EarlyBritish Alum – People, Quarries, Industry

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Key Words: Agricola alum bioprospecting Blount Bludder Bouchier Brooke Burlamachi Camden Cecil Chaloner Clavelle Clayton cloth copperas Cotton Courteen Canford Crispe Deptford Draper draperies dyeing dyestuffs Elizabethan Foulis Guisborourgh Hastings Ingram Lambay Lane leather Leycolt Lowe Malynes Medley monopoly Mountjoy Mulgrave Palavicino patents Petty Pinnar pyrite quarries Salter Sheffield Skelton sulphuric acid Tudor Turner Wight Whitstable wool woollen cloth

Text date 14 April 2016

Synopsis:

In the mid sixteenth century, alum was an essential mordant to make colour-fast the dyes used on woollen cloth textiles. The first English alum industry began on the south coast near Poole. It almost or entirely failed to make alum, but profited instead from producing copperas, a salt of hydrated ferrous sulphate which had many commercial uses.

Alum production on a large scale began in Yorkshire in the first years of the seventeenth century.

This account looks at the people involved in promoting the early alum industry, as well as the organization and techniques of production during the period 1560 to 1660. A brief summary is also given of later developments in Yorkshire, Lancashire and Scotland up to 1850.

Details of alum and copperas production techniques and quarries are given in the Appendix. This also contains further information about the family backgrounds of prominent early investors, and details about the industries which purchased alum, particularly cloth making and leather processing. There is also more about Cornelius de Vos, an important but elusive early promoter of the alum industry and sometime member of the influential Company of Mines Royal.

Family networks and political patronage played a very considerable role in commercial activities during the sixteenth and seventeenth centuries.

Technical and commercial information about the projects on the south coast informed and influenced the first alum works in Yorkshire

Family connections existed between James Blount, the principal alum and copperas experimenter on the south coast in the sixteenth century, and the wealthy politician and courtier who is generally credited with establishing the early seventeenth century large scale alum industry in North Yorkshire.

The significant link was Sir Thomas Chaloner (d.1565). He was the stepfather and ward of Catherine Leigh (1539-1577). Her husband James Blount, Baron Mountjoy (d.1582), experimented to make alum, and mined potential alum 'ores' on the Isle of Wight and near Poole.

Thomas's heir and namesake, Sir Thomas Chaloner (d.1615) of Richmond Palace, later opened the important Yorkshire alum works at Guisborough. A seventeenth century deception that the younger Sir Thomas was the first to find alum in Yorkshire has been perpetuated in many modern accounts.

There are two contenders with strong claims to have made the discovery of alum in Yorkshire. One was Thomas Chaloner of Lambay in Ireland, the impoverished grandson of Sir Thomas (d.1565). The other was Richard Leycolt from Dorset.

Leycolt was one of several independent technical experts, like Edward Lane, who had gained industrial experience in Dorset and, despite their lack of substantial capital, moved north to play a significant early role in Yorkshire.

Alum production in Yorkshire, using aluminous shale rock from very extensive quarries, remained an important industry up to the mid nineteenth century (see Appendix 43). Large scale alum production using

similar techniques, but processing waste shale from underground coal mines, began in Scotland in 1797 (see Appendix 44).

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(1) The Economic Background

Sir William Cecil (1520-1598), chief minister to Queen Elizabeth I, had two principal policies – to preserve the stability of England and to make the nation as self-sufficient as possible (Williams 1980, 45; Peck, 1990, 136). This included encouragement for the production of alum, a mordant used to make colourfast or 'fix' the dyes used on textiles.

Alum has been described as "*a kind of mineral salt, of an acid taste, leaving in the mouth a sense of sweetness, with a considerable astringency*" (LEUD, 1829, 1, 705). "*Its taste is nauseously sweet and astringent*" (Croker, 1764, 'alum')

Alum (allome, allum), as known in the sixteenth century, referred to an expensive crystalline salt, imported into western Europe from Italy and the eastern Mediterranean. In chemical terms, all alums are double-sulphate molecules (containing the element sulphur), forming salt crystals which consist of an alkali sulphate, a metal sulphate, and water of crystallization (Hicks, 1963, 353).

It was not until 1797 that Louis Vauquelin (1763-1829) published his "*dissertation, demonstrating that alum is a double salt, composed of sulphuric acid, alumina and potash*" in the Annales de Chimie (vol.22) (Enc.Brit., 1842, 1, 571). In the same volume, Jean Chaptal (1756-1832) published the same conclusion after his later analysis of four varieties of alum: Roman, Levant, and British; and alum he made himself. Their results were not immediately accepted, and in the 1840s alum was wrongly considered a triple salt (Enc.Brit., 1842, 2, 571).

Early commecial alums contained the metal aluminium (as aluminium sulphate) together with either potassium sulphate (making potash alum), or ammonium sulphate (making ammonium alum). Often, commercial 'alum' was a mixture of both potash and ammonium alums

Natural alum can occur in small quantities in some exceptional 'ore' rocks, but most commercial alum had to be made synthetically by chemical processes in which a source of alkali (such as stale urine or a solution of potash from plant-ashes) was reacted with a heated solution of aluminium sulphate obtained from shale rocks, which are varieties of mudstone.

Samuel Parkes, an influential chemist, believed in 1812 that: "*Alum cannot be made without a portion of ammonia or potass* [potash]*...All alum is either a sulphate of alumine* [aluminium] *and potass, or a sulphate of alumine and ammonia. Urine* [for ammonia] *is generally used in Scotland, and sulphate of potass in Yorkshire*" (Parkes, 1812, 123). In the early nineteenth century even the initial aluminium sulphate was sometimes synthesized using sulphuric acid, itself made by burning sulphur with saltpetre (see Appendix 1).

English wool was regarded as being of exceptionally high quality (James 1889, 590-600). Export taxes were much higher on raw wool than on cloth (Ponting, 1971, 17). William Camden claimed in 1607 that Isle of Wight wool "*next unto that of Lemster and Cotteswold, is esteemed best and in speciall request by clothiers, whereby there groweth unto the inhabitants much gaine and profit"* (Sutton 2004). This praise was repeated in Ephraim Chambers's influential 'Dictionary' (Smith, 1747, 2, 406). Savary's 'Dictionaire Universal du Commerce' published in Geneva in 1741 similarly declared: "*The best English wool is that of Leominster in Herefordshire, of Coteswold in Gloucestershire, and of the Isle of Wight in Hampshire. It is so fine, that the Stuff, thereof made, comes near to Silk*" (Savary, 1741, 2, 955; Smith, 1747, 2, 421). John Smith in 1747 dismissed the silk allusion as "*silly Hyperbole*", and claimed these varieties were "*over-praised by English Writers and some others, or else undersold in the English Markets; both of which I think to be the case*" (Smith, 1847, 2, 407) (see Appendix 47).

During the first half of the sixteenth century, production of relatively heavy, un-dyed broadcloth in Witshire, Somerset and Gloucestershire was the most important English industry. It was exported almost entirely to Antwerp via London, to be processed for ultimate sale as dyed cloth to Germany (Ponting, 1971, 21; Anderson, 1778, 2, 108).

Many cities, including London, Southampton and Winchester, held regular **cloth markets** selling plain white broadcloth, mainly to Flemings who refused to take dyed cloth (Mackie 1966, 468). The cloth was then dyed in Flanders (Belgium) (Hart-Davis 1995). Finished cloth from Flanders was mostly sold in Germany (Ponting, 1971, 33).

Nevertheless in the 1540s the woad, madder and alum required for use by English dyers formed ten percent of total imports (Ponting 1971, 23).

In c.1506-9 the alum imported through Southampton by Lewis de Fava, was stored in Lord Beaulieu's "*grete seller*" pending payment of customs duty (Merson, 1952, 1, 11). William Cholmeley employed a dyer from Antwerp and promoted *A Project for Dyeing Cloth in England* (1553*)* (Allen 2004, 29).

In 1564-5, cloth and woollens made up eighty percent of the value of exports from protestant England (Derry & Williams 1970). At this time, European alum production was mainly by the Pope at Tolfa near Civita Vecchia, which had rare high grade alunite ore, and by catholic Spain near Carthagena (Clow & Clow, 1952, 235).

Cecil encouraged the immigration of skilled European artisans to improve various strategic industries. These included successful German prospectors in Cumberland whose activity was regulated by inclusion within a new Company of the Mines Royal (1568). By bringing in German workmen, they made Keswick the leading English centre for the mining and smelting of copper, lead and silver ores (see Appendix 52).

Foreign miners also opened the Seathwaite graphite deposit in Borrowdale. This was a strategic mineral used for casting high quality cannonballs (Stone 2010, 190; Firman 1978, 226).

Between 1450 and 1550 considerable technological improvements in mining and metallurgy had been made in Central Europe, particularly at Freiberg, Goslar, Mansfield, Trento and Chemnitz. These had been important silver mining centres since the thirteenth century (Rosenberg, 2009, 53). From there, skilled craftsmen began exploring new areas for their copper and silver protential, including Hungary, the Tyrol, Carinthia, Lorraine and Saxony. Copper, zinc, lead, gold and silver were extracted. German miners and metallurgists became renowned throughout Europe for their expertise (Ricard, 2015, 68).

The term 'Dutch' meaning Deutsch, often written as Doutche or Doutchman, became a common English word for Germans during the sixteenth century (Ash, 2004, 225).

Improved textile technology and changing fashions from the mid sixteenth century, together with the immigration of skilled Europeans, brought a gradual transition in the English cloth industry from traditional 'Old Draperies' to the 'New Draperies' (Musson, 1978, 44). This resulted in an increased demand for alum, because the 'New Draperies' were dyed in England before export, unlike the 'Old Draperies' (see Appendix 45).

Some historians like J. U. Nef have claimed that an **early industrial revolution** occurred between 1540 and 1640 (Musson, 1981, 30). Adam Anderson's account of '*The Origin of Commerce'* (1764) was an early attempt to examine the chronology of British technological and economic changes. Precise dates were not always accurate, but Anderson provided a new perspective on national progress. This marked a change in emphasis by historians. Instead of concentrating entirely on changes in landed wealth, politics and warfare, there was a new appreciation of the significance of technology and commerce.

"1521 Muskets first brought into use". 1535 Brass-cannon first made. " *1543 Pins made in England, before which the ladies used skewers*". 1547 Iron cannon first made. "*1552 Hops and saffron planted in England"*. 1557 Glass first made. *"1561 A copper mine and lapis calaminaris found in Cumberland"*. 1563 Knives first made. *"1565 Two new projects in England for making brimstone and oil - Wire-drawing by a mill first introduced"*. "*1567 Persecution in the Netherlands drives people into England, who introduce the manufacture of bays, says, &c –the old Royal Exchange built in London*". "*1569 The art of Italian accounts, or book keeping by double entry, first published in England"*. 1580 the first coach used in England. *" 1605 Coaches come into general use by the nobility and gentry at London. 1606 Alum first made in England.". "1645 Private banking by the goldsmiths in London began"* (Anderson, 1764, 332).

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(2) Monopoly by Letters Patent

The provision of patents, which granted their owners the exclusive rights of monopoly in a commercial activity, was a relatively new innovation. Patents were first issued by various European city authorities from the mid fifteenth century, but covered only the area of their jurisdiction.

England developed a systematic national patents policy before other countries (Price, 1906, 7). During the first ten years that this was in place, 1561-1570, twelve patents were granted for chemical products and processes, and six for mechanical inventions.

Industrial patents granted by the English government up to the mid sixteenth century had been in effect "promises of protection to foreign workmen introducing new arts, especially those connected with the clothing trade" (Price, 1906, 3).

Through the provision of patents, German armourers, Italian ship-wrights and glass-makers, and French iron-founders were induced to establish new industries in England, and could hope for royal patronage (Price, 1906, 5).

Moses Stringer in 1713 showed that the alum patent granted to Cornelius de Vos was regarded as sufficiently important to be quoted in several later mining patents to avoid any conflict over mineral rights. In his "Copy of the first Patent of the Mines, to William Humfrey and Christopher Shutz: Dated 17th of September, 7 Eliz." (1565), the document began: "*To all men to whom these Letters Patent come, Greeting. Where heretofore we have granted Privilege to Cornelius de Voz, for the Mining and Digging in our Realm of England, for Allom and Copperas, and for divers Ewers of Metals that were to be found in digging for the said Allom and Copperas, incidentally and consequently without fraud or guile, as by the same our Privilage may appear"*.

Later Daniel Houghstetter and Thomas Thurland had been authorized to seek gold, silver, copper and quicksilver (mercury) in eight named counties, for the Society of Mines Royal. In 1565 Humfrey and Shultz were being authorized to extend that search for precious minerals to the remaining counties of England and Wales, and to Ireland, but "*Copperas and Allom in our Realm of England as afore is said only except* [excluded]" (Stringer, 1713, 26; Anderson, 1787, 2, 122).

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(3) Origins of the Solent Coast Alum Industry

The Isle of Wight was a potential source of alum minerals. Bristol dyers may have tried using '*Alym de Wyght*' in 1364 (Nef, 1932, 184). The quality was apparently very poor and 'Ordinances for Dyers' in Bristol soon instructed '*that no Alum de Wyght or Bitterwas be used*' (OIH, 2000; Salzmann, 1913, 144; Page, 1912, 3, 453).

Oxidation of pyrite in some of the Eocene mudstone strata of Alum Bay on the Isle of Wight produces the mineral **melanterite**, which is hydrated ferrous sulphate, also known as '**copperas**' (Kourimsky, 1977, 209). This can serve as a mordant, if only for black dyes. Once regarded as an 'alum', it may have provided the name for the Bay (West, 2014).

It is possible that the melanterite of Alum Bay was originally discovered by prospectors from Bristol seeking Fullers' Earth for the cleaning or 'fulling' of wool cloth. Chemists in 1812 believed : "*Fullers' earth is alumine combined with very fine silex* [quartz]. *It is owing to the affinity which alumine has for greasy substances, that this article is so useful for scouring cloth. Hence pipe-clay is frequently used for the same purpose"* (Parkes, 1812, 21). **Pipe clay** was available at Alum Bay, in a seam now called the Alum Bay Leaf Bed, part of the Poole Formation of Middle Eocene age (Insole, 1998, 106). "*Alumine, or pure clay…acquired its name from its being the basis of alum; it has also been called argil, as it is the principal part of all clay"* (Parkes, 1812, 120). Other chemists used the term 'alumine' for the metal aluminium, which is abundant in clay and shale ('*schistus'*).

There is no record of further interest in alum at Alum Bay for two centuries, until the 7th March 1561. It was then that Sir William Cecil provided a Mr Bendall (sic) with a letter to Sir Richard Worsley (d.1565) of Appuldurcombe, on the Isle of Wight. As the head of the Island's leading family, Sir Richard was required to assist Bendall in questioning Islanders about the presence of alum, and in obtaining '*Oure of Alume*' for testing (Worsley, 1781, xvi; Boucher James, 1886, 481-9).

On 31st December 1562 a patent (No. IV) for 20 years was granted to William Kendall to make alum in six southern coastal counties from Cornwall to Sussex, and Surrey, because he claimed to have discovered a successful technique (Hulme, 1896, 144). However, Kendall's production attempts in Devon soon failed. No details can be found, and Kendall is not mentioned in histories of woollen cloth production in Devon (Lysons and Lysons, 1822, 7, ccxcviii to ccciv; Hoskins, 1954, 125).

Shortly afterwards, on 3 July 1564, a patent for 21 years (No.VIII) was granted to Cornelius de Vos to make alum and copperas, based on his claim to have discovered the ores of both at Alum Bay on the Isle of Wight. Which Eocene strata he used is unknown, but the carbon-rich Marsh Farm Formation is one possibility.

De Vos was from Liege, and regarded himself a London merchant (Donald 1955). Very little is known about his career. On 11th December 1558 he married Helen, the widow of a London vintner called John Gylmym, or Gilimene (Turton, 1938, 39).

It is possible that De Vos first visited Alum Bay in search of coal fuel to sell to coastal saltworks operating seawater saltpans. The industry was well established along the south coast of England, especially on the nearby mainland at Lymington and Portsmouth, and also on the Isle of Wight at Newtown.

De Vos seems to have had some expertise in the salt industry (see Appendix 58). When he later left Dorset for Scotland, his first project there was to open a new saltworks in May 1567 at Newhaven on the coast close to Edinburgh (RBE, 1567). Scottish saltworks used local coal as fuel, when available, for heating large iron pans of brine to complete the evaporation process (Turnock, 2005, 24). Similar pans were used in northern England on the Tyne and Wear (Ramsey, 1972, 3).

It is possible that some springs on the Island were thought to taste of alum. One geologist, Dr. Berger, in about 1800 recorded beds of "*marl*…[with] *nodules or kidneys of sulphurat or iron* [pyrite], *some of which have undergone a partial decomposition…on the south-western coast…between a stratum of loose quartzose sand ,and one of calcareous freestone with chert* [Upper Greensand] *above the source of an alum chalybeate spring*" (Stevenson, 1812, 472). That site was probably near Chale, and the alum was illusory.

Alum Bay is a relatively small sheltered cove north of The Needles chalk peninsular at the western end of the Isle of Wight It has very similar geology to Whitecliff Bay, sheltered on the north side of the similar chalk promontory of Culver Down at the eastern end of the Island. There, a bed of lignite a metre thick known as the Whitecliff Bay Bed forms part of the Wittering Formation, of Eocene age (Insole, 1998, 39). Though of poor quality, it has long been occasionally used locally as fuel.

His alum patent of 1564 allowed De Vos to take up to three financial partners. He was obliged to provide the Queen with one tenth of the alum output and, if requested, all the copperas-containing residue.

He failed to raise sufficient capital for the enterprise and soon moved off the Island to the nearby Dorset coast at Canford Cliffs (Turton, 1938, 39). He later assigned his rights to Lord Mountjoy who obtained a Parliamentary Act in 1566 confirming the grant (JHC, 1566). Both men later became shareholders in the Company of Mines Royal (1568), and may have met during preliminary negotiations over the establishment of that company.

William Cecil and the Queen kept a financial interest in the success of the alum venture, which soon showed some success. By 1571 Bristol merchants were complaining about loss of trade in iron and alum from Spain because both were now being made better and cheaper in England (Hulme, 1896, 145).

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(4) James Blount (6th Lord Mountjoy) - The Early Dorset alum industry

William Cecil was a lifelong friend of **Sir Thomas Chaloner** (1521-1565) senior (HPM, Chaloner, 2015) (cf. 1521-1579 in TP, M#468139). Sir Thomas provided an important link between the alum projects in the south and the north of England. His role may have included a transfer of technological information northwards (DNB, 2004, 10, 896).

Sir Thomas sn. was the son of Roger Chaloner (died c.1550) (TP M#468140) and Margaret Middleton TP, F#468171), and had two brothers, John and Francis. Sir Thomas became secretary to Sir Henry Knyvett (1540), and later Head Clerk to the Privy Council. He was a poet, an intellectual and a statesman, serving as an ambassador in Brussels and Spain (1560-64). His wealth enabled him to acquire estates at Guisborough in Yorkshire, Steeple Claydon in Buckinghamshire, and St Bees in Cumberland.

In 1550 Sir Thomas married **Joan Leigh** (Joanna, nee Cotton, d.1556) (TP, F#468177), the widow of Sir Thomas Leigh (also spelt Legh or Lee) of St. Oswalds in Yorkshire (DNB, 2004, 33, 205; Emerson, 2012). Joan's father was William Cotton (TP, M#468178), a distant descendant of Sir Henry Cotton of Cotton Hall, Cambridgeshire, and Anne Le Fleming. William Cotton of Oxenheath, Kent, married Margaret Colpepper, and their children included Joane who married Sir Thomas Leigh, and Margaret who married Thomas Gargrave.

Thomas Leigh (d.1545) had been a jurist and diplomat. He was also a “visitor” to monasteries and played a major role in their ‘Dissolution’ under Henry VIII and Thomas Cromwell. He became wealthy by acquiring monastic lands and properties. His will of March 1544 assigned one third of his lands to the Crown for the wardship of his daughter **Catherine Leigh**.

Catherine became the ward of Sir Thomas when he married her mother, and he then arranged for her marriage in May 1558 to **James Blount** (c.1533-1582), sixth **Baron Mountjoy** (DNB, 2004, 6, 290). This marriage enabled Blount to avoid military service in Calais, though he still had to equip and finance a contingent of troops. He was immediately obliged by Sir Thomas senior to borrow heavily on bonds to pay Chaloner for the marriage agreement (Turton, 1938, 21, 36).

The Lords Mountjoy were descendents of Sir John Blount (d.1357) (TP M#165265) of Sodington, Worcestershire. John married twice, first to Isolda Mountjoy (daughter of Sir Thomas Mountjoy). Later as a widower he married Eleanor Beauchamp.

James’s grandfather William Blount (c. 1478-1534) (TP M#107603) of Barton Blount in Derbyshire had been a very wealthy, prominent courtier to Henry VIII. A pupil of Erusmus, under Henry VII he led royalist forces against a rebellion by Perkin Warbeck. His third wife, Alice Keble (d.1521) was the widow of Sir William Browne (d.1514), a Lord Mayor of London (1513). She was the mother of James’s father Charles. Although William died too soon to influence James directly, he had been Master of the Mint in the Tower of London, providing a family connection to the world of precious metal ore smelting and metal refining.

James Blount had been born in Newport, Devon, the eldest son of Charles Blount (1516-1544), 5th Baron Mountjoy, and Ann Willoughby. James may have been tutored by Richard Whitford (d. 1542/3), one of the Syon bretheren who were finally ousted from their monastery by Henry VIII in 1534 (Fanous and Gillespie, 2011, 233).

After the Crown’s harsh suppression of the Pilgrimage of Grace rebellion of 1536-7, when Rebert Aske and the northern rebels tried to prevent monastic closures, all monasteries surrendered to the Crown by 1540. There were executions for treason at Reading, Colchester and Glastonbury, but most monks left peacefully, often taking books and other goods with them. Whitford had actively opposed the Syon dissolution in 1534, but reluctantly transferred to the household of Charles Blount, the fifth Baron, and remained there until his death. His 1537 book ‘*A dayly exercyse and experyence of dethe*’ proved popular with displaced monks.

James Blount became a staunch Protestant. With Catherine he had five children, William, Charles, Christopher, Ann and Edward.

After the death of his father in 1544, Blount spent large sums of money on alchemy experiments. In 1558 he inherited two thirds of the manor of **Canford** and the manor of Puddletown (Sheldrick, 2006). He moved his residence to Canford from Brook House in Wiltshire. In London he leased out his town residence, Mountjoy House, as three flats. Two of his tenants were George Carlton, and a relative of the Earl of Huntington called John Hastings (Turton 1938, 40).

At Canford, Blount’s estate extended eastwards along Poole Harbour towards Bournemouth. It went about six miles inland towards Wimborne Minster. By 1535, alum ‘ore’ was already being mined at Durley Cliffs near the later named Alum Chine (Sheldrick, *2006*).

Chaloner would have been aware that Blount’s chemical interests potentially offered important national benefits. He would have kept an active interest in Mountjoy’s work. In 1568, along with De Vos, Cecil and Robert Dudley, Blount was among the twenty-four founding members of the **Society of Mines Royal** (DNB, 2004, 6, 290).

Blount raised many personal loans from fellow shareholders including Sir Lionel Duckett, Sir Roger Martin and Mr. Byrde (Turton 1938, 45). Sir Lionel (1511-1587), a Merchant Adventurer who became master of the Mercers Company, governor of the Mines Royal (1568), and Lord Mayor of London (1572), was particularly wealthy.

De Vos received £300 from Blount for skilled alum workmen to be brought from Italy. Unfortunately, they proved less competent than local employees (Turton, 1938, 39). In about 1564 Blount began to mine and process shale for copperas at Parkstone (Bournemouth). This was possibly the first large-scale copperas works in England (Sheldrick, *op. cit*.).

Copperas is hydrated ferrous sulphate, a salt once widely used as a mordant, as well as for making ink, and blackening leather. It is also a source of sulphuric acid (Allen, 2001, 94). An intense black dye of iron tannate was made from copperas and oak galls (Williams, 1970, 267).

The type of **'alum'** made in Dorset, if any, is unknown. Natural alum in the local rocks is most unlikely. It may have been possible to make **ferric alum** using copperas, but the process would have been very tedious, involving high fuel costs and the production of dangerous, noxious chemicals. It is also uncertain if a sufficiently high concentration of the necessary sulphuric acid could have been achieved.

Ferric alum contains ferric sulphate and either potassium sulphate or ammonium sulphate. It can be used as an effective mordant (Hicks, 1963, 542).

Heating copperas (hydrated ferrous sulphate) releases water vapour, and the gases sulphur dioxide and sulphur trioxide. By capturing and condensing these gases in water, a mixture of sulphurous and sulphuric acids was produced. This was the normal method of making sulphuric acid at that time.

To make ferric alum, it was necessary to concentrate the acid by evaporating some of the water. Then, the concentrated sulphuric acid and copperas were heated together to give ferric sulphate solution, with the release of sulphur dioxide gas. This was followed by the addition of a suitable alkali (stale urine or potash) to the hot solution, to produce ammonium-iron alum or potash-iron alum. There is no evidence that this process was ever used. It seems to have been sufficiently profitable just to sell copperas rather than make alum.

About 1565 De Vos ostensibly returned to Liege, deserting his London wife Helen Gylmyn (Turton, 1958, 39). He did, however, make legal provision for Helen to have full use of his property at number 28, Pudding Lane, for the remainder of her lifetime In 1573 Helen complained to the Court of Requests that she had been dispossessed of her lands by strangers. Later that year, on 31st May, Lionel Duckett, Lord Mayor of London, informed the Court that De Vos was alive and staying with his cousin Arnould in Liege (Luick). Helen seems to have regained the property, which passed after her death to Christ's Hospital, a school for orphans. They rented it out, to fund the De Vos charity which continued into the nineteenth century to provide an annual gift of coal fuel (together originally with shifts or textiles) to the poor of Billingsgate Ward (see Appendix 53).

By 1568, de Vos was in Scotland prospecting for precious metals, copper and lead (Allen, 2004, 31). James Stewart (c.1531-1570), Earl of Moray, acting in his capacity as Regent (1567-70) on behalf of the infant King James V of Scotland, gave De Vos (De Vois) a 19 year license from 1568 to seek minerals on Crawford Moor (Meikle; Minexplorer, 2015)(see Appendix 58).

In 1565 Blount wrote to Cecil claiming that his copperas works was profitable and expanding, and that he now hoped to produce alum. He soon wrote again requesting the Queen to invest £6000 in return for 150 tons of both alum and copperas to be delivered within two years. As a result, he received a monopoly for 21 years of both alum and copperas production from April 1567. Ten percent of the profits were assigned to the Crown (Sheldrick, 2006). It is very likely that Thomas Chaloner senior was involved in organising this arrangement.

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(5) James Blount - Dorset Alum Financial Problems 1567- 1570

From 1566 to 1572 Cecil himself was encouraging Blount, who invested heavily in equipment (DNB, 2004, 6, 290). At Boscombe and Brownsea Island he leased extra land to expand his copperas production. Unfortunately, the rocks of the area proved unprofitable as 'ores' for alum, and by 1566, Blount was already heavily in debt.

In 1567 James and Catherine Blount and mortgaged their part of Canford Manor within the family to **John Browne** (c.1513-1570) and Charles Browne. The latter was probably one of John's younger sons (HPM, Browne II, 2015). Blount had already transferred some of his Yorkshire properties to John Browne.

John Browne was the son of a London mercer and Lord Mayor, George Browne (d.1514). John's mother remarried, to **William Blount**, 4th Baron Mountjoy (c. 1478-1534). Sir William was a favourite of Henry VIII, and served as Master of the Mint at the Tower of London from 1509 to 1533 (Allen, 2012, 91; Challis, 1992, 231). Robert Amadas and Ralph Rowlett were deputies to Sir William, the Master Worker, and undertook the day to day business. In 1526 Martin Bowes (1496/7-1566), a goldsmith apprentice of Amadas, became his assistant at the Mint (DNB, Bowes, 6, 938). Sir William in 1530 accused all three of defrauding him of his rightful profits. He dismissed them and employed instead Hugh Welshe. Sir William later arranged for his stepson John Brown to become Warden of the Mint in 1536, and he remained Master until the position was abolished in 1544. John's sister Anne married John Tyrrell, grandson of the 3rd Baron Mountjoy.

In 1568 James Blount leased most of his alum and copperas business to two trustees. These were George Carleton (DNB, 2004, 10. 108), and John Hastings (Emerson, 2012). Hastings had been recommended by the Earls of Huntingdon and Bedford (Turton, 1938, 40).

The Earl of Bedford, Francis Russell (1527-1585), was a politician and a close friend of Cecil. Russell exercised widespread territorial patronage, and was very similar to Huntingdon in both his puritan views and the charities he supported (Neale, 1963, 188). He had travelled in Italy (1555) and in 1557 became Lord Lieutenant of Dorset, Devon and Cornwall (DNB, 2004, 48, 238). He was also Warden of the Stanneries (1559-1580) in Cornwall, and owner of Kingston Lacy Manor (1557) in Dorset (HPM 2015 Russell).

Catherine may well have corresponded with her stepfather over these financial difficulties. **George Carleton** (1529-1590) was related to Blount. He and Anthony were the two brothers of Catherine Carleton, who had married Francis Blount, the younger brother of James (HPM, Carleton A. 2015; HPM, Carleton G. 2015). George was also related to Catherine Blount, as both were grandchildren of Margaret Culpepper. He was a substantial landowner who pioneered the use of windmills for drainage in the Lincolnshire fens. A lawyer and member of Gray's Inn (1552) he became MP for Poole (1571) and later Dorchester.

John Hastings (*c*.1525- *c*.1585) of Kingthorpe in Lincolnshire, was the son of either Henry or William Hastings, the two illegitimate sons of George Hastings, 1st Earl of Huntingdon (HPM, Hastings, 2015). From *c*.1568, John operated a woollen cloth factory in Christchurch, making '*frisadoes*' for export to Spain and Portugal (Page, 1912, 3, 486). These were copies of Dutch cloths. He obtained a 21 year patent in 1569 for dyeing and finishing to resemble Harlem cloth. John was pugnacious and often in litigation with the weavers of Coggeshall who had long made the similar 'broad-bayes' cloth.

Despite the intervention of his trustees, Blount's debts on bonds and mortgages eventually rose to £30,000 (Emerson 2012. At about this time, Henry Bennet claimed that Blount was a close friend of the astrologer and physician Eliseus Bomelius (d.1579) (DNB, 2004, 6, 499). Bomelius was arrested in 1567 for practicing medicine without the authority of the College of Physicians and fled to Russia in 1570. In his '*Fragmenta regalia' (1641)*, Sir Robert Naunton (c1563-1635) claimed that Blount wasted his fortune seeking the Philosopher's Stone (DNB, 2004, 6, 290). Others attributed his debts to earlier financial problems and his costly attempts to make alum.

Eventually, on behalf of his wife and sons, Blount formed a separate trust to operate his main alum works at **Canford**. This was called **Okeman's House** (or Totnam's House). The trustees were Thomas Randolfe (Randolph 1523-1590), George Carlton, Thomas Cotton, and Catherine's cousin Cotton Gargrave (c.1540-1588) (HPM, Randolph, Gargrave 2015). The works included thirty acres of land between Canford Launde and the sea. In John Hutchins' publication '*The County of Dorset'* (1774*)*, this is shown on a reproduced map of 1585/6 (Turton, 1938, 40, 41).

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(6) Henry Hastings - Investment in Dorset alum works 1570

In 1570 **Henry Hastings** (c.1536-1595), third **Earl of Huntington**, bought out the Brownes's interests. The price for Canford Manor was £2,100 and that for Puddletown Manor was £2,500. He did not exert control over these properties until Catherine Blount died in 1577 (DNB, 2004, 25, 758).

Hastings was based at Ashby-de-la-Zouch in Leicestershire, and became closely allied with Cecil after the papal excommunication of the Queen in 1570. Hastings concurred with Cecil that Catholicism equated with disloyalty to the state, and he was now prospering. He was appointed President of the Council of the North in 1572, and spent heavily from his own funds promoting loyalty on the Scottish borders

He was perhaps encouraged to invest in industry by the speculations of his brother in law Robert Dudley (1532/3-1588) (Turton, 1938, 45). Robert had invested in the voyages of navigators like Gilbert and

Frobisher, as well as in the Company of Mines Royal, and the Mineral and Battery Company which made hammered (battered) metalware (DNB, 2004, 17, 103).

In 1572, writing to Cecil, Mountjoy recorded that three alum houses were working in the Canford area. The earliest was at Boscombe, on the Alum Chine Road, leased originally to Cornelius Stephenson, who was possibly from Liege (Turton, 1938, 40). Stephenson also supervised operations at Okemans House. Merchant's House was the alum works at Darling Chine.

The Boscombe lease was later transferred to John Mansfield, Richard Leycolt and Clement Draper. They paid £800 in cash to Blount, and an annual rent of £900. Another alum works was named at Branksea (Brountsey), probably Brownsea Island. Havens House works may be just another alternative name for one site.

(7) The Society of New Art - at Canford, Dorset

Meanwhile, the alchemist **William Medley** had persuaded 'Customer' Thomas Smythe (Smith, 1522-1591) of the Port of London, and explorer Sir Humphrey Gilbert (1537-1583), to finance a project to transmute iron into copper using vitriol (Campbell, 2009, 129; DNB 2004, 22, 176; Turton, 1938, 42). Vitriol was sulphuric acid, which was made from copperas.

Medley may have been inspired by a supposedly secret letter sent in 1556 to the Spanish king Felipe II by his trusted informant **Diego Delgado**, which claimed that iron metal put into the Rio Tinto, and left there for a few weeks, turned into copper (Ricard, 2015, 260; Yeoman, 2010; MDPI 2015; IMM 1994**).** **Agricola** also had written about water springs near Newsol in Hungary "*which had the property of transmuting the iron which was put into them into copper"* (Watson, 1782, 1, 234)

Smythe, Gilbert and Medley formed a partnership and received a Charter on 4th December 1571 (Turton, 1938, 42). Details of their partnership clearly show that Smythe expected to profit from both the production of copper, and also large sales of alum as a by-product thereby circumventing the De Vos patent on alum.

The partners later persuaded Robert Cecil and Sir Robert Dudley to join them, becoming the **Society of New Art**, which finally received Letters Patent in January 1574, although the details were apparently drawn up two years earlier (4 Dec. Reg.Eliz. 14) (Strype, 1820, 282). The Society in 1572 leased **Okeman's House** at Canford from Catherine's trustees for £300 per year. For this, Smythe stood surety of £1000.

'**Customer' Smythe** was a member of the Haberdashers Company (1583). The second son of a clothier with a cloth mill at Corsham, he received only a small inheritance but become a leading Customs official and merchant in London. He acquired extensive estates and had wide commercial interests, including the Russia and Levant Companies, and later a monopoly from 1578 to 1581 over alum sales in England (HPM, Smith II, 2015). From 1567 to 1570 he spent most of his time as a Justice of the Peace in Esex (Strype, 1820, 97).

Smythe was the main instigator of the Society of New Art in 1571, according to his biographer, Strype (Strype, 1820, 100) *"The first occasion of this business was by one Medley, who had by vitriol changed iron into true copper, at Sir Thomas Smith's house in London, and after at his house at Essex*" (probably by cryptically salting the liquid with copper salts)*. "But this was too costly, as Sir Thomas saw, to make a benefit by: therefore he propounded to find out here in England the* primum ens vitrioli*, and therewith to do the same work at a cheaper rate. Upon which, Sir Thomas, Sir Humphrey* (sic) *Gilbert … and our Medley, entered into a company, under articles, to find this out…Medley should be employed in this business at the charge of the other two, till, by the profit he should reap… he might bear his proportion* [of the partnership cost]. *The place where this was to be attempted and laboured was in the Isle of Wight, or at Poole, or elsewhere; but at Winchelsey he had made his first trial, because of the plenty and readiness of wood. He received of Sir Thomas and Sir Humphrey* (sic)*, an hundred and one pounds apiece, for the buying of vessels and accessories. They removed to Poole, thinking this* ens of vitriol *to be there, and took a lease of the land of the Lady Mountjoy, of 300 L. per annum; for the payment of which, Sir Thomas, with the other two, entered into a Bond of 1000L."*

Smith persuaded Cecil, the Lord Treasurer, and the Earl of Leicester, to send two observers to join him and Gilbert and view Medley's work in London (Strype, 1820, 102; Maxwell-Stuart, 2012, 93). They invested £100 each. "*The Earl of Leicester was very forward, offering iron, and lead, and money also, and making more vessels".*

Medley undertook "*1. To make of raw iron good copper, and of the same weight and proportions, abating one part in six; as six hundred ton of iron should, by boiling, make five hundred ton of perfect copper. 2. The liquor wherein the iron was boiled, to make copperas and alum ready for the merchant; which, keeping the price they then bore, should of the liquor of five hundred ton of copper be worth 10,000 L. that is, for every ton L1000. sir Thomas was satisfied that true copper was made of iron; but whether all the other incident expenses, which would be considerable, would countervail, that was the matter to be examined*" (Strype, 1820, 102).

