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THE GERMAN MINERS AT KESWICK AND THE QUESTION OF BISMUTH

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Abstract: The background to the production of a small quantity of bismuth at the Keswick smelthouses in the year 1569 has been researched. The evidence appears to throw a little more light on the extent of the Elizabethan mining activity in Cumberland.

INTRODUCTION

Several attempts were made by Henry VIII to develop the mining of copper and precious metals in England but it was not until the reign of Queen Elizabeth that with the help of German expertise the Keswick copper industry finally got under way. In the early years of the enterprise (ie from 1564 to 1577) the Augsburg business house of David Haug, Hans Langnauer and Co. provided a large part of the financial backing and also the skills and technical knowledge needed to set up the industry (Hamilton 1926). Daniel Hochstetter, an associate of the company at that time, managed the works at Keswick and also held shares on Haug and Co's behalf in the controlling partnership of English and German capitalists which in 1568 became known as the Company of Mines Royal (Scott 1911). Early this century the German account books for that period were discovered in the Augsburg archives by Collingwood (1912) who took on the task of transcribing and translating the contents. Although few records remained for the first years of operation detailed Keswick *Journals* were found to exist for the years 1569, 1571 and 1573 to 1577 and the Germans also left accounts relating to their business in London. Without doubt these meticulously kept records provide a unique insight into the Keswick mining scene, but because of the missing years and the fact that they were only intended to record income and expenditure many questions regarding the extent of the mining operations at the time and the location of some of the smaller workings remain unanswered. This is not helped by the unorthodox spelling of English names, often barely recognisable, as the accountant struggled with a strange language and dialect.

The Accounts list term by term the expenses of raising, dressing and carting copper ore from mines in Newlands and Borrowdale and also from smaller ventures such as one at Buttermere. Copper ore raised at Caldbeck is also covered but the important reserves at Coniston had not at that time been exploited. Also recorded are the consignments of bulk copper supplied to the Crown, which were shipped from Newcastle to London and delivered to the Lieutenant of the Queen's Ordnance at the Tower, and from 1572 when export restrictions on copper had been lifted foreign sales begin to feature, eg. in Bordeaux and Muscovy. In July 1574 the first coppersmiths arrived in Keswick and soon a large water powered copper-hammer was under construction. During the next three years, after a permit had been obtained from the Mineral and Battery Works who held the monopoly for brass making and battery, sales of wrought copper in the form of utensils and copper sheet figure both locally and in London. Lead mining is also recorded, mainly at Caldbeck, Grasmere and 'St Joseph's' at Newlands, and before the year 1572 additional lead ore was brought in from other areas including Teesdale and Allendale as well as lead from Richmond and, at the start of operations, from the Bleiberg mines of Carinthia. This was needed for the extraction of silver from the copper and the lead ore provided an additional (and ultimately the principal) source of silver. The company also required lead for building purposes and eventually found a market for their excess lead. The Accounts record silver separation by Christmas 1569 though apparently it was not until August 1572 that a sample was sent to London. By 1574 regular deliveries of silver were being made to Richard Martin, goldsmith and Master of the Mint.

But in early 1569 an unexpected product appeared on the scene. On January 31st of that year 14/6d was paid to "Old Stable", a partner of James and William Stable the London carriers employed by the company, for the carriage of four hemispheres of bismuth weighing 147 pounds. These were sent in a cask from Keswick to London and Antwerp. At the same time 1/1d was paid for transporting another cask of bismuth to London. This is the only mention of bismuth in Collingwood's transcript of the Accounts.

EARLY REFERENCES TO BISMUTH

In the early days bismuth was frequently confused with other metals with which it was associated such as lead, antimony and tin and it was not until the middle of the 18th century that the independent researches of the German chemist Johann Heinrich Pott and the Frenchman Geoffroy established beyond doubt that bismuth was a specific element (*Encyclopaedia Britannica* 1991). Nevertheless a hundred years earlier the Spanish priest and geologist Alonzo Alvaro Barba (1640) clearly recognised the uniqueness of the metal "discovered a few years ago in the Sudnos mountains of Bohemia" in his attack on the belief held by astrologers that each of the seven metals of antiquity (gold, silver, copper, iron, lead, tin and quicksilver) was influenced by one of the seven planets, and as early as 1530 Georgius Agricola had spoken of bismuth in *Bermannus*, his first work relating to mining. He coined the latin name 'bisemutum' and described the metal as 'plumbum cinereum' or ash-coloured lead to differentiate it from 'plumbum nigrum' or true lead, adding that "it generally shows that there is silver beneath the place where it is found, and because of this our miners are accustomed to call it the roof of silver". The earliest reliable reference to bismuth appears to have been in about the year 1500 when 'wismuth' was mentioned in association with silver in a small book on mining geology called *Eyn Nutzlich Bergbuchlein*, thought to have been written by Dr Ulrich Ruhlein von Kalbe, burgomaster at Freiberg in Saxony who helped survey and design the mining towns of Annaberg and Marienberg.

