v, 63, 64, 65, 71, 81-3, 89v.

[19] John Woodward, 'Gemms, or Pretious Stones, rang'd according to their Difference in Hardness; beginning with the Softest' in 'John Woodward's Geological Notebook', Cambridge University Library, Add. 9386/10.

[20] Woodward, 'Gemms', Cambridge University Library, Add. 9386/10: 1.

[21] Woodward, 'Gemms', Cambridge University Library, Add. 9386/10: 1.

[22] Woodward, 'Gemms', Cambridge University Library, Add. 9386/10: 1-4.

[23] Woodward, 'Gemms', Cambridge University Library, Add. 9386/10: 4.

[24] Woodward, 'Gemms', Cambridge University Library, Add. 9386/10: 1-3.

[25] I am grateful to Dan Pemberton from the Sedgwick Museum for sharing this information with me.

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