Smythe planned many aspects of the venture meticulously, with close stipulation of the role of Medley, and appropriate organization of the Society itself. "*Smith also put on the Lord Burghley*[Cecil] *to make orders when and how it should begin; and that one man or two should be fixed upon, as chief overseers*", to keep books of daily accounts, itemizing all expenditure and income, "*and that Burghley also would, out of other statutes for other societies, cull out some good and wholesome statutes and orders for this*", to regulate the business affairs of the Society (Strype, 1820, 102).

The Letters Patent restricted the Society to a maximum of twenty members, and contained regulations covering the conduct of the Society which were very similar to the 'Articles of Association' adopted by later joint-stock companies (Strype, 1820, 282-6). The Queen was to receive *"the rate of XL shil. For every parcel of any of the said commodies* [goods manufactured] *amounting to the value of an 100 L. The same to be valued after these rates: …every hundred pound weight of Copper at 40 s. English; Quicksilver at 5 L. English; Vitriol or Coperas at 2 s. English, Alome at 5 s. English, to be paid after such manner as the subsidy called poundage granted by Parliament "* (Strype, 1820, 284). If anyone else copied their methods, the "*prerogative royal shall be extended to the disturbance of such persons, and the defacing and destroying of their engines and instruments"* (Strype, 1820, 285).

The Society chose Sir John Hibbord to be responsible for ordering equipment and paying expenses. Smythe appointed a Mr Cole as overseer of the works, who was "*chief doer and worker of the melting, and not to go* [away*] from the works*". A separate clerk was appointed to record the labourers' daily work, and the weekly output.

Medley delayed his departure from London, demanding payment for *"the charges in making* [previous] *experiments now this two years and more, and for his buildings and vessels, the sum of 400 L. But in reply to him, Smith urged , that for two years past Medley and Topcliff (who was his partner) had made* ***crocus,*** *of which they might have made benefit for the reimbursing of themselves. They said they had sent it away for essays (sic), and part of it was purloined*" (Strype, 1820, 104).

Smith then said that he personally was equally entitled to payment, "*he and Sir Humphrey* (sic) *Gilbert being out of purse 400 L. in making trials, paid into the hands of Medley and Lord Mountjoy".* Smith complained to Cecil that Medley's skill was becoming known in London, "*that Sir John Perot had a whole discourse of the complete manner of the work in writing; and that the Lord Mountjoy had gotten one of Medley's chief workmen to him"* (Strype, 1820, 104).

Gilbert oversaw the project, but Smythe was very soon sceptical. He reputedly said of alchemists, "*Fain they would be fingering of money, but when once it is in their hands, we must seek it in the ashes"* (Strype, 1820, 104). He tried unsuccessfully to get the partners to abandon Medley's project and to purchase Mountjoy's alum patent instead. Mountjoy valued his "*bauble"* at £2000 a year, so Smith anticipated a price of £20,000.

In 1572 Medley reassured Cecil that progress was slow simply because the "*earths*" had to be kept unwashed for ten or twelve months before releasing a sufficiently strong solution or liquor. He also claimed that he could not use his best techniques in case Mountjoy learned them.

He later proposed seeking a better and perhaps more secluded location, having heard of suitable mines in Yorkshire. Which Yorkshire mines he referred to remains an important unanswered question. The Society eventually went to **Anglesea**, but this project collapsed in 1576 (Turton, 1938, 44).

Strype did not document those later events, but concluded: there was "*no doubt Sir Thomas smarted in his purse for his chymical covertness, and Gilbert seems to have been impoverished by it: and Medlay was beggared; for I find him in the Counter two years after, viz. in the year 1576, made a prisoner there by Courtis, and some others, who were commissioners from the Lord Burghley, Lord treasurer, for debt I make no question. Though the Lady Mary Sydney, wife to Sir Henry Sydney, was concerned for him, having, it is probable, some opinion of his skill in chymestry, and wrote to the said Lord* [Cecil] *in his favour and against those that prosecuted him: but he* [Cecil] *gave her his grave and wise counsel with respect to him, knowing better than she what kind of man he was.*

Thus did this matter detain Sir Thomas Smith three or four years, to his no little care and cost" (Strype, 1820, 105).

In 1813 Walter Davies, in his account of agriculture and commerce in North Wales, published extracts from two letters sent to **Lord Eure** (qv) by **John Wynn**, who had witnessed Medley's operations (Davies, 1813, 485). Although undated and written some considerable time after the New Art ceased, these provide insight into both the techniques used by Medley, and the ambitions of Lord Eure. The mineral projects by Eure are poorly documented, but he was regarded as a serious potential opponent to the 'Alum Company' in Yorkshire in 1606. He had to be politically out manoeuvered and paid a gratuity by the Yorkshire Patentees of 1606.

John Wynn wrote to **Lord Eure** (qv), possibly in 1604, in reply to an earlier enquiry from Eure. He stated that twenty eight years earlier he was watching, in the company of *"the late Lord Treasurer Burley* {Robert Cecil], *the Earl if Leister, and Sir Francis Walsingham, who were partners in the worke*", when Medley boiled water to make "*alome and copperas, and transmuted iron into copper"*, but "*the evente succeeded not*" (Davis, 1813, 485).

The second letter seems to have been sent later: "*Extract of a Letter from Sir John Wynn of Gwydir to Lord Eure, President of the Marches of Wales, respecting the Copper Mines of Anglesey.*

…… I sende you the mineral water of Anglesey to be tried…I saw when Medley made the trial befor Sir Henry Sidney, and I laid down the particulars.

First- a quantitie of iron was beaten small into powder' which was put into the water in a great boiler of lead, whereof there were either half a dozen or more. Anie of these boilers, havinge flat bottoms, and not verrie deep, not unlike the form of a cooler, did contain manie barrels of licker, beinge that water; which beinge boiled with an exceedinge hot fire of turf to a great height, and afterwards suffered to coolle, there was congealed in that water a threefold substance; - the one, copperas, being green, highest; the seconde alome, being white, in the middle; and the thirde, called the earth of iron, being yellowe, in the bottome. The alome and copperas seemed both to be perfectlie good. The earth of iron, after it was fullie dried, grewe to a substance like the ruste of iron which had long been canckered, yet yellowe. Of this earth of iron I have a greate quantitie laide upon charcoale in a bricke furnace, and blowne down and smelted like lead; and downe came a great quantitie of iron synders intermingled here and there with copper. The 1/10th parte of that which came downe proved to be copper; whereof parte was sent to the Lo. of the counsell that were partners in the worke, parte to others of the nobilitie; and everie gentleman of quality there present had part to carrie in his pockette, who were of opinion that the worke would not quitte coste; and so it proved, for that in a while it was given over.

Wishinge your Ld. good successe in all your attempts, and especiallie jn these your alcymycall conclusions, I do rest.

Yours, &c John Gwyn"

In 1813 Davies stateded that Medley had been employed by Cecil in 1579 (not 1575) to precipitate copper from the acidic 'vitriolated' waters of **Paris Mountain** (formerly Mynydd y Trysclwyn) but the project had not been a commercial success (Davis, 1813, 44). In 1673 Dr. Brown published details of a better technique used successfully in Hungary, to recover copper from the vitriolated water at Herrngrundt mines near Newsol (Davies, 1813, 45). That was not immediately adopted in Anglesey, and although Paris Mountain was a rich mineral area the successful use of the copper sulphate ores to make copper came only after 1762.

In 1782 Richard Watson of Cambridge university was aware of the transmutation attempts made by Medley in Dorset in 1571, from the account in Hutchins' 'History of Dorset' (1774, vol. 2, p.110). He also knew

Dr. Brown's 1673 account of two springs at Hern Grundt, near Newsol in Hangary, which were reputed to transmute iron into copper. Sceptics by that date already realized that the water must contain " *vitriol of copper, and meeting with the iron, deposited its copper*" (Watson, 1782, 1, 234). Brown had not accepted this, because he could not understand what had happened to the iron.

Watson was confident that "*it is now very well understood what becomes of the iron; it is taken up by the water, and remains suspended in it, in the place of the copper…and* [just] *as the copper is precipitated by the iron, so the iron might* [could] *be precipitated by pot-ash, or any other substance which has a greater affinity with the acid of vitriol* [sulphuric acid in the water] *than iron has*" (Watson, 1782, 236).

If Medley had used some recipe to covertly dissolve blue vitriol (copper sulphate) in the water used to demonstrate his technique in London in 1571, his choice of Dorset for a commercial operation appears perverse. He would have been aware that copperas (iron sulphate) was being made there, but since scrap iron was used during the manufacturing process it should have been obvious that no copper was being deposited from the copperas liquor. The later choice of Paris Mountain was sensible, and the project should have had a good prospect of success there.

"*Most copper ores contain sulphur, and when the sulphur is in any degree decomposed, its acid unites itself to the copper, and forms blue vitriol, which is the substance with which the water issuing from the* [Newsol] *copper mines are impregnated. It has been the custom in Germany, for some centuries, to collect the copper contained in these waters; the method is simple: into pits filled with the coppery water they put old iron; the iron is dissolved, and the copper is precipitated, and being raked out in the form of mud, it is afterwards melted into very fine copper"* (Watson, 1782, 1, 237). 100 tons of iron precipitated 84 to 90 tons of copper. The German method would have remained secret until Agricola's revalation.

Paris Mountain ore was rich in sulphur but poor in copper. In 1782 it was being roasted, to remove some of the sulphur as gas, but the remainder formed sulphuric acid which dissolved some of the copper. The calcined ore was washed with water before smelting. One hundred tons a year of extra copper was recovered from that water by using old iron to cause precipitation (Watson, 1782, 2, 241).

(8) Henry Hastings at Okeman's House alum works, Canford

After the 'New Art' left Dorset, Okeman's House at Canford was transferred by Mountjoy's trustees to Edward Meade, a London goldsmith (Turton, 1938, 46). It required renovation costing £800. This cost was deducted from the first three years of his annual rent of £300 (Turton, 1938, 46).

After Catherine Blount died in 1577 her sons William (later 7th Baron Mountjoy) and Charles (1563-1606) began complex legal proceedings against Hastings over Canford Manor. During this time, Huntingdon was personally active in the area, organizing bands of armed men to intimidate and sometimes imprison both the workmen and the fuel-carriers who were employed by those who leased alum works from Mountjoy's trustees. Some workmen were arrested while carting copperas to Poole for shipment (Turton, 1938, 50).

In 1577 a Crown commission, which included **Edward Lane**, reviewed the alum works at Boscombe, Branksea and Alum Chine (HPM Lane 2015). The Queen still received one tenth of the profits under the original agreement by De Vos, valid until April 1588 (Turton, 1938, 56). The works at Alum Chine works were being run by John Mansfield, **Richard Leycolt** and Clement Draper, a London ironmonger. Haven House was held by Thomas Hampton and the brothers John and Edward Lane (Turton, 1938, 46).

In 1580 both Alum Chine and 'Branksea' (possibly Brownsea Island) works were still run by Leycolt, Mansfield, and Draper. **Clement Draper** had originally prospered in London in partnership with his cousin Henry Clitherowe (Harkness, 2007). They traded in flax, leather, saltpetre and gunpowder between London and the northern European ports of Lubeck and Gdansk. Clement married Elizabeth Garton, from a family of prosperous landowners in Kent and Sussex, with interests in the Weald iron industry. His financial position became insecure after lending some ships to Martin Frobisher to mine gold ores in Canada. The ore was worthless and he made a heavy financial loss.

The alum business seemed to offer Draper the chance to recoup his losses. He raised a total of £8,000 on bonds for the works, but in 1581 was imprisoned for non-repayment of a bond for only £120. Huntingdon gained possession of both Alum Chine and 'Branksea' works. In consequence Draper was imprisoned for debt for a prolonged period at the King's Bench in Southwark, where he studied Paracelsus and alchemical books. His prison notebooks are extant and have been researched by Elizabeth Harkness (Harkness, 2007, 186-8). Leycolt was only briefly in prison.

In 1580 Okeman's House was employing over thirty men (Turton, 1938, 47). **Edward Meade** was running this business for Mountjoy's trustees, but when he began to favour Huntingdon the Privy Council ordered local Justices to take possession. With the Justices, the Blounts sent forty armed men to evict Meade. He was replaced by John Poole, supposedly a neutral party but actually financed by Leycolt who was the Mountjoy tenant at Alum Chine. Edward's brother Samuel Meade later took repossession by force.

By 1581 Okeman's House works had been taken from Meade by **Edward Lane** on behalf of Huntingdon (Turton, 1938, 48; Allen, 2004, 30). This was probably Edward (c.1552 – c.1596) the fourth son of John and Elizabeth Lane, a minor landed family at Walgrave (HPM Lane 2015). When the Privy Council again ordered the alum works to be returned to Mountjoy, Lane changed his allegiance. After the Mountjoy heirs granted him a lease John Lane and Thomas Hampton, Edward now opposed Huntingdon. Later the Lane family became involved in early Yorkshire alum industry and in 1583 Edward obtained Walgrave Manor .

Henry Hastings himself had financial problems. During 1582 Christopher Southouse (d.1591) and John Mansfield intervened on his behalf in the continuing dispute with Mountjoy (HPM 2015 Southouse). Southouse was a wealthy money lender, who had made several loans to Henry. Hastings had already been obliged to sell some of his Devon lands to Southouse, and also mortgaged Stokeham manor (1581) to him.

A detailed extant inventory of Okeman's House in 1583 includes 'lead furnaces' for boiling alum liquor, and eleven cannon 'mouths' for scrap iron. The cannon components were to be dissolved in the liquor by reacting with, and removing, any sulphuric acid present. A tank of liquor which had already been boiled produced 14 hogsheads of copperas crystals. There were also a hundred heaps or "*oare*" being weathered ready for processing (Turton, 1938 55). Turton claims very little alum was ever produced in Dorset, but the works were profitable because of their large output of copperas which sold at about £12 10s 0d per ton (Turton, 1938, 46 & 58).

Huntingdon and the Earl of Bedford allowed John Hastings and George Carleton to act as trustees to resolve legal issues in the dispute (HPM. Hastings 2015). John employed Thomas Randolph in 1581 to assist him, but then resigned as a trustee in 1582. In connection with the alum dispute, John Fulford arranged for the under-sheriff of Hampshire to seize John's property, and he later had to appeal to the Star Chamber for its return.

The Privy Council ruled in 1581/2 that Lane could retain Okeman's House. But his workmen, who slept there or walked from nearby Parkstone, were required to lodge at the Haven House works run by Edward Meade.

In 1586 Lords Cecil and Bromley finally ruled that Huntingdon should have the alum mines and Okeman's House, but pay £6000 to Mountjoy's trustees (Turton, 1938, 56). Previous transactions had already cost Huntingdon £20,000.

Huntingdon put money into the Canford alum works, and was rather more successful than Blount at making copperas and alum, even gaining a modest profit (Norgate, 2006). He planned to improve the quality.. In 1584 a shipment of 100 tons of alum from Poole to London fetched £1200 (Allen, 2004, 34). By 1586 Huntington claimed to be making £400 per year from the trade (Cross, 1966)

Philip Smith, Huntingdon's new leaseholder at Canford in 1587, paid £1300 a year (Allen, 2004, 34). The Dorset copperas industry was later superceeded by developments closer to London, and by 1608 this Canford works had long been abandoned (Turton, 1938, 47).

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(9) Charles Blount - the Isle of Wight Mountjoy connection

Charles Blount (c.1562-1606) (TP M#438022), Earl of Devon, the litigant against Henry Hastings at Canford, was the second son of James Blount (d.1582), 6th Baron Mountjoy. He had a distinguished military career and succeeded to the title as 7th Lord Mountjoy in 1594 after the death of his elder brother William. Charles Blount fought in the Low Countries against Spain. In 1600 he was appointed Lord Deputy in Ireland. Near Kinsale in 1601 his cavalry attack routed an Irish army led by the Earl of Tyrone, Hugh O'Neill, leading to the withdrawal of an invading Spanish army.

Charles had three illegitimate sons with Lady Penelope Rich (1563-1607) (DNB, 2004, 6, 305). Penelope (TP F#67849) was the daughter of Walter Dervereux, first Earl of Wessex. She wished to marry the poet Sir Philip Sidney (d.1586). But in 1581 she was compelled by her guardian, the same Henry Hastings (d.1595), to marry Robert Rich (1559-1618/19) (TP M#67848) first Earl of Warwick. They were divorced in 1605 because of Penelope's adultery, but both were forbidden to remarry during the lifetime of the other.

Charles and Penelope married in 1605, contrary to canon law. The ceremony was performed by Charles's chaplain William Laud (1573-1645), later Archbishop of Canterbury (1633). Laud later claimed implausibly to have been unaware that Robert Rich was still alive.

Charles's eldest son was **Mountjoy Blount** (c.1597-1666), who in 1628 became the first Earl of Newport on the Isle of Wight (DNB, 2004, 10, 305). His name was used for the 'knight' or small artillery bastion built onto the southeast tower of Carisbrooke Castle in 1587 and then for the tower itself (Young, 2000, 27-8 & 68). It was also applied to the nearby hill which became Mount Joy (Kokeritz, 1940, 103).

Mountjoy Blount was half brother to Henry Rich (c1590-1649) first Earl of Holland, and Robert Rich (1587-1658), second Earl of Warwick.

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(10) New Rival Copperas works near London

Dorset alum and copperas works soon faced two rival works in England, but these only made copperas, which was reputedly sometimes so acidic it burned cloths while they were being dyed (Turton 1938, 57).

The first works at Queensborough, Sheppey, in Kent, were begun by **Mathias Falconer** from Brabant (Allen 2004, 35). Edward III established a castle and "*Town of Quinborow*", originally called "*Reginae Burgus*" in 1366. Henry VIII later renovated the Castle, which attracted the attention of a London lawyer and eminent antiquary, William Lambarde (1536-1601): *"Being at this Castle (in the yeere 1579) I found there one Mathias Falconar (a Brabanter) who did (in a furnesse that he had erected) trie and drawe very good Brimstone and Copperas, out of a certain stone that is gathered in great plenty upon the shoare neare unto Minster in this Isle*" (Lambarde, 1576, 227). The 1579 date is clearly an error, possibly a misprint for 1569. Brimstone (sulphur) is an essential ingredient of gunpowder, but is very difficult to extract from pyrite, and in the sixteenth century sulphur was normally imported from Mediterranean mines working volcanic deposits. The Castle, built in 1361, was demolished about 1650 (Pennant, 1801, 1, 64).

Not far away the small works at Whitstable was operated by **Cornelius Stephenson** (Stevens), possibly from Liege (Turton, 1938, 57). He obtained a copperas patent in 1565 for this locality, but remained as a manager at Okeman's House, Canford, until the lease terminated in 1587, before opening Whitstable works the following year (Allen, 2004, 41). It became very successful and in 1597 employed about twenty poor people collecting pyrite '*gouldstones*' on sea beaches (Allen 2004, 45). Ownership disputes later arose there between Stephenson, Edward Meade and Edward Lane, all with former experience at Canford.

In 1634 Queensborough copperas works was visited by the diarist Sir William Brereton (1631-1680) from Cheshire, 3rd baronet Brereton of Leighlin (DNB, 2004, 7, 474). Under the guidance of Lord Goring, Brereton had been educated at Breda in the Low Countries, by the mathematician John Pell. He was interested in science, and attended the 1658 meetings at Gresham Colledge which preceeded the formation of the Royal Society, in which he participated. He embarked from London in 1634, travelling by stages to Holland, and on Thursday 22nd May was becalmed on the 'Pink', which put into Queensborough village (Brereton, 1634, 2).

Despite leaving the next day on the 'Unicorn' to Chatham, he spent enough time at the alum works to make detailed notes, which were later worked up for publication.

On a square shaped site of about an acre, he reported that the soil had been removed and replaced by a clay platform. This was subdivided into a number of 'beds' by an arrangement of wooden troughs or channels. The troughs were probably partly sunken, with raised wooden sides bored with holes. They held back the 'beds' of pyrite stones which were placed on the platforms to decompose. The holes allowed rainwater enriched with copperas to run off the stones into the troughs. These beds of pyrite stones were overturned manually each summer, probably using shovels.

The liquid solution in the troughs flowed along to old barrels, sunk into the ground and surrounded by clay. From these barrels, the liquid was later "c*onveyed*" into several large wooden '*cisterns'* set in clay, and apparently located inside a building. From the cisterns, it was supplied to a '*great tub'* in another buildiing, positioned next to the "*mighty cistern of lead*", set over a five coal-fired furnaces (separated by partitions). That cistern was used to boil the liquid, and a quantity of iron was added to be dissolved.

When the solution was sufficiently strong, it was let out through lead pipes into six or more lead cisterns which acted as coolers. Birch twigs were suspended into these cisterns from poles across the top, and during cooling the copperas crystals formed around the birch twigs.

At '*Quindborrow*', Brereton saw : "*Here was a most ingenious copperas work erected. A square plot of ground, about an acre, the earth hath been taken all away, and a kind of stone brought from Essex shore, which, falling into the sea, is tempered by salt water; which stone, by rain and sun, is beaten and reduced to soil; this ground is clayed in the bottom, and is made a fair bottom.*

Betwixt every bed is a trough made with three deane [deal] *boards, bored full of holes; this* [bed] *is digged over every summer, the bottom laid highest and the top lowest. This trough receives and conveys away all the liquor and moisture which doth flow from from that* [pyrites] *soil in rainy and moist weather; old barrels, into which these troughs lead, are prepared and placed in the earth, in clay, which receive the moisture, out of which* [barrels] *the liquor is conveyed into divers great cisterns of [wood] boards, two bayes of buildings, all of which are laid and set in clay; out of which it runs into a great tub, placed in another spacious house, and near unto a mighty cistern of lead, wherein this liquor is boiled. Under this cistern are five furnaces, a partition 'twixt them; these furnaces spend half a chaldron of coals a day, and this leaden cistern will last four years. There is half a barrel* [volume]*of old iron boiled in this liquor, which is consumed to* [leave only] *dirt.*

When it is sufficiently boiled, it runs through a leaden pipe into cisterns of lead, six of them at least, and it cools in those cisterns; the copperas matter thickens [crystallizes] *and adheres to birch twigs, or bushes, which they hang upon over-cross poles, into the cisterns. When this earth* [decayed pyrites stones] *is cast with the bottom upwards, a fleece* [thin layer] *of this stone [fresh pyrites] is laid upon it, which resolves* [decays] *to earth ; the thicker the richer* [the copperas liquor]. *We lodged at the Ship* [tavern], *and were well used; six lobsters bought for one shilling"* (Brereton, 1634, 2)

Brereton's editor, Edward Hawkins, commented that *"the stone brought from the Essex shore was iron pyrites, which abounds there, as it does also at Sheppey. 'All the water of the island is so impregnated with the taste of the pyrites or copperas stone, with which it abounds, that it is scarcely drinkable' – Pennant* ['Journey to the Isle of Wight'] *p.65*" (Brereton, 1634, 2).

Copperas production gradually expanded near London. By 1639 there were six copperas works at Tankerton near Whitstable (Zell, 2000, 133). In 1656 Whitstable shipped out 225 tons of copperas, and Faversham 27 tons. In 1787 the antiquarian and geographer Thomas Pennant set out to observe coastal military defences from London to the Isle of Wight. He had previously visited the Isle of Sheppey in 1750 or 1751, to collect fossils (Pennant, 1801, 1, 77). He recalled that: "*Numbers of the poor inhabitants gain livelihoods by picking up for the Copperas-makers the Pyritae that are washed out by the waves. They received (when I visited) only one p-enny a gallon for their labours; but get a considerable addition for the extraneous fossils they pick up at the same time. The success of these poor people depends much on the storminess of the season: a boistrous east wind is of great service to them, as it washes a greater number of Pyritae out of the cliffs, which extend from about half a mile beyond Minster, to a quarter of a mile beyond Warden; in all, nine miles, allowing for the winding of the shore.*

These are divided into three liberties, Minster, Eastchurch, and Warden, which are rented to the masters of the Copperas works at an annual rent: Eastchurch at thirty pounds per annum; and Warden, with a Copperas-work Gillingham, at forty-five pounds" (Pennant, 1801, 1, 78).

Pennant know of the patent by "*Cornelius de Vot*", and the 1579 works of Falconer, and speculated that copperas probably had to be imported to England from abroad before the reign of Elizabeth I. He believed *"we did not export any until the latter end of the last* [eighteenth ?] *century* ", and quoted Campbel to the effect that by 1774 England exported 2000 tons of copperas a year. Charles Whitworth had recorded 400 tons exported over three months in 1776 (Pennant, 1801, 1, 78).

"*The Pyritae are lodged in the cliffs in such abundance, insomuch that they infect the water on that side of the island, especially above Warden, with such a vitriolic taste as to render it scarce drinkable. They are found of various forms- globular, botryoidal, oblong, and of several other shapes. Within they are of striated texture, generally radiated from a centre, and externally covered in a ferruginous coat. Dr. woodwatrd, in his Catalogue of Fossils, describes most of the varieties*" (Pennant, 1801, 1, 80).

Spontaneous combustion of pyrite was a hazard at copperas works. Richard Watson, profesor of chemistry at Cambridge, drew attention to "*an account, in the Philosophical Transactions for 1693 of a covertous master of a copperas work at Whitestable* [sic] *in Kent, who, in order to break his neighbour's work, had engrossed all the pyrites or copperas-stone in the country: he built a shed over two or three hundred tons of these stones, to keep off the rain. In the space, however, of six or seven months, the mass (being probably wetted by the moisture of the atmosphere, or by the rain…) took fire and burned for a week; it quite destroyed his shed, and disappointed all his hopes of profit; for the pyrites was in part converted into a substance like melted metal…all the sulphur was consumed, and the neighbourhood was miserably afflicted by the noxious exhalation which it sent forth"* (Watson, 1782, 1, 195)

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(11) Kimmeridge Alum Works in Dorset

Entrepreneurs tried to establish rival alum works at Kimmeridge (Hawkins, 1996, 45), and Brownsea Island (*West, 2014*).

Sir William Clavell (Clavile, 1568-1644) of Smedmore succeeded '*by much Cost and Travell*' to make alum at Kimmeridge, only to have the works seized by '*Farmers of the Allom Works*' on behalf of the Crown. (Hawkins, 1996, 45). Clavell's undated account of reasons *"he ought to bee allowed to make allome, or well recompensed*" is extant (Perkins 2015).

Forty years earlier, Mountjoy had joined his father in opening mines to seek alum, and had proposed a partnership. Sir William had learned of that ten years earlier. Subsequently he had spent money seeking appropriate 'coals' to process alum.

About 1605 Sir William Clavell began producing alum, using Jurassic Kimmeridge shale as both raw material and fuel (PHHP 2015). There is no reference to the shale being calcined before processing, a technique used on the Jurassic shales in Yorkshire. Reputedly Clavell built four alum houses, each with forty liquor-boiling pans. These were capable of producing 500 tons per year (Turton, 1938, 92). A small quay built to ship out the alum cost £4000.

Clavell may have petitioned for exemption from the Crown monopoly of 1609 and could have been refused. He then seems to have used the alum works for salt manufacture, possibly to conceal illicit alum production. Eventually the "Marchuante Patentees" arrived to examine his works, "*took composition for his houses, furnaces, and cole pits and agreed for £1000 per year rent"* (Perkins 2015).

For unstated reasons they returned a year later, "*ruined and ransackes all the allom houses*". They also seized his cattle (Perkins 2015). Around 1612 the **Alum Company** from Yorkshire used its royal monopoly to try making alum in Dorset (Turton, 1938, 94). They seem to have paid £2000 to Sir William for his buildings and equipment.

Sir William later stated that in about 1613 he was allowed to reopen the works, and built two alum houses. With Abraham Bigo he also began a glassworks for green drinking glasses, using shale as fuel (Rowley, 2015). This was licensed by Sir Robert Mansell (1570/1-1652), who held the English glass monopoly from 1615 to 1642 (HPM Mansell 2015; DNB, 36, 539; Price, 1906, 72). Clavell broke the terms of this agreement and suffered severe financial losses. His quay at Kimmeridge survived until 1745. Remains of the shale quarries and deposits of burnt shale are still present (NRHE 2015).

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(12) Brownsea Island Copperas Works in Dorset 1665

At Brownsea Island in Poole Harbour, **Sir Robert Clayton** (1629-1707) resumed copperas production in 1665 (DNB, 2004, 11, 991). His works continued operating until 1704 (Sheldrick, 2006).

Clayton was an extremely wealthy London land agent, broker and banker (HPM Clayton 2015; TP M#226559). His career began as a scrivener in partnership with Robert Abbot, his maternal uncle, and John Morris, writing legal documents and lending money. Abbot died in 1658. The two remaining partners expanded their banking business, which eventually became the Bank of England. Unlike the existing goldsmith bankers, who invested in royal loans and in foreign exchange, Clayton and Abbot concentrated on lending to landowners. There was much demand for their services during the Civil War and Interregnum. Clayton owned large plantations in Bermuda, and purchased ironworks in Ireland. He founded the Royal Mathematical School at Christ's Hospital in London, to improve the navigational skills of seamen.

Celia Fiennes (1662-1741) of Salisbury visited Brownsea before 1696 and described the works "*where there is much Copperice made"* (Morris, 1982, 39). They reputedly used local pyrite stones, "*found about the Isle in the shore in great quantetyes*".

"*They gather the stones and place them on the ground raised like the beds in gardens, rows one above the other, and* [these*] are all shelving so that the raine dissolves the stones and it* [the solution] *draines down into trenches and pipes made to receive and convey it to the* [copperas] *house".*

The copperas house was "*fitted with iron panns foursquare and of a pretty depth at least 12 yards over* [presumably 12 square yards surface area, and] *they place iron spikes in the pans full of branches and so as the liquor boyles* [evaporating water to increase the concentration] *to a candy it hangs on these branches". "I saw some taken up* [attached to the branches, and] *it look'd like a vast bunch of grapes*, [because] *the coulour of the Copperace not being much differing* [from grapes, and] *it lookes clear like sugar candy".*

Fiennes was relying on memory for her description, and admitted some imprecision. "*When the water* [solution] *is boyled to a* [concentration sufficient to yield this] *candy they take it* [the copperace crystals] *out and replenish the pans with more liquor*." "*I do not remember* [if] *they added anything to it* [the liquor] *only the stones of Copperice dissolved by the rain into liquor*".

"*There are great furnaces under* [the iron pans], *that keepes all the pans boyling*; it [the copperas house] *was a large room or building with severall of these large panes*; [and] *they do add old iron and nailes to the Copperas Stones*" (Morris, 1982, 39). Commercial secrecy rather than poor memory may have prevented Fiennes recording that the old iron was actually added to the pans during boiling. Her description of the pans as being made of iron rather than lead must be regarded as possibly inaccurate, since sulphuric acid in the liquor would have destroyed iron pans.

Poole Harbour Historic Trust undertook an archaeological excavation of the Brownsea copperas works in 2008.

Extant maps show copperas and alum mines at Parkstone (1695, 1777), Ockeman's House and Canford Launds (Norgate, 2006). Copperas 'houses' are shown at Bascamb (Boscombe) and Alum Chine near Bournemouth (*Allomchine*) on maps by Norden in 1595 and 1607 (Norgate, 2006).

An alum (*allom*) 'house' near Boscombe was mapped by Speed in 1611 and Blaeu in 1645 (Norgate, 2006). Reference to an alum works in Parkhurst Forest before 1579, in a 1921 Geological Survey account of the Isle of Wight (White, 1921, 183), is almost certainly a mistake for Parkstone.

By 1613 no alum was being made in Dorset (Turton 1938, 110).

Rival European alum works were established in Germany at Schwemmsal and Chemnitz in the mid sixteenth century, and much later at Andrarum in Sweden in 1630 (Clow & Clow, 1952, 237; Turton, 1938, 4).

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(13) Sir Horatio Palavicino - Papal alum and espionage 1578

In 1578 the importance of papal alum supplies was re-emphasised to Cecil and Elizabeth I when a dispute arose among Italian merchants supplying alum to Europe.

From 1566 to 1578 the Pope gave a monopoly of trade from the Tolfa alum mines to **Tobias Palavicino (d.c.1580)**, a merchant aristocrat in Genoa. He employed family members as regional agents. He was wealthy enough to be invited to become the Doge (chief magistrate) of Genoa but declined. When he lost the alum monopoly, the family attempted to exclude trade rivals by purchasing all available alum supplies and negotiation exclusive agreements with consumers.

Horatio Palavicino (c.1540-1600), the second son of Tobias, was the Antwerp agent (DNB, 2004, 42, 439). He married a "very mean person" and later concealed her existence and that of their son Edward (c.1578-1630). He moved to England where the Catholic queen Mary I (1516-1558) appointed him collector of papal taxes. After her death he reputedly kept the taxes for himself and renounced Catholicism (DNB, 1900, 43). He became immensely wealthy (Beresford and Rubenstein, 2011, 229).

Communities of Italian merchants were already established in both London and Antwerp, to handle luxury textiles and other goods carried overland from Italy to 'Flanders' (usually Brabant) (NA Prob 11/62). Palavicino was close friends with Giovanni Battista Giustiano, and with **Benedict Spinola (1519/20-1580).**

Benedict was the second son of Battista Spinola of Genoa, and his wife Elisabetta nee Spinola (DNB, 2004, 51,952). Palavicino's mother was Battina (1522-1607) the daughter of Andrea Spinola, so he may have been related to Benedict. Benedict was living in London by 1541, employed by Bastian Bony as a clerk in the postal service serving London's resident foreign merchants. Benedict's brothers Francisco, Pasquale and Giacomo lived in Antwerp.

Benedict was granted Engish denization (a form of naturalization) in 1552, and by 1559 was exporting large quantities of woollen cloth (kerseys) and importing wines. Robert Dudley bought hangings for the dining room at Kenilworth Castle from his friend Spinola. Benedict was a founding member of the **Society of Mines Royal** in 1568, by which time he was apparently no longer Catholic and attended a local protestant parish church. In 1578 Benedict and Palavicino jointly arranged an English loan to the Union of Brussels.

In 1578 Horatio sought monopoly agreements for the supply of alum to England and the Low Countries. Cecil refused, but the Low Countries granted a six year monopoly and in return Palavicino (in partnership with Spinola) provided alum worth £30,000 on loan to the Dutch Estates General. They were to sell it to clothiers, in order to raise money which would repay the loan and finance the war against Spain. Since 1567 the revolt in the Netherlands had been growing, in response to a policy of terror pursued by Fernando Alvarez de Toledo (1507-1582), a Spanish general and leading minister under Philip II (Williams, 1980, 14).

The City of London and Elizabeth I jointly underwrote Palavicino's alum loan, to show England's support for the Dutch. In 1581 Palavicino acquired the Spinolas' share of the alum loan for himself (DNB, 2004, 42,439). Spain instructed its navy to seize Palavicino's ships whenever they were encountered (Turton, 1938, 5). In 1579 he replaced Gresham as Elizabeth's main financial agent and diplomat abroad (Picard, 2003, 113; Black, 1969, 48).

Through the early 1580s, Horatio lived in France to conduct his family's alum trade. At Paris in 1583 he befriended William Parry (d.1585). He had a large network of commercial correspondents, in order to take early advantage of any new commercial opportunities. They helped the espionage he undertook for England, sending reports to Walsingham and Cecil (Hutchinson, 2006, 287). He was also laundering money, enabling English funds to reach the Duke of Anjou and finance campaigns against the Spanish in the Low Countries. In Italy his brother Fabritio was arrested by the Pope and tortured. In 1584 Horatio himself was condemned *in absentia* by the Inquisition, and his property in Italy was seized.

From 1586 to 1587 Palavicino served as an English emissary to the German princes of Brandenburg and Saxony, trying to persuade them to raise troops to support Henri of Navarre. In 1590 he was urged to arrange their joint action in France. In 1591 he did arrange for Elizabeth I to finance their campaign, but the £15,000 was one third more than anticipated, and she ceased to employ Palavicino.

He was granted denization in England in 1585, and knighted in 1587. He invested £20,000 on the purchase of estates in Essex (1585), Norfolk (1588) and Cambridgshire (1589), and lived at Babraham manor near Cambridge. In 1588 he returned from Germany to equip an English vessel against the Armada. In 1589 he tried to persuade the Spanish commander in the Netherlands, Alexander Farnese, to become King of the Netherlands and open the ports to English merchants.