There is little doubt that the Germans at Keswick knew what metal they were dealing with. In his *De Re Metallica*, published in 1556, Agricola described seven different practices for extracting bismuth from its ores, most of them variations on the simple method of heating the ore on an open wood fire in a natural draught and collecting the bismuth which dripped out the bottom. This method would be suitable for native bismuth which can be extracted by simple liquation (its melting point being only 271° C) but in one case the ore was reduced with charcoal in a furnace "similar to an iron furnace" suggesting that secondary ores, ie the oxide bismite and possibly the carbonate bismutite, were also being worked at that time. The above three ores, particularly native bismuth, were found associated with cobalt or silver in the mines of Saxony and Bohemia, notably at Schneeberg and

Joachimsthal (now Jachymov) in the Erzgebirge mountains (Dana 1893) on the border between what was until recently East Germany and Czechoslovakia, a mining area familiar to Agricola who was born in that region and for a time held the post of physician at Joachimsthal. The sulphide ore bismuthinite which also occurs in the area (and is the principal bismuth ore found in the Lake District) would probably need fusing with iron to remove the sulphur (Dennis 1961), a procedure not described by Agricola, but it is significant that in the methods described the extracted bismuth was poured into, or re-melted in, round-bottomed iron pans from which it was later removed in the form of hemispherically shaped cakes such as those described in the Keswick Accounts [Fig 2].

LOCAL OCCURRENCE OF BISMUTH

This then prompts the question - where did the Keswick bismuth come from? Of the three sites in the Lake District traditionally noted for the occurrence of bismuth (Young 1987) the deeper levels of Coniston copper mine and Shap granite quarry can be ruled out immediately. The third site is Carrock mine in the Caldbeck Fells where bismuth has been found in the N-S tungsten bearing veins, but there is no direct documentary evidence that these veins were worked before the year 1854.

Up to 1569 the copper ores smelted at Keswick came principally from two sources - Goldscope mine (and possibly other lesser veins in the Newlands valley) and the Copper Plate vein in Borrowdale (Collingwood 1912). It has long been recognised that small quantities of bismuth often occur with copper sulphide deposits (Crookes and Rohrig 1869) - in fact one commercial source of bismuth today is a by-product from the treatment of copper ores (Kirk-Othmer 1978). When interest in copper mining was revived in the Duke of Somerset's Cumberland estates after the Civil Wars the mineral collector Dr John Woodward suspected the presence of bismuth in certain specimens of grey ore taken from Goldscope mine and St Thomas' Work in the Newlands valley (Woodward 1729). Woodward was possibly the first person in this country to collect geological specimens for their scientific interest rather than as mere curiosities and began his well documented collection, which is still to be found in the Sedgwick Museum at Cambridge University, in about 1696 (Cooper and Stanley 1990). He classed these grey ores as "marcasites" which he claimed "all hold copper more or less" but his specimen descriptions suggest that they were either of the tennantite-tetrahedrite series (ie. mixed sulphides of copper, iron and either

Fig. 1. Engraving from De Re Metallica showing the extraction of Bismuth.

arsenic or antimony which are of variable composition (Percy 1861) and known sometimes to contain bismuth (Dana 1893, Stanley 1992)) or predominately arsenopyrite - minerals which have since been recorded at Newlands (Young 1987). It was "grey ores" such as these that Thomas Robinson, Rector of Ousby, found predominant when he first surveyed Goldscope in 1697 with a view to re-working the mine for copper, ores for which he never managed to obtain a satisfactory analysis even from the leading experts of the day (Grant 1985). Presumably he would only have inspected the workings above adit where the principal copper ore, chalcopyrite, had already been worked out by the Germans.