Palavicino travelled to Frankfurt in 1591 to marry Anna Hoffman, daughter of an Antwerp banker. Not until 1593 did Elizabeth I stop payments on the 1576 alum loan, after discovering that £45,479 had already been paid to Palavicino in interest. During 1596 Cecil consulted Palacicino over the construction of his spy network.

He loaned money on a large scale, including significant loans to Elizabeth I and Henry of Navarre. He also bought a share in the 'farm' of Sir Edward Stafford's license to export undressed cloth, which included the cloth sold to the important Merchant Adventurers Company. He speculated on corn prices (futures), making high profits in times of shortage At the time of Palavicino's death, Elizabeth I reputedly owed him £29,000. His total assets were estimated at £100,000.

Palavicino's widow Anna remarried to Sir Oliver Cromwell of Hinchinbrook, the brother of Robert Cromwell (d. 1607) who was father of Oliver Cromwell (1599-1658) the Lord Protector of England. Under his influence, Palavicino's daughter Baptina (1594-1618) married her step-brother Henry Cromwell, and his two sons Henry (1592-1615) and Tobie (1593-c.1644) married their step-sisters Catherine and Jane Cromwell. Tobie squandered his wealth and died in Fleet prison.

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(14) 'Customer' Thomas Smythe - the alum import monopoly 1578-80

Palavicino's proposed monopoly over alum imports into England in 1578 may have persuaded Cecil to grant a rather similar monopoly in the same year to **'Customer' Thomas Smythe** (Smith **1522-1591**), the collector of customs for London (HPM, Smythe, 2014).

The import monopoly was for three years, and was not renewed. It seems to have enabled Smythe to increase the import duty, and take a 25 percent profit on existing alum stocks. Part of Smythe's large profits reputedly went to Cecil and to Robert Dudley.

Cecil and Dudley were members of the **Company of Mines Royal**, which Smythe rescued from collapse in 1580. In 1563 Elizabeth I had granted a licence to prospect for minerals to Daniel Hoechstetter (1525-1581) from Augsburg in Germany (DNB, 2004, 27, 519). He arranged finance from the Augsburg firm Haug, Langnauer & Co., and sought extra English investment. The English partners strongly distrusted the German management. Profits were low and in 1579 Haug, Langnauer & Co. withdrew from the company.

In 1580 the English partners refused to increase their investment which was already £1200 per share. Hoeschatter was prepared to continue production but only in return for a fixed-price lease of the mines. Thomas Smythe, who by then was one of the wealthiest London merchants, organised some of the English partners to help arrange and finance that lease. By careful cost-cutting they made the works profitable. .

Thomas Smythe (d.1591) was the second son of Joan (nee Brouncker) and John Smythe (d.1538) of Corsham, Wiltshire, a yeoman and clothier (Wadmore, 1887, 193; DNB 2004, 51, 468). His elder brother John inherited almost all the property. Thomas received only a farm at Amesbury, worth £20 per year, which he sold to finance his business ventures in London. In 1558 Thomas purchased the position of Collector of Customs (**'Customer'**) for London, paying £2500 to the previous post holder. He was already a successful merchant as a member of the Haberdashers Company and Skinners Company (through his father-in-law), and a close friend of both William Cecil and Robert Dudley. He served as an MP from 1553 until after 1563, for various towns including Portsmouth (1563), where he associated with Adrian Poynings, the Port Captain.

At one stage, Thomas was discovered to have deprived the Crown of some revenue by issuing private warrants at a discount, presumably in return for a consideration. Cecil intervened with the Queen to prevent his imprisonment, but ensured that the deficit was gradually repaid. Cecil had handled a similar problem at the Royal Mint when the Assay Master, Cecil's friend William Humfrey, had been caught conspiring with a colleague to steal money in the keeping of the Under Secretary of the Mint, Thomas Stanley, in order to get Stanley dismissed. Thomas Smythe advised Cecil to have Humfrey briefly imprisoned and then restored to his post.

Smythe was a member of the Muscovy Company (1569) and Levant Company (1581). He 'farmed' the duty on imports (other than wine) through the Port of London, and on both imports and exports (other than wine) through the ports of Sandwich and Chichester. He was a close business associate of John Byrd, and of William Burd, a Mercer trading cloth to Antwerp (Harley, 2006, 76).

He reputedly gained £48,000 from these duties due to the expansion of trade. He purchased land in Kent and Wiltshire, owned Westhanger Castle in Kent, and built a large mansion in Corsham. He was disliked by Sir Walter Raleigh who claimed that Burleigh (Cecil), Leicester and Walsingham were "*all three pensioners to Customer Smith"* (Harley, 2006, 76).

Smythe remained an active member of the Mines Royal, and the Mineral and Battery Company. He also bought shares in the alchemical venture promoted by Sir Humphrey Gilbert, **The Society of New Art**, and helped to finance the voyage of Edward Fenton in 1582.

In 1554 Thomas had married Alice, the daughter of **Sir Andrew Judd** (c.1492-1558), Lord Mayor of London (1550-1). Judd was one of the richest and most prominent overseas merchants in early Tudor London (DNB, 2004, 30, 812). A member of the Skinners Company (1520), Judd became wealthy exporting English wool through Calais. He was a founding member of the Russia Company, promoted trade to Guinea and West Africa, and dealt in lead, alum and bullion. Judd was also a money-lender, arranged loans for the crown, and speculated in sales of former monastic lands.

Thomas and Alice Smythe had seven sons and six daughters. One daughter, Katherine, married Sir Roland Hayward (TP M#117917), Lord Mayor of London. Another, Joan (Johanna) married Sir Thomas Fanshaw (d.1601) of Ware Park.

Sir John Smythe (1557-1608), the son of Thomas, married three times: firstly to Judith Culverwell, later to Joan Hobbs, and thirdly to Sarah Blount, daughter of William Blount. Sarah may thus have become the sister-in-law of Thomas Chaloner the younger (d. 1615). After John's death, Sarah remarried to Robert Sidney, first Earl of Leicester.

Sir Thomas Smythe junior (c.1558-1625), Thomas's second surviving son, followed a very successful commercial career in the footsteps of his father (DNB 2004, 51, 469). He inherited immense wealth. He was first governor of the East India Company (1600) and Sheriff of London (1601), but tainted by the abortive coup of the Earl of Essex (1601). After a brief period in prison, and heavy fine, he was governor of the East India Company 1603-5 and 1607-21, obtained a new charter for the Virginia Company (1609), and became governor of the Somers Islands Company (1615-21) colonizing Bermuda.

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(15) Sir Thomas Chaloner the younger - Yorkshire Alum

Alum production in Yorkshire was a new industry at the start of a new century. Many published accounts credit its origins entirely to the Chaloner family. However, Turton concluded from meticulous archival research in the 1930s that the history of the industry had been "distorted and misrepresented" (Turton, 1938, 1). Several skilled workmen with experience of the industry in Dorset, but very limited capital, were prospecting in Yorkshire at the same time as the Chaloners. The Yorkshire alum industry became very extensive over the following three centuries, and extant buildings have been the subject of much modern interest (NAMHO Bib. 2015)

Catherine Blount's mother Joan died in 1557, and **Sir Thomas Chaloner senior** (1521-1565) (TP, M# 468139) remarried in September 1565 to **Etheldreda Frodsham** (1529-1605) (TP, F#468179).

Her child Thomas, 'son of Audrey' was illegitimate. He was probably fathered by (and certainly the heir of) Sir Thomas senior (DNB 2004, 10, 896; HPM, Chaloner yn., 2015). He too was known as **Sir Thomas Chaloner (c.1563-1615)** (DNB, 2004, 10, 895-6; TP, M#217688), or Sir Thomas the younger (Young, 1812, 2, 826). He was stepbrother to Catherine Blount (nee Leigh).

Sir Thomas senior changed his will in October 1565, disinheriting both of his brothers, John and Francis (DNB, 2004, 10, 895). To prevent any litigation by his younger brother John against his heir, Sir Thomas assigned most of his lands to trustees. These were led by Robert Cecil, who became guardian to his son (HPM Chaloner yr. 2015). The feudal custom of taking wardship of young orphaned heirs was very profitable (Hill, 1969, 102). Robert Cecil himself acted as ward for many orphans.

Neverrtheless there was still a dispute between the Chaloner brothers, mediated by William Gerard (HPM Gerard II 2015). After Thomas senior died in 1565, Etheldreda took Edward Brockett as her third husband.

Cecil took a personal interest in the upbringing of Sir Thomas the younger (yr), and in his education at St Paul's School and Magdalen College, Oxford. Taking an early interest in chemistry and medicine, he acquired a large collection of manuscripts (Allen, 2004, 30). These may have included his father's written material on Blount's alchemical work. Later, his financial investments included venture capital in the North West Passage company (1612) and Guiana trade (1613).

He was an acquaintance of the mathematician John Dee (1527-1609), and a friend of the prolific Dutch inventor, instrument maker and mechanical engineer **Cornelis Drebbel** (1572-1633) from Alkmaar. Drebble was the first to use tin salts as mordants (Derry & Williams, 1970). Cochineal scarlet dye was first brought from Mexico to Europe in the sixteenth century by the Spanish. When treated with tartaric acid and Drebble's tin mordant, it produced a much more intense colour (Williams, 1972, 32). In 1643 Drebble opened a dyeworks at Bow, near London, to use cochineal scarlet for British army uniforms (DNB 2004, 16, 900; Brunello, 1973, 201).

Drebble is best known for demonstrating a submarine moving under the River Thames. Designed like an inverted boat it had an open base, similar to a diving bell, with air-pressure keeping water out. It was propelled using oars, with the rowers seated inside above the water-level, possibly for ten miles while submerged (Ricard, 2015, 161).

Drebble was also reputedly the first in England to make sulphuric acid by burning a mixture of sulphur and saltpetre and condensing the fumes in water (DNB, 2004, 16, 900). In the eighteenth century the same process was improved by Joshua Ward to supply apothecaries. It was later used on an industrial scale by John Roebuck, and superseded the use of copperas for making sulphuric acid.

Sir Thomas the younger went to Italy in 1596-7 and visited Florence, but according to Turton he did not see the Pope's alum works at Puteoli, as was later often claimed (Turton 1938, 1).

Sir Thomas the younger is widely but wrongly credited with publishing '*A Shorte Discourse on the most rare Vertue of Nitre, wherein is declared the sundry cures effected by the same'* (1584). This recounted the medical benefits of saltpetre on a variety of skin conditions. Normally saltpetre was used as an ingredient in gunpowder (DNB, 2004, 10, 896).

Some historians have also wrongly claimed he was an early bioprospector who used distinctive features of the flora to recognise alum 'ores' that were similar to those of Italy, at several locations on his Guisborough (Guisbrough) estate (Clow & Clow, 1952, 236; Enc.Brit., 1842, 2, 573). A similar myth was attached to the discovery of alum at Tolfa in Italy by John de Castro in about 1459. Castro, having "*visited the* [alum] *manufactories at Constantinople, discovered a matrix* [alum 'ore'] *at Tolfa, by means of the ilex aquifolium* [holly tree], *which he had also observed to grow in the adjacent mountains of Turkey; and his opinion was confirmed by the taste of the stones"* (Bergman, 1784, 1, 340)

The apparent myth that Thomas Chaloner the younger (d.1615) visited Puteoli in Italy may have been reinforced by John Graves comments about a letter from the topographer **Michael Drayton** (1563-1631). It was preserved in Robert Cotton's collection of manuscripts, and was published in 1808 by John Graves who implied an incorrect date. He made it appear that Drayton had written to Sir Thomas senior (c.1521-c.1579), and had likened Guisborough to the Puteoli, which had an important alum works, long before the presence of alum ore was known in Yorkshire. It seemed that Drayton had known more than he was willing to reveal, possibly through the presence of **alum springs** near Guisborough.

Guisborough manor had been acquired by Sir Thomas senior (d.1579) in 1554. Graves claimed that Sir Thomas had quickly sought advice, apparently from Drayton, about the geography, social and commercial aspects of his new lands.The letter, recorded as being from Drayton, did refer to Chaloner's request "*to be informed of Rarertyes that lie in this Lordshippe of yours called Gysbrough in Cleveland".* The writer stated that *"the Seate of the place being a Jorney remote out of all common Highwayes, I can lyken yt to noe place more than Puzzuolo, antiently called Puteoli, unto which it yields neither in Pleasantness nor Rarities but in Ayre the same*" (Graves, 1808, 418).

The statement about rarities is piquant. If the letter had indeed been sent in the 1550s it could eventually have led Thomas Chaloner the younger to visit Puteoli out of curiosity. The author praised the salubrious atmosphere of Guisborough town, three miles from the coast, the availability of seafood there, and the good state of agriculture. On Graves chronology, this letter would have considerably predated Camden's book, '*Britannia*' (1607). Graves made a point of questioning why Camden, who was well aware of the alum congruence between Italy and Yorkshire by 1607 (but avoided referring to it directly), had also compared Guisborough to Puteoli. Graves drew attention to a later publication in whic*h "Mr. Pennant describes the town as pleasantly situated in a vale surrounded at some distance by hills … but cannot see the reason why Camden compares it to Puteoli*" (Graves, 1808, 418).

Guisborough alum, like nearby shales with ammonite fossils, was one of the natural curiosities celebrated in Michael Drayton's '*Catalogue of the Wonders of the North Riding'*, part of his poetry book '***Poly-Olbion*'** published in 1612 (Part 2, page 146), with a second volume in 1622 (Poly-Olbion, 2015). After describing the "*Rocks by Moultgrave… Out of their crannied Cleeves can give you perfect Jet"*, a black mineral used for ornaments, Drayton advised visitors to "*Marke Gisborough's gay Seite, where nature seems so nice…Her earth with Allome veines most richly intermin'd*" (Young, 1817, 2, 807). In George Young's history of Whitby, he used the reference to "*Cleeves*" to claim that "*the name of Cleveland is only Cliff-land softened*" (Young, 1817, 2, 807).

It seems likely that Thomas Chaloner the younger wrote to Drayton, a possible friend of Shakespeare, after reading the 1612 poem. Drayton was not born until 1563, in Warwickshire, and resided in London from 1590. It was not until about 1598 that he embarked upon an extensive project to celebrate the topographical and antiquarian features of Britain. Graves's implied claim, that he did not know Puteoli was once the site of an important Italian alum works, is disengenuous. His 'History of Cleveland' (1808) quoted without acknowledgement some of Torbern Bergman's 1784 account of alum technology, and Bergman made references to Puteoli alum works (Bergman, 1784, 1, 360 and 371). "*In Italy particularly, about Puteoli, Clays and marly Earths frequently are full of it* [alum]" (Hill, 1751, 108)

Claims that Sir Thomas Chaloner secretly brought some of the Pope's alum workmen to Yorkshire are implausible (Turton, 1938, 39). A further false elaboration insisted that in consequence he was solemnly cursed by the Pope (Graves, 1808, 428; Young, 1817, 2, 808). These myths were repeated in the 1808 'History of Cleveland' by John Graves, and the 1811 'History of Scarborough' by Hinderwell (Graves, 1808, 447-8; Moulton, 1837, 2, 447; Hinderwell, 1811, 285). Young, in his 1817 'History of Whitby', quoted from Aubrey's '*Lives of Eminent Men'* (volume 2, page 281) that Thomas Chaloner, while out hunting on horseback, "*tooke notice of the soyle and herbage, and tasted the water, and found it to be like that where he had seen the allum works in Germanie"* (Young, 1817, 2, 807). The Chaloner myth remains popular even today (Winn, 2010).

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(16) The Chaloners of Lambay – discovery of alum at Belmont Bank, Yorkshire

The actual author of 'Nitre' (1564) was Thomas the son of **John Chaloner** (pre.1526-c.1581*)*. John was the brother of Sir Thomas Chaloner senior (d.1579) (HPM. Chaloner yr. 2015; HPM. J.Chaloner II 2015). He had been educated at Lincoln's Inn (1541), served as M.P. for Calais (1555), and became an Irish Secretary of State under Elizabeth I (HPM. Chaloner yr. 2015). In 1556 John leased the Island of Lambay and its minerals, fifteen miles from Dublin in Ireland, from the Archbishop and Holy Trinity Church (Turton 1938, 10; HPM, 2015, J.Chaloner II). In return he had to build a fort, a harbour and a village for fishermen.

Nitre gave genuine medical benefits, and Thomas Chaloner's book is cited in a review of modern and historical medical uses of nitrite and nitrate (Butler and Feelish, 2015). The 'calcination' he recommended would have produced potassium nitrite, with an anti-bacterial effect. Nitrites accelerate would-healing. It may be significant that Cornelis Drebbel had used saltpetre heated in a retort to refresh the air in his submarine (DNB 2004, 16, 900). Since Sir Thomas the younger was friendly with Drebble, the interest taken in nitre by his namesake cousin Thomas may indicate that they corresponded and had a good relationship.

John opened mines on Lambay and started to make alum and copperas there about 1564. He copied techniques from the remarkable technical handbook ***De Re Metallica*** (1556) by **Georgius Agricola** (Georg Bauer 1494-1555), a Saxony doctor at the mining centre of Chemnitz (Turton, 1938, 12).

When a ten year alum monopoly on alum production in Ireland was given to James Blount, 6th Baron Mountjoy (q.v.), in 1569, John strongly objected. In 1579 he acquired the next ten year monopoly. He also seems to have been making saltpetre. His son and heir, **Thomas Chaloner (c.1548-1634)** reputedly travelled widely in Ireland prospecting for copper and alum ores (Turton, 1938, 130). After being dispossessed of Lambay, Thomas seems to have sought a home in Yorkshire with his cousin Sir Thomas the younger, and became the first to find alum 'ores' on his Guisborough estate (HPM. Chaloner yr. 2015; Turton, 1938, 64). The estate was near the later towns of Redcar and Skelton-in-Cleveland (Hadfield, 1970, 762; Danby, 2015).

The supposed role of Sir Thomas the younger (d.1615) in finding alum was first stated in a manuscript of uncertain provenance called '***Cott.M.S. Julius F. vi, 453***,' bound in a book in the library of his friend Sir Robert Cotton (1571-1631) (Turton, 1938, 59).

Robert Cotton (1570/1-1631), one time MP for Newport, Isle of Wight (1601), was a renowned collector of manuscripts (BL 2015) and an early member of the Society of Antiquaries (DNB, 13, 624). Turton considered the manuscript authors to have been Francis Tresham and Thomas Chaloner from Lambay, around 1604. **William Camden** (1551-1623) had seen this document before 1607.

The manuscript described an imaginary perambulation around the Guisborough area, during which the author visited a new alum and copperas works at **Slape Wath** ford. There he talked to Thomas from Lambay who stated that twelve years earlier Sir Thomas had discovered alum ores after noticing that the local oak trees had shallow roots, little sap, and leaves of an unusual green colour. Thomas from Lambay had then experimented with the ores, and recommended the setting up an alum works at **Belmont Bank**. Camden's published account in '*Britannia*' (1607) praised the role of Sir Thomas, and was copied by later authors (Aikin, 1801, 2, 573).

The literary device of an imaginary perambulation was very similar to that used by Agricola in his first book, '*Bermanus: A Treatise on Mineralogy'* (1530). Agricola described the characteristics of minerals using a conversation between two physicians and an experienced miner called Bermanus, during their exploration inside a mine in Saxony (Ricard, 2015, 69). This enabled him to compare and update the still popular Greek description of minerals given in *'De Materia Medica'* written by Pedanius Dioscorides (c.40 – 90 AD).

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(17) Richard Leycolt – discovery of alum at Slape Wath, Yorkshire

A rival account is given in the 1613 complaint made to Chancery by **Richard Leycolt**, once Mountjoy's tenant at Alum Chine works. He objected to Sir Thomas the younger obtaining a pension for the discovery of alum in Yorkshire. Leycolt claimed he had been the first to find alum in the county, by **tasting** for it (Turton, 1938, 66). Tasting spring waters was quite a reasonable method of prospecting. At Whitwell, near Chester le Street in County Durham, the early iron-bloomery centre had an "*alum well*" with water known for "*a strong aluminous smell and taste"* (Moule, 1837, 2, 312). Yorkshire mineral springs led in the 1670s to Scarborough becaming health resort, and in the 1710s similar springs were found below the cliffs between Whitby and Upgang, and at Larpool Wood (Young, 1817, 2, 783). A warm water spring smelling of hydrogen sulphide emerged at Kilton Mill. The area also had many chalybeate springs depositing iron oxides, and petrifying springs depositing calcium carbonate, including some springs in the so-called alum hills. The spa at Scarborough was said to have aluminous waters, but 'aluminous' seems to have meant a particular metallic taste, not the taste of alum itself (Croker, 1764,'alum').

The Yorkshire 'alum shales' contain very little natural 'native' alum, but plenty of the ingredients required to make it, aluminium (known as 'alumine' to Parkes in 1812) and pyrite (for sulphuric acid) (Parkes, 1812, 120). However, natural weathering processes have occassionally resulted in both alum and copperas (ferrous sulphate) being formed in a noticeable quantity on a local, small scale. Early mineral prospectors needed to find these.

In 1828 George Young recorded one of these rare sites below Whitestone Cliff, east of Cayton Mill, where the outcrop of one shale bed (not the commercial alum shale) had "*on its surface an efflorescence of sulphate of alumine, or native alum, as well as some sulphate of iron. These same phenomenon may be seen in a few other spots, particularely near the White Nab"* (Young, 1828, 91). Samuel Parkes in 1812 thought that "*the sulphate of alumine is abundant at Whitby*" (Parkes, 1812, 242).

Leycolt found his alum at **Slape Wath**, also called Spring Bank, on the **Skelton estate** of John Atherton, near Whitby (Danby, 2015, 15). In 1603 he began to build alum houses there before persuading Atherton, who was already deeply in debt, to finance them.

He listed all the equipment necessary, and undertook to produce 2.5 tons of alum a week. He was also required to provide production training to Henry Cowell of Hornby Castle, Rodger Tadcastle of nearby Mygrove (Margrove) Park, and a Lancashire alehouse keeper named Oliver Kearsley. Cowell and Tadcastle provided £140 towards the construction costs, but Leycolt was incompetent. He received £40 annually for three years without producing alum.

In June 1604 the site was visited by **Sir John Bourchier** (1567/8-1626) a Yorkshire sheep grazier and land speculator, who undertook many risky financial projects (HPM Bourchier 2015). He was accompanied by a skilful alum maker called **Mr. Layne**, probably Edward Lane with previous experience at Canford and Whitstable (Turton, 1938, 67). Bourchier was exactly the type of financier that an impoverished Yorkshire landowner like Atherton could have actively sought out to provide an illegal concealed loan. Details of he exceptionally complex legal problems surrounding the Skelton estate were later published (Graves, 1808, 42 and 353).

In October 1606 Bourchier leased the Slape Wath site from Atherton for 21 years. He undertook to enlarge the works, provide suitable equipment, and pay the operatives. These were Edward Startcliffe and John

Blanch (Turton, 1938, 68). In 1619 two Dorset men, Richard Southwold and Richard Atwater, were employed at Slape Wath (Turton, 1938, 113). Leycolt eventually died in a debtors goal in London in 1614 (Allen, 2004, 49).

Later, several members of the Lane family worked in the Yorkshire industry. Thomas Lane married Anne, sister of the Poole mayor (1589) Edward Man (c.1550-1622) (HPM, Man, 2015). Man's daughter Amy married the important alum 'farmer' and later leaseholder **William Turner** of Islington, who lived at Highway, Wiltshire near the residence of Anne, Lady Mountjoy (Turton, 1938 74). Turner helped his relative George Lane to find employment at Whitby port (Turton 1938, 157). By 1639, Richard Lane and William Toomes were acting as cashiers and accountants to the very wealthy alum 'farmer' Sir Paul Pindar (d.1650).

The **Mulgrave** alum works of Lord Mulgrave, **Edmund Sheffield** (1565-1646), may have commenced at a similar time to Slape Wath (Turton 1938, 162). **John Turner** stated in 1624/5 that he had begun work in the industry in 1606, but not where. He became a master workman in 1611, acted as a 'contractor', and claimed to be the first Englishman to have produced alum at a profit. He had originally worked in Waterford, Ireland, and may well have known John and Thomas Chaloner of Lambay (Turton, 1938, 74).

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(18) de Malynes, the 'Alum Company', and the Alum Monopoly Patentees 1605/6

In March 1605/6 a partnership of **Sir Thomas Chaloner** the younger (d.1615), **Edmund Sheffield** (d. 1646) and **Sir David Foulis** (d. 1642) obtained a 21 year patent or monopoly on English alum mining and production and established a very productive works at Belmont Bank (VCH 1923, 352, 365). Sheffield, Chaloner and Foulis are usually credited with initiating this enterprise. Instead, Turton has shown that they profited greatly by serving as powerful political allies for a venture already planned by merchants trading to Middleburg (Turton 1938, 70).

An important role was played by the Antwerp born **Gerard de Malynes** (c.1584-1641), a London merchant since 1585, who became a business consultant, author, economist, and mining promoter. His financial resources seem to have been slender, but he had influential contacts and a flair for business.

He stated in an undated letter of c. 1607/8 to the Lord Treasurer, Dorset, that two years earlier he had been consulted by an **'Alum Company'** over the possibility of obtaining an alum monopoly (DNB, 2004, 36, 380). That Company had many partners, led by **William Turner**, William Angell, William Hawses and John Archer. Exactly how the Alum Company already knew the alum potential of Yorkshire is an unanswered question. Malynes was aware of Atherton's alum works of 1604, and wrote about it in his '*Lex Mercatoria, or The Antient Law Merchant'* (1622) (Turton 1938, 64). He advised the Alum Company to obtain influential supporters, because alum was not a new invention, and there would be **opposition from Lord Eure and Lord Danvers** who had alum interests. Eure may have had an interest in the Shropshire **alum springs at Okengates** (4 miles east of Wellington), which **Dr. Edward Jordan** (b. 1569) recorded as being used by the dyers of Shrewsbury (Turton 1938, 71and 114). Jordon had studied in Padua (M.D. 1591), and was a fellow of the College of Physicians (1597) with a medical practice in London (Turton, 1938, 111). Eventually, Dr. Jordan leased Slape Wath alum works in 1614, and his eccentric changes to the methods used there quickly proved disastrous. The existance of alum at Oaken Gates is known only from his published account of '*Baths and Mineral Waters'*, and was not mentioned by later historians.

Joseph Plymley made no mention of alum springs in his 1803 account of Shropshire, although the staple trade of Shrewsbury was still fine flannels and 'Welsh webs' (Plymley, 1803, 338). At Kingley Wick, two miles west of Lilleshall-hill, near Wellington, he did record a brine spring producing 5000 gallons a day, apparently once used for salt, "the salt-pans and buildings still remaining" (Plymley, 1803, 72). There was also a medicinal salt spring at Admaston, nearby. A soda factory had recently been opened at Wormbridge, near Wellington.

Samuel Garbett, in his 1818 'History of Wern' was similarly unaware of any alum spring at Oaken Gates. By this time the location was industrial, with coal and iron mines at Oaken Gates and Ketley (Garbett, 1818, 874). "*Eastward of the Wrekin is found clay and shale containing coal. Next to this, from Newport to Coalbrookdale, between Wellington and Shiffnal, extends a vast body of ironstone and coal*" (Garbett, 1818, 408). Coal had long been supplied by road from Oaken Gates to Shrewsbury. In 1788 William Reynolds (b.

1735), son-in-law of Abraham Darby II of Coalbrookdale, built a canal with an inclined plane to link Oaken Gates with his iron works at Ketley (Smiles, 1863, 84).

Danvers held land in Cleveland. The Alum Company did duly acquire powerful supporters to counter any opposition from Lord Eure and Henry Danvers..

Witton Castle on the River Wear at Witton Le Wear, 12 miles south west of Durham, was the ancestral home of the Eure family (Moule, 1837, 2, 320). **Ralph Eure** (1558-1617) (TP, M#105351), born in Berwick castle, was the eldest son of William (2nd Lord Eure, Captain of Berwick castle), and Margaret nee Dymnocke (HPM Eure 2015). Educated at Cambridge, and in law at Gray's Inn (1575), Ralph travelled in France and Italy during 1582-3. In 1584 he became MP for Yorkshire, where he served as a J.P. and later Sheriff (1593-4). He was a member of the Council in the North (1594-1614) and Warden of the Middle March (1595-8). In 1595 that March was visited by the Council, which complained to Cecil that it was a place with no religion, no justice, no horses and no supplies.

A major problem was uncertainty over which laws applied in the Borders. To combat lawlessness Eure collected and codified the main penal laws, and provided a copy to Cecil for the Privy Council. He tried to enforce the laws but lacked sufficient resources. Other aristocrats in the Borders profited from the lawlessness and slandered Eure at the Court in London. Lord Scrope, warden of the western March, tried to turn Cecil against Eure. In May 1598, in London, Ralph and his brother William were attacked by a gang of the Widdrington family from the Borders, and William was severely injured. Eure was a loyal officer of the Crown, but little is known of his commercial ambitions. He may have had personal ambitions to produce alum by alchemy. Possibly as early as 1604, he had made detailed enquiries about the methods used by the Society of New Art (qv) on Anglesey. He even obtained a sample of the mineral water they had uses, for his experiments (Davies, 1813, 485). Eure served as president of the Council in the Marches of Wales (1607-1617), but again found that the gentry of the English border counties effectively blocked him from enforcing the laws.

Danby manor, about eight miles south east of Guisborough, had been owned by the Barons Latimer, but when **Sir John Latimer** (d. 1577) died with no male heirs, this portion of his lands passed to the youngest of his four daughters, Elizabeth (1545/50-1630) (Graves, 1808, 270; DNB, 2004, 40, 510). She was the wife of Sir John Danvers (1540-1594) of Dauntsey in Wiltshire. Their second son, **Henry Danvers** (1573-1594), as a teenager joined English forces fighting in the Low Countries (DNB, 2004, 15, 98). His older brother Charles (c. 1568-1601) graduated with Charles Blount (later 8th Lord Mountjoy) at Oxford University in 1589. In 1594, well before her remarriage to Sir Edmund Carey in 1598, Elizabeth transferred Danby manor to her eldest son, Charles, with remainder to his brother Henry and then to John (VCH Danby, 1923, 2, 332).

In 1594, during a dispute withh their Wiltshire neighbour, Henry Long, the Danvers brothers murdered him and fled to France. There they served with distinction in the army of Henry IV, and were eventually pardoned by Queen Elizabeth I in 1598.

Henry Danvers then joined the English army in Ireland, where he received patronage from Essex, Southampton, and later Charles Blount. He avoided implication in the conspiracy between his brother Charles and Essex, which ended in an abortive rebellion in London in 1601, followed by their execution. In 1602 Mountjoy sent Henry back to England, carrying his private letters. James I in 1603 made Henry into Baron Danvers of Dauntsey, and Parliament restored to him the ancestral privilages lost by the attainder of Charles. From 1621 he was Governor of Guernsey.

Under Charles I, Henry became Earl of Danby, in Yorkshire, in 1626. When his mother died in 1630 he received further estates. He became very wealthy, and founded the Oxford Botanic Garden.. His interests regarding the alum industry are unclear, but may have resulted from the location of the Latimer lands and his close association with Mountjoy. Danby had been a medieval iron-working centre. In 1613 repairs to the alum works required about twelve tons of bar iron, bought from Sir Francis Hildesley's Lealholm Forge at Danby (Turton, 1938, 101). Henry's younger brother, John Danvers (1584/5-1655), was an Oxford graduate, knighted by James I in 1609, a lawyer at Lincoln's Inn (1612), and at one time MP for Newport on the Isle of Wight (1624) (DNB, 2004, 15, 101). John had commercial interests, particularly in trade with North America, developed Italionate gardens at his Chelsea house, and may heve advised Henry on the alum business.

Lord Danvers did receive an annuity from the Yorkshire alum patentees, for unstated reasons. There is a faint possibility that, as a result of his friendship with Charles Blount (who had knowledge of the Dorset alum industry), Henry had been investigating the alum potential of his Yorkshire lands when the first alum works were opening in that county. If so, this could have involved cooperation with de Malynes and Robert Cecil. His associates were also interested in alum. In 1609/10 Danvers' friend, Henry Wriothesley, with William Turner obtained permission from Robert Cecil to make alum, but never pursued the project (Turton, 1938, 111). Wriothesley, Earl of Southampton, had provided refuge for the Danvers brothers at Tichfield in Hampshire during their flight abroad, and was also a close friend of Charles Blount. Southampton was also one of the influential supporters of Dr. Jordan (d.1569) in his unsuccessful 1613 bid to take control of all the Yorkshire alum works (Turton, 1938, 111).

Malynes himself seems to have been the leading promoter of an earlier partnership, involving Lord Eure and several prominent London merchants. They undertook to work silver in County Durham, and lead and alum in Yorkshire (Bense, 2013, 125). He is thought to have privately blamed a very senior politician for the failure of that project. Under their scheme, mining experts from Germany had been employed, but the project collapsed, apparently by 1606 (DNB 2004, 36, 381; Bense, 2013, 125). Details are lacking, but the very early date of that venture makes the possible involvement of German experts in Yorkshire intriguing (Malynes, 1622, 262). If they opened mines in Yorkshire, these may have been the mines referred to by alchemist William Smedley in the early 1570s when Society of New Art (qv) was considering relocating away from Canford in Dorset. In 1801 the Cleveland antiquary John Graves carefully surveyed the ruins of an alum works called Allum-Garth on Goadland-Beck near its confluence with the River Esk (Graves, 1808, 291). He claimed, on the basis of ancient trees among the ruins, and probably also the views of local residents, that it could have been Elizabethan and possibly the first alum works in Yorkshire. If so, it might have been part of Malynes' enterprise, but Graves also reported the presence of calcined alum, which suggests instead a later, seventeenth century date.

In the first edition of '*Lex Mercatoria,'* (1622), Malynes stated: *"…I call to memorie a conference, which in the yeare 1606 (being in Yorkshire about some Allome Mines, and certain lead mines in Richmondshire) passed betweene the Archbishop of Yorke Doctor Mathew, and my selfe, in presence of Ralph Lord Eure, with whom I went to Yorke to congratulate the said Archbishop newly come to See, which was concerning the Center of the earth, which he said was unknown*…" (Malynes, 1629, 184). The date is likely to be correct, since Tobias Matthew (1546-1628), a former Vice Chancellor of Oxford University, did become Archbishop of York in 1606. It is possible that Malynes had then visited Slap Wathe, and was himself the originator of the 'Alum Company' rather than simply its adviser. Some of its members may even have been connected with the earlier lead mining project.

Malynes (1622) asserted that *"…it is now about 14 years since* [1608] *I caused divers workmen to come out of* Saxony, Brunswicke*, and other places of* Germany*, at my great charges, to the number of seventeen persons, some for the Silver Mines in the Bishoprick of* Duresme *[*Durham], *others for the Lead Mines in* Richmond-shire *in the county of* York*, some for the Allom works there also and some for the making of Steel in* Wales*, wherein the noble Lord* Eure *deceased, and certain London Merchants had undertaken to proceed with me. The action being applauded by a great person then in authority, and now deceased, who promised all the favour that he could do; but he had some other privat designs herein, as he had also in the Silver Ore of* Scotland*…Insomuch that the actions of these two lords were like unto* Phaeton's *horses, for all was fed into a combustion, and the poor men* [apparently the German miners] *went begging homeward, to our exceeding great loss of the benefits in expectation".* The great person could well have been Robert Cecil (the son of William Cecil), who along with many wealthy and influential associates, held investments in the rival Company of Mines Royal in Cumberland.

In 1608 Malynes could have been seeking an opportunity for personal investment in a new alum site in Yorkshire. His financial affairs were complex and precarious, as were those of Sir John Bouchier, and he may have first become aware of Bouchier's interest in alum at Slape Wath, through mutual acquaintances in London.

The 'Alum Company' seems to have persuaded Sheffield, Chaloner (d.1615) and Foulis of the commercial advantages in forming a partnership to obtain an alum patent. All three had considerable influence at Court. The 1605/6 letters patent provided them with a monopoly over digging for alum and making alum, outside the area of the original De Vos patent held by Mountjoy's heirs. If the Yorkshire alum quality could be shown to match that of imported alum, and output matched the annual average of alum imports over the past seven years, then the Crown pledged to prohibit further alum imports.

It was a common practise for merchants to run successful companies while aristocrats worked the Court and received a rake-off (Hill, 1969, 75). Conversely, merchants were very wary of Court-sponsored enterprises unless they were in control. A royal official confided to the Duke of Buckingham in 1622 that “men of ability will not join in partnership with your lordships, for merchants are jealous to hazard their goods with their betters” (Hill, 1969, 75). However, Ramsey claims that English aristocrats were generally more willing than Tudor merchants to invest in the coal, iron, lead, alum and glass industries (Ramsey, 1972, 94)

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(19) Political Clout - the Yorkshire Alum Patentees 1606/7

The 1605/6 letters patent provided Sheffield, Chaloner and Foulis with a monopoly on digging for alum and making alum, outside the area of the original De Vos patent held by Mountjoy’s heirs. If the Yorkshire alum quality could be shown to match that of imported alum, and output matched the annual average of alum imports over the past seven years, then the Crown pledged to prohibit further alum imports.