One cannot attach too much weight to Woodward's observations which lacked analytical confirmation, but recently bismuth has been positively identified in the Newlands copper veins by Stanley and Vaughan (1980) from the microanalysis of the ores. In the Dale Head North vein (otherwise known as Long Work) small concentrations of bismuthinite in the form of aggregates up

to 0.2 mm were found in association with other sulphides together with lesser amounts of native bismuth. Similar mineral assemblages were found at Goldscope, in small copper veins at Castle Nook (a group including St Thomas' Work), and also in the Copper Plate vein of Borrowdale. Even if the German miners had ignored the grey ores these recent studies leave little doubt that a small quantity of bismuth would have found its way to the Keswick smelthouses with the chalcopyrite, or 'ganz erzt' as the Germans called it.

As for the lead ores, a Lake District survey of mineralization also carried out by Stanley and Vaughan (1982) makes no reference at all to bismuth in the lead-zinc veins, and according to Dunham (1985;1990), apart from an isolated occurrence in Weardale, only trace levels have been found in galena throughout the whole of the Northern Pennine orefield.

SMELTING OF THE COPPER ORES

Methods developed in the Keswick smelthouses to cope with the different types and grades of ore from the different mine workings were recorded in a notebook by Daniel Hochstetter (jnr) from an accumulation of notes and papers going back half a century. This collection was started in 1615 and as well as giving detailed instructions for mixing and smelting the ores to produce malleable copper and for the extraction of silver it includes prescriptions for dry assays and also accounts and other affairs up to the year 1639. The notebook eventually came into the hands of the Duke of Northumberland and has recently appeared in print together with a second notebook containing drafts and copies of letters written by Daniel (jnr), a total of 324 pages of manuscript (Hammersley 1988).

These notes show that the extraction of copper from the sulphide ores required a long series of roastings and smeltings which could involve as many as twenty firings and take up to six months. Essentially the method consisted of a preliminary roast at low temperature to burn off some of the sulphur after which the ore was smelted at a moderate temperature with a limestone flux to remove the gangue material and produce a matte or regulus which they called 'green stone'. A series of roastings at progressively higher temperatures followed to oxidize and remove most of the remaining sulphur to produce 'black copper', which was then smelted and reduced to 'rough copper'. Finally this was refined by smelting with charcoal to obtain the ductility necessary for the manufacture of battery ware. When silver was to be extracted further stages were introduced involving the addition of lead or lead ore (ie. "drowning the copper with lead") and then separating the lead from the copper. During this process the silver concentrated in the lead-rich layer and was afterwards extracted from the lead by a well-established cupellation method.

Any native bismuth present would run out during the early stages and it is expected that most of the bismuth in sulphide form would follow the copper into the matte and separate out at a later stage, a fraction perhaps fuming off (Kirk-Othmer 1978). During silver extraction some of the bismuth may have gone into solution with the lead but at least part of that from the original ore should have been recoverable from the bottom of the furnace. Yet there is no evidence from the Hochstetter notebooks nor from any other published correspondence relating to the industry (Donald 1955) that the Germans at Keswick recognised the presence of bismuth while smelting copper ores.

Apart from selling off excess lead the operators appear to have shown little or no interest in by-products from their regular smelting runs before 1579. By that time the shareholders had become disillusioned. Despite the additional income from sales of battery they were continually being asked to provide more capital due to the depressed state of the copper market (Donald 195;, Hammersley 1973) and to make matters worse Haug and Co. had been taken over by their creditors and had were in the process of pulling out (Collingwood 1912). At the end of 1575 Queen Elizabeth had advanced a loan of £2500 and a request for a further loan seems to have fallen on stony ground. So in May 1579 the shareholders agreed to provide £100 for trials on a new method for recovering sulphur for the manufacture of gunpowder (presumably for ordnance) invented by the chemist Henry Pope (Donald 1955). They were also showing increasing concern over Daniel Hochstetter's handling of the business and were encouraging independent experts to try out the ores and inspect the mines, hoping for a better deal than they were getting out of Hochstetter. Consequently in April 1579 two German mining experts, "Hugh Brinckhurste the younger (of Erffurt) and Phillipp Bayer of Strassburg", came to Keswick and from an assay on the copper ores claimed that three times as much copper could be extracted (Donald 195; Hammersley 1973). But that exercise came to nought and Daniel Hochstetter, understandably annoyed by "diverse slanderous reports" and "secret dealings" behind his back (Abrahams 1901), proposed that he should take on the burden of the running costs himself and that the mines should be leased to him in return for a fixed rent. In the event the company granted a lease to Daniel Hochstetter and Thomas Smythe, the latter a wealthy merchant and Collector of Customs at the Port of London (Scott 1911), and in 1581, the year of old Daniel's death, independent advice on the smelting methods was again sought. In that year George Nedham, a company shareholder who had been actively involved in the industry, brought a Jewish chemist and metallurgist to Keswick. His name was Joachim Gaunse.

Gaunse (Gans or Ganz) made a careful study of the copper ores and after some experiments of his own managed to identify "tenn severall substances" (Abrahams 1901). One of these was the copper itself and the other nine, described by Nedham as "hurtfull and venomous humors to the copper", were identified as "Iron, a kinde of black stone (wherin the copper groweth), a kinde of white stone named sparr, sulpher, arsenique, antimony, vitriall, calcator (ie. calc-ochre or iron oxide), and allom". Not only was Gaunse able to recommend a drastic reduction in the number of firings needed to reach the rough copper stage, but in doing so was able to present the company with two commercial by-products, vitriol and copperas, which he dissolved out by "letting water passe through the ures" after the first roast. The latter was in great demand for dyeing cloth and although Nedham claimed to have some knowledge of vitriol production (presumably meaning blue vitriol or copper sulphate) the secret of separating the iron from the copper in sulphate form was something new to Keswick. The potential market for copperas he extolled at length: "For vent of this Coppris ther wilbe great quantitie used in Cumberland, Westmorelande, Yorkshire, Cheshire, and Lancashire onely for dyeing ... and likewise ther wilbe much solde in the north-partes of Scotlande" - areas previously forced to import the product from foreign countries. But nowhere in the reporting of Gaunse's work (two long documents in the *Domestic State Papers* (Abrahams 1901)) nor in any other development of by-products at this time do we find a mention of bismuth. Moreover Gaunse commented on the ignorance of the German operators when it came to understanding the impurities in their copper ores.

A MINER CALLED FECHTENBACH

All the evidence therefore points to the bismuth consignment of 31st January 1569 being the result of a trial run on a bismuth-rich ore not normally encountered at Keswick - and here Bernhart Fechtenbach may provide the clue. Fechtenbach was one of the earliest miners to arrive at Keswick from the Schwatz area of the Tyrol and according to the Accounts was employed at different times both as a pickman and in the Keswick smelthouses (Collingwood

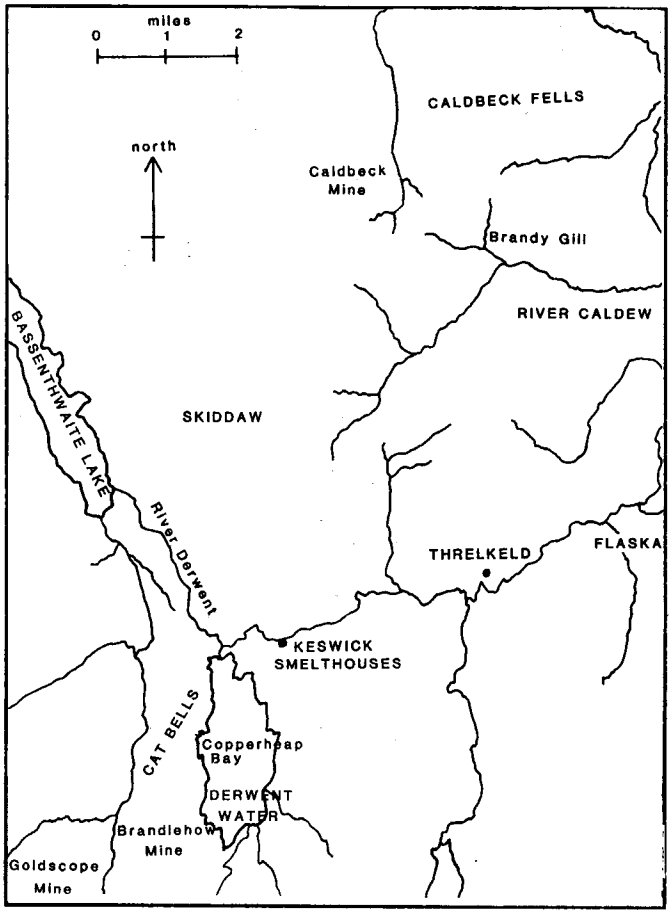

Fig. 2. Mine sites in the Keswick area.