Sir Thomas Chaloner the younger (d.1615), at Richmond Palace, was an adroit and experienced courtier, who already knew of the alum potential at Belmont Bank. He had travelled to Edinburgh in 1603 to accompany James I on his journey to London to succeed Elizabeth I. On 17th August 1603 Sir Thomas was appointed by king James to superintend the education of Prince Henry, and accompanied him to Oxford University in 1605 (Chalmers, 1813, 9, 73). Sir Thomas was also closely associated “*with queen Anne, and appears to have been employed by her in her private affaires*” (Chalmers, 1813, 9, 74).

Sir Thomas had married Elizabeth , nee Fleetwood (d.1603) (TP, F#217689). His youngest son, the Reverend Edward Chaloner (1591-1625) (TP, M#468138), principal of Alban Hall at Oxford University, was chaplain to James I and later to Charles I.

His son James (c.1602-c.1660) (TP, M#468189) and his daughter Frances (1612-1692) (TP, F#468197), from his second marriage, both married into the important Fairfax family in Yorkshire. Frances’s husband William Fairfax (b.1582) was a son of Frances nee Sheffield (1586-1645) (TP, F#479051) (DNB Fairfax P. 18, 943).

Sir Thomas’s eldest son became baronet William Chaloner of Gisborough in 1620.

Sir Thomas Chaloner yr. himself remarried, to the widow Judith Gregory, nee Blount (d.1615) (TP, F#468194). But there is no known family relationship between her father, William Blount (TP M#468195) of London, and the Mountjoy line.

It is possible that Sarah Blount, the third wife of Sir John Smythe (1557-1608), was the sister of Judith , since Sarah’s father was also an otherwise unknown William Blount John Smythe was the second son of wealthy ‘Customer’ Thomas Smythe (d.1591) who held the alum import monopoly from 1578 to 1581 (HPM, Smythe, 2015).

Sir Edmund Sheffield (1564-1646) (TP, M#29726), 1st Earl of Mulgrave and 3rd Baron Sheffield, was the Lord Lieutenant of Yorkshire (1603), and had previously invested in the Virginia Company and the New England Company (DNB 2004, 50, 162). He was related to Huntingdon (q.v.) because his widowed mother, Lady Douglas Sheffield nee Howard (c. 1537 or 1542/3 – 1608) (TP F#17050), had given birth to the illegitimate son of Robert Dudley (d. 1588), also called Robert Dudley (1574-1649). She had married three times: firstly in c.1562 to John Sheffield, then in 1573 to Robert Dudley, 1st Earl of Leicester, and finally in 1579 to Sir Edward Stafford.

Sheffield was not wealthy, and employed his own stewards instead of contractors to run his alum works (Turton 1938, 163). Over the years he sold and mortgaged parts of his future alum income to raise money. Sheffield maintained a more active interest in his alum mines than did his associates (Turton 1938, 115). The Earls of Mulgrave became progressively wealthy.

Sir Edmund the 1st Earl married twice, originally in about 1581 to Ursula Tyrwhitt (d.1618) (TP F#575481) They had six sons and five daughters (Stonehouse, 1839, 270). Three of the daughters were Lady Mary (d.1619), Elizabeth, and Frances Sheffield (d.1615). Sir Edmund (d. 1646) had six sons by Ursula, but all predeceased him. "*Sir John, Edmund, and Philip were drowned in their passage of the Whitgift ferry over the river Ouse, with all their attendants, in December, 1614. George broke his neck in a new riding house, said to have been made out of an old consecrated chapel. Edmund William was drowned in France, and Charles the only survivor died a bachelor"* (Stonehouse, 1839, 270).

Among those drowned was the eldest son, called Sir Edmund (d.1614)* (TP M#29726), who had been knighted in 1610. Another son, Sir John Sheffield (TP M#575482) and his wife Grizel nee Anderson also both drowned on the Ouse Ferry, but they already had a son **Edmund (1611-1658**) who survived. It was this grandson of Sir Edmund (d.1646) who eventually became the **2nd Earl Mulgrave**. Sir Edmund (d.1646), 1st Earl Musgrave, married a second time to Mariana Erwin (Irwin, Irwyn). They had two daughters and three sons, James, Thomas and Robert (Stonehouse, 1838, 270) and moved residence from West Butterwick to Normanby (Stonehouse, 1838, 270).

Meanwhile, Sir Edmund (d1658), the grandson, grew up as the ward of Arthur Ingram. He married Elizabeth (1607/8-1672) nee Cranfield, a daughter of Lionel Cranfield (d.1645), Earl of Middlesex. After receiving the earldom he became Vice Admiral of Yorkshire (1646) and a member of the Council of State during the Commonwealth. He helped to get the state monopoly on alum removed in 1648 (HPM E. Sheffield 2015). He declined to serve in Cromwell's Upper House of Parliament in 1658. One of his two sons, John Sheffield (1647-1721), became wealthy as the first Duke of Buckingham and built Buckingham House, the later Palace.

David Foulis came from a Scottish family with experience of royal finances and mineral mining. The Foulis family came from Colinton near Edinburgh, an estate purchased by the lawyer James Foulis (d.1549) (TP M#310821), who was Lord Clerk Register in Scotland, a judge (1526) and Lord of Session (1532). James had two grandsons, **Thomas Foulis** (c.1560-1628) and James Foulis. Thomas became an Edinburgh goldsmith, in 1581, after an apprenticeship there and experience of the trade in France (1578-9) (DNB, 20, 549). Thomas began designing sinking-irons for the Scottish Royal Mint (1584-1614), as well as coins and seals. He became the royal financier to James VI of Scotland (Clow & Clow, 1952, 24). He opened an agency in London. From 1591 he handled the subsidies being paid by Elizabeth I of England to King James, and employed as his courier David Foulis (d.1642) (4c). This laid the foundation for David's later career as a courtier. In 1593 when James VI already owed him £14,594, Thomas was granted a lease of 21 years on the gold, silver and lead mines of Crawford Moor and Glengonner in south Lanarkshire (Canmore 2015).

Thomas's brother James (TP, M#25789) married Agnes (d. 1593) (TP F#414600) nee Heriot. They had at least two daughters and four sons. One of the sons was **David Foulis** (d.1642) (TP M#414641), who eventually became Sir David, the first baronet of Ingleby in Yorkshire (Young, 1817, 2, 827). Another son, variously called John (a mine supervisor at Leadhills) (TP, M#414642) or Robert (a lawyer) (MacGregor 2015) had a descendant (grand-daughter or daughter respectively) named Anna (TP, F#426467) whose dowry comprised lands with immensely valuable lead mineral rights. Anna married Sir James Hope (1614-1661) (TP M#346446), who later called himself 'Sir James Hope of Hopetoun', and became very wealthy through lead mining.

From 1591 goldsmith Thomas (d. 1628) handled the subsidies being paid by Elizabeth I of England to King James in Scotland, and employed as his London courier his nephew David Foulis (d.1642) This laid the foundation for David's later career as a courtier. David married Cordelia nee Fleetwood (d.1631) (TP F#658661).

In 1593, when James VI already owed him £14,594, Thomas was granted a lease of 21 years on the gold, silver and lead mines of Crawford Moor and Glengonner in south Lanarkshire (Canmore 2015). He soon opened lead mines called ‘Friar Muir of Glengonnar’, and employed foreign mining technicians. In 1597 he worked the gold mines, but was harassed by the lawless Border Reivers (Meason, 1827, 42). The mining engineer Gavin Smith, in a letter of 1598 to Robert Cecil, stated that Thomas Foulis had visited the north of England to gain advice about mining techniques (Carlton, 1840, 4, 99). He consulted Smith, and later hired Bevis Bulmer, before forming a partnership with the Englishman George Bowes (Lindsay, 1877, 4, 259). Bulmer and Bowes were members of the Company of Mines Royal (1568-1603) (Skepton, 2002, 99).

The banking business of Thomas Foulis (d.1628) gradually became over extended. King James began to keep his English subsidy from Elizabeth I in Foulis’s account, but was heavily overdrawn. Political intrigues delayed his repayments. At some stage, Thomas seems to have transferred ownership of his mineral lands near Leadhills to either his nephew John, or to John’s heir Robert (TP, M#426468), from whom it passed to Robert’s daughter Anna (TP, F#426467). Thomas had a nervous breakdown in 1598 when he became bankrupt. Not until 1606 did Parliament raise a tax to repay most of the royal debts. In 1613 the Scottish Crown awarded the right to operate Hilderstron silver mine, near Linlithgow, to a partnership of Sir William Alexander, Thomas Foulis, and the Portuguese investor Paulo Pinto. The seam was soon exhausted and did not restore Thomas’s fortunes.

David Foulis became the keeper of King James’s secret papers (1598). He brought to the Yorkshire alum enterprise both his influence at Court and his broad background knowledge of mining technology through the experiences of his uncle Thomas. He later invested also in the manufacture of alum in Scotland, in 1609 (DNB 2004, 20, 542). Foulis and Sir Thomas Chaloner were brothers-in-law, because they both married daughters of the eminent lawyer William Fleetwood (c. 1525-1594) (DNB 2004, 20, 29). Chaloner may have recruited David Foulis to the Yorkshire alum project while both were members of Prince Henry’s household, where Thomas acted as tutor to the Prince and Foulis was the cofferer, the next highest post to comptroller of the household (Graves, 1808, 249).

(**20) Sir John Bourchier and the Alum Patent of 1606/7**

To accommodate **Sir John Bourchier (1567/8-1626**), with his Slape Wath works, a new monopoly was obtained with him as one of the patentees on 3rd January 1606/7. Patent Pat.4 Jac.I pt.20 was for 31 years, and did not permit an alum import ban unless the patentees met their target output within the following two years. They had to pay compensation of £700 per year to the ‘Farmers of Customs’, equivalent to imports of 4,200 tons paying a duty of 3s 4d per ton (Turton 1938, 73). The late inclusion of Bourchier, apparently a member of the ‘Alum Company’, suggests that Slape Wath had an authentic claim to be first alum works (Turton, 1938, 91).

Sir John Bourchier (d.1626), of Hanging Grimston, is the most enigmatic of the alum patentees. An energetic economic speculator, Bourchier was also the most financially insecure patentee. He has often been confused with Oliver Cromwell’s regicide nephew, the Puritan Sir John Bouchier (c.1595-1660).

John (d.1626) was the second son of Elizabeth and Sir Ralph Bourchier (d. 1598) of Beningborough, Yorkshire. John’s older brother inherited the family wealth and married the sister of Sir Francis Barrington, but was declared a lunatic and his property was administered by the Barringtons.

John studied law in London at Grey’s Inn. By 1588 he had married Elizabeth Verney (c.1566-1612), daughter of George Verney (d.1594) of Compton Verney in Warwickshire who could not afford a dowry. John’s father had no capital to give to him, and instead provided the manor of Hanging Grimston. This had been converted into very profitable sheep pastures in the 1580s. John raised £9,500 capital for other ventures by selling half of the manor in 1623. At 15 years’ purchase price, that half must have given a revenue of £600 per year. John used the capital to rent estates to keep more sheep, and began speculating in property deals with landowners who were already deeply in debt. Complex legal arrangements were made.

In 1598 he made a large but dubious land purchase of Newton-Upon-Ouse Manor (HPM, Bourchier, 2015). Bourchier rented out this manor, and other lands he acquired, at very high rates. In 1602 he leased of Seamer Manor near Scarborough, from John Thornborough. This concealed a loan on which Bourchier received interest in the form of a very low rent (HPM, Bourchier, 2015).

Bouchier probably became aware of the alum processing project at Slape Wathe through his extensive network of financial contacts. He took decisive steps to intervene with hired technical expertise at the critical early phase of development. Through his land dealings he contacts with London financiers, who may have helped him to press his claim to become an alum patentee in 1606/7 (HPM, Bourchier, 2015).

His retained a long term interest in the Yorkshire alum industry, despite the failure of several of his later commercial enterprises. In 1610, with William Turner, he leased the brassworks of the Mineral and Battery Company at Maidstone and Lambeth, but these closed in 1621. Also in 1610 he was arrested as a result of underwriting a bond to help his once wealthy cousin Arthur Hall mortgage his Lincolnshire estates in 1602 (Pele, 1905, 267). In 1614 he became MP for Hull, a seat which was in the gift of the 1st Earl of Mulgrave., despite being ineligible as an outlaw. The same year, with Mulgrave, he took a patent for making copper by dissolving the ore in water. Their experiments failed.

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(21) The 'Farmers' - Financial Organization of Alum Production

In February 1606/7 the patentees leased their rights for three years to five **'farmers of customs'**, also called 'undertakers'. These were **William Turner**, the brothers **Nicholas and Ellis** (d.1562**) Crispe**, William Hinde and Abraham Chamberlain. All were probably members of the 'Alum Company' (Turton 1938, 94). The lease specified how net profits would be distributed, after deducting the expenditure made by the 'farmers' and ten percent interest rate on their working capital. One twentieth of profits went to those patentees who had built alum works, in proportion to their output of alum. Of the remainder, half went to the patentees to be shared out, and half went to the 'farmers'.

Similar '**farming out'** was already used by the Crown**.** Traditionally Customs duties levied by the Crown were justified as a means of financing the royal navy in order to protect merchant shipping (Hill, 1969, 105). But they soon became essential to royal revenues for general expenditure. (Hill, 1969, 105) By **'**farming out' the collection of customs duties, the Crown received a fixed revenue known in advance, without paying wages regularly to customs officers and policing them to prevent embezzlement. The disadvantage of 'farming out' was the high profit margin demanded by the 'farmers'. However, wealthy 'farmers' were expected to provide loans to the Crown. Such loans became vital to Charles I until the Long Parliament suspended the leasing of royal Customs in 1641.

Contractors were employed by the 'farmers' to actually make the alum. These contractors bargained with them to supply alum at a set price, usually under £10 per ton (Turton 1938, 86). Thomas Chaloner of Lambay, Richard Leycolt and John Turner were all contractors.

The 'farmers' were London merchants trading to **Middleburg** in Holland, which was the 'Staple' town for cloth designated by the Merchant Adventurers (Price, 1906, 106; Carus-Wilson, 1967, 150). Turner and the Crispes had been founding members of the East India Company (Turton, 1938, 74). The **Crispes** from Whitstaple in Kent were wealthy merchants in the Guinea trade and London Merchant Adventurers (Allen 2004, 37). They later invested in the Deptford copperas works near London.

William Turner, the grocer and haberdasher of Islington who married the daughter of a Poole mayor, was probably familiar with Canford alum works (Turton, 1938, 74). Turner had been in partnership with two members of the Salter family and William Robson, in a London glassworks using Jerome Bowers' patent method to make Venetian-style drinking glasses. **Edward Salter (1562-1647**), a barrister, was married to the daughter of Edward Brockett (q.v), half-sister of Sir Thomas Chaloner (d. 1615).

Sir Thomas Chaloner yr. (d.1615), living at Richmond Palace, was superintending the education of King James's son **Prince Henry** (d.1612) (HPM, 2015, Salter; Chalmers, 1813, 9, 74; Nichols, 1828, 3, 204). He arranged for Edward Salter to join the Prince's household. After Turner left London to join the Yorkshire alum works in 1606, Chaloner showed Edward a legal loophole to evade Bowers' patent and hire Venetian labourers (Price, 1906, 70 & 215). He then helped Salter to establish a glasswork in Southwark in 1608.

London merchants supplied much of the capital and marketing expertise for the new Yorkshire industry. But within a year £20,000 had been spent and little alum produced.

(22) German alum workers in Yorkshire - 1607

On the advice of William Turner, between ten and sixteen experienced German alum workers from Liege and Cologne were employed for one year to teach the Yorkshire workforce (Turton, 1938, 76). After they had improved the quality, *Stow's Annals* (Howes, 1631, 895) claimed they were the first to calcine the shale, using layers of wood as fuel. **Calcining** was of fundamental importance to the success of the industry in Yorkshire. It was so fundamental that Turton in 1938 decided the Germans could not have been the first to calcine shale in Yorkshire (Turton, 1938, 76). They undoubtedly did improve the quality of the alum, mainly at the stage where the crystallized alum was purified. It therefore remains unclear who first calcined the shale to generate commercial quantities of aluminium sulphate, to be extracted in the liquor for making alum.

Coal rather than wood was suitable for heating the 'liquor' evaporation pans, so Bourchier leased **coal mines** at Harraton**,** County Durham. This fuel was then shipped down the Wear and along the coast to ports near the works.

After their contract expired, some of the Germans returned home but a few stayed. Lambert Russell assisted the Earl of Mulgrave's alum works at Sandsend. Another, Anthony Snyder, was employed by **Sir Richard Houghton** (1570-1630) in 1609 to establish an alum works at **Pleasington** near Houghton Towers in Lancashire, four miles west of Blackburn (HPM, 2015, Houghton; HEP, 2015; Turton, 1938, 80).

At the Yorkshire alum works the debts continued to rise, to £30,000. In 1608 the patentees appealed to Lord Salisbury, Robert Cecil (1563-1612) the new Lord Treasurer, for the imposition of a ban on cheap foreign imports of alum. He responded by appointing a commission of inquiry into the extent of the industry and the quality of alum. This was led by **Arthur Ingram**, former controller of customs at the Port of London, and **Sir Nicholas Salter,** cousin of Edward Salter (HPM Chaloner jn. 2015; Upton, 1961). Nicholas was a prominent Levant merchant (Peck, 1990, 153).

The commissioners visited works and gathered evidence. Alum quality was now considered to be equivalent to that from the Pope's works in Italy. London dyers were satisfied with it, except for the "*greenness"*. Although Turton has interpreted this as a need to store the alum before use, it could imply the presence of green copperas as an impurity (Turton 1938, 83). In the commission report, Ingram favoured a Crown monopoly over the industry; Salter opposed it.

(23) Lancashire alum works at Pleasington - 1609

Houghton Towers ('Hoghton' Towers) is a large fortified manor house, completed in 1565, on a hiltop above the Darwen valley, between Preston and Blackburn (Radford, 2001). The nearby **Pleasington alum works** site was sometimes referred to as **Salmesbury**, after the adjoining township which extended along the Darwen valley to Arley Brook. Pleasington supplied alum to cloth dyers and leather workers (tawyers) in Bolton, Wigan and Coppull.

Thomas Houghton (TP, M#348415) was murdered in 1589, and his son **Richard Houghton** (1569-1630) (TP, M#204301) became the ward of Sir Gilbert Gerard, master of the rolls. Richard later married Gerard's daughter. He became a local JP (1593), sheriff of Lancashire (1598-9), was knighted in 1598 and purchased a baronetcy in 1611 (Baines, 1836, 1, 587). He entered Parliament in 1601, and later became a courtier to James I. He began selling some of his manors in 1605 to raise funds, and in 1608 obtained a licence to dig for lead, coal, copper and slate in Bowland Forest (HPM, 2015, R. Houghton).

To finance his **1609 alum venture**, he mortguaged Walton Manor on the River Darwen, one of his best assets. He was later sued by Robert Bannister for repayment of a mortgage of £7000 on that property.

Alum was produced successfully, with between 5 and 7 tons in the first year. It was sold to Bolton dyers at 28 s per hundredweight (cwt).

Richard was soon embroiled in disputes with the Yorkshire alum patentees. He replied that he was unaware of their patent, that alum was not by tradition a royal mineral, and it had been made experimentally by his predecessors nearby in 1584 (Turton, 1938, 81). He claimed that a miner from Richmond had sought alum on the estate forty nine years earlier. On 22nd June 1614 the Crown granted Houghton a license to make alum for 21 years, and to export up to 500 tons a year (Turton, 1938, 40).

Nevertheless, his financial problems increased, and large sums were borrowed which could not be repaid. During the overland progress of **James I** from Edinburgh to London in **1617**, the King received three days of extravagant **entertainment at Houghton Towers**.

Richard's eldest son and heir, Gilbert Houghton (1591-1647) (TP, M#348240), attended the royal Court from his youth, and as a courtier was an early favourite of Prince Charles (1600-1649). He was knighted in 1604, became MP for Clitheroe (1614) and served in the King's Household from 1616 to 1637 (MPM, 2015, G. Houghton). Gilbert joined the royal progress to Scotland in 1617, and was probably the main promoter of the King's visit to Houghton Towers, which he helped to organise.

Details of the visit are extant from the diary of Nicholas Assheton from Downham, Whalley, one of many local residents who attended by invitation from Sir Richard, all wearing Houghton livery. On 16th August 1617, after a morning spent hunting deer stags, followed by lunch, at "*about four o'clock the King went downe to the allome-mynes and was ther an hower, viewed them preciselie, and then went and shot at a stag, and missed*" (Nichols, 1828, 3, 399; Baines, 1836, 1, 619).

Richard hoped to sell the alum works to the King, but Sir Francis Bacon intervened, demanding a commission of enquiry to first determine their value. The Crown later offered to pay £4,000, which Houghton declined (HPM, 2015, R.Houghton).

In about 1619 the complaints of his creditors resulted in Sir Richard being committed to Fleet Prison for debt. He spent his final decade there, with brief periods out on bail.

Sir Gilbert Houghton avoided these financial problems through marriage to Margaret, the co-heiress of Sir Roger Aston, master of the king's wardrobe. In the Civil War (1642-6) Sir Gilbert and two of his sons, Roger and Gilbert, fought for the Royalist cause. He lost Houghton Tower in 1643. An accidental explosion there later destroyed part of the building and killed Parliamentary soldiers. Gilbert's eldest son and heir, another Richard Houghton, began to rebuild the family fortunes by his 1633 marriage to the daughter of Philip, Lord Chesterfield.

Foundations of the Pleasington alum works survive, in woodland south of Alum House Brook (also called Arley Brook) near its confluence with the River Darwen (HEP, 2015; VCH Pleasington). There are also the remains of an alum quarry on the north side of Alum Crag..

Some historians claim alum production at Pleasington continued as late as 1771 (HEP, 2015). But John Webster, in his 1671 'History of Metals', stated the works were already closed (Webster, 1671 124). Aikin recorded for Blackburn parish in 1795 that : "*In one of the hills there is a mine of alum stone, which Fuller says was worked in his time, but had long been neglected on account of the increasing expense of removing the super-incumbent strata. When Sir G. Colebrooke's project* [qv] *of monopolizing alum took place, he purchased and worked these mines; but since its failure* [1773] *they have again fallen into neglect*" (Aikin, 1795, 272).

In 1828 Nichols noted that "*the alum mines at the foot of the hill…are no longer worked, and are scarcely known to exist by many of the inhabitants*" (Nichols, 1828, 3, 459). As for Houghton Tower in 1830, "*the remains of this extensive pile are now inhabited by families of poor cottagers*" (Clarke, 1830, 67)

Webster claimed that 50 to 70 years earlier (between 1601 and 1621) "*Sir Gilbert Houghton, or his father*" had forced Sir Bevis Bulmer to abandon the profitable silver mine of Skelkorn Field, Brunghill Moor in Slaidburn parish, at Craven in the West Riding of Yorkshire, by disputing ownership of the land (Webster, 1671, 21 and 24). The silver seam was then concealed by Bulmer, and never refound. That time period coincides roughly with the supposed mineral explorations in north east England by a partnership including de Malynes and Lord Eure, as well as the claim that alum making had been tried near Pleasington at a very early date.

Webster continued: *“Sir Richard Houghton, had set up a very profitable Mine of Allom, near unto Houghton Tower in the Hundred of Blackburn, within these very few years, where great store of very good Allom was made and sold; but whether some persons that had Works of the same nature in other places, found that the store gotten there, would bring down the price of that commodity; as it had all about near unto those parts; or for what other cause I know not, a contention was raised against him about the same Mine, so that he was either compounded with, or otherwise forced to give it over; so that now it is quite left, to the loss of the Nation in general, and to the damage of many a poor man in particular, that got their living by working there*” (Webster, 1671, 24).

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(24) Crown Monopoly of Yorkshire Alum Production - 1609

In May 1609 King James bought out both the patentees and the merchants on generous terms (Turton 1938, 86). Through complex financial arrangements, the Crown took ownership of the alum works in the expectation of unrealistic profits. The purchase involved payment of an agreed sum to both the **original promoters** (Sheffield, Chaloner, Foulis and Bourchier) who owned a monopoly (letters patent) on alum production, and the **original ‘farmers’** (the **‘**Alum Company’ of ‘undertakers’) who had leased the right to make alum and had built the alum works.

The Crown appointed overseers, but relied on a new partnership of ‘farmers’ (mainly members of the same original ‘Alum Company’) to lease the Crown’s rights, meet all its obligations, build and maintain the alum works and promote output. Again, ‘operators’ (contractors) made bids to these ‘farmers’ for the franchise to operate each alum works for a fixed period of time and to supply alum to them at a fixed price.

Payments by the Crown would be made by instalments, financed out of the anticipated profits. In effect, the Crown was cozened into paying an almost guaranteed income to the original political promoters of the monopoly, and to the self-styled Alum Company they patronized, by the imposition of higher wholesale prices throughout England.

Combining the monopoly of production with an import ban provided the Crown, the patent holders, and the original ‘Alum Company’ ‘farmers’ with a profit margin, and with a level of financial security which these experienced financiers knew they could not otherwise achieve. Conversely, Simon Healey has suggested that after receiving favourable reports from Ingram and Salter, Salisbury bullied the alum farmers into surrendering their rights, and Bourchier’s knighthood a few weeks later was in partial compensation (HPM, Bouchier, 2015; Congleton et al., 2008, 256). Over time, James I regretted his involvement in the alum business, but never succeeded in escaping his commitment (Price, 1906, 93).

A much simplified version of events was published in 1951 and 1961 as a political morality tale: *“The* [alum] *work was so successful that King James I (1603 to 1625) became interested and decided that the Crown should share the profits. In 1609 Chaloner’s monopoly was transferred to the Crown and, to stifle competition and thus counter the adverse effects that might follow through any rise in price due to maladministration, the importation of alum from abroad was prohibited. The usual result of ‘nationalization’ accrued; for many years the industry was not a success; bu 1637 things had improved and the Yorkshire industry reached its zenith in the latter half of the eighteenth century”* (Friend, 1961, 162).

The original **patentees** were to receive nothing until 1616, then £3,000, and from 1617 £6,000 per year. The **original ‘farmers’ (**merchants**)** were to receive £6,044 each year up to 1637/8, representing about 20 percent on the £30,000 they had already spent.

They also got £1000 per year to cover the annuities or pensions previously arranged, including payments to a schoolmaster (Robert Wemyss) and two preachers (Mr. Leake at Hythe near Mulgrave, and Mr. Ward at Guisborough). Other annuities were £23 13s to Thomas Chaloner from Lambay, and £200 to Lord Danvers (Turton 1938, 129). Also covered were the payment of rents and a proportion of profits, as previously agreed, to the patentees for alum houses on their own properties. Through all later vicissitudes at the works, Thomas Chaloner of Lambay received his annuity of 40 marks regularly until 1618 (Turton 1938, 129).

In June 1609 the importation of foreign alum was prohibited. The Crown immediately appointed two former alum managers, probably William Turner and John Bourchier, as factors and agents (Turton 1938, 88).

They were instructed to provide buyers with a sufficient store of alum in the City of London and at all other appropriate ports. Kingston upon Hull imported about 128 cwt. of foreign alum in June 1609, but none thereafter.

The price of alum within England was raised from £20 to £25 per ton, but exports were sold at £15. Smuggling of both German and re-imported English alum occurred. In 1620 about one hundred offenders were being charged with importing 4000 tons of alum.

In April 1610 Salisbury leased out all the Crown alum works to a **'farmers'** partnership comprising **William Turner, John Bourchier, Richard Bowdler and Thomas Jones**. All were members of the 'Alum Company', as were William Easington, Robert Barlow and Francis Greenhouse (Turton 1938, 91; EEB 2014). Bourchier gave Turner a bond of £12,000 to cover any expenditure he made that could not be recovered out of future profits. Bourchier also bought a quarter of Turner's 'farm', and joined him in investing in the Mineral and Battery Company.

The 'farmers' partnership undertook to pay rent to the Crown, rising after three years to £11,000 per year. They would also cover all the cost of the Crown's annuities owed to the patentees and its annual reimbursements to the merchants up to 1637/8 (Turton 1938, 87)..

The State monopoly of both alum mining and manufacturing continued until 1648. Recurrent financial problems, when 'farmers' failed to meet their obligations, resulted in periodic royal commissions being appointed. These investigated the conduct of the 'farmers' and how well they managed the works. The political affiliations of commission members resulted in the Crown's choice of successive 'farmers' being based largely on their political power and family connections.

The commissions repeatedly produced over optimistic assessments of future profits, and the Crown then found it politically expedient to make substantial subsidies to the 'farmers' rather than allowing their bankruptcy. Attempts were sometimes made to coerce 'farmers' into raising net profits by inserting excessive production targets and financial penalties into their leases, without a realistic appraisal of the technological problems involved, or the political possibility of enforcing payment of fines.

The alum 'farmers' invested heavily in the Yorkshire works, reputedly £60,000 during 1609-12 , but the works were still only a modest success. In July 1612 a statement by Bourchier to the Treasury stated that the works could make 700 tons of alum a year, worth £16,100 at £23 per ton (Price, 1906, 87). A separate account by William Turner summarized the balance sheet since the Crown monopoly began in 1609. Total outgoings were £80,740, comprising £42,216 money sent to Guisborough for local expenditure, £2,039 to Sir William Clavell for his Kimmeridge operations in Dorset, £5,000 rent paid to the King, £15,010 to annuities stipulated by the contract, and £16,474 for materials and tools.

Total income was only £44,008. Guisborough had sent 1936 tons of alum to London, yielding £40,158 from the 1746 tons sold at £23 per ton, plus £2,850 from 190 tons exported at £15 per ton. Coal sales from the mines raised a further £1,000 (Price, 1906, 88). Turton reinterpreted the data to state that 1936 tons of alum was produced in all Yorkshire for a total expenditure of £58,700, or about £30 per ton (Turton, 1937, 94).

The Yorkshire alum industry gave employment to 400 men, and another 300 worked in the coal mining and shipping sectors (Turton 1938, 96). In reality many of **the ships** were Dutch or Flemish (Turton 1938, 102 & 108). They delivered coal from Sunderland to the alum works, carried almost the entire alum output to London, and returned with barrels of urine from London (Turton 1938, 116).

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(25) 'Alum Company' Bankruptcy Crisis - 1612

In March 1612 **Richard Bowdler** and Thomas Jones, a partner of Turner and Bouchier, petitioned Lord Salisbury, Robert Cecil, on behalf of the Alum Company for a temporary reduction in its obligations because there were arrears of £4000 owed to the Crown and needed new buildings (Price, 1906, 86). Salisbury declined to help.

Bowdler had previously worked as a merchant at **Middleburg** in Holland for many years. From October 1609 the Alum Company authorised his former apprentice, **George Morgan**, to borrow money there on its behalf through bills of exchange, which were promises to pay an agreed larger amount at a fixed future date. Middleburg was a progressive town, where Hans Lipperhey patented the first telescope in 1608 (Henbest, 2015). Merchants and artizans had migrated to Middleburg from Antwerp after Spanish forces seized that city in 1585.

On 20th May 1612, four days before the death of Robert Cecil, '**Bowdler and Company'** also known as the '**Alum Company'** became bankrupt with **debts of £22,600** owed at Middleburg and raised through Morgan. This included £3,460 owed to him personally and £14,900 to Peter Courteen (Turton 1938, 92).

The same month, the Crown gave the alum 'farmers' six months protection against lawsuits by their creditors, to allow time for a suitable rescue package (Turton, 1938, 94). Bourchier was able to retain the lease on his coal mine (HPM Bourchier 2015). Crown legal protection was renewed in November 1612 and August 1613 (Turton, 1938, 94). Nevertheless, Bourchier reputedly went into hiding, and only appeared in public "*armed with pistols and other extraordinary weapons so as few or none dared adventure to take him"* (HPM, Bouchier, 2015).

Richard Bowdler enjoyed the Crown protection, but George Morgan did not. Cross bills were launched in Chancery by Morgan and Bowdler in 1616-17, and presented in summary before Parliament in 1621. Pamphlets regarding the dispute continued to be published until 1624 (Kyle, 2012, 167).

Peter Courteen was probably the grandson of William Courteen **(**Courten or Courteene) (DNB 2004, 13, 670) a refugee Protestant tailor, who fled to London from Spanish persecution in Flanders (1568). He made 'French hoods', and later traded in silk and linen from Pudding Lane to markets in Middelburg, Amsterdam and Flushing. His son, **Sir William Courteen** (c.1568-1636) was born in London and moved to Haarlem as a factor for his father's business. He gained a dowry of £60,000 by marrying Margareta Cromlyn, the daughter of a Dutch merchant. Peter (d. 1624/5) was their son. Sir William built a large business empire of shipping and finance. In 1619 he was fined £20,000 by the Star Chamber for illegal exports of gold from England. Nevertheless he was knighted in 1622, as was Peter in 1624 (DNB 2004, 13, 692).

Peter withdrew from commerce at a young age, possibly as a result of the alum debt crisis, and died childless. William courteen went on to build over twenty ships, and employ over 4000 seamen. He traded to Guinea, Portugal and the West Indies. He remarried, to Hester Tryan, and their children included William, who became a merchant but became bankrupt through commercial errors, and Anne who married Essex Deveraux. In 1624 one of Sir William's fleet discovered an uninhabited island, soon named Barbados. With support from the Earl of Pembroke and royal approval, Sir William sent colonists there and appointed a governor. But James Hay, Earl of Carlisle, claimed ownership of the island under his 1627-8 Crown grant of Caribbean islands. In 1629 Hay seized Barbados by force and Courteen reputedly lost £44,000 over the venture. He had a large holding in the Dutch tobacco colony of Guiana. He purchased extensive estates in England, worth £6,500 a year in 1633. He became an important moneylender in London, providing £18,500 to James I in 1613-14, £13,500 to Charles I in 1625, and £4,500 to the King's favourite, Buckingham, in 1627. In 1635, with partners, he sent an expedition of six ships costing £120,000 to China and Japan. Paul Pindar provided £36,000 of the funding. It was a disaster, and Pindar died before they returned. Peter Courteen's losses in 1612 were not so exceptional in seventeenth century mercantile businesses

In Yorkshire from **April 1612 until August** the alum contractors and their employees were unpaid, but continued working until their stocks of coal and urine ran out (Turton, 1938, 95 & 99). In July a statement by Bourchier informed the Treasury that the works could make 700 tons of alum a year, worth £16,100 at £23 per ton (Price, 1906, 87).

A separate account by Turner summarized the **balance sheet** since the Crown monopoly began in 1609. Total outgoings were £80,740, comprising £42,216 money sent to Guisborough for local expenditure, £2,039 to Sir William Clavell's works, £5,000 rent paid to the King, £15,010 to annuities stipulated by the contract, and £16,474 for materials and tools. Total income was only £44,008. Guisborough had sent 1936 tons of alum to London, yielding £40,158 from the 1746 tons sold at £23 per ton, plus £2,850 from 190 tons exported at £15 per ton. Coal sales from the mines raised a further £1,000 (Price, 1906, 88).

In June, **William Turner** on behalf of the 'farmers' offered to continue managing the works at a reduced rent to the Crown of £1000 per year. Ingram recommended the Crown to accept despite opposition by Sir Walter Cope (c.1553-1614) (HPM Cope 2015). Therefore in **July 1612 a Crown commission** of four London merchants, led by **Robert Johnson** was sent to examine the works.

They found six alum buildings had been in use, all dating from before the Crown monopoly, although one had been enlarged. They estimated the annual average expenditure per year of each building as £2,193 17s. This included 1000 chaldrons of coal delivered to the works (£666 13s), 10 tons of urine delivered weekly at 12s per ton (£300), 60 workmen paid 8 pence per day (£600), 18 carts with their drivers employed six months at 10 pence per day (£100), specialist coopers, smiths and carpenters with their materials (£66 13s), the chief workman or overseer with his servant (£60), wood £75, lead £36, wrought iron £96, bricks £40, transport of 166 tons of alum from the works to the sea at 6s 6d per ton (£53 19s), and shipment of that alum to London at 12s per ton (£99 12s) (Price, 1906, 87). Johnston reported that the workmen and colliers had been unpaid for three to four months, and the furnaces were rapidly deteriorating (Price, 1906, 87). The commission still produced an optimistic report.

In August the Crown instructed the Company's London-based paymaster **Richard Willis** to return,. Workmen were destitute, but probably not paid until December 1612 (Turton, 1936, 101). New supplies had to be organized. In December 1612 Willis and Thomas Carpenter went to get the **Harraton coal mines** working again, and drained them with a horse-powered water pump (Turton, 1938, 108). The alum works required large quantities of new ironwork, including eleven tons of bar iron from Danby (Turton, 1938, 101).

Arthur Ingram became a commissioner and later claimed that, with Robert Johnson, he was employed by the Crown from the beginning of the crisis to oversee the resumption of work (Turton, 1938, 99). According to Turton, Ingram not involved until February 1612/13 (Turton, 1938, 109). The commissioners appointed Carpenter to be Paymaster, assisted by Willis. Ingram became Secretary to the Council in the North in March 1612/13, with his brother William as deputy (Turton, 1938, 98). He raised £2,300 through William to use as working capital for the alum plant renovations, and was later recompensed by the Treasury (Turton, 1938, 100).

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(26) Crown Rescue Package for Alum Manufacture - 1613

In September 1612 **Arthur Ingram,** Sir Walter Cope and Robert Johnson all supported a proposal for the Crown to take direct control of the alum works, with themselves directing the management for an interim period of four years.

The **Privy Council** arranged another rescue package, to compensate the original Patentees, the original Farmers (Merchants or undertakers of 1606), and now also the 'Farmers' who had operated the industry on behalf of the Crown since 1610. Annuities to the original Patentees would continue normally. A committee consisting of Ingram**,** Cope and Johnson negotiated with the Original 'Farmers' and the '**Farmers' of 1610** to reach an arrangement in principal to pay a total of £77,500.

Of this, £30,220 was to be paid to the original Merchants, allowing the Crown to purchase their guaranteed annuity of £6044. The 'Farmers' of 1610 had spent £44,000. They were to receive £30,000 plus £12,000 (representing ten percent interest on their expenditure over four years), and a further £5,280 for their freight costs and sundry expenses. (Turton, 1938, 96). All of the £77,500 was expected to be paid by the Crown within four years. In April 1613 the Crown persuaded the **Original 'Farmers' (**Turner, the Crispes and Chamberlain) to take only £3650 in cash, and the remainder in goods. By a separate agreement in May 1613, the Crown accepted the return of the 1611 lease from the 'farmers' of 1610 (partners Bourchier, Turner, Bowdler and Jones) without charging any penalties for non-fulfilment. The Crown also took over their lease of Harraton coal mines.

The Crown provided Ingram, Cope and Johnson with money to pay the arrears of wages, as well as repair and restock the works. Although Johnson and Ingram later claimed to have spent some of their own money, the Crown may have spent as much as £72,760 on the business at this time, including repayment of debts owed by the 1610 Farmers (Price, 1906, 90).

The Crown undertook to produce 1000 tons of alum a year for four years, to be shipped by the 1610 Farmers to London and sold there at £25 per ton wholesale (or £26 retail for quantities of 1 cwt.). These London sales were expected to raise £25,000 per year. From this the King would receive £3650. The 1610 Farmers would receive £2000 to pay for shipping, £10,000 to pay for manufacture, and £9350 towards repayment of their debts. Over four years that income would reduce their debts by £37,400. During the same four years the alum works would also supply a further 3500 tons, at £15 per ton, to go for export. On the exports the Crown was to receive £10 per ton, leaving £5 to the 1610 Farmers to repay their remaining debts.

With the 1610 Farmers left in charge of shipping and selling the alum, the Crown in 1613 had to 'farm out' the actual alum works to suitable operators capable of producing the output it required. Carpenter leased out various works to different operators.

In May 1613 the two alum houses at Belmont Bank and one at Newgate Bank went for three years to a new partnership of 'farmers' comprising **Maurice Long, John Crispe, John Turner, and George Powell** (Turton, 1938, 110). They undertook to produce 1500 tons a year, but only managed 766 tons. The Crown provided £2450 for renovation of the works. This included the purchase of 15 tons of bar iron from Danby and Kent, and 20 tons of cast iron from Kent. In March 1614 Carpenter made the mistake of leased out Slape Wath works to the eccentric **Dr. Edward Jordan** (d.1669, qv).

There were serious flooding problems at the Harraton coal mines during 1614 (Turton, 1938, 115).

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(27) Ingram, Lowe and Freeman – Alum Farmers in Yorkshire - 1614

In 1614 the new Lord Treasurer**,** A dmiral **Thomas Howard** (1561-1626) 1st **Earl of Suffolk**, was anxious to terminate the Crown's direct involvement in the alum works. He proposed a similar arrangement to that of the 1610 Farmers (Turton 1938, 118). Arthur Ingram agreed to this and persuaded two of his associates, already 'farming' the customs of Ireland, to join him (Peck, 1990, 156). They were George Lowe and Martin Freeman (HPM Lowe 2015). They would operate in both Yorkshire and Dorset, and received a lease of 21 years from April 1615 (Turton, 1938, 118). The Crown supplied £10,000 to repair existing works and build new ones.

Sir Arthur Ingram (c.1565/70-1642), a London tallow chandler, was becoming one the greatest landowners in Yorkshire (DNB, 2004, 29, 280; HPM, Ingram, 2015). **George Lowe (c.1569/71-1639)** was a Londoner and member of the Drapers Company, who ran a cloth export business in 1606. By 1616 his was one of three such enterprises that together exported over half of the dyed and dressed cloth leaving England. He moved to the Yorkshire alum works as resident manager while Ingram tried, unsuccessfully, to raise more capital in London for improvements.

The terms of the lease were onerous. Within three years the 'farmers' had to supply 1800 tons of alum annually at £10 per ton, under a penalty of £13 for every ton of shortfall. Output actually fell, to 575 tons in 1616-17, and on paper the partners made heavy losses. Slape Wath had been leased to a London physician, Dr Edward Jordan, who had eccentric ideas of using chalk instead of urine, and peat fuel instead of coal. He was financially ruined and the 'farmers' evicted him in 1615, in favour of John Turner (apparently unrelated to the contractor William Turner)

Howard was in debt to Ingram but was also susceptible to bribes (DNB Howard 2004, 28, 437). During 1616 his wife accepted £1900 from **William Turner** and in return Suffolk ordered the 1614 'Farmers' to pay Turner £30,000 of the arrears owed to the 1610 'Farmers' (the Alum Company) (Turton, 1938, 119). She then accepted £1,500 from **Sir Francis Hildesley**, and Howard appointed Hildesley, William Turner and John Reeve as both Crown overseers of the alum works and agents for the sale of alum. They received an annual salary of £766, and a bonus of £2 for every ton of alum sent to London. That bribery was later revealed, and the three men were obliged to resign in 1619 (Turton, 1938, 134). Howard was dismissed as Lord Treasurer and tried for bribery (Turton, 1938, 132; Peck, 1990, 181). He protested that the King had profited by £8,763 on 674 tons of alum produced in 1613-14, and £8,060 on about 576 tons in 1614-15.

This bribery of Howard angered the **heirs of Sir Thomas Chaloner** the younger. Like Turner, Chaloner was entitled to an annuity. After Thomas's death in 1615 his brother-in-law **Sir William Fleetwood**, acting on behalf of the children of his first marriage, was entitled to receive £500 in 1617 and then £1000 per year until 1636/7. In 1637 **James Chaloner**, one of the surviving children, claimed they were owed £3291 because only two payments had been made, the first £500 and then £750 in 1636-7 (Turton, 1938, 122).

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(28) Brooke, Russell and Lowe - The Shallow Pans Fiasco - 1616

In 1616 the Crown appointed a new commission to investigate the alum works. **Ingram** used his influence over Howard to get his 1615 lease revoked without the King's prior permission. That absolved the partners from paying fines already incurred by their poor performance. But Ingram was forced to accept another lease under the same conditions. Howard eventually faced trial over his actions, in 1619, when he was fined £30,000 and dismissed as Tresurer (Turton, 1937, 132).

The 1614 'Farmers' tried to reduce their ongoing losses by sub-leasing the alum works to another company. This was the partnership of **Sir John Brooke** (1575-1660), **Thomas Russell**, and the incautious **George Lowe** (Turton, 1938, 124), who agreed to supply alum at £9 per ton.

In 1615 Brooke, the younger son of Lord Cobham, had purchased half of Bourchier's patent on alum production (HPM, Brooke, 2015). Russell was Brook's agent, who planned to improve evaporation by using shallow pans, only six inches deep, and also to use kelp seaweed instead of urine for a different type of alum (Clow & Clow, 1977, 236).

During the previous year, 1615, Sir John Brooke and Christopher Brooke had helped Ingram to bribe his way into a position at the King's Court (HPM 2015 Ingram). He paid £2000, plus an annuity of £700, to the cofferer, head of the 'Board of Green Cloth', to take that post, but within four months was forced out by other members of the Board. Ingram may have persuaded Howard to illegally write off £13,000 of his own debts to the Crown in order to encourage Russell's alum scheme, which seemed to promise high profits (HPM Brooke 2015).

In practise, the heavy expense incurred in converting the old lead pans to shallow ones, and the experimental use of kelp, were costly mistakes. Russell was to melt down most of the old lead pans to make the new pans at all of the alum houses: Guisborough, Skelton, Mulgrave and Sandsend. When problems became obvious, Lowe restricted him to the Mulgrave and Sandsend works.

Eventually Russell proposed to melt down most of the lead pans to make ingots or '*sows*' for sale in France to raise cash. He was only prevented by the intervention of Sir William Chaloner acting through the Treasury.

By 1618 Brooke had sold his share of the alum patent back to Bourchier. Surprisingly, Brooke and Russell in 1626 tried another unsuccessful chemical venture in Yorkshire, to make saltpetre (HPM Brooke 2015).

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(29) Arthur Ingram – solitary alum 'farmer' 1618

Ingram had paid £8000 towards the shallow pans project, out of a Crown grant of £10,000. Lowe claimed to have spent £29,826 and claimed to be bankrupt.. He stopped paying the workmen's wages, and gave up both the sub-lease and the main lease in 1618 (Turton, 1938, 128). Martin Freeman had died (Turton, 1937, 131)

This left Ingram as sole leaseholder of all the alum works, and political support prevented him becoming bankrupt. He refurbished the alum works at a cost of £3,200. Ingram renewed his lease for nineteen years in 1617 and in 1619 he received £1000 from the King to cover part of the unpaid debts of the 1616 sub-lease holders (Turton, 1938, 131}. He took a final lease in 1621 for thirteen years. Output rose to 1800 tons in 1619-20, and totalled 4600 tons over the next four years (Turton, 1938, 133)

Ingram benefited considerably from his association with **Lionel Cranfield** (1575-1645) MP. Lionel was the son of Thomas Cranfield (d.1595), a London Mercer, and Marther nee Randall the daughter of another London Mercer. Educated at St. Paul's school, he became a merchant factor in Germany (1594-7), and member of the Temple (1618). He married twice, firstly in 1617 to Elizabeth, the daughter of his grandfather and employer Vincent Randall. Cranfield made his early fortune trading northern kersey woollens (DNB, 14, 1). He became a Mercer (1597), a member of the Virginia (1612) Company, and a Merchant Adventurer (1601). He was on the Council of Virginia in 1620-3. His brother-in-law helped him obtain profitable government posts in Somerset and Dorset.

Arthur Ingram and Cranfield speculated successfully in pepper imports and ordnance exports. Ingram introduced him to the profitable field of revenue farming, and to his own patrons, the Howard family (Earl of Sussex) (Peck, 1990, 153). Cranfield received his patronage from Northampton, and was friends with Edward Sackville, Earl of Dorset. Among many business ventures, Lionel acquired a small share in the 'Great Farm of Custom' covering multiple revenues (1604-11). In 1612 Cranfield advised Northampton, on a Treasury commission, how to increase government revenue from the 'Great Farm' through a new post of Surveyor General of Customs, and another for extra tax on aliens (immigrants). He was appointed to both positions.

Cranfield was knighted in 1613, later becoming **Baron Cranfield (1621),** and eventually first **Earl of Middlesex (1622)** (HPM Cranfield 2015). He tried to introduce business efficiency into government, and led an ostensible reform movement opposed to corruption in office. He became Lord Treasurer in 1621, but his harsh manner and opposition to war with Spain caused a rift with Buckingham. He was impeached in 1624 for corruption, lost his position and was fined £24,000. Cranfield's daughter Elizabeth married Edmund Sheffield (1611-1658), 2nd Earl Mulgrave, who had grown up as a ward of Arthur Ingram, and their son John Sheffield eventually became the Duke of Buckingham and Normandy.

Although Ingram restored production at the works, responsibility for shipping alum to London rested with Hildesley, Turner and Read who had bribed Howard for their contract. To control other aspects of marketing, Ingram formed a quite separate partnership with **Martin Freeman** (d.1617) and Sir Thomas Bludder during 1616/17 (Turton 1936, 13). Howard licensed them to take 800 tons of alum a year for seven years at a price of £24 per ton. Out of that, £10 went to the alum leaseholder (who was Ingram himself), £2 to cover shipping transport costs to London, and £12 was to be paid to the Crown. In London the alum had to be sold at £26 per ton. Although alum output remained well below the target, this sales arrangement benefited the Crown.

Sir Thomas Bludder (c.1597-1655) was the son of Thomas, a Lancashire merchant working in London and patronized by Charles Howard, Earl of Nottingham. Thomas became joint surveyor of marine victuals (1603-12), and invested in the Virginia Company as well as, reputedly, in alum works. Sir Thomas (d.1655) married Elizabeth Brett who was related to both Lionel Cranfield and the Marquess of Buckingham. He was a 'farmer' of sea-coal imports (1618-1655), and of tin in Devon and Cornwall (Devon, 1836, 66), a Barber Surgeon (1621) and a member of the Virginia company (1620) (HPM Bludder 2015). For a short time from 1627 he joined Buckingham in purchasing for re-sale any gunpowder made surplus to Crown requirements by monopoly holder John Evelyn.

The dismissal of Howard as Lord Treasurer, for bribery, invalidated the shipping contract of Hildesley and partners. In July 1619 a new partnership between **Ingram and George Lowe** was awarded the right to ship the alum from Yorkshire to London, in return for a fee of £200 (Turton, 1938, 134). They received £2 per ton, and faced a fine of £10 per ton for any alum lost at sea, stolen, or wasted on route.

In December 1619 the partners **Robert Johnson** and **William Essington** were licensed to ship and sell all alum produced in excess of the 800 tons handled by Ingram and Bludder (Turton, 1938, 135). They paid £10 per ton at the works, and the Crown paid £2 per ton for transport to London, where they could sell the alum unrestricted. They and their heirs continued the trade until 1627/8. Until 1623 they were allowed to export alum, and in 1620-21 818 tons went abroad.

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(30) Arthur Ingram Accused of Mismanagement – 1623-4

Sir John Bourchier and **Sir Paul Pindar (1565/6-1650**) tried unsuccessfully to acquire the lease of the alum works from Ingram for £35,000 in 1623. They then accused Ingram of embezzlement. Soon, Bourchier and Ingram were both placed under house arrest, possibly after an affray (Turton, 1938, 153). Ingram retained the alum 'farm' and control of the works until his patron Lionel Cranfield (d. 1645) was impeached in 1624.

At that time the Guisborough works were being run by contractor John Turner, and the Whitby works by William Tappsfield (a relative of Ingram) and Richard Haslam (d.1624), the steward to Lord Sheffield. The contractors employed 2000 men and held a lease for seven years at a rent of £2,700. They were required to make 1800 tons a year, but only produced 1300 tons (Turton 1938, 156; cf. Price, 1907, 95)

During 1624 the Yorkshire workmen were paid irregularly, sometimes at intervals of eight or nine months (Turton, 1938, 144). They sometimes received corn (wheat) and meat instead of cash, and the cost of this was later deducted from their wages at inflated prices. (Turton, 1938, 135). Some carters received sacks of grain instead of cash, and it was wrongly valued at prices much higher than at local markets (Turton, 1938, 145).

Bourchier's criticism of Pindar's conduct led Sir Thomas Coventry, the Attorney General, to record at the Exchequer in 1623 those fines which Ingram should have paid for under-production of alum, the irregular way in which Howard had allowed him to relinquish his unfulfilled contract without paying penalties in 1615, and the alleged poor quality of alum sent for export (Turton, 1938, 139).

Several royal commissions were appointed to look into Ingram's arrangements. Four commissioners investigated the alum operations in London. They included Ingram's friend **Sir John Gibson** (1576-1639), who had accompanied him in 1616 to Spa in Germany for a health cure (HPM. Gibson 2015; Turton, 1938, 124). Commissions were also sent to Rouen, Middleburg and Amsterdam but were denied commercial information. A separate commission in Yorkshire examined the state of the works, their output, and the quality of alum.

Ingram had permitted a **decline in alum quality**. The original German advisers stipulated that five or six inches of dross alum at the base of the 'roaching' casks (which were used for crystallizing the alum) had to be recycled and not sold. Ingram was accused of selling this dross as good alum (Turton, 1938, 141).

Lambert Russell, one of the original Germans who still remained at the works, testified that the alum crystals were not washed as well as before, leaving some nitre and copperas in the product. Nearly two centuries later, Russell featured in the Chaloner alum myth as one of the supposed Papal alum workers smuggled out of Italy by Sir Thomas, who "*conveyed them on board a vessel by concealing them in large casks*" in 1595 (Young, 1817, 2, 806).

In spring 1622/3 fourteen tons of foul alum was returned from Amsterdam to London, and had to be refined there on the Strand to give under eleven tons of good alum. However, on behalf of Ingram many witnesses claimed that alum became contaminated mainly during shipment. It was carried in open wagons over muddy roads to the ports. Some was carried in re-used coal sacks, and alum was also trampled underfoot in the works and in the boats.

Abroad, English alum sold less well than the white alum from Liege (Luk). Some English alum was therefore deliberately coloured slightly **red with cochineal dye**, to resemble good Italian alum (Turton, 1938, 143). This dyeing was done at the Mulgrave works, and by John Crispe at the Cargo Fleet (Cawkers Nab) works.

After the death of James I in 1625, Ingram was out of favour at Court. With help from the Duke of Buckingham, he was able to relinquish his alum lease in return for a modest fine and received a discharge from debt for himself and George Lowe.

Sir John Bourchier tried and failed to get the vacant lease. In 1623, with help from Secretary Conway, he had unsuccessfully petitioned the Crown for a joint monopoly over alum and soap production, promising to offset any losses on alum with high profits from soap (Price, 1907, 93). After 1625 he lost the remainder of his fortune attempting to establish a soapworks using English potash, which met opposition from soap import merchants and London soapmakers who effectively blocked the project (HPM Bourchier 2015; Turton, 1938, 138).

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(31) Sir Paul Pindar and William Turner - Alum 'Farmers' 1625-37

The Yorkshire alum works were leased out by Charles I from 1625 to 1637/8 to Sir Paul Pindar and **William Turner** (DNB, 2004, 44, 357). The rent was £11,000 per year and more comprehensive regulations were imposed (Turton 1938, 155). They had to operate at least 70 (and up to 80) boiling pans, sufficient to make 1800 tons of alum per year. Workmen, carriers and creditors were to be paid promptly. The home market was to be neither surcharged nor glutted. Alum quality was to be improved. **Harraton mines** continued to supply coal to the works in the 1630s, but by then the alum 'farmers' no longer held the mine lease (Turton 1938,160).

Sir Paul Pindar (1565/6-1650) used his extensive business experience to develop a very successful enterprise. He was a merchant and diplomat (DNB, 2004, 44, 356). Born in Wellingborough, Northamptonshire, he became apprenticed to a London merchant trading to Italy. He was sent to Venice as a 'factor', but while there also acted both on commission and as a trader himself. By 1602 he was managing some of Robert Cecil's Italian investments. He gained a detailed knowledge of the Italian and Venetian banking systems, and proposed an English national bank to James I. It would be able to keep detailed accounts of *"the trewe estate of every particular man"*, to facilitate duties payable to the Crown, and deposits in the bank could be freely borrowed by the king.

In 1609 Pindar served as consul to the English merchants at Aleppo, and in 1611 as English ambassador to Constantinople, which had particular importance to the Levant Company. He was knighted in 1620, and returned to England in 1623. He then invested his wealth in 'custom farms', both great and petty customs. Often he bought out several existing partners to gain control of profitable 'farm' consortia..

William Turner built a new **alum works at Wapping** in London in 1626, where urine was boiled, alum made, and foul alum sludge carried away in lighters to be dumped in the Thames (Turton 1938, 156). London dyers favoured this works, but it was closed in 1627 after complaints about the stench and the death of fish in the river (Turton, 1938, 156). A proposed move to Newcastle-Upon-Tyne was not implemented (Price, 1907, 97).

War with France disrupted trade in 1627-8 (Davies, 1959, 63). Two ships carrying alum were captured. A coal ship was sunk, with the loss of the crew. One laden alum ship remained a long time in the harbour at Scarborough for fear of attack, and could not be insured. Production stopped at the Yorkshire works, and London manufacturers dyeing cloth and dressing leather complained about the lack of alum (Turton 1938, 157).

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(32) Arthur Ingram and John Gibson (for Thomas Wentworth) - Alum 'Farmers' - 1637

The political situation was changing. Ingram had a strong new patron, **Sir Thomas Wentworth** (1593-1641). Gibson and Ingram and John Gibson had jointly provided surety for Wentworth when he became Sheriff of Yorkshire in 1616 (HPM, Gibson, 2015). Wentworth was himself patronised by Lionel Cranfield. He became the first **Earl of Strafford,** Lord Lieutenant of Ireland, and in 1628 was appointed by Charles I as Lord President of the North. In June 1630 **Sir John Gibson** (acting on behalf of his political ally Wentworth) was granted the alum 'farm' (the patent lease) by Charles I. But the lease would only commence in January 1637/8 when the existing lease held by Turner and Pindar expired (Turton, 1938, 161).

Gibson's lease was to be for 31 years, at the higher annual rate of £12,500. He was acting in effect as Wentworth's business manager, but may have a small fraction of the profits (Turton, 1938, 161). The new 'farm' lease of 1637/8 gave a monopoly over alum mining and manufacture, but the leaseholders were expected to enter into negotiations with landowners for permission to operate on their land (Turton, 1938, 160).

Ingram joined with Gibson in the alum 'farm' and in 1629 had also acquired the 'farms' of Irish customs and Northern recusancy fines (paid by non-churchgoers) (HPM Wentworth 2015; DNB, 58, 142). Thomas Wentworth was authoritarian and made many enemies. He prosecuted the alum patentee Sir David Foulis in 1633 over a relatively trivial issue, had him gaoled in Fleet Prison, and received £3, 000 of the fines imposed.

The landowners with alum works at this time were Sir William Chaloner at Belman Bank and Newgate Bank; Sir William Pennyman (husband of the grand-daughter of John Atherton) at Slape Wath and Selby Hagg; and Lord Mulgrave at Sandsend and Asholme (Turton, 1938, 161). The farmers paid anually £1,640 to Mulgrave and £600 to Pennyman (Hinderwell, 1811, 285).

Sir William Pennyman (1607-1643) was the eldest son of William Pennyman (d.1628) of St. Albans, a Clerk in Chancery who bought one third of the manor of Marske in 1616 (DNB, 2004, 43, 602; Burke, 1838, 755). Sir William married Ann Atherton (c.1609-1644), grand-daughter of Katherine Conyers, and thereby gained the remainder of the manor (VCH Marske). He became wealthy from the alum mine, and built Marske Hall in 1625. He served on the Council of the North, became a baronet in 1628, and later High Sheriff of Yorkshire (1635-6) and Deputy Lieutenant. He fought for Charles I at the battles of Nottingham and Edgehill (1642). After Pennyman the manor passed to the Lowther family, and was then sold together with Redcar manor to Lord Dundas (Graves, 1808, 382)

In 1635 the financier **Philip Burlamachi** puchased 1960 tons of alum made by John Turner at Asholme and Sandsend works (Turton, 1938, 167). Burlamachie was closely connected with members of the 'Alum Company' like Sir William Courteen (qv) and Peter Vanlore (Judges, 1926; Ashton, 1957; Grell 1989, 150). He later claimed to have played a major active role in increasing total alum output and sales in Yorkshire during a four year period.

The **Burlamachi, Diodati and Calandrini families** had been part of the merchant oligarchy at Lucca in Italy, trading with Calvanistic commercial centres in France like Lyon (Pettegree, Duke & Lewis, 1996, 259). The three families were closely inter-married, and many became Protestants. Most fled from the Counter Reformation in Lucca during 1556-7, well before the St Bartholomew's day Massacres (1572). They resettled in Antwerp, Frankfurt, Nurenberg and Hamburg. Several lived in **Antwerp** from the late 1570s until the fall of the city in 1585. They included Fransesco Turrettini who later set up The Grand Boutique, the main banking and merchant organization in Geneva. His partner there was Gian Luigi (b.1585), who became closely involved in the financial and merchantile businesses set up in London and Amsterdam by his father, Giovani Calandrini. Giovani and his son-in-law Philip Burlamachi moved to London at the start of James I's reign. Gian was later ruined by the spectacular bankruptcy of Philip (Pettegree, Duke & Lewis, 1996, 261).

Philip Burlamachi (d.1644) was born in Sedan, France, and settled in London in 1605, becoming a denizen and then naturalized in 1614 (DNB, Burlamachi, 8, 865). He was a merchant, trading to Amsterdam in partnership with his wife's brother, Philip Calandrini. He loaned £6,000 to James I in 1613, and also stood security for loans taken out by the Crown. He helped to finance English expeditions abroad, to organise payments to English ambassadors abroad, and to pay subsidies to Charles I's foreign allies. Between 1624 and 1629 he loaned £127,000 to the Crown to finance military operations, as well as part of the £55,000 loaned in conjunction with Sir Ralph Freeman of the Russia Company in 1624. He became obliged to take out loans himself to cover his commitments, and these reached £14,763 by 1632. In **1633 he became bankrupt** when the Lord Treasurer, Richard Watson 1st Earl of Portland, failed to make repayments by the due dates. He was given royal protection from his own creditors, but the Crown did not complete repayments to him until 1637, without interest or repayment of miscellaneous expenses. He had made extra payments for the Crown at the verbal requests of Portland, with no written record, and eventually received only £49,752 for these, leaving £46,803 unpaid. He died in poverty (DNB, Burlamachi, 8, 865).

In **1636** a new **Crown commission** was sent to investigated the alum works and ensure that the leaseholders Turner and Pindar would not leave them badly maintained for start of the new lease by Ingram and Gibson (Turton, 1938, 167). Edward Eyscough (1589-c.1646), a lawyer from Lincoln's Inn (1609) who specialized in investigating fraud over customs duties, was appointed from 1635 to 1640 to investigate the alum trade (HMP Eyscough 2015). He had been a fees and debts commissioner since 1627, levying old debts due to the Crown. But like Ingram he was allied to Lionel Cranfield, after seeking patronage in 1621.

The commissioners found that from 1635 **William Turner** had achieved the stipulated output of 1800 tons, but about 1300 of this was from Asholme and Sandsend. The Guisborough works were deteriorating. Subsequently Turner made large financial loans to Charles I, and died in poverty (Turton, 1938, 168).

Gibson oversaw the alum business with competence, and dutifully continued to pay £10,860 to the Crown, and £1640 to the trustees of the Earl of Mulgrave, up until his death in 1641. Then, **Gibson's lease was transferred back to Paul Pindar** for an undisclosed fee (Price, 1907, 98;Turton, 1938, 171). Edmund, the 2nd Earl Mulgrave, invested over £3000 on equipment at the alum works over his lifetime (Turton, 1938, 178).

Besides loosing the alum 'farm' in 1637, Paul Pindar's relationship with the Crown had been further strained by political intrigues. In 1637 his ally, the Earl of Portland, was replaced as Lord Treasurer by Bishop William Juxon, who was patronized by **George Goring**, 1st Earl of Norwich (1585-1663), a courtier and diplomat. Juxon proposed that the 'farmers' of customs should join Goring and his associates, to loan money jointly to the King under their joint security rather than making loans as individuals. Pindar refused**.**

Goring persuaded Charles I to grant him the entire 'Great Farm of the Customs' for one year (DNB, 2004, 22, 998). Goring had support from the alum investor Sir Nicholas Crisp, Sir Job Harby and Sir John Nulls. Because of Goring's high handed approach, Charles I had to negotiate directly with Pindar to get the substantial loans he needed.

Pindar advanced £18,520 to the Naval Treasurer in 1637 to pay seamen's wages, £93,000 to the king in 1638-9, and £36,000 to Sir William Courteen's East India Expedition. By 1639 Pindar's estate was valued at £236,000 (Sheppard, 2000, 137). Goring quickly lost his Customs 'farms'. From December 1640, both the great and petty farms of customs were leased out to combinations of new and old syndicates of 'farmers' led by Pindar, with Goring excluded.

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(33) Political Turmoil, Civil War (1642-46), and Abolition of the Alum Monopoly (1648)

In October **1641** Charles I was obliged to call what became **the Long Parliament** to raise further finance. He instructed Wentworth to leave Yorkshire and attend the volatile situation in London. There, Wentworth persuaded him to hold a review of troops, during which the Charles was supposed to order the arrest of the leaders of Parliament on a charge of plotting treason with the Scots.

This scheme was abandoned, but details reached Parliament. The fearful Commons drew up an immediate **impeachment of Wentworth**, and took it to the Lords (Peck, 1990, 204). They acquiesced, after "all the personal and class insults which the House of Stuart had heaped on the nobility, and the ungracious manners of Laud and Strafford" according to Trevelyan (Trevelyan, 1965, 185). Wentworth was executed in 1641 on charges of high treason (HPM Wentworth 2015).

The alum 'farmer' Arthur Ingram (d. 1642) had earlier fallen out with Wentworth, and in 1640 obtained a seat in Parliament from his new patron, Henry Rich (1590-1649), 1st Earl of Holland (HPM 2014 Ingram). Rich was the husband of Penelope nee Deveraux (whose paramour was Charles Blount, later 7th Lord Mountjoy). In 1641 Rich married his son and heir to Ingram's daughter.

The Long Parliament in 1641 demanded that Pindar and other 'farmers' of customs should refund £150,000 for collecting customs duties which Parliament had not authorized.

The **heirs of Thomas Chaloner the younger** (d.1615) expressed their own grievances against the Crown. The death of King James's son Prince Henry in 1612 had left Thomas liable for the repayment of heavy debts he could not afford. His will assigned two thirds of his £1,500 annuity from the alum works to his two sons Thomas (1595-1661) (TP M#468185), MP for Richmond (1645-53), and James (1602-1660) (TP, M#468189), MP for Aldborough, Yorkshire (1648-1653), and Governor of the Isle of Man (1658-1660) (HPM Chaloner jn. 2015). In 1625 they petitioned the Crown for money they claimed was still owed to their father when he died in 1615 (DNB 2004, 10, 897). They also thought **Charles I had wrongly dispossessed them** of the mines, and in 1657 Thomas claimed the Crown owed him £6000. The brothers became two of the 135 commissioners in the court which tried Charles I.

Thomas Chaloner (d.1661) was a vociferous opponent of the king, and signed the King's death warrant. He became a key figure in the establishment of the Commonwealth (Aubrey, 1607, 202). After the Restoration of Charles II in 1660, he was excluded from the Act of Oblivion and fled to the Netherlands under the alias George Saunders.

None of the original Yorkshire alum patentees or their descendents fought for King Charles (Turton, 1937, 170).

The turbulent events of the **English Civil War of 1642-1646** did not entirely prevent alum production (Williams, 1980, 92). During the five years 1639 to 1646 Pindar could only make 5804 tons of alum instead of the 9000 tons stipulated, because of disruption caused by military activities in the area. No alum was made in 1644.

From 1645 to 1647 London had to import about 260 tons of foreign alum a year. Pindar sold 572 tons of Yorkshire alum in 1646, and 896 tons in 1647. One ship carrying 100 tons of kelp to the works was seized by a man-of-war of the Irish rebels (Turton 1938, 171). A Whitby ship carrying 82 tons of alum was seized by a man-of-war from Jersey.

In 1647 Edmund Sheffield, the 2nd Earl of Mulgrave, petitioned the Commons to have the alum monopoly lifted and his mines returned under his own control (Price, 1907, 99). The London Dyers also complained of deficiencies under the monopoly (JHC, 1648, 501).

In **1647/8** both **Houses of Parliament**, after much disagreement, decided to **cancel the alum Letters Patent** and thereby abolish the Crown monopoly leased to Gibson (for the period 1637/8 to 1668/9), and transferred at the end in 1641 to **Pindar** in Gibson's will (Turton 1938, 174). The Commons voted 55 to 44.

Edmund Sheffield (2nd Lord Mulgrave d.1658) regained full ownership of all the alum works and mines on his property. He immediately faced a legal dispute with Pindar over the buildings and equipment his family had financed. This was resolved amicably, with Pindar retaining control of the Mulrave works for the remaining duration of Gibson's lease, in return for an increase in the annual rent from £1,640 to £2,140.

Pindar still owned the 'farm' rights to control alum sales. He died in 1650, leaving the 'farm' to his executors Mathew Pindar and the wealthy Londoner **William Toomes** (Turton 1938, 174). Toomes moved to Yorkshire to manage the works, and in 1652 transferred management of the Mulgrave works to Thomas Shipton (steward to Lord Mulgrave) and Thomas Coventry. He continued to run the works at Guisborough and Skelton, including Slape Wath. A complex dispute arose in the Atherton family over ownership of Slape Wath, leading to Tooms taking his own life in 1655 (Turton 1938, 174).

Thomas Browne published a pamphlet **biography of Paul Pindar**, '**Vox Veritatis'** (1683), republished in April 1787 in '*The European Magazine and London Review'*. Pindar was educated for university, but instead at seventeen became apprenticed to an Italian merchant in London, John Parvish (Browne, 1683). The second half of his apprenticeship was spent in Venice. He remained in Italy for fifteen years, trading on his own account, and on commission. Returning to London, he traded for five years on the Exchange. In 1611 the Turkey Company persuaded James I to send him to Constantinople as ambassador, where he remained for nine years with a high reputation. In London in 1620, Sir William Cockayne and Sir Arthur Ingram persuaded him to become "*one of the Farmers of the Customs, and to advance monies for the supplies of the late King's occasions; and to furnish the crown with jewels, to his infinite loss and prejudice".* "*He lent several considerable sums of money, in gold, to the late King Charles, at Oxford, by Madam Jane Whorewood, in the years 1643 and 1644 for transportation of the Qeen and her children".*

"William Toomes and ***Richard Lane****, his cashiers and accomptants, cast up Sir Paul Pyndar's estate, in the year 1639, which consisted of ready money, alum, and good debts upon tallies and obligations from noblemen and others at court, and which amounted then to the sum of 215,600 l. sterling; a greater part thereof was employed in the maufacture of alum: for which alum Sir Paul Pyndar paid annually 12,000 l. sterling rent to the Crown; - a branch of the public revenue lately extinguished, under the notion of monopoly, and that staple commodity of the growth and manufacture of England exposed to undervalues for want of a due regulation of trade".* Pindar had to "*furnish the city of London and all parts of England with alum at twenty pounds a ton, and to transport the overplus, which he did in great quantities into Holland, France, Hamburg and other parts, to the advantage of the king and kingdom*". Pindar spent £10,000 on the porch of St Paul's Church in London, and in his will left £7,000 to London Hospitals. Browne claims that Pindar's executor, William Toomes, found his finances so complex, with so many loans impossible to call in because the debtors were insolvent, that he took his own life.

Alum producers faced increased domestic competition, lower prices, and renewed conflict abroad. The Navigation Act of 1651 was designed to encourage the expansion of the English navy, in order to displace the Dutch from the carrying trade across the Atlantic. War between England and Holland in 1652 was the first of numerous wars of economic nationalism (Hammond and Hammond, 1966, 39). In the absence of a Crown monopoly many speculators entered the industry, despite alum prices falling during the Commonwealth to £10 per ton (Turton, 1938, 179). In 1655, for example, **Zacharie Stewart** from Loftus-in-Cleveland persuaded three Salters and Dyers from London to invest in alum mines and works on his land, as well as a pier, but these were abandoned by 1664 (Turton, 1938, 180; Moule, 1837, 2, 448).

Alum works still needed to be close to the coast, to obtain cheap coal by sea for heating the evaporating pans. As late as 1800, John Tuke explained that coals "*are found in many parts of the* [North] *Riding, but in general are so poor in quality…The inhabitants in general are extremely hurt by the expensive land-carriage of coals from the county of Durham"* (Tuke, 1800, 26). *"The Eastern Moorlands also produce* [contain] *alum, but the mineral either lies too deep, or is situated too far inland, to admit of being worked with profit"* (Tuke, 1800, 17).

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(34) 1660 Restoration of Charles II

Soon after the Restoration of **Charles II** (1630-1685) in 1660, the Crown considered the possibility of regaining an **alum monopoly** by acquiring all the alum works, but doing so in return for compensation and not through use of the royal prerogative. The political necessity for negotiation doomed it to failure.. **Sir George Charnock** and **Gerard Fox** were appointed to contact the owners of alum works and mines to determine the possibility of purchasing them. Charnock reported in 1662 that several new mines and alum works had opened after the state monopoly ended in 1648. Zacherie Stewart ran an active alum mine at Lingberry Hill; Sir Hugh Cholmley had mines at Whitby serviced by a wharf at Spittle Bridge; the Mulgrave works remained active; Sir William Darcy and his son George operated the Slape Wath works; and Sir Richard Houghton was operating the Samlesburgh works near Preston in Lancashire (Turton, 1938, 183).

Several of the original alum works were in disrepair (Turton, 1938, 181). At the **Mulgrave works** John Sheffield (1647-1721, 1st Duke of Buckingham and Normanby), the son of the 2nd Earl of Mulgrave (d.1658), was using equipment valued at £11,000 that had been provided earlier by the 'farmers' Pindar and Toomes. In 1661 his business manager overseeing the Asholme and Sandsend alum works was **Sir John Monson** (1599-1683), a politician and financier of fen drainage (DNB, 2004, 38, 696). Monson granted a lease on the works to the partnership of Sir Nicholas Crispe, Dr. John Twisden, Francis Pargiter, and John Sammes (Turton, 1938, 182). The works themselves were run by the Mulgrave estate steward, Thomas Shipton, so the leaseholders were only involved in marketing the product.

Sir Nicholas Crispe (Crisp c.1598-1666) (DNB, 2004, 14, 210; MRP 2012) was the son of Ellis Crisp (d.1625) of Hammersmith, one of the richest merchants in London where he became Sheriff (HPM Crisp 2015). The Crisps descended from a landed family in Gloucestershire. The Nicholas and Ellis Crispe (qv) who were 'alum farmers' in 1606/7 were Sir Nicholas's uncle and father respectively. Sir Nicholas (TP M#361967) was a member (1619) and later master (1640) of the Salters Company, as well as a Merchant Adventurer and member of the Barbary and Guinea companies. He traded to the Mediterranean, was a major shareholder in the East India Company, and was involved in the slave trade from Africa. Some of his ships were probably involved in piracy under 'letters of marque' (DNB, 2004, 14, 210). By 1619 he had married Anne, daughter of Edward Prescott, a Salter and goldsmith of London (MRP 2012) In about 1638 he entered into customs 'farming'. He was an associate of George Goring (qv), Earl of Norwich, in an ill judged attempt to undermine the financial eminence of the principal 'farmer' Sir Paul Pindar (DNB, 2004, 44, 356). His brother Samuel Crispe in 1638 was a member of the partnership leasing the 'petty farm' of duties on wines and currants. Another brother was Tobias Crisp (1600-1643), the third son of Ellis and a controversial clergyman. He was a popular rector at Brinkworth in Wiltshire from 1627 until 1642 when persecution by Royalist soldiers forced him out. He moved to London, where his religious views (later published as '*Christ alone Exhaulted'*) became widely known, but he soon died of smallpox.

Sir Nicholas invested in the **Deptford copperas works** near London, and made significant technological improvements at that important manufacturing site. He made a substantial loan of £15,000 to Charles I in 1643. As a leading Royalist, he may have spent £300,000 in support of the Crown, and fled to France in 1647. His London properties were looted during the Civil War and he was imprisoned briefly for debt in 1661. After the restoration, he became an M.P. and regained wealth through a modest Crown grant for his earlier assistance, his ability to reclaim long overdue payments from his Guinea trade, and a share of the 'farm' of sea-coal (pit coal) exports. Nicholas Crispe introduced the cultivation of the madder plant into Kent, for the roots to be as a dyestuff, probably by London dyers(Pennant, 1801, 1, 96). During the Commonwealth, Sir Nicholas heen the leading promoter of a project to excavate a harbour for two hundred sailing ships at Deptford. £6,000 was spent on purchasing 200 acres of land. But after the Restoration, Charles II refused to grant a fee-farm on the land and the project collapsed (VCH Deptfort St.Paul).

At Saltwick **Sir Hugh Cholmley (1600-1657)** senior (Cholmley, 1870, preface; TP M#224366) of Roxby Castle, had taken advantage of the absence of a Crown alum monopoly to open his own alum works, hoping to restore family fortunes after disasters during the Civil War (DNB, 11, 504). His family were descendents of Hugh Cholmondely of Cheshire. Sir Hugh senior's great grandfather Richard had bought 26,000 acres of Whitby Abbey lands between 1540 and 1565. Sir Hugh was the eldest son of the Sheriff of Yorkshire, Sir Richard Cholmley (1580-1631) (TP M#224367) and Susannah (1578-1611) (TP F#224368) nee Legard (Turton, 1938, 183).

Sir Hugh senior (d.1657) married Elizabeth (1600-1665) (cf. TP F#224350) nee Twisden (Twysden) of East Peckham (DNB, 11, 504). He took control of the near-bankrupt family estates in 1626. In the Long Parliament he condemned monopolies and forced loans. With Elizabeth he had two sons, **Sir William Cholmley** (1625-1663), 2nd baronet (TP M#224373) and **Sir Hugh Cholmley** (1632-1688), 4th baronet, commissioner of Tangier, Morocco (Charlton, 1779, 320). An insult from Thomas Wentworth (d.1641), Earl of Strafford, led to a bitter dispute between the two men. In 1641 Sir Hugh accepted a baronetcy. His friends were Parliamentarians, and Strafford's friends were Royalists. Sir Hugh took control of Scarborough castle and town for Parliament, but came to dislike the conduct of the war, and in 1643 defected to the Royalists. That year he fought for the King at Gainsborough and Malton. Scarborough castle was besieged, and after five months he was forced to surrender, but was allowed to go into exile, to Rouen in France (Young, 1817, 2, 837). In 1649 he returned to Whitby after paying a fine of £850, and opened Saltwick alum works. In 1651 Sir Hugh, "*conceiving my being in Yorkshire would draw a greater suspicion upon me, chose my brother-in-law Sir Thomas Twisden's house at Peckham as the place for my confinement; yet*[despite] *having before intended and prepared for* [staying at] *Whitby, where my son William was necessarily to reside touching* [for] *the erecting of the allum works*" (Cholmley, 1870, 47). Distrusted by Parliamentarians, he was later imprisoned for two months in Leeds Castle, Kent, and in 1655 left Yorkshire to live at Roydon Hall in Kent.

The alum works "*directly brought a great conflux of new inhabitants to Whitby, which considerably increased the town, so that more staithing* [embanking] *was built in several places*" to prevent flooding by the river and the sea. "*Many of the new inhabitants, having bought leases of Sir Hugh* [Cholmley], *erected houses on or near this staithing"* (Carlton, 1779, 317)

Sir William the 2nd baronet (d.1663) married twice, beginning with Katherine nee Hotham (d.1655). Later he married Catherine nee Savile, but their son Sir Hugh (1662-1665), 3rd baronet, died young. The title reverted to Sir William's brother, Sir Hugh Cholmley (1632-1688), 4th baronet, (HPM, 2004, Hugh Cholmley; TP M#224384) who was responsible in 1662 for operating Whitby alum works, with its new wharf at Spittal Bridge. His brother-in-law, Dr. John Twisden, acted as his trustee at Whitby alum works in 1662, and later as trustee of Hugh's share in the 'alum farm'.

His alum-works partners were Sir Nicholas Crispe, who was the main organiser, and two London merchants, Francis Pargiter and John Sammes (Turton, 1938, 183). Sir Hugh was also active as **commissioner for Tangier** (1662-8), surveyor general for the Tangier harbour mole or breakwater (1669-76), and he became an alum 'farmer' (1665-79). The mole, undertaken with admiral Sir John Lawson and the Earl of Teviot, governor of Tangier, was based on Hugh's study of Whitby pier (Young, 1817, 2, 842). "*He took out with him a number of Whitby people acquainted with building piers, and a small fortified village beside Tangiers, where they resided, was named by them Whitby; and they termed one of the forts there York Castle"* (Young, 1817, 2, 839), But the breakwater project proved too difficult and had to be abandoned.

Sir Hugh became MP for Northampton (1679) and Thirst (1685-7). He married Lady Anne nee Compton (TP F#224385), and their daughter Mary (1667-1748) married a London merchant with the same surname, her cousin Nathaniel Cholmley (d. 1687) (Young, 1817, 2, 839). Anne (d.1788), daughter of a later Nathaniel Cholmley (d.1791), married Constantine John (1744-1792), Lord Mulgrave, Captain RN, whose father Constantine Phipps had been made Lord Mulgrave of Ireland in 1767, and in 1774 purchased from the Crown the lease of the Mulgrave estates in Yorkshire (Young, 1817, 2, 865). Abbey House in Whitby became the Cholmley family home (VCH Whitby 1923). After 1688 the family fortunes declined. Saltwick alum works was "*very indifferently managed"* and operated at a loss before its closure in 1708 (Carlton, 1779, 327).

(35) Yorkshire Alum Monopoly 1665 - 1679

On behalf of the Crown, the Treasury planned to lease all the Yorkshire alum works by direct agreements with the owners, and then to assign them to a partnership of 'farmers' to run as a monopoly. Agreement with all but one was reached in June 1665, and finalised in November (Turton, 1938, 187). The exception was **Zacharie Stewart**, so the Crown attempted claimed that he had no right to mine (although he did) and that he had agreed to their proposals (which he had not). They eventually imposed terms on him of £100 per year, with another £200 to Thomas Lechmere and £100 to Houghton, his partners.

The Crown's new alum mining monopoly of **1665** was leased to **four 'farmers'**: Sir Nicholas Crispe, Dr.John Twisden (trustee for Sir Hugh Cholmley the younger), Francis Pargiter and John Sammes. They became responsible for meeting the Crown's annual payments to the owners of the alum works and mines, plus a fee of £5,260 to the King. For the first four years, £1000 out of the King's allocation went to Sir Edmund Turner because owned the remaining period of Sir John Gibson's original Crown patent monopoly (1637/8) until its expiry date of 1668.

The 'farmers' **annual obligation** involved paying £1,800 to John Sheffield (1647-1721), 1st Duke of Buckingham and Normanby (son of 2nd Earl Mulgrave), and his associate Sir John Monson; £1,500 to the trustees of Sir William Chorley; £300 to Isaac Fairfax; £400 to Sir William Darcy and George Darcy; £400 to the operators of Lingberry Mines; and £340 to Sir Richard Hoghton with respect to Samlesbury Mines, near Preston in Lancashire (Turton, 1938, 187). Total payments by the 'farmers' were about £10,000 on a total output of 1,200 tons of alum. Turton states that these payments raised alum prices by £8 6s. 8d. per ton. The Treasury stipulated that if the 'farmers' failed to use the existing alum works or their equipment within three months, then the former operators were entitled to remove and sell all equipment and buildings as they saw fit (Turton, 1938, 188).

Special arrangements were made by the Crown to assist the alum 'farmers. Because kelp was increasingly being used in the manufacturing process, they received widespread powers to **collect seaweed** around the coasts (Turton, 1938, 188). Alum workmen, and the seamen employed for shipping alum, were **exempt from military conscription**. The minimum alum price was set at £26, and an import ban was introduced in April 1667 (Turton, 1937, 189). Sir John Monson estimated that alum manufacturing costs at this time were £9 12s 6d per ton. During the Plague (1635), Great Fire of London (1666) and Dutch War (1666) the Crown allowed a reduction in alum production output without imposing penalties (Turton, 1938, 190). In 1663 Timothie Langley made an ansuccessful attempt to begin alum production in Scotland (Clow&Clow, 1952, 237).

As a result of the King's decision, for political expediency, not to issue Letters Patent which would have imposed a legal monopoly like that under Charles I, there was no prohibition against entrepreneurs opening new mines and alum works. During 1670 separate mines were opened each side of Saltburn mouth, one by **Sir John Lowther** and Nicholas Trotter, and the other by **John Turner**. Together these cost the 'farmers', on behalf of the Crown, £900 per year (Turton, 1938, 191). At Marske in 1673 Anthony Lowther opened an alum mine in 1672 and the rights were demised (transferred) to a partnership of Sir Hugh Cholmley, Sir Nicholas Crispe, and others at £400 per year (Moule, 1837, 2, 448).

The Lowther investment in alum production at Marske coincided with energetic commercial activity by that wealthy family at Whitehaven in Cumberland. The family descended from Sir Christopher Lowther of Lowther, and Eleanor nee Musgrave, whose sons were Sir John Lowther (1581-1637) and **Robert Lowther** (d.1655) (TP M#12212) of London (Bouche, 2016).

Two sons of the sons Sir John Lowther (d.1637), and his wife Elanor nee Fleming, expanded the family's commercial interests in north west England : **Sir John Lowther** (1605-1675) of Lowther (1st bart.) and **Sir Christopher Lowther** (1611-1644) of Whitehaven (1st bart.). Meanwhile, Robert had become a wealthy draper and alderman in London.. At Whitehaven, the former monastic estates were inherited in 1637 by Sir Christopher (d.1644). He had been educated at the Inner Temple, London, and seems to have also learned commerce through his uncle, Robert. He began the developoment of Whitehaven port and established nearby saltworks, as well as becoming a merchant, trading with Ireland and the Canary Isles.

In September 1649 Robert Lowther (d.1655) and his nephew Sir John Lowther (d.1675) jointly invested £13,000 in purchasing the estate of Marske in Yorkshire, "*in trust for our children*" (Bouche, 2016, 102). Robert's half share passed in 1655 to his eldest surviving son **Anthony Lowther** (1641-1693), MP for Cumberland (HPM, 2016, A.Lowther; TP M#12215). In 1667 Anthony married Margaret (d.1719), the daughter of Admiral Sir William Penn (1621-1670) of Walthamstow, and sister of the William who was the founder of Pennsylvania). Their son, Sir William Lowther (1676-1705) became MP for Lancaster (HPM, 2016, W. Lowther; TP M#12217).

Sir John Lowther (d.1675) had been educated at the Inner Temple, and became a J.P. in Westmorland, and MP for the county. He served in the Royalist army, but was not in active combat (HPM, J. Lowther). He became a wealthy landowner but was not an industrial entrepreneur.

The Whitehaven estates inherited by Sir Christopher passed in 1644 to his son Sir John Lowther II (1642-1706) (HPM, 2016, J. Lowther II). It was this Sir John (d.1706), a member of the Royal Society and MP for Cumberland, who improved the prosperity of that area. After the Reformation he established a town market, improved the seaport at Whitehaven, and actively developed collieries and saltworks. His success may have encouraged Anthony Lowther (d.1693) to enter alum production in Yorkshire.

Sir David Foulis (qv) opened a mine and alum works at Staintondale in 1673 to compete with the Crown. The 'farmers' received from the Crown £464 compensation for the 28 tons that Foulis made over two years. This was equivalent to £26 per ton after deducting the £9 10s per ton cost of manufacture (Turton, 1938, 191). A strange measurement system was used for weights. One ton of alum was 20 cwt, but one cwt. of alum was only 92.5 lbs. rather than the normal standard of 112lbs (Turton, 1938, 193). Over the next four years various mines were opened or renewed around Guisborough. **Nicholas Conyers** opened new mines at Easington and Boulby (Turton, 1938, 191; Graves, 1808, 335-40).

Between December 1665 and June 1674 the Crown should have received £5,260 per year making a total of £44,710, but instead received only £24,610 from the 'farmers'. From June 1674 to December 1678 the expected Crown income was £23,670, but it only received £4,560 (Turton, 1938, 191). The 'farmers' lease was due to continue until June 1686, but in May 1679 they persuaded the King to allow them to relinquish it without penalties. Sales of alum, even at the elevated prices, were increasingly becoming inadequate to cover the cost of purchasing the increased output and compensate owners of new mines (Turton, 1938, 191). Many alum works had been opened along the coast, making it very **difficult to detect illegal shipments** and exports.

After the **termination of monopoly in 1679** the alum industry continued to prosper, especially the Mulgrave and Sandsend works (Turton, 1938, 194; Moule, 1837, 2, 448). At Lord Mulgrave's works alum production continued under the supervision of Matthew Shipton, the son of Thomas Shipton. During times of international tension, cannon were positioned along the coast, including some alum-works, to deter invasion. In 1694 the cannon at Saltwick alum-works itself exploded, killing Ann and Henry Jefferson from Cotehouses (Charlton, 1779, 326).

Since the 1560s, investment in the alum industry had involved a complex interplay of business acumen, politics and family connections. Many early investors were extensive landowners with strong political allies, and they included both long established families and the nouveau riche. They travelled widely, both England and in Europe, gaining commercial intelligence through networks of personal family contacts, and through diverse partnerships involving trade, manufacturing, and the 'farming' of customs.

Politics and patronage played a major role. Under the Crown monopoly, political influence dominated the appointment of lease-holding alum 'farmers', whose ingenuity was expended on dubious accountancy and political machinations rather than on improvements to technology. Patron-client relationships have been shown by Linda Peck as a widespread and integral component of the hierarchical society in early Stuart England (Peck, 1990, 4).

Many of the commercial problems which were experienced in the alum industry became more familiar in other sectors after 1750, including the difficulties of raising adequate working capital, maintaining quality, and allowing adequate depreciation for timely renewal of equipment.

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(36) Developments after 1679

The alum industry in Yorkshire persisted for centuries. John Graves in 1808 published an account of the techniques then being used at the Boulby and Lofthouse works in Cleveland (Graves, 1808, 335-340 and 346). There were also large works at Lythe, and some at Ayton (Graves, 1808, 317 and 210). "*The following are the alum works now carried on in Yorkshire; viz. Peak, Stoup-Brow, Little-Beck, Eskdale-Side, Sands-End, Kettleness, Boulby and Lofthouse: those at Guisbrough; Ayton, Carlton, Osmotherley, and some others, have been long discontinued*" (Graves, 1808, 428; Moule, 1838, 2, 447).

Copperas made at alum works:

Copperas was a valuable **byproduct** of alum production, but the freight costs on coal needed to evaporate the alum solution eventually made it uneconomic. Tuke recorded in 1800 that "*Pyrites is found in considerable quantities in all the alum mines, and copperas was formerly extracted from it in most of the alum works; but as* [because] *much coal is consumed in crystallizing the* [copperas] *salt, and the pyrites is found with coal in Durham and Northumberland, the process is given over in this* [North] *Riding, and removed thither*" (Tuke, 1800, 17).

In about 1664 Mr Wilson of Ealand in Yorkshire discovered the hazards associated with pyrites, possibly in connection with proposed copperas production. He "*had piled up in a barn many cart-loads of the pyrites, or brass-lumps, as they were called by the colliers, for some secret purpose of his own: the roof of the barn happened to be bad, the pyrites were wetted by the rain; in thgis state they began to smoke, and presently took fire, snd burned, like red-hot coals*" (Watson, 1782, 1, 195).

An independent **copperas works** was opened in 1748 at **Hartley,** near Newcastle upon Tyne, by Thomas Delavel, who later sold them to his brother Lord Delaval (Armstrong, 1864, 175; Clow & Clow, 1952, 245). The first built on the Tyne was by Messrs Barnes and Forester in 1798 at **Walker**, and it was still operating in 1860 (Armstrong, 1864, 175; Clow & Clow, 1952, 245). They used techniques virtually unchanged from the sixteenth century works in Dorset.

Most of the output went to French dyers at Rouen, Paris. Lyons and Maresilles. Copperas was made in Scotland at Hurlet from 1753, by a Liverpool company, and another works opened nearby at Househill in 1807. The Campsie alum works produced some copperas, and a small works opened at Baldernoch in Stirlingshire (Clow & Clow, 1952, 245)..

List of alum works:

George Young, in his 1817 'History of Whitby', attempted to provide a chronological listing of all the Yorkshire alum works (Young, 1817, 2, 810; Carleton, 1779, 360). He was mistaken about many events before 1700, but was apparently well informed on eighteenth century changes, and even detailed the economic vicissitudes of the industry during that century : (1) Belman Bank near Guisborough [wrongly] c.1595-c.1605, moved to a new site [wrongly] c.1605-1620. (2) Lord D'Arcy's works on Whitby road near Guisborough, [wrongly] c.1600 to c.1620. (3) Sandsend Ness, c.1615, still open in 1817. (4) Old Peak. (5) Boulby. (6) Lofthouse (originally called Lingberry), still open 1817.

(7) Peak, opened by Sir Bryan Cooke, operated in 1817 by Messrs Cooke. (8) Saltwick opened 1649 by Sir Hugh Cholmley, assisted by Sir Henry Cholmley and Sir Richard Crispe; closed 1708, reopened 1755 by Ralph Carr, John Cookson, Richard Ellison and Jonas Brown, closed 1791. (9) Littlebeck 1660 to 1809 (opened about 1755 by Howlett and Mathews, according to Lionel Carleton).

(10) Carleton opened 1680 by Captain Prestwick, closed 1774. (11) Holmes, near new Mulgrave Castle, opened 1680 to supply Sandsend alum house. (12) Ash Holme near old Mulgrave Castle, c.1680 to c.1705. (13) Rock Hole, between East Row and Rock Head, worked for only about six years. (14) Selby Hagg near Skelton c.1680 to c.1720, reopened 1765 by Sir John Hall, supplied Saltburn alum house, closed 1776. (15) Hobb Wood near Upleatham.

(16) Kirkby in Cleveland, closed c.1730. (17) Kettleness c.1728 to c.1736, reopened 1742 by Ambrose Newton, closed 1754, reopened 1767 by Lord Mulgrave and still operating in 1817. (18) Osmotherley (Thimbleby), the most westerly alum works, c. 1752 to c.1772. (19) Stape Brow opened c.1772, continuing in 1817.

(20) Eskdale-Side opened 1764 by John Yeoman and Richard Jackson, still producing in 1817. (21) Godeland Banks near Sleights, opened 1765 by Messrs Searth and Sleights, closed 1805 (Carleton recorded a works opened in 1765 close to Little-Beck, by Messrs Scarth and Thornhill, but closed before 1779). (22) Ayton in Cleveland 1765 to c.1771.

(23) Guisborough reopened 1766 by William Chaloner, closed 1804. In 1764 £1000 was spent trying unsuccessfully to open a works at Hawsker Bottoms. Saltwick sent alum liquor by boat to an alum house at Shields for a short period up to 1770, in an attempt to reduce freight costs on fuel used for evaporation. Stape Brow, also called Stoupebrow, was on a rough road from the moors to Robin Hood’s Bay (Hinderwell, 1811, 285). Pleasington alum works in Lancashire opened c.1680, and closed c.1771. An unsuccessful works opened in Wales in 1736, probably at Neath in Glamorganshire (Wilson, 1812, 277). Alum was produced on a significant scale at Hurlet near Glasgow from 1797.

The number of alum houses in eighteenth century Yorkshire fluctuated with the market price of alum. Young quotes the following market prices per ton : 1736 £10, 1740 £12, 1742 £13, 1746 £14, 1756 £12, 1760 £11, 1764 £20 to £22, 1765 £24 to £26, 1767 £20, 1769 £14, 1770 £13, 1771 £13, 1783 £22 (after the American war of independence 1776-83), 1789 318, 1790 £18, c.1800 £26 to £27, 1817 £20 (Young, 1817, 2, 816).

Another alum monopoly attempt - 1716:

George Young claimed in 1817 that in about 1716 (or 1726) the **Duke of Buckingham** tried to gain a **monopoly** over production by persuading the owners of alum works to close them for twenty one years in return for an agreed annuity. The main operators included Sir G. Cooke who received £430 per year for the closure of Peak Works, Godrington Prestwick at £400 for Carleton Works, and Hugh Cholmley at £220 for Saltwick Works.

Buckingham succeeded in raising alum prices. But his monopoly soon failed because imports of cheaper alum increased, and so many new works were opened in Yorkshire that he found it too expensive to negotiate their closure (Young, 1817, 2, 815). The fall of alum prices to £10 per ton by 1736 left only four works still operating, and they formed a cartel to restrict output: Sandsend output was too be 520 tons, Lofthouse 420 tons, Boulby 320 tons, and Carleton 240 tons. More works later opened as prices rose.

This **Duke of Buckingham** would have been John Sheffield (1648-1721), Lord Mulgrave, the son of Edmund (d.1658), 2nd Earl of Mulgrave. His own son Edward (1716-1735), the 2nd Duke, succeeded while a minor, and it seems unlikely that his trustees organized an alum monopoly in 1726, after the financial experiences of his father.

John (d.1721) served in the Royal Navy during the second Dutch war, became Lord Chamberlain to James II, but accepted the Glorious Revolution and in 1694 was created Marquis of Normanby. Under Queen Anne he became Duke of Buckingham and Normandy in 1703, and lived in London on the site of the present Buckingham Palace. His third wife, in 1705, was Catherine Darnley (1680-1743), an illegitimate daughter of James II and Catherine Sedley (1657-1717), Countess of Dorchester.

In 1705 Buckingham leased a set of alum works in Yorkshire for nineteen years to **John Ward (1685-1761**), an unscrupulous London merchant. John was eventually sued by the Duke’s executors in 1725. John was the son of William Ward (d.1718), a dyer (alum-maker in some accounts) at Guisborough, and his wife Anne, daughter of Thomas Flood of Hackney, London (HPM 2016 two articles, J. Ward IV 1682-1755 and J. Ward d.1755; HPM 1715-1754 Weymouth and Melcombe Regis). John’s brother was Joshua Ward (1684/5-

1761) (qv), a quack London doctor who manufactured sulphuric acid by burning a mixture of saltpetre and sulphur (DNB 2004, 57, 323; Williams, 1969, 542)..

John Ward originally made floor cloths in London, but through family connections and sharp practices soon became wealthy. He traded to the East Indies, became an MP (Reigate 1710-13, Weymouth 1722-6), invested in the United East India Company, and gained wealth through government contracts. He became alum manager for Buckingham, and undertook large financial transactions on Buckingham's behalf.

Under his contract Ward was to sell alum at £15 per ton, but could oblige Buckingham to purchase up to 740 tons per year of any unsold alum at £10 per ton. On the excuse of a slump in the market, he made the Duke purchase the entire 740 tons each year, but persuaded him to leave it at the works in storage pending an upturn in demand. Ward then illegally sold that alum on the open market. By the time the fraud was discovered, the Duke had lost £70,000 of which only £10,000 was recovered (HPM, 2016, J.Ward d.1755). At the termination of the lease, he also failed to leave the required stock of 351 tons of alum .

John Ward and his absent brother Joshua (in France), who had some involvement, were sued in 1725 in Chancery over the alum contract, by the Duke's executors. John forged a document for his defence. The following year he was fined £500, expelled from the House of Commons, and sentanced to an hour in the pillory at Palace Yard (MEHC 2016). John later went into hiding, but was imprisoned in 1732 by the bankruptsy commissioners, and convicted of embezelling £50,000 from the funds of the South Sea Company, for which he had handled subscriptions in 1711. A number of manuscript documents regarding the long period of alum operations by the Lords Mulgrave remain extant (MAM 2016).

Alum Cartel proposed - 1769:

In 1769 the sixteen works then operating had a combined capacity of 5000 tons per year from 60 pans, but prices had fallen to £14 per ton. An attempt was made to form a cartel and restrict total output to 3200 tons from 40 pans. Disagreements between the proprietors prevented it being implemented.

Some owners instead went bankrupt. The works at Ayton, Godeland Banks, Carleton, Osmotherley, Saltburn and Pleasington closed, though Godeland Banks later reopened (Young, 1817, 2, 816; Carleton, 1779, 360). In about 1770 Messrs Gilbert and Company made an unsuccessful bid to monopolize the alum trade (Graves, 1808, 337).

Colebrooke's attempted monopoly – 1771-3:

In 1771 the wealthy and ostentatious banker **Sir George Colebrooke** (1729-1809) (TP M#226984) from Chilham in Kent, made a determined attempt to gain a monopoly over alum sales (Clow & Clow, 1952, 237; Brooke, 2016; Sutherland, 1936, 237; HPM 1754-1790 III- The Members).

The third son of a London banker, he was educated at the University of Leyden (1747-49), like the industrialist John Roebuck (qv) and many English nonconformists, and inherited the banking business of his father Thomas (1680-1752) (DNB, 2004, 12, 539; HPM 2015 Colebrooke). He became MP for Arundel (1754-74), bought plantatons in Antigua, Grenada and Dominica, and in 1764 invested in a Dublin bank (which failed in 1773). He acted as chairman of the East India Company (1768-73), but some of his financial dealings were underhand. In 1771 he bought large Lanarkshire estates, including Leadhall lead mines.

Seeking an alum monopoly in 1771, Colebrooke purchased large quantities of alum, arranged exclusive deals with many producers, and attempted to lease or buy other English alum companies. He had also reopened the Pleasington alum mines (qv) at Blackburn in Lancashire (Aikin, 1795, 272; Wilson, 1812, 277).

Lord Dundas (qv) was the only large producer who had refused to co-operate in the alum monopoly (Clow & Clow, 1952, 237). Colebrook was "*unsuccessful in the attempt, which proved the ruin of his fortune, and procured him, among the directors of the East India company, the appelation of* <u>*shah-allum*</u>*"* (Graves, 1808, 338). During 1771 he also lost £190,000 speculating on the market for hemp. Further heavy losses came in 1773, trying to buy votes in elections at the East India Company. Colebrooke's bank failed in 1773 and he became bankrupt.

Ayton Banks alum works, near Roseberry Topping, was one of the small operations Colebrook was obliged to purchase, in 1772 (GAC 2016). John Liddell had only opened the works and quarry in 1765 and became bankrupt in 1771. John Ridley from Robin Hood's Bay was employed by Colebrooke as the new manager, and he acquired the works after Colebrooke's bankrupcy.

Whitby Port and the alum industry :

Whitby port was largely a creation of the alum industry. The alum trade "*raised us out of obscurity, made us acquainted with navigation, and has rendered us of such consequence as a maritime town*" according to local historian and maths teacher **Lionel Charlton** (c.1722-1788) writing in 1779 (Charlton, 1779, 305; Young, 1817, 2, 869). There were only about 200 inhabitants of the town in 1540, but by 1660 there were 3000 and ship-building was well established.

Carleton had never found "*any certain account of either ship or vessel belonging to our port during the long reign of Elizabeth, except fishing-boats only, till the erecting of the allum works at Gisbrough*" (Charlton, 1779, 304). Until 1690 ships from Whitby needed a master or pilot from other ports like Newcastle, Hull or London.

"*The harbour mouth was so much obstructed with land, and so dangerous to approach*", it was difficult to get in or out. The piers were "*only formed of oak timbers framed*", and "*fishermen, more effectually to secure their boats, and the cottages wherein they lived, time after time threw into these frames a parcel of loose stones, to curb the violent run of the sea into the harbour in stormy weather*". The stones were soon washed away again.

The alum works needed "*large quantities of coals…an article till then but little known on our part of the coast"* (Charlton, 1779, 307). The best supply was from Newcastle and Sunderland. Turton in 1938 showed that the early vessels carrying coal to the alum works, and alum to London, came from distant and often foreign ports. But storms probably increased the costs of shipment.

Charlton claimed that the alum industry quickly initiated the start of **shipbuilding** in Whitby: "*it being found very expensive to bring ships for that purpose from distant parts of the nation, a design was formed to have vessels always in readiness on some convenient part of the coast, whence they might put to sea in moderate weather*" (Charlton, 1779, 307).

Whitby was chosen because "*it contained a harbour, but also had in it a number of fishermen*" who provided maritime skills. Charlton stated that these **local fishermen**, encouraged by the original alum-works owners, "*purchased two or three vessels of small burden, about the year 1615*", to fetch coal. Soon "*with a little assistance from pilots, they next adventured themselves and ships as far as London"* carrying alum, fish and butter. They went on to develop a coastal trade in coal.

"*More vessels were purchased; and in twenty or thirty years time, by a resort* [arrival] *of several ship-carpenters to the place, the inhabitants themselves were enabled to build new ships at the port of Whitby, with the oak timber that was then very plentiful and very cheap in the neighbourhood, so that commerce kept gradually increasing"* (Charlton, 1779, 306).

The famous navigator **Captain James Cook** (b.1728) served an apprenticeship to John Walker of Whitby, at first onboard a collier (Young, 1817, 2, 851). A Custom House had been built at Whitby under Charles II, and 1817 the outdoors staff included "7 tide-waiters and boatmen, 5 coal-meters at the alum works along the coast, with the crews of two boats" at Staiths and Robin Hood's Bay to intercept smugglers (Young, 1817, 2, 569).

At Whitby in 1779, "*our staple commodity is allum, an article wherewith we furnish the greatest part of Europe, and which is at present made in no part of Britain except in the neighbourhood of Whitby, where the greatest part of the country, for an extent of thirty miles in length, and near twelve miles in breadth, is one continued allum-rock, consequently we can always send to market any quantity of allum that may be required:*

But the misfortune is, we generally overstock the market; for when the price of it advances, and any considerable profits attend to it, the owner of every allum-work wants to engross all the trade to himself; and so great a quantity of allum is made, that the price is soon reduced, and it lies on their hands [unsold] *as a dead-*

stock, insomuch that far from being enriched, they frequently lose large sums thereby, and are even reduced to beggery" (Charlton, 1779, 359).

Proposals to rationalize the trade by forming **a cartel** to restrict output to agreed quantities always failed because "*the principal owners will not consent, who* [instead] *want to knock off, and wholly disable, all petty dealers in the allum trade that are not so rich as themselves, and then afterwards to divide the advanced profits among them*[selves]*"* (Charlton, 1779, 359).

In 1779 the area produced 3000 tons of alum each year, sent 400 to 500 tons abroad, and the remainder went to London. Shipping was also needed to deliver alkali. "*From Ireland and Scotland we **import Kelp** for the use of our allum-works; a considerable quantity of which is wanted yearly, over and above what is made on our own coast"* (Charlton, 1779, 361).

In 1811 Whitby served a hinterland with seven alum works employing 550 men to produce 3000 tons of alum each year, much of it for export to the continent. The alum works consumed about 10,000 chaldrons of **coal** a year, brought by sea from Newcastle and Sunderland (Hinderwell, 1811, 288).

In 1812 the alum trade "*in England is now engrossed by five companies, who manufacture about 3000 tons per annul, and is confined to rhe district around Whitby"* (Wilson, 1812, 277).

Despite criticism of the Yorkshire alum industry for slowness to modernize, the quality of English alum was high. Nicholson commented in 1808 that the French chemist Louis Nicolas Vauquelin (1763-1829) " *has lately instituted a set of experiments to ascertain the differences between various kinds of alums*…[but] *it appears to have been his object, to prove to the French manufacturers* [using alum*], that the alum of their own country is equal in quality to the English, which, next to the Roman, they decidedly prefer*" (Nicholson, 1808, 'alum').

Scottish Alum Works:

At **Hurlet**, near Paisley in Renfrewshire, coal miners found a bed of "*schistus*" between the pyrite-rich coal and an overlying bed of limestone. It varied from ½ to 3 ½ feet thick. When exposed to warm air after removal of the underlying coal, it decomposed to "*a flaky or downy appearance… a beautiful vitriolic efflorescence resembling plume alum*" (Clow & Clow, 1952, 238; Wilson, 1812, 26).

Experiments were undertaken by **Nicolson and Lightbody** in 1766-9, seeking ways to produce alum from the rock. Further tests were made in 1796 by the experienced chemist **Charles Macintosh,** son of George Macintosh who ran 'The Cudbear and Turkey Red Dye Works', a very successful cloth-dyeing business. In 1797 Charles established **'Macintosh, Knox and Company'**, to make alum using techniques similar to those in Yorkshire. Contemporary accounts recorded they did not need to calcine the rock, making the process much cheaper (Parkes, 1812, 217). The main problen at Hurlet was the overabundance of copperas in the decayed shale. It was necessary to crystallize and remove the copperas from the 'mother liquor' first, before extracting the alum. This was very difficult to do.

Charles was successful because, unlike Nicolson and Lightbody, and acting on the advice of John Wilson, he used of potassium sulphate to crystallize alum from a relatively weak solution (Macintosh, 1847, 46). He then improved the efficiency of the works by inventing an improved boiler furnace to concentrate the mother liquor, and a better hydrometer ('Twaddel' hydrometer) to monitor the concentration of that liquor. But Brian Skillen has claimed that calcining of the shale was a crucial improvement made by Macintosh (Skillen, 1989, 53).

Charles Macintosh studied Torbern Bergman's account of Swedish alum works, as published in his 1764 book 'Physical and Chemical Essays' (Macintosh, 1847, 46). The company produced alum at Hurlet on a very large scale (Clow & Clow, 1952, 240). In 1809 Charles was on friendly terms with George Dodds of Boulby alum works in Yorkshire, and sent to Dodds samples alum-schist and crystal alum recently collected in Sweden by his son George Macintosh (Macintosh, 1847, 47).

The Hurlet alum company opened a second works in 1808 at **Campsie** in Stirlingshire. Charles Macintosh went on to patent a method of making waterproof clothes, using a solution of rubber in naptha to seal together two layers of cloth. From 1822 'Charles Macintosh and Company' used his process to manufacture clothes and various novelty goods (Clow & Clow, 1952, 253).

Spence's Pendleton Alum Works in Lancashire- 1846:

Peter Spence (1806-1883) was a self-taught chemist who transformed the alum industry (DNB, 2004, 51, 808). The younger son of a handloom weaver at Brechin, Forfar, he bacame a grocer and in 1832 married Agnes nee Mudie (d.1883), daughter of a Dundee linen manufacturer.

That year he joined Dundee gasworks, and learned practical chemistry. In 1834 he moved to London to open his own chemical business, but later moved to Burgh by Sands, near Carlisle. In **1845** he patented a novel method of **making alum**, using **coal shale** (waste spoil from coal mining) and for alkali the **ammoniacal liquor** produced by **gasworks**, a by-product of gas purification. The shale was calcined and then treated with **sulphuric acid** instead of relying on pyrite in the shale to provide the acid (Kargon, 1977, 140). The patent (no. 10,970) referred to the treatment of roasted iron pyrites and calcined shale with sulphuric acid to make both alum and copperas (Clow & Clow, 1958, 251).

In 1846 he opened an alum factory at **Pendleton** near Manchester (Catalyst, 2016). A stench of hydrogen sulphide gas was vented from the works, and was noticeable half a mile away. Spence employed the chemistry professor Edward Franklin at Owen's College, and the Manchester city chemist John Leigh, to reduce the pollution problem, but complaints from local residents increased throught the 1850s.

In 1857, when the works were making 80 tons of alum a week, Spence was sued for causing a noxious nuisance (Regina v. Spence). Both sides used expert witnesses. Spence received support from Robert Smith, the assistant to Lyon Playfair working for the Royal Commission on the Health of Towns, and the first to coin the term 'acid rain' (Reed, 2014).

The judgement went against Spence, who was obliged to move the works to Newton Heath, Manchester, where it retained the name 'Pendleton Alum Works' (Kargon, 1977, 140). By 1862 he was producing 7,000 tons of ammonia alum a year, and went on to make half of all English alum. Later alum factories followed in Goole and Birmingham (Clow & Clow, 1852, 240). At the Great Exhibition of 1851, the two alum works displaying their wares were Pendleton, of Manchester, and J. Wilson of Glasgow (OCGE1851, 2011, 22).

In France, an important market for the British industry, alum began to be produced on a large scale using so-called "*artificial sulphate of alumina*", made by calcining clay and reacting it with sulphuric acid, instead of using shale calcined outdoors (Parkes, 1812, 122; Ure, 1842, 45).

"*Chaptal has fabricated alum on a large scale from its component parts*" (Nicholson, 1808, 'alum'). Jean Antoinine Claud Chaptal (1756-1832) was one of the first to adopt Lavoisier's system of chemistry (Williams, 1969, 104). He opened the first sulphuric acid works in France. As, professor of chamistry at Montpellier he made alum in new ways. Originally he used clay, ground into a fine powder and them mixed with sulphuric acid. Later, at Montpellier Alum Works, "*the clay being well ground* [to powder], *was mixed with half its weight of the saline residue from a mixture of sulphur and nitre. This residue is little else than sulphate of potash. The mixture was formed into balls about five inches in diameter, which were calcined in a potter's furnace"* (Enc. Brit. 1842, 2, 578). They were then broken into pieces and spread over the floor of a chamber in which sulphur was burned to make sulphuric acid gas which reacted with the clay over a period of several days. After several more days exposed to the atmosphere, under cover, the clay was steeped in water just like calcined shale, to give a solution of aluminium sulphate. This was then processed in the normal way to make alum.

In Britain, alarm over the scale of changes occurring in the alum industry, as in other chemical industries, can be seen in an 1840 pamphlet, '*Review of the Neapolitan Sulphur Question, by a British Merchant'* (Macintosh, 1847, 818). This exaggerated account was published as propoganda during the British government's coersion of the King of Naples, who was forced to abrogate his new trade agreement with Messrs Taix, Aycard and Co. of Marsailles.

"*Since 1823, the importers of sulphur, the makers of sulphuric acid, the makers of alkali, the soap and glass makers, and the makers of <u>factitious alum</u>, in Britain, have reaped millions at the public cost, by the repeal and reduction of the duties on common salt, sulphur, barilla, and tallow. They have been enabled by such concessions to annihilate the kelp trade, and <u>nearly to annihilate the native nanufacturers of alum and copperas, whilst, by a remarrkable fatality, they have also been enabled to crush the trade in pot ashes</u>, which* *was the branch to which the emigrants, ruined in the highland kelp trade, betook themselves in our transatlantic colonies"* (Macintosh, 1847, 140).

By the time of the Great Exhibition in London in 1851, the alum industry was well integrated into the broader British chemical industry. Two manufacturers displayed material in Class Two, in the South Gallery: *"(6) WILSON, J., Glasgow, Manu. – Alum slate, raw and manufactured. Iron pyrites and sulphate of iron. Sulphate of ammonia obtained from the distillation of coal. A rare specimen of naphthaline.*

(7)SPENCE, P., Pendleton Alum works, Manchester, Inv. And Manu. – Iron pyrites and its products. Shale or schist, and alum produced from it. Patent zinc cement, or hydraulic mortar; and specimens of the waste materials from which cement is manufactured" (OCGE1851, 2011, 22).

APPENDICES

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(37 A) Making Alum - the manufacturing process

The early English alum industry was a high-risk enterprise. The technology was poorly understood and substantial investment was required, but it was fundamentally the local geology that determined the prospects for success (Musson, 1981, 35).

Copperas alone was much easier to make than alum. Pyrite nodules were collected, usually on the surface of beaches following cliff erosion, and then shipped to the processing works. There they were exposed outdoors, heaped on special platforms.

Natural weathering and bacterial activity over many months produced copperas, hydrated ferrous sulphate. This was dissolved by rainwater, and the solution flowed into collecting gutters ready to be concentrated in boiling pans and then crystallized.

By contrast, **alum 'ores'** were **sedimentary rocks** containing the correct proportions of aluminosilicates (very abundant components of rock minerals), sulphur in the mineral pyrite (iron disulphide) and carbon compounds (from ancient plants and animals) (Osborne, 1998, 18). The 'ore' was called "**mine**, *a provincial term at Whitby for schistus or alum rock*" (Wilson, 1812, 26).

The 'Alum Shales' of Yorkshire are beds of grey micaceous marine shales up to 37 metres thick, within the Upper Lias, which is part of the Upper Jurassic rock succession (Kent, 1980, 40). They consist of three rather different layers. The upper 20 metres, known as 'Cement Shales', contains calcareous nodules which were used to make hydraulic cement. Below these, the 'Main Alum Shales' were about 15 metres thick, and in turn underlain by the lowest layer comprizing about 6 metres of non-bituminous 'Hard Shales'.

Early European production and use of alum is well summarized in Ure's 1842 'Dictionary Arts, Manufactures and Mines'. **Andrew Ure (1778-1857**) was an army surgeon (MD 1801 Glasgow), who became a prominent and influential lecturer in chemistry and mechanics at Anderson's Institution (1804) in Glasgow, as the successor to George Birkbeck.

"ALUM. (Alum, Fr.; Alaum, Ger.) A saline bodyconsisting of the earth of clay, called <u>*alumina*</u> *by the chemists, combined with sulphuric acid and potash, or sulphuric acid and ammonia, into a triple* [three component] *compound.*

It occurs in the crystallized form of octahedrons, and has an ascerbic subacid taste, and reddens the blue colour of litmus or red cabbage.

Alum works existed many centuries ago at Roccha, formerly called Edessa, in Syria, whence the ancient name of ***Roche alum*** *is given to this salt. It was afterwards made at Foya Nova, and Smyrna, and in the neighbourhood of Constantinople. The Genoese, and other trading people of Italy, imported alum from these places into western Europe, for the use of dyers of red cloth.*

About the middle of the fifteenth century, alum began to be manufactured at La Tolfa, Viterbo, and Volaterra, in Italy; after which time the importation of oriental alum was prohibited by the pope as detrimental to the interests of his dominions." (Ure, 1842, 39).

The "*insoluble or basic alum exists native in the* ***alum-stone*** [alunite] *of Tolfa, near Civitia Vecchia, and it consists in 100 parts of 19.72 parts of sulphate of potash, 61.99 basic sulphate of ammonia, and 18.29 of water. When this mineral is treated with a due quantity of sulphuric acid, it dissolves, and is converted into the crystallizable alum of commerce"* (Ure, 1842, 39). Ure also provided an analysis of the alunite mineral by M. Cordier which showed 18.53 percent sulphate of potash, 38.50 percent sulphate of alumina, and 42.97 percent 'hydrate of alumina' (Ure, 1842, 45)

"*The alum-stone is a rare mineral, being found in moderate quantities at Tolfa, and in larger* [amounts] *in Hungary, at Bereghszasz, and Muszag, where it forms entire beds in a hard substance, partly characterized by numerous cavities, containing drusy crystallizations of alum-stone or basic alum*" (Ure, 1842, 40).

"*The sorted pieces* [of alum-stone] *are roasted or calcined…in common lime kilns in the ordinary way* [like lime]…

The calcined alum-stones, piled in heaps from 2 to 3 feet high, are to be exposed to the weather, and meanwhile they must be continually kept moist by sprinkling them with water. As the water combines with the alum the stones crumble down, and fall, eventually, into a pasty mass, which must be lixivated with warm water, and allowed to settle in a large cistern.

The clear supernatant liquor, [after] *being drawn off , must be evaporated, and then crystallized. A second* [dissolution and] *crystallization finishes the process, and furnishes a marketable alum. Thus the Roman alum is made, which is covered with a fine red film of peroxide of iron* " (Ure, 1842, 40). "*It is probable that the **Roman alum** is a sulphate of alumina and potash, with a slight excess of the earthly* [sic] *ingredient"* (Ure, 1842, 44). "*Roman alum…has a few peculiar characters: it crystallizes always in opaque cubes, whereas the common alum crystallizes in transparent octahedrons*" (Ure, 1842, 44). Alunite ore contained 18.53 percent sulphate of potash, 38.50 percent sulphate of alumina, and 42.97 percent hydrate of alumina "(Ure, 1842, 45).

The Encyclopaedia Britannica of 1840 gave a slightly different version of the porcessing techniques at La Tolfa: The alum-stone, if "*kept constantly moistened with water for about two months, it falls to powder of itself, and yields alum by lixivation* [steeping in water]". But instead, it was "*broken into small pieces, and piled on the top of a perforated dome, in which a wood fire is kindled*" (Enc.Brit., 1842, 2, 575). Heat and smoke penetrated the broken stones, releasing "*a sulphureous odour*". The roasting was done twice, with ore from "*the edge of the dome being the second time put in the middle*". Roasted stone was then watered daily for a month, reducing it to a powder. This was "*thrown into a leaden boiler filled two thirds with water*", and after sufficient boiling the solution was drained into deep, square, wooden vessels to crystallize" (Enc.Brit., 1842, 2, 575).

"The manufacture of this [alum] *salt was extended to Germany at the beginning of the sixteenth century, and to England at a somewhat later period, by Sir Thomas Chaloner, in the reign of Elizabeth. In its pure state it does not seem to have been known to the ancients* [of Greece or Rome]" (Ure, 1842, 39).

William Nicholson (1753-1815), in an 1808 account which was later closely copied by Ure, claimed there were six possible sources or 'ores' for making alum (Nicholson, 1808, 'Alum'; Ure, 1828, 136). Nicholson, the son of a London solicitor, had been educated in Yorkshire before working for the East India Company, and later as commercial agent for the pottery manufacturer Josiah Wedgewood. He then became a tutor of mathematics and a highly respected author of books on science and navigation. His 1788 'Elements of Natural History and Chemistry' was based upon a French textbook by the Count de Fourcroy.

The best alum 'ore' was the sulphureted clay called petra aluminaria, found at La Tolfa in Italy. Second was pyritaceous clay, black and hard but brittle. At Schwemsal in Saxony this was prepared by exposure to the air for two years, while at Hesse and Liege it was '*torrefied*' (heated and calcined). The third type was 'schistus aluminaris' with "*a variable proportion of petroleum and pyrites intimately mixed with it*". Provided there was not too much pyrite present, it could be "*torrified"* as at Whitby in Yorkshire and at Becket in Normandy. Fourth was "*volcanic aluminous ores. Such as that of Solfaterra near Naples*". Fifthly, "*Bituminous alum ore is called shale, and is in the form of a schistus, impregnated with so much oily matter, or bitumen, as to be inflammable*"; found in Sweden and in the coal mines of Whitehaven in Cumberland. Sixthly, and incorrectly, "*Alum might also be extracted from many species of pyrite; but so contaminated with iron as scarce to pay the expences*" (Nicholson, 1808, 'Alum').

By the 1840s,*"The only manufactories now working in Great Britain, are those of Whitby, in England, and of Hurlett and Campsie in Scotland; and these derive the acid and earthly constituents of the salt from a mineral called **alum slate**. This mineral has a blueish or greenish-black colour, emits sulphureous fumes when heated, and acquires thereby an aluminous taste"* (Ure, 1847, 39).

"*The greater portion of the alum found in British commerce is made from **alum-slate*** [shale] *and analogous minerals. This slate contains more or less iron pyrites, mixed with coaly or bituminous matter, which is occassionally so abundant as to render them somewhat combustible"* (Ure, 1842, 40).

'Alumina' was known to be a component of one of the two salts in alum. But it could not be proved, until an 1825 experiment by Oersted, that this was an element, which is now called **aluminium** (Friend, 1961, 162). Thus Andrew Ure, in his 'Dictionary of Chemistry', recorded *"ALUMINA. One of the primitive earths, which, as constituting the plastic principle of all clays, loams, and boles, was called argil of the argillaceous earth, but now, as being obtained in the greatest purity from alum, is styled alumina. It was deemed elementary* *matter until Sir H. Davy's celebrated electro-chemical researches led to the belief of its being, like barytes and lime, a metallic oxide*" (Ure, 1828, 134).

'Alunite' remains the correct tern for the natural alum mineral used to make alun at La Tolfa. But many of the terms, such as 'schistus' or 'alum slate', used up to the late nineteenth century to identify the rocks used as 'ore' to obtain aluminium sulphate, are now obsolete or redefined. They were sedimentary mudstones, and did not yield alum but only the aluminium sulphate needed to make alum artificially.

In Britain the type of mudstone was 'shale', which splits horizontally into thin layers or 'laminae', representing successive episodes of deposition. This sediment formed by the settling of small particles of clay and mud out of suspension in water, in a low energy, calm environment, usually a freshwater lake or a fairly deep offshore marine area below the wave-base. Organic matter, both plant and animal, was present with the muds. Its decay, caused by bacteria, released hydrogen sulphide gas which reacted with iron in the muds and produced the mineral **pyrite.**

After millions of years of burial, exposure of the rock to air after quarrying or mining caused this pyrite to become oxidized, either naturally by bacterial action, or quickly by deliberate roasting. That produced the **sulphuric acid** needed to generate aluminium sulphate in the mudstone.

The word 'slate' is now used only to describe mudstones (familiar as roof-slates) which have undergone considerable metamorphic chemical changes due to natural heating, either in proximity to a major volcanic intrusion, or during very deep burial undrground. 'Schist' is now used only for a very highly altered metamorphic rock.

Alum Making in England:

In England, when **shale** ('**schistus'**) was used to make alum, large quantities of 'ore' had to be quarried and calcined, and much fuel was used to heat the resulting liquids. In Yorkshire suitable **alum shales** in the Jurassic Upper Lias extended south along the coast from Loftus south past Whitby to Blea Wyke. They were very widely exploited, especially after the end of the state monopoly on alum production.

Calcining was of fundamental importance to the success of the industry in Yorkshire. It was so fundamental that Turton in 1938 decided the German experts employed in 1607 could not have been the first to calcine the shale, as many later claimed (Turton, 1938, 76). They undoubtedly did improve the quality of the alum, mainly at the stage where the crystallized alum was purified. It remains unclear who first calcined the shale to generate commercial quantities of **aluminium sulphate**, to be extracted as the liquor for making alum.

Croker in 1764 hinted that calcination was not as essential as Turton came to believe: "*The alum slates near York, in England, are considerably sulphureous; by lying in the air, they become aluminous* [form aluminium sulphate] *of themselves; but to promote this effect they are usually calcined*" (Croker, 1764. 'alum').

Richard Winter in 1810 claimed that at least one bed of shale in Yorkshire did indeed produce aluminium sulphate readily without the need for calcination:. "*An ingenious landscape painter, and a good mineralogist, Mr. Bird, of this place* [Whitby], *has recently discovered a new variety of alum rock, containing silex* [silica] *and sulphur, with oxide of iron. This rock effloresces on exposure to the atmosphere, and a sulphate of alumine is produced. The Stratum is of great extent, and inestimable value. I am not permitted to point out its location"* (Winter, 1810,245)

In 1784 Bergman recorded his understanding of the chemical processes involved when carbon-rich shale was used to make alum: "*The bituminous ore, in its sound and natural state, contains indeed the vitriolic acid and the argillaceous matter, but not yet combined. In order that the pyrites may yield its acid for that end, it is necessary that it should be destroyed; and this may be effected either by a slow spontaneous calcination, or by roasting, which takes less time"* (Bergman, 1784, 354).

The spontaneous process required the ore to be piled up on clay-lined platforms, and left there for a long period of time, just as was done at a copperas works. Early chemists had a mistaken view of the reactions involved. *"The destruction of the pyrites is necessary, that its sulphur may be deprived of* ***phlogiston****; for when that is dissipated, the vitriolic acid, being set at liberty, attacks partly the iron, and partly the clay"* (Bergman, 1784, 354).

Pyrite decay can cause **combustion**. "*The aluminous schistus* [in Yorkshire] *abounds with pyrites, which makes it subject to spontaneous combustion, when great quantities of that substance become suddenly exposed to moisture and the effects of the atmosphere. Some years ago* [before 1817], *a considerable part of the cliff between Sandsend and Kettleness fell down and took fire, and continued to burn for two or three years" (*Young, 1917, 2, 771; Winter, 1810, 246). A similar fire caused by pyrite occurred in 1751 in the cliffs near Charmouth in Dorset, when a very hot, dry season was followed by heavy rainfall (Watson, 1782, 1, 197).

In **Yorkshire, piles of shale** for making alum were **ignited using brushwood**, and in 1817 'underwood' and furze (gorse) was still used (Young, 1817, 2, 811; Clow & Clow, 1952, 237). Beckman in his 'History of Inventions' claimed that from 1678 coal was used in Yorkshire to calcine the shale, but this has not been verified (Clow & Clow, 1952, 237). The Encyclopaedia Britannica of 1842, published in Edinburgh, contained an article on alum by a chemist familiar with the industry in Scotland, who admitted he had not visited Yorkshire. He claimed, apparently mistakenly: "*At Whitby, coal is employed for roasting the alum-slate. Indeed the alum-slate of Whitby is lighter coloured than that of Sweden, and probably would not burn of itself*" (Enc.Brit., 1842, 1, 575).

Yorkshire shale contained sufficient carbon to continue burning slowly for months. Thomas Pennant observed the shale at an alum works near the road from Scarborough to Robin Hood's Bay in the 1769 : *"It is first calcined in great heaps, which continue burning by its own phlogiston, after being well set on fire by coals, for six, ten, or fourteen months, according to the size of the heaps, some being equal to a small hill"* (Pennant, 1774, 28).

In the heaps, hot pyrite (ferrous disulphide) lost half its sulphur as sulphur dioxide gas which was wasted, while the remaining residue of ferrous monosulphide reacted with water to form hydrated ferrous sulphate, **copperas.**

At elevated temperatures the copperas then changed to **sulphuric acid** which reacted with the aluminosilicates to make **aluminium sulphate**. The temperature during burning had to be hot enough to produce the acid, but not enough to decompose the aluminium sulphate into clay and anhydride (Turton 1938, 104).

After nine months, combustion heaps were cooled gradually (the 'mellowing' stage) so any accidental sulphuric anhydride had time to react with the clay to make more sulphate. The heaps were then opened and water was used to dissolve the sulphate, making the '**mother liquor'**.

This was carried along channels into the alum house to be heated over furnaces. Stone from Whitby abbey was used to build some furnaces (Turton 1938, 107). Barrels of **human urine** containing ammonia were then added to produce ammonium-aluminium sulphate or alum.

Thomas Chaloner of Lambay received one penny per firkin for his urine in c.1607 (Turton 1938, 76). Some works kept 20 tons of urine on site (Turton 1938, 125). Alternatively, potash from burnt seaweed or kelp was added, to give a double potassium-aluminium sulphate, another type of alum (Balston, 2015).

This was important because different mordants produce different colours from the same dyes (Clow & Clow, 1979, 250. The two types of alum were very similar in the amount of sulphuric acid required (from pyrite) and their final weight (for transport to markets).

"*When the ore itself does not contain potash, as that of la Tolfa does* [contain*], it is necessary to add a sufficient portion of this alkali, or of ammonia; to furnish which many use putrid urine. Some of the English manufacturers use a lixivium* [solution] *of the ashes of kelp; but this is a bad practice, as only the potash in these is of any service"* (Nicholson, 1808, 'alum').

"*When, instead of potash or its salts, the ammoniacal salts are used, or putrid urine, with the aluminous lixivia* [liquor off calcined shale], *ammoniacal alum is produced, which is perfectly similar to the potash alum in its appearance and properties*. [In the laboratory] *At a gentle heat both loose their water of crystallization, amounting to 45 ½ per cent. for the potash alum, and 48 per cent. for the ammoniacal. The quantity of acid* [consumed*] is the same in both, as* [is], *also, very nearly the quantity of alumina*" (Ure, 1842, 44). "*Ammoniacal alum is easily distinguished from the other* [in the laboratory] *by the smell of ammonia it exhales when triturated* [ground to a fine powder] *with quicklime"* (Ure, 1842, 44)

The **crucial difficulty** in making alum salt was that the '**mother liquor' contained both aluminium sulphate and copperas, which had to be separated.** The addition of alkali changed the aluminium sulphate into alum, and encouraged its crystallization and precipitation, but had to be postponed until the 'mother liquor' had reached the appropriate concentration.

Alum is less soluble in water than is copperas. Alum salt could be extracted separately as crystals from the combined solution by heating the liquid in expensive pans over furnaces until the concentration increased to the correct level.

Salt solubility decreases as the temperature of the solution falls, so the most difficult problem was judging the correct concentration while the liquid was still hot. Doing so ensured that the solution, when cooled, produced only alum crystals and left the copperas still dissolved.

Too concentrated and the product would be a mixture of alum and unwanted copperas crystals. One great secret of alum production was the fact that a hen's egg would float on the surface of the hot liquid when the correct concentration was reached (Osborne, 1998, 22).

Once the alum had been crystallized and removed, further concentration of the remaining liquid, by heating and cooling, allowed the copperas to also crystallize and be collected.

In a detailed account from 1625, the quarried shale (called *'**mine***) was calcined and then transferred to sunken tanks (Turton, 1938, 104). The earliest tanks were lined with wood. Those of 1625 had stone walls and a floor of deal planks. They measured between 26 and 29 feet by 12 feet, and 3 feet deep. The tank was then filled with water.

A day later this liquid was run off and added to freshly calcined shale in another tank. This was repeated until sufficient strength (concentration or density) was achieved, as indicated by a **floating egg** (Turton, 1938, 105). Other, more elaborate techniques, to establish its density (**specific gravity**) could also be used. By 1784 Bergman had revealed the secret that *"Some take the floating of a newly laid egg as a token of the boiling being finished – The specific gravity of such an egg is about 1,081"* (Bergman, 1784, 365).

Nicholson reitterated this in 1808: "*Some take the floating of a **newly laid egg** as a token of the boiling being finished; a rough method indeed, as well because the part above* [at the top of] *the liquor may be very different* [to that below], *and likewise because the specific gravity of an egg soon changes. The specific gravity of a fluid which just prevents the newly laid egg from sinking is 1.081*" (Nicholson, 1808, 'alum')

An alternative, and similarly once secret method to find specific gravity, used a **short-necked bottle** holding about one third of a pint of liquor or 'lees' (Young, 1817, 2, 814; Winter, 1810, 252). It was first filled with distilled water, or clear spring water, and placed on one side of a good pair of scales. A piece of **lead called the "*water weight***" or "*counter weight*" was cut to exactly balance the water-bottle on the scales. The bottle was then emptied and dried, and put back on the scales. Small, uniform **lead spheres** (called "*shot*") were then added alongside the empty bottle until the scales balanced.

That total quantity of lead spheres, which exactly matched the weight of the original water, was called "***80 pennywts***." (penny-weights). This quantity could be subdivided "*to form 40, 20, 10, 5, and 2 ½ pennywts.; with smaller fractions as low as ½ and ¼ ".* Alum liquor was then put in the bottle, which went on one side of the scales, while on the other side was placed the "*water weight*" plus however many lead spheres (shot) were necessary to balance the scales. If "*80 pennywts*" of shot was needed, the liquor had twice the weight of pure water. "*The relative specific gravity of any fluid may be ascertained, 80 pennywt. being equivalent to 2.0, and 1 pennywt to 1.0125*" (Young, 1817, 2, 814).

Once a suitable concentration had been achieved, the 'Liquorman' added some recycled 'mother' liquor from later in the process. The 'Houseman' supervised labourers boiling this solution for a day in lead pans measuring 9 feet by 5 feet and 2 feet 6 inches deep. These lead pans were set in furnaces of brick (Turton, 1938, 125)

.From every eight pans the liquid was run off into three 'settlers' where it was mixed with urine or alkaline 'lee', and a chemical reaction occurred, producing the alum compound. Sediment was allowed to settle out. After two hours the liquor was channelled to coolers, made of deal planks, and left to crystallize.

Four days later whatever liquid remained (called 'mothers') was recycled. The alum crystals were then collected into a tub. These crystals were washed with "water" (a solution containing some alum), and then left in bins with holes, like colanders.

The alum was later dissolved and boiled a second time, using the least possible amount of water needed to completely dissolve it while boiling. The solution was then transferred into '***roaching*' casks** and left to crystallize. About two weeks later, all residual liquor was run out of these, to be used as "*mothers and green liquors*". It was recycled to the boiling pans, or used as "water" for washing new alum crystals, or for making copperas.

The alum crystals were then removed, by dismantling the casks, and those from the centre of the cask were ready for marketing. German craftsmen had explained to the early Yorkshire alum makers that the impure crystals coating the base and walls of the cask had to be scraped out and recycled, not sold as alum. The process was complex and skilful..

(38 A) Georgius Agricola - Alum and Copperas production in 1556

The 1556 Latin edition of 'De Re Metallica' by Georgius Agricola detailed several alternative methods of producing Alum and Copperas. When Herbert Clark Hoover and Lou Henry Hoover translated the book, they also researched the history and technical details of the processes described, and explained these in footnotes after each 'Book' or chapter. Some of the techniques are only explained in outline, and possibly not always entirely accurately, leaving plenty of scope for errors by novices trying to copy them, and sometimes giving difficulties for modern chemists trying to reconcile the descriptions with known chemical reactions. Book XI dealt with the production of "*solidified juices ... prepared from waters in which nature or* [human] *art has infused them*", such as sea-salt, saltpetre, and alum.

The first method of preparing alum (page 565) involved digging three hundred wheelbarrows volume of alum "earth", and then submerging it in large tanks of water to which urine was added. The Hoovers regard this "earth" as having been shale rock. The ore had to be stirred manually in the tanks for many days, using long poles, until a solution had been produced of sufficient concentration to be run-off ready for further concentration by evaporation. If the ore also contained '*vitriol'*, then the urine was not added until after the solution had been run off into the second set of tanks, where Agricola claimed the urine would cause it to divide into separate portions. Those would accumulate near the top and the base of the tank, and could be run off separately. The Hoovers state that this was a misunderstanding of the chemistry, since the urine would convert aluminium sulphate in the original solution into ammonia alum which would precipitate out and could be recovered from the lower portion of liquid.

The second method seemed to the Hoovers to be only appropriate for rich alum ore, and was probably that used on Alunite ore at the Pope's works in La Tolfa. However, it is likely to be the method adopted by Mountjoy in Dorset, because it closely resembles the techniques suitable for copperas production. The ore was *"first conveyed into open spaces and heaped up, for the longer it is exposed to the air and the rain, the better it is; after some months ... there are generated veinlets of far better quality... Then it is conveyed into six or more tanks, nine feet in length and breadth and five in depth, and afterwards water is drawn into them of similar solution*" prepared earlier. Alum dissolved out of the ore, and the enriched solution was then drawn off. The residue of ore was then covered in water and urine, and stirred with poles, to recover any remaining alum. The alum solutions were evaporated by heating in lead pans, then run into a sunken tub to cool, and finally run into vats where the crystals condensed on "*horizontal and vertical* [wooden] *twigs*". This produced "*small white transparent cubes, which are laid to dry in hot rooms"* (page 568)

In the third method, deemed by the Hoovers to apply to shale, "*Aluminous rock is first roasted in a furnace similar to a lime kiln"* (page 569). This took about eleven hours and expelled sulphurous fumes. The ore was then heaped up outdoors and sprinkled with water two or three times a day for forty days. It was then boiled in water in a large copper cauldron set over a furnace, to produce a strong alum solution which was eventually poured into troughs to crystallize.

Fourthly, *"Alum is also made from crude pyrites and other aluminous mixtures. It is first roasted in an enclosed area; then, after being exposed some months to the air in order to soften it, it is thrown into vats and dissolved. After this, the solution is poured into the leaden rectangular pans and boiled until it condenses into alum. The pyrites and other stones which are not mixed with the alum alone, but which also contain vitriol, as is most usually the case, are both treated in the manner which I have already described*" (page 572). This probably required similar treatment to the first method.

Agricola described various methods for making '*vitriol'* meaning copperas (ferrous sulphate) (page 574). One began with natural water enriched in 'vitriol'. Another used mined ores of '*melanteria*' and 'sory', which were left in tanks of water to dissolve and produce a solution of copperas. Alternatively, "*the vitriolous pyrites ... are roasted as in the case of alum, and dissolved in water, and the solution is boiled in leaden cauldrons until it condenses into vitriol. Both alum and vitriol are often made out of these, and ... these juices are cognate, and only differ in ... that the former is less, and the latter more, earthy*" (page 578).

Agricola's method of making 'vitriol' "*from vitriolous earth or stones*" is that which most lclosely resembles the techniques used in Dorset at the end of the sixteenth century (page 577). "*Such ore is at first carried and heaped up, and is then left for five or six months exposed to the rain ... and to the rime and frost of winter".* It was periodically "*turned over several times with shovels*" until it "*crumbles and loosens, and the stone changes from hard to soft*". The ore was then roofed over, or carried below a roof, for six to eight months, before being "*thrown into a vat*" measuring "*one hundred feet long, twenty four feet wide, and eight feet deep*", half filled with water. An opening through the base of the vat allowed later removal of the dregs of ore. "*At the height of one foot from the bottom, three or four little holes*" were present in sides of the vat, and were sealed but could later be opened to drain out the solution. In the vat, the ore was "*stirred with poles and left in the tank until ... the water absorbs the juices"*. Then the solution was drained out, "*and is caught in a vat below it, ... the same length as the other, but twelve feet wide and four feet deep*". It seems most unlikely this vat was set vertically below the first vat, but was probably located nearby down a slope.

If that solution proved too weak, it was recycled over more of the softened ore. If it was suitably strong, the old ore was treated with more fresh water to capture any '*vitriol*' that remained undissolved. A solution of suitable strength "*is poured into the* [main] *rectangular leaden cauldron through launders, and is boiled until the water is evaporated"*, to an undisclosed concentration. "*Afterwards as many thin strips of iron as the nature of the solution requires, are thrown in, and it is boiled again until it is thick enough, when cold, to congeal into vitriol"* (page 578). It was then poured into vats and left two or three days to cool and allow the copperas crystals to form. The remaining solution was then run out, and either re-boiled to concentrate it further, or was used in the first vat to dissolve new, softened ore. From the vats, "*the solidified vitriol is hewn out, and ... thrown into the caldron, is re-heated until it liquefies; ... [then] poured into moulds that it may be made into cakes"* ready to transport to market. One surprising omission from this account is the absence of organised channels to collect the liquid running off the ore while it was originally exposed to rainfall outdoors to become softened. The earliest descriptions of English copperas works show their pyrite was placed on specially constructed platforms, with channels and collecting cisterns. These collected the runoff of rainfall trickling through the ore, and this provided the entire supply of copperas liquid, ready for later concentration by evaporation in large open pans heated by a furnace. The ore was not put into a vat of liquid to be stirred.

(39 A) Daniel Colwall: on alum production in 1677

In 1677 Daniel Colwall (d.1690) F.R.S., a merchant and philanthropist, prepared two accounts, describing for the Royal Society the manufacture of alum and of copperas (Colwall, 1677; DNB, 12, 839). These were published in the *Philosphical Transactions* and are often quoted by modern authors (Lowthorp, 1705,2, 538). The techniques had probably changed little over the previous fifty years.

"*Alum is* [made of] *a Stone digged out of a Mine* [quarry], *of a Seaweed, and Urine*". The stone was "*a blewish colour,… like Cornish slate*". Within the shale ('ore'), confusingly called '**Mine'**, there sometimes occurred 'veins' called 'doggers' which were of poorer quality.

Quarries existed in the Yorkshire hills between Scarborough and the River Tees, and also near Preston in Lancashire. Colwall is thought to have based his account on the alum works of Yorkshire. In a good alum quarry the ground was moist, but not too dry or too wet

The *'Mine'* ['ore'] was up to 20 yards below the ground surface, and that overburden had to be "*taken off and barrowed away*". Quarrying was best started along the side of a hill, at a site with access to water. "*They digg down the* ['ore'] *Mine by stages, to save carriage; and so throw it down near the places where they Calcine it".*

Any 'ore' exposed naturally to the air, would "*moulder in pieces, and yield a Liquor whereof Copperas may be made; but being Calcin'd , is fit for Alum".*

While the '*Mine'* remained underground, or was kept submerged "*in Water, it remains a hard Stone*". "*Sometimes a Liquor will issue out of the side of the* [excavated 'ore' or] *Mine , which by the heat of the Sun is turned into Natural Alum*".

"*The Mine* ['ore'*] is **calcined with Cinders of New-Castle Coal, Wood and Furzes**. The fire [*fuel*] made about two feet and a half thick, two yards broad, and ten yards long. Betwixt every fire are stops made with wet Rubbish; so that any one or more of them may be kindled, without prejudice to the rest."*

That base layer of fuel was then covered by 'ore' or "*Mine*" to a height of 8 to 10 yards. A group of five or six adjacent heaps was prepared and ignited together.

As the fire burned up towards the top of these heaps, more 'Mine' was added onto the top, without requiring any extra fuel. Eventually, heaps about 20 yards high were fully calcined without adding extra fuel, since they burned "*stronger than at the first kindling, so long as any Sulphur remains in the Stones*".

Windy conditions during calcining affected alum quality. In some heaps, wind could tunnel the fire "*too quickly through the Mine, leaving it black and half burnt; and in others* [result in*] burning the Mine too much, leaving it Red."*

A good, steady burn "*leaves the Mine white, which yields the best and greatest quantity of Liquor".* The calcined 'Mine' was then placed in **water tanks** to dissolve out the alum salts.

The tanks were 10 yards long, 5 yards wide and 5 feet deep, described as "*Pits of water, supported with Frames of Wood, and rammed on all sides with Clay".* A nearby water supply was required to service them. Water-pumps to move 'liquor' around were also necessary.

The system involved a circuit of four tanks, which were operated together.

The **strength of the alum solution** was raised by passing it through all four tanks in sequence, leaving it for 24 hours in each tank.

Fresh water (called "***Virgin-Liquor***") had the greatest power to dissolve alum into solution. It was run into the tank which contained calcined 'Mine' that had already been submerged three times, in order to dissolve whatever alum remained.

One day later, it was pumped into a tank where the 'Mine' had already been submerged for three days running; and the next day pumped over 'Mine' previously submerged for two days.

Finally the solution entered a tank with freshly calcined 'Mine' with the greatest capability of yielding alum. After a day there, it was sent to the boiling house.

Increasing concentration of the liquor was judged by the weight it gained.

The "*Virgin Liquor*" usually increased in concentration in the first tank of "*Mine*" to "*two pound weight*", in the second tank to five pounds, in the third to eight pounds, and in the fourth tank to twelve pounds.

The **final concentration** (weight) achieved varied week by week, depending on the quality of the "*Mine*" and the success of the calcining process. The final value could be as low as six or seven pounds, or as high as twelve or more.

"*The Liquors are weighed by the Troy-weight. So that half a pint of Liquor must weigh more than so much [*an equal volume of*] water, by so many penny weight".*

In the **Troy weight system**, one pound was equal to twelve ounces. Troy weight was normally used for precious metals and gems. One penny weight was one twentieth of one ounce in Troy weight. One ounce Troy was about 31 grams.

One pound Troy was therefore about 372 grams. One half pint of Liquor from the first tank, at two pounds weight, would therefore mean that half a pint weighed 744 grams. This can be compared to pure water.

Because of impurities, the **weight of the liquor** (representing its concentration), was a poor guide to the final output of alum. Sometimes a liquor of six or seven pounds gave more alum than one of ten or eleven pounds.

Experience showed that passing any weak liquor through an extra tank of freshly calcined 'mine' to improve it was a bad practice. Instead of increasing the alum content, it could instead dissolve mainly "*Nitre and Slam, which poisons the good Liquors, and disorder the whole House, until the Slam be wrought out".*

Slam was the name for a fine suspension of red particles, caused either by poor quality '*Mine'*, or more usually by bad calcining. Slam had to be removed in the '*Settler*' as a red sediment. Liquor which was white when it left the fourth tank gave the best alum.

At the start of operations using a set of four tanks, the alum output came entirely from the 'mine' ore "*without any other ingredients*". As production continued, kelp and urine were used to boost output.

Colwall found it necessary to explain that **kelp** was "*a sea-weed, called Tangle, such as comes to London on oysters*". This grew on rocks between the high and low tide marks. "*Being dried, it will burn and run like Pitch; when cold and hard, 'tis beaten, steeped in water, and the Lees drawn off to two pound weight, or thereabout*."

Colwall indicated that **urine** was obtained locally, rather than from London. "*Because the country people, who furnish the work with urine, do mingle it with sea-water"*, and such fraud could not "be *discovered by weight*" of the urine, a small amount always needed to be tested by adding it to boiling alum-liquor. "*If the Urine be good, it will work, like Yest* [*yeast*] *put to Beer".* "*The best Urine is that which comes from poor labouring People, who drink little strong Drink".*

In the production sequence, the liquor spent twenty four hours in each of the four **tanks of 'mine'**, before it was sent to the boiling house. Each batch of 'mine' in a tank was exposed to liquor four times before it was removed and thrown away.

Colwall did not explain the detailed arrangement of the tanks, but a complex arrangement of pumps and freshwater inlets was clearly required. The weakest liquor had the greatest capacity to dissolve alum, so it was used to draw alum out of 'mine' that had already given up most of its alum.

On the fourth day, the strongest liquor reached the tank which had just been filled with freshly calcined 'mine' to boost its concentration as much as possible before it went to the boiling house.

The arrangement of tanks and of liquor circulation had to ensure that on the last day of each production run the liquor entered a tank containing fresh calcined 'mine'. That tank had to be a different one each time, to ensure that every tank was restocked with fresh calcined 'mine' over the course of four production cycles.

At the boiling house, the **boiling pans** or '*Boilers'* were 9 feet long, 5 feet wide, and 2 feet 6 inches deep. They were made of lead, *"commonly new cast*", and rested on iron plates about two inches thick. The iron plates required repair about five times over each two year period.

The boiling pans were kept warm over damped-down fires during the interval between successive sequences of operation.

At the outset, the boiling pans were two-thirds filled with a concentrated recycled alum solution ("*wherein the Alum shoots*" forming crystals), still warm from the previous run, and "*which they call Mothers*". To this was added a fresh batch of cold liquor from the last tank of 'mine', to fill the pans.

The fires were then stoked up, and brought the liquor to boiling after about two hours. Thereafter, evaporation reduced the liquor volume by a depth of four inches every two hours, and more "*green Liquor"* was added.

This evaporation and refilling continued every two hours for twenty four hours, raising the concentration to "*thirty six pound weight".* If the quality was good, the liquor would simmer well on the surface, but "*if Nitrous, it will be thick, muddy, and red".*

Finally, a hogs-head (about 50 gallons) of **Kelp lees** solution, "*of about two peny weight",* was added to the '*Boyle*r'. This changed the solution concentration "*too about twenty seven pound weight".* If the alum liquor was of poor quality and nitrous, then extra, stronger lees would be added.

From the Boiler, the liquor was transferred to a "*Setler*", of the same size and also made of lead. Over the following two hours, "*most of the Nitre and **Slam** sink to the bottom*".

Colwall wrongly believed that the main function of the **Kelp lees** was to cause this precipitation of impurities, rather than contributing a chemical component of the alum itself. He stated that when the Boiler was filled only with "*Green liquor drawn from the Pits"* or tanks of 'mine', without adding any "*Mothe*r" liquor, then it was not necessary to use the kelp.

From the **Settler**, the liquid was "*scooped out*" and transferred to a **Cooler** made of wooden deal-boards rammed with clay. In the Cooler, 20 gallons of urine was added, and more if the liquid was red and nitrous. "*The use of Urine, is as well to cast off the Slam, as to keep the Kelp-Lees from hardening the Alum too much".*

During "*temperate weather*" the solution was left for four days in the Cooler, before the remaining liquid was removed and then the alum crystals collected. During "*the second day the alum begins to strike [*crystallise*], gather and harden about the sides, and at the bottom of the Cooler*".

If it was left longer than four days, "*it would as they say turn to Copperas*". "*In hot weather*" the solution was left in the Cooler one extra day.

In frosty weather the alum crystallized too quickly, before any remaining Nitre and Slam had settled out. The result was a mixture of all three, and the impurities may have caused the whole of it to dissolve during later washing: "But being foul, is consumed in the washing".

After four days or so of cooling, the remaining liquid was "*scooped into a cistern*", and became termed the **"*Mothers***", which would later be recycled into the boiling pans: "*The Mothers are pumped back into the boyler again".*

Colwall's description of the recycling suggests that the Boilers were only operated once every five days. This is significant because it implies is that the entire four-tank system of seeping the 'Mine' in liquor ran on a single five day cycle.

Thus freshly calcined 'mine', and a fresh influx of "*Virgin Liquor"* water was added every five days, and not every day as it could have been under a continuous production regimen. "E*very five days the liquor* [*'*mothers*'*] *is boyled again until it evaporate or turn into Alum or Slam".*

Once the '*mothers*' liquor was removed from the Cooler, workmen could reach the layer of alum crystals coating its sides and bottom. These were gathered and put "*into a cistern, and washed with* [reused] *water that hath been used for the same purpose"* and already had a concentration of "*about twelve pound weight*".

By recycling this solution for use as the so-called **'water' for 'washing' alum crystals**, the operators avoided completely re-dissolving the alum.

"**Roaching**" was the next and final process. The washed alum crystals were dissolved in the minimum possible quantity of hot water: "*put into another Pan with a quantity of Water, where it melts* [dissolves] *and boils a little. Then it is scooped out into a **great Cask**, where it commonly stands ten days, and is then fit to take down for the Market."*

When John Wilson researched the history of alum making in 1812, to prepare his description of the new alum industry in Renfrewshire, he found that: "*accurate accounts of the Whitby process have been published by Mr. Colwall in the Philosophical Transactions for 1666, and by Mr. Walker in Nicholson's Journal for 1810. With the exception of the use of a greater variety of salts with pot-ash base* [replacing urine], *no important change has been made in this long interval"* (Wilson, 1812, 278).

(40 A) Deptford Copperas Works: 1677

Copperas, known in commerce as Green Vitriol, or English Vitriol, was the name for the pale green, crystalline, hydrated (heptahydrate) salt now called Ferrous Sulphate (Hicks, 1963, 540). "*This salt is called green Vitriol; green from its colour, and vitriol from its resembling vitrum, or glass, by its transparency*" (Watson, 1782, 1, 210). Oil of Vitriol was the name for Sulphuric Acid, which for centuries was normally made by heating copperas to release sulphur trioxide and sulphur dioxide gases, which were then dissolved in water.

Daniel Colwall (d.1690) in 1677 recorded the raw material required for ferrous sulphate manufacture as "*copperas stones, which some call Gold-stones"*, now called pyrite, obtained from the beaches of Essex, Hampshire, and westwards. He based his account on the important **Deptford copperas works**, where Sir **Nicholas Crisp** had introduced some important improvements of his own design. Sir Nicholas was also involved in alum production in Yorkshire. Richard Watson commented a century later, "*there is, perhaps no mineral more commonly met with than that which is composed of iron and sulphur…This mineral is called in some parts of England, copperas-stone; in others, brazi*l", or brass-lumps, or horse-gold, or marcasite, but "*the scientific name is Pyrites…The pyrites also, accidentally, contains copper, silver, and perhaps gold*" (Watson, 1782, 1, 190).

Watson was aware of the patent of Cornelius Devoz to make alum and copperas, but had been unable to determine when copperas production began in England. No copperas was thought to have been exported until the end of the seventeenth century, wheras about 500 tons were then being imported each year (Watson, 1782,1, 227}. By 1782 England exported 2000 tons of copperas annually. The Port of London had handles 400 tons of copperas for export between January and March 1776. Only about 50 or 60 tons of copperas was still imported, for use by those dyers who prefered it "*as containing a little copper*" (Watson, 1782, 1, 228)

By 1780, experiments involving iron being dissolved in sulphuric acid (made by burning pure sulphur from Italy), to make copperas salt, had proved that copperas or "*green vitriol consists of the acid of sulphur united to iron, or more properly to the earth of iro*n" (Watson, 1782, 1, 208)

Deptford, about four miles downstream from London Bridge**,** had become an industrial site processing pyrite in mistake for gold-ore in the late sixteenth century. **Sir Martin Frobisher (c.1535-1594)** (DNB, Frobisher 21, 52), was financed by the Muscovy Company under the direction of **Michael Lok** (Locke, c.1532-1620/22) to explore for a **Northwest Passage** to Cathay and the far East. (Ricard, 2015, 15). Lok's brother John had been a captain on Frobisher's second voyage to West Africa (Ruby, 2014). Michael made a large fortune, probably in the cloth trade, and by the early 1570s was the London agent of the Muscovy Company, overseeing all trade to and from Russia. He cultivated a close friendship with Frobisher in 1575 (Ruby, 2014).

Frobisher opened a mine on the small Kodlunan Island, close to Baffin Island in the Canadian Arctic, and, returned in 1576 with a sample of black stone he thought was sea-coal. Lok claimed the pyrite in it was gold. Three reputable analysts could find no gold, but the alchemist Giovanni Baptista Agnello produced gold which he stated was from the stone.

Frobisher had a long time connection with the gold trade. As one of the five children of Bernard Frobisher, his widowed mother sent him to her brother, his **uncle Sir John Yorke**, at the Mint in London, for his education (McDermott, 2001, 22). Yorke had been a trader to Antwerp, a spy for Thomas Cromwell, and in

1544 Assay Master oft the Tower Mint. By 1549 he was a leading London merchant, Under-treasurer at Tower Mint and Sheriff of London. He was responsible for setting up the new Southwark Mint in 1551 (McDermott, 2001, 22).

In 1577 the **Cathay Company**, established and promoted by Michael Lok, financed Frobisher's second expedition to 'Meta Incognita'. He took a German assayer, Christopher (Jonas) Schultz the former assistant to Agnello, and returned with red sandy rocks (possibly weathered gossan). Again, reputable analysts could find no gold, but the rock was smelted by Schultz at Lydney Manor in the Forest of Dean, where he claimed to produce gold. Burchard Kranich, a mystic healer trusted by Queen Elizabeth, also made gold from the ore using a special 'flux', but falsified the test by hiding gold in the 'flux' (Ricard, 2015, 17).

Christopher Schultz (1521-1592) was a German copper worker who, with his workshop, had originally been brought to England by William Humphrey (c.1515-1579) on behalf of the Company of Mineral and Battery Works (Price, 1906, 55). 'Battery' referred to the hammered metal goods the company produced.

Cecil had encouraged Humphrey's project to reduce English reliance on imports of the iron wire required for the 'cards' used to comb wool for making cloth. The Company opened the first British wireworks at Tintern, Monmouthshire, in 1567. Schultz was supposed to also make brass there, using ore from the Mendips, but this was not successful. Even the wire was regarded as inferior to imported wire.

Schutz was commissioned in 1577 to build a very large **blast furnace at Deptford** to process the Arctic ore. Frobisher returned to the Arctic with 150 impoverished recruits falsely called 'miners', to establish a colony. They failed to locate the red rocks, but collected 1370 tons of black, hornblend-rich rock that was taken to Deptford. Special smelters were built, with water-powered bellows, but **the 'gold' was pyrite**, fool's gold (Pearce, 2003, 44).

Worthless **unsmelted ore was dumped** nearby to weather naturally. Lok and Schultz unsuccessfully promoted a new scheme to use the smelter in 1580 (Skepton, 2002, 99). Schultz kept the official title 'Master of the Works for Ores from Cathay and the North West Parts'. After his death in 1592, that position was given to Sir Bevis Bulmer (d.1615) (qv).

It is likely that some attempts were made to profit from the weathering pyrite rich mounds. Making copperas was an obvious possibility. The site of the smelter itself was used in 1586 by the first English paper-mill, run by John Spilman.

Some time subsequently an important **copperas works was established at Deptford**, and by the late seventeenth century it was supplied mainly with pyrite from the Isle of Wight (Colwall, 1677; Lowthorp, 1705, 2, 531).

At **Deptford in 1667**, Colwall found the **outdoor beds for processing pyrite** were "*about an hundred feet long, fifteen feet broad at the top, and twelve feet deep, shelving all the way to the bottom"*. They were **lined with clay** to make them impermeable, and strengthened with stone, possibly flint: "They ram the bed very well, first with strong clay, then with the Rubbish of Chalk".

This bed was covered with pyrite stones to a depth of about two feet. A shallow wooden trough across the centre of the base of each bed collected the copperas liquor released after rainfall, and carried it to **a Cistern** built of oak boards. The Cistern could hold 700 tons of liquor and was located under the Boiling-House.

"These Stones will be five or six years, before they yield up any considerable quantity of Liquor". Later accounts of the process suggest that Colwall was misinformed about the time taken. The process required rainfall, and it was believed that artificial watering with perforated watering cans actually hindered the production of a useful liquor solution.

"In time these Stones will turn into a kind of Vitriolick Earth, which will swell and ferment like leavened Dough". Every four years, new pyrite stones were added to the top of a bed. Whenever a new bed was constructed, it was necessary to "take a good quantity of the **old fermented Earth, and mingle with new Stones**, whereby the Work is hastened".

This would have **transferred suitable bacteria** to the new bed of pyrite. The strength of the liquor produced was measured by its weight. "*Fourteen peny weight is Rich. Or, an Egg being put into the Liquor, the higher it swims above the liquor, the stronger it is*."

The **Boiler House** had brick-built furnaces. About two feet above the surface of the fire (burning New-Castle coals), massive cast-iron beams 12 inches square in cross-section and over 8 feet long spanned the furnace at intervals of one foot. This was to support the weight of the Boiler. Above these beams they positioned "ordinary flat Iron Bars, as close as they can lye", to protect the Boiler from the fire.

The *'**Boyler**'* was made of lead and about 8 feet square. It held about 12 '*tuns'* of liquor. Placed at the centre of the base inside the Boiler was a lead 'Trough' containing 100 pounds of old scrap iron. During the boiling process, extra iron was added to this, gradually rising to a total of 1500 pounds.

The Deptford furnaces were designed to spread heat across the base and sides of the Boilers. The works output was three Boilers of liquor per week. Working conditions were unpleasant. "*The steam which comes from the boyling is of an acrimonious smell".*

Sir Nicholas Crisp made sure that adequate amounts of **scrap iron** were added to the boiling solution. "*As soon as they perceive the Liquor to boyl slowly, they put in more Iron, which will soon quicken it".*

Without that scrap iron, the copperas liquor could only be boiled "*with difficulty*", and *"the Boyler will be in danger of melting*". Unless there was enough iron added, "*the Copperas will gather at the bottom of the Boyler and Melt*".

As the liquid evaporated from the Boiler, more was pumped in from the Cistern. After about 20 days the strength of the **liquor was tested** by placing a small amount in a shallow earthenware pan, to observe how quickly crystals formed on the sides.

To prevent the lead Boyler from melting, it was important to remove the liquor to the Cooler as soon as the solution was sufficiently strong, and presumably to also reduce the furnace fire.

An important innovation at Deptford, made by Sir Nicholas Crisp, was the use of a '**Heater' supplied with waste heat** from the furnace, to **pre-heat the cold liquor** as it arrived from the Cistern to be used to top-up the Boiler. The Heater was made of lead, just like the Boiler.

Previously, "*they were wont to pump cold Liquor into the Boyler to supply the waste [*losses due to evaporation*] in boyling, whereby the Boyler was checked [*cooled down*] some times ten hours."* The Heater was positioned at the end of the Boiler, and was more elevated, but was supported on iron bars just like the Boiler. "*By a conveyance of heat from the Furnance,* [it] *is kept near boyling hot*".

After boiling, the concentrated solution went to a **Cooler**. The Cooler was a cement tank made of "Tarras", which measured 20 feet by 9 feet, by 5 feet deep (tapering in towards the bottom). Here the copperas would crystallize (called "*gathering or shooting*") for 14 or 15 days.

A thickness of about five inches of crystals formed on the sides and bottom of the tank. Unlike many other Copperas works, Deptford did not insert bushes with small wood branches for the crystals to adhere to.

At all works of this type, the copperas "*which sticks to the sides, and to the Bushes, is of a bright green" colour.* But those copperas crystals that formed along *"the bottom* , [were] *of a foul and dirty colour*".

At the end of a fortnight, all liquid remaining in the Cooler was emptied out and transferred out into another, unused Cooler for storage. From there it was later recycled to the Boiler.

Copperas crystals were then recovered from the original Cooler: "*the Copperas they shovel* [out] *on [*to*] a Floor adjoining, so that the Liquor* [coating the crystals] *may drain from it"*, and be recycled. Colwall makes no mention of any further processing before the sale of the copperas.

In 1704 the description of copperas production used in a technology textbook published anonymously in London, the *Dictionarium Rusticum & Urbicum,* was closely copied from Colwall's account of Deptford.

A number of later changes in the mode of operation at Deptford are found in the much later account published in **1773** by **William Lewis**, probably based on observations by Casper Neumann, a professor of chemistry in Berlin. The accuracy of information divulged by the works to an outside observer is difficult to judge.

The initial **processing platform in 1773 was sloping**, and was covered in pyrite to a depth of only about six inches. Every ten paces, small channels run down the slope, carrying the liquor solution produced from the pyrite by natural rainfall. The channels discharged into wooden troughs running across the foot of the slope. Pyrite was said to remain on the platform for between a few weeks and eighteen months.

The wooden troughs carried liquor into a sunken wooden Cistern. From this, "*the liquor is laded up with wooden jets".* If it was sufficiently concentrated, it went into a trough leading to the boiling house.

Excessive rainfall produced a weak solution, which instead was "*returned by another canal*" and released onto the pyrite at the top of the platform. They deliberately avoided artificial watering of the pyrite, except during droughts.

Deptford received its '***Pyritae'*** **stones "*by water, chiefly from the Isle of Wight*,** *under the name of Copperas stones".* In his description of Alum Bay in 1781, Richard Worsley recorded that "*Copperas-stones are found on the coast, in such abundance, and of so good a quality, that vessels are often freighted with them for London".* (Worsley, 1781, 273). The seventeenth century account books of Sir John Hayward record the quantities of copperas supplied from the Isle of Sheppey to Deptford copperas works (MGB 2009). A plan of 1674 shows the works on the 200 acre Sayes Court estate which was rented from 1647 by the diarist and writer john Evelyn (1620-1706) (MGB 2009; DNB 2004, 18, 771). In 1695 a rival copperas works was opened in the area, at Lamb Lane in Greenwich, by Samuel Thompson (MGB, 2009).

During the Commonwealth, Sir Nicholas Crispe was the leading promoter of a project to build a mole at Deptford in order to create a harbour for 200 sailing ships. £6,000 was spent buying 200 acres of land in the parish of St Paul. After the Restoration, Crisp enlisted support from the Duke of Ormond, but Charles I would not support the project, which collapsed (VCH Deptford StPaul).

Richard Watson of Cambridge University recorded copperas technology at Deptford in 1782, but noted that throughout England "*all the vitriol* [copperas] *works have sunk in value of late years*" (Watson, 1782, 1, 226. : "***The acid****, which used to be* ***procured from the distillation of vitriol*** [copperas] *has been obtained from the burning of sulphur*" at rival works (Watson, 1782, 1, 226).

They had been undercut by new **sulphuric acid** works using the **lead-chamber process** devised by **John Roebuck** (1718-1794), in which pure sulphur (imported from mines in volcanic regions like Italy) was burnt, and the resulting sulphur dioxide gas dissolved in water (Smiles, 1863, 133)..

In partnership with the Birmingham merchant Samual Garbet (1717-1803), Roebuck opened an acid works in Birmingham in 1746, but the market was restricted by the difficulty of transporting acid in glass carboys by road (Clow and Clow, 1952, 133; Cotterill, 1991, 33). In 1749 the partners opened a much larger sulphuric acid works at **Prestonpans** on the Firth of Forth near Edinburgh, with the advantage of being able to ship large glass carboys of sulphuric acid by sea to distant markets (Clow and Clow, 1952, 135; Butt, 1967, 136; Cotterill, 1991, 43).

In 1782, "***Green vitriol*** *[copperas] is made at Deptford and other places, from a species of the* ***pyrites*** *found on <u>Shepey Isle</u>, the Isle of **<u>Wight</u>**, and various parts of the <u>Essex, Kentish, Sussex</u> and <u>Dorsetshire</u> coasts.*

Large quantities of the pyrites are laid in ***heaps in the open air****, on beds properly prepared; in half a year, a year, two years, sooner or later, according to its quality, the pyrites acquires a spontaneous heat; that heat, without being increased to such a degree as to fire the pyrites, insensibly disperses the inflammable principle of the sulphur, one of the constituent parts of the pyrites; the acid of the sulphur being thus disengaged [separated] from the inflammable principle,* [then] *unites itself to the other principal constituent of the pyrites, the iron, and forms green vitriol.*

The vitriol ths formed is washed from the pyrites' bed by the rain: the rain water which has dissolved the vitrion [copperas] *of the pyrites, cannot sink into the earth,* ***the bed*** *on which the pyrites is spread being*

formed of clay*; and being made, moreover, in a sloping position, the dissolved vitriol [copperas] runs into receptacles properly placed to receive it*" (Watson, 1782, 1, 225)

Then, after "*being* ***boiled with old iron*** *till it is of a proper consistency, it is run off into coolers, and left to crystallize. Vitriol may be made without the use of old iron, but the liquor which drains from the pyrites being often not saturated with iron, the iron is added to saturate the acid, and at the same time to purify it from any particles of copper it may chance to contain: by this means a* ***pure iron vitriol*** *[copperas] is obtained, which is known in commerce under the name of* ***English vitriol.***

The quantity of old iron [used] , in some works, amounts to two hundred weight in making a ton of vitriol.

Much after the same manner, vitriol [copperas] is made from the pyrites found amongst coal; there are manufactories of it near Wigan, at Whitehaven, at Newcastyle Upon Tyne and in several other parts of the kingdom" (Watson, 1782, 1,226).

Today on the Isle of Wight, pyrite is mainly found on beaches along the south coast, eroded from cliffs of Cretaceous rocks, especially beds in the Wealden and the Chalk.

On 29th August **1739,** a contract was signed between **John Rice** (or Rite), **copperas maker of Deptford,** Kent, and two local men from Brighstone (Brixton) near the south coast of the Island. They were to supply "merchantable copperas stones" for fourteen years from 29th September 1739 (IWRO 1739). John Rice was the copperas maker from 1736 to 1747 and issued trade tokens.

Richard Gosden, chapman, and John Smith, gardener, undertook to supply to Rice all the pyrite that was gathered by themselves, or by others under their instructions. They were to arrange for its transportation to Deptford, and would receive £1 5s 0d per ton. The contract included a penalty of £5 per ton on any copperas-stone (pyrite) they supplied to other parties, and the same penalty was applied to Rice if he refused to accept any delivery of proper quality pyrite.

Shipments continued throughout the eighteenth century. Richard Warner stated in 1795 that the copperas collected near Shanklin was "*sufficient to freight small trading vesels, which carry the same to the London markets"* (Warner, 1795, 263). Charles Tomkins in 1796 noted that copperas stones on the beaches from Freshwater Gate to Brixton (Brighstone), "*collected in great quantities by the inhabitants of the adjacent villages, are shipped for London, for the purpose of extracting the copperas*" (Tomkins, 1796, 1, 125). A record survives of one ton of copperas shipped from **Chale** on 28th June **1797,** followed by another three tons on 11th July, at 7s 6d per ton. Shipment was organized by Robert Wheeler, a local fisherman and smuggler (Hunt, 1902, 225-7).

(41 A) The Role of Bacteria in Copperas Production

Bacteria play important role today in the industrial leaching of ores to obtain metals (Schlegel, 1986, 359 & 525). They are also involved in the decay of any fossils that have pyrite within them or in the adhering sediments, and this is a serious problem for museum collections.

In modern mining operations, Thiobacillus ferrooxidans is a species widely used to recover minerals from low grade ores, especially copper from chalcocite ore (Brock, 437). It is significant in pyrite decay .

T. ferroxidans is classified as an acidophilic chemolithotroph species, because it prefers acidic conditions and uses inorganic chemicals for its primary energy-generating process. It does not get its main metabolic energy from photosynthesis either directly, or indirectly by feeding off living or dead organisms. T. ferrooxidans gets energy by oxidizing ferrous iron (Madigan, 1997, 575 - 579).

The oxidation of pyrite actually involves a combined sequence of both chemical and bacterial-catalysis reactions (Lottermoser, 2010, 47). Pyrite exposed to air in the presence of water begins to decompose by reacting with oxygen to form to ferrous ions, sulphate ions, and hydrogen ions.

The hydrogen ions make the water more acidic. Because the ferrous ion is relatively stable in the presence of oxygen, it accumulates and as a consequence the decomposition of pyrite is very slow. The acidic conditions, however, favour T. ferroxidans which obtains its metabolic energy by converting ferrous ions to ferric ions.

Acidic conditions prevent these ferric ions from reacting with water to make insoluble ferric hydroxide. Instead, the ferric ions react with the pyrite, producing more ferrous ions.

These feed the bacteria, creating a positive feedback cycle which greatly accelerates the decay of the pyrite. At the Copperas works, rainfall on the beds of pyrite flushed out a solution containing sulphate ions and ferrous ions. This solution was the 'liquor' for making Copperas.

The role of bacteria in copperas production was long ignored (Cotterill, 1993; Cotterill 1999). Several different species were probably involved, but the diverse activities of T. ferrooxidans have been described by several popular science writers, including Postgate and Davis (Postgate, 1992, 152; Postgate 1995, 99; Davis, 1998, 145).

As Colwall stated in 1677, whenever a new bed of pyrite was constructed the workmen would "*take a good quantity of the old fermented Earth, and mingle with new Stones, whereby the Work is hastened*". This was a good way to seed the new bed with suitable bacteria.

(42 A) Allum-Garth : an early Yorkshire alum works ?

In about 1801 a local historian and antiquary John Graves visited the ruins of an old alum works known as Allum-Garth on Goadland-Beck near its confluence with the River Esk (Graves, 1808, 291). He was sufficiently impressed by the age of woodlands covering the site, and probably by the speculations of local residents, to measure and record the structures. Graves seems to have been surprisingly unaware of exactly when Chaloner, Mulgrave and Foulis began alum operations in Yorkshire. In his 'History of Cleveland' (1808, Carlisle) he claimed ambitiously that Allum-Garth works was probably pre-Elizabethan and therefore the earliest alum works to have operated in Yorkshire The presence of burned alum shale makes this most unlikely, but his description of this early alum works is nevertheless interesting.

Allum-Garth was on the lands of Newbiggin Manor, owened by the Salvine (Salvyne) family, later by a Mr. Duck, and later by the Yeoman family of Whitby. It was located in Egton parish, immediately west of Whitby parish. Goadland Beck was described as "*a black and rocky mountain river, the banks of which are rudely ornamented with wood, and afford a great variety of wild and romantic scenery*".

"On the banks of this river [Goadland-Beck], *not far from its confluence with the Esk, on a narrow neck of land, there are the remains of buildings, which we conjecture to have been used in the process of crystallizing alum, and probably at a period prior to the date generally assigned for the introduction of that manufacture into England. The place has been long known by the name of Allum-Garth; and though now covered with a grove of aged trees, which appear to be the successors of others still more ancient, the works may be distinctly traced, consisting of two rows of circular pits, 20 in each row, three feet in diameter, and 2 ½ feet distant from each other. On the north side of these, which are built with hewn stones, there is a large cooler, one foot in depth, of the form of a parallelogram; and on the south, a square cistern, similar to those used in modern allum-works. The bricks which appear to have been used in placing the furnaces, &c. are strongly glazed, and bear evident marks of fire. An alum rock near at hand, which appears to have been wrought, and particularly pieces of burnt alum-shale, frequently found in the vicinity of the place, are circumstances that concur with its name, to strengthen the conjecture of its being an alum-work; and if this be admitted, we leave it to the consideration of the reader, whether it might not probably have been wrought, some time prior to the reign of Queen Elizabeth, when the manufacture of alum was first established in the neighbourhood of Guisborough by Sir Thomas Chaloner"* (Graves, 1808, 291).

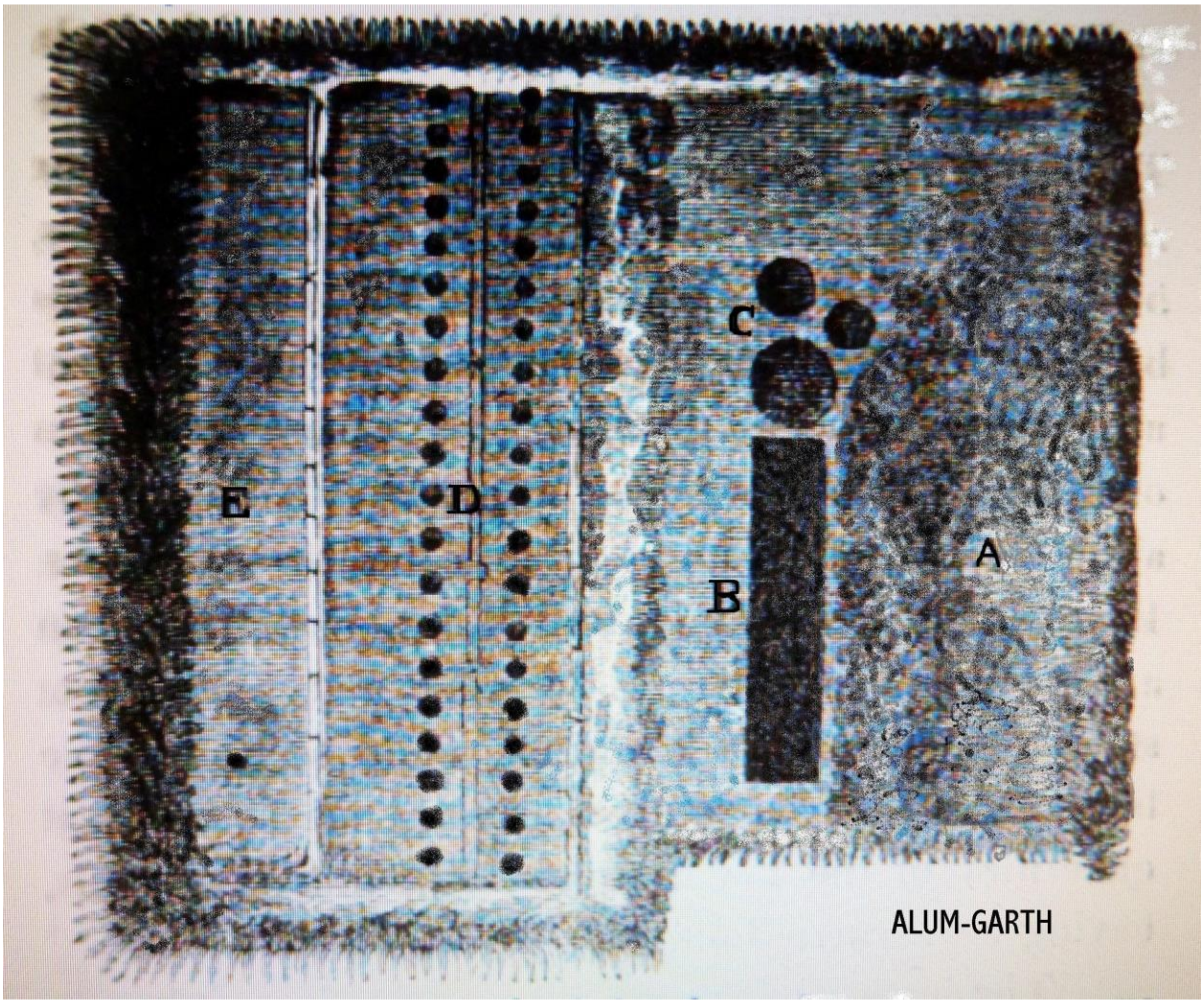
The historian George Young took a particular interest in Alum Garth, and published an annotated plan of the ruins in his 1817 'History of Whitby' (Young, 1817, 2, 758-761). They were located near

Growmond Bridge, on the south-west bank of the Mirk Esk, a little way above its confluence with the Esk, and covered an area of one hundred square feet. The works were elaborate and would have involved a considerable expenditure. The site had been labelled "*allum garth"* on a plan of Egdon estate drawn in 1636 for the owner Robert Carey Elwes. "*It had not been a work* [in use] *for several years before that date, as there were then no houses on the spot, but only trees*" (Young, 1817, 2, 161). "*The history of this work is entirely lost; it has no place even in tradition; but… the field has been called the* <u>alum-garth</u> *since time immemorial*". "*Its high antiquity is obvious from its singular form* [most unusual design], *and from the age of the trees that grow on it, some of which have sprung from the roots of a more ancient race".*

Young was convinced that this alum works was older than that at Belmont Bank, regarded as the earliest in Yorkshire. He considered and rejected the possibility that it was built by the ancient Romans. Because it was close to the former site of Growmond Priory, he decided it was likely that the monks "*might steal the art from Italy, and hope to carry it on undiscovered in this sequestered spot"*. "*On one or two of the hewn stones I observed a cross"*. Young thought this confirmed the role of monks in building the alum works, but it seems far more likely the symbol was instead present on reused stones from the abandoned Priory.

There was considerable evidence that it had functioned as an alum works- "*there is excellent alum-rock near it that bears the marks of having been wrought* [quarried]*". "There are heaps of uncalcined alum-shale scattered on the narrow plain on each side".* "*The oxide of iron, the usual* <u>residuum</u> *left at old alum-works, is found in the pits and cisterns". "We see a spot on the adjoining bank, where the calcined shale has been thrown over, to be carried down by the river".*

Structures on Allum Garth site:



(A) "*In the space marked A, there has been a range of furnaces, or places for boilers, extending… from SSE to NNW. The furnaces have been built with bricks".*

(B) "*B is a deep cistern, 44 feet long, and 8 ½ wide, behind the furnaces and parallel with them.*"

(C) "*At C are three round cisterns*", drawn a little south of their true location. "*All the four cisterns have been lined with hewn stone, and each of them may have been 4 or 5 feet deep*".

(HH) Houses – "*Near the three round cisterns, on the north of the range of furnaces, are foundations of houses*". This seems to mean alum houses rather than dwellings.

(D) At D, "*parallel to the cistern B, are two rows of circular cisterns or pits… 20 in each row. Each pit has been 3 ft. deep, and 2 ft. 10 in. diameter , neatly lined with hewn stone*". "*The bottom of each pit is formed of an entire flat stone; the seams have been filled with clay*". There was no inter-connection between the pits. The rows were 5 feet apart, and along each row the pits were 1 ft. 10 in. apart.

(SW) Walls of a shallow cistern: "*The whole space occupied by the rows has been paved with flags, and enclosed by an edging of upright stones, so as to form a large, shallow cistern or cooler*." This was "*divided longitudinally, by a low wall of hewn stone passing between the rows*".

(E) "*Parallel to the rows* [of circular cisterns], *has been a large and deep cistern E, now in a very imperfect state*".

(OW) "*The whole work