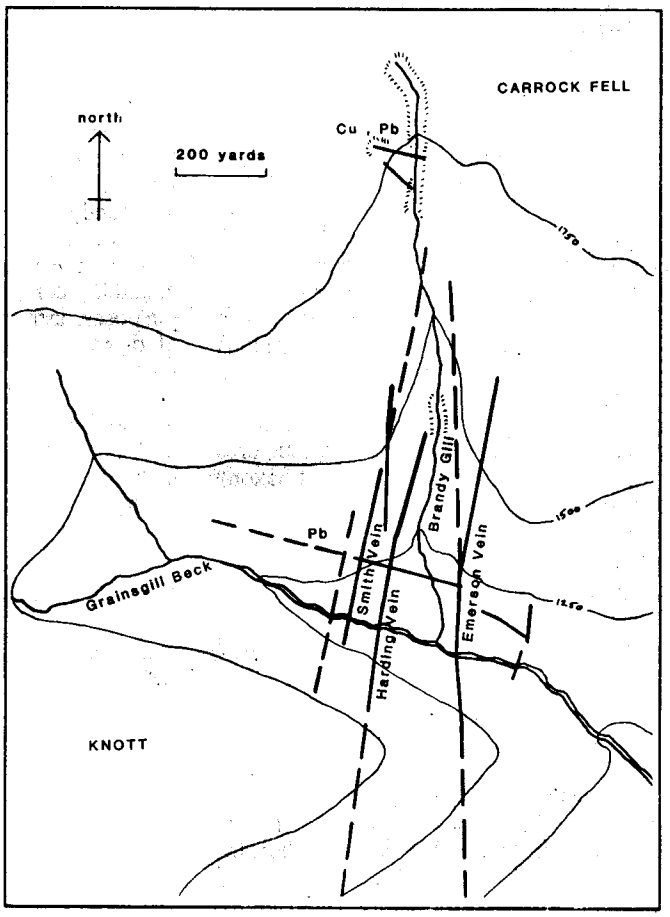

Fig. 3. Mineral veins at Brandy Gill, Carrock Fell.

1912). In the early days of the industry a considerable amount of prospecting must have been carried out, as shown by a letter written in 1568 by Daniel Ulstat, deputy governor of the Company of Mines Royal, which states "We have also in that short time, since I did write, here found eighteen new mines, the which according to the assay made therof might be wrought with good profit" (Donald 1955). Fechtenbach also made a contribution in this field. In March 1574 he was paid 10/- for discovering a new mine near Wythburn where he subsequently raised 22 kibbles of ore, and at an earlier date, ie. late 1568, we find him working alone on a contract developing the 'Waiss nit' vein called 'Windenburg', the exact location of which is not recorded though it appears under the Newlands accounts. It is also noted that sometime in early 1569, possibly January 12th but the date is not clear, six kibbles of unspecified ore were carried from Fechtenbach's Nick in 'Brandlgil' at 6d per kibble.

Collingwood identifies Brandlgil as one of the water courses down Cat Bells into Brandlehow wood. A hand-chiselled adit level suggests that the lead bearing Brandlehow lode was worked in the 16th or 17th centuries and there is documentary evidence that there were workings known as 'Minersputt' here as early as 1566 (Collingwood 1912, Wildridge 1988). Also, from Hochstetter's notes we learn that Brandlehow 'ganz' ore was used in trials for the extraction of silver in 1567 (Hammersley 1988). But in the case of Fechtenbach's Nick we happen to know the name of the ore carrier - a Richard Hodgson of Threlkeld who was largely employed in transporting peat from mosses to the north and east of Keswick:

Early carrying peat 1569 — Richardt Hudgson - from Skiddaw
" — Richardt Hudson - carrying peat from Skiddaw
" — Richardt Hogdson - carrying ore from Fechtenbach's Nick

Summer 1569 — Richardt Hudgson - carrying peat from Flasco

1571 Richard Hudson - carrying peat from Skiddaw and Flasco of Trelkhet

1574 Ritzart Hutson - creditor of Drilket

Why should a Threlkeld carrier with a team of workers cutting, drying and stacking peat on Skiddaw and carting it to the smelthouses in early 1569 take on an isolated job at Brandlehow across the River Derwent when there are other carriers in that area? Moreover why should the company be prepared to pay 6d per kibble for ore to be transported only a mile along the lake shore from Brandlehow to their landing stage at Copperheap Bay in the 'Vorwald', from where it would be taken by boat to Keswick, when the going rate for carting ore the greater distance from God's Gift (Goldscope) to the landing stage was only about 1d per kibble?

Now if by Brandlgil the accountant meant Brandy Gill, situated eight miles north of Keswick in the Caldbeck Fells, and included the earlier entry with the Newlands returns by mistake, then the employment of a Threlkeld carrier at a rate of 6d per kibble would make sense (Fig 2). And there is supporting evidence for this. In 1747 an anonymous traveller journeyed to the Lake District to visit the graphite mines in Borrowdale but finding them closed diverted his attention to the Caldbeck Fells. His description of the visit appears in the Gentleman's Magazine together with a crudely drawn pictorial map of the area showing a gill to the north of the River Caldew below Carrock Heights, he called "Brandle-gill Beck".

This then raises the question - what interest would the German miners have had in Brandy Gill? There are two E-W lead bearing veins the upper of which is said to have also yielded copper (Adams 1988). This was developed in the 1720's and again in Victorian times from levels on both sides of the gill (Cooper and Stanley 1990; Shaw 1972) [see Fig 3]. The anonymous visitor of 1747 spoke of abandoned copper mines there "long since worn out". It is also recorded that

lead or copper mining began at or near Brandy Gill as early as the 16th century (Whellan 1860). But the evidence here suggests that in late 1568 the Germans, maybe Fechtenbach himself, had hit upon one of the strong N-S tungsten bearing veins. Could it be that the Windenburg vein (which Fechtenbach was working in the winter and spring of 1568/1569) and Fechtenbach's Nick (from which ore was carted in early 1569) both referred to the same vein, Emerson's or Harding's, and that the nickname 'Waiss nit' or "Don't know" described its chief ore wolfram which they were unable to identify? In their search for copper and lead could they have recognised the bismuth ores and, knowing that in the mines of Saxony and Bohemia bismuth generally indicated that there was silver beneath the place where it was found (Agricola 1530), continued their trials long enough to explain the consignment of bismuth sent to London and Antwerp around the end of January 1569?

The principal bismuth ore in these veins is again the sulphide bismuthinite (Shackleton 1973) but here elongated crystals up to 25 mm have been found in quartz (Cooper and Stanley 1990), associated with the sulpho-tellurides (principally joseite) and small amounts of native bismuth (Cooper and Stanley 1990; Hitchen 1934; Firman 1978; Hartley 1984). Fine specimens of the latter are said to have been found in Emerson's vein (Shaw 1972). There are early open cuts on these veins, from two to seven feet wide, in a highly fractured granitic bedrock which is weathered and in many places lichen-covered, and although the use of pre-powder techniques is not immediately evident they cannot be ruled out.

This attempt to pull together several apparently unrelated facts perhaps throws more light on the extent of the mining operations carried out by the Germans in Tudor times, though it is unlikely they would have found the rich silver deposites they appear to have been searching for. It is ironic that over three centuries later German miners William Boss and Frederick Boehm should have come to the same place to extract wolfram (Blundell 1992), the very ore which in all probability baffled their forefathers.

EARLY USES OF BISMUTH

By the end of the 16th century an alloy containing bismuth and antimony was being used for casting type (Boon 1976). As well as having the advantage of a low melting point and high fluidity, bismuth shares with antimony the unusual property of expansion on cooling thus enabling the manufacture of alloys which undergo zero dimensional change on solidification (Kirk-Othmer 1978), a fact which may already have been recognised by the printers of the time. Also, small amounts of bismuth were occasionally added to the tin-lead alloy used in the manufacture of pewter to improve its hardness. Antimony was also employed for this purpose and the practice had been adopted in Europe before 1600, though apparently not in England until the late 17th century (Hornsby, Weinstein and Hower 1990). The first recorded use of bismuth compounds for therapeutic purposes, in particular for the treatment of digestive disorders, appears to have been in the 17th century (Kirk-Othmer 1978), but its potential in this direction may well have been appreciated earlier as also its value as a cosmetic in the form of bismuth oxychloride, more commonly known as 'pearl white'.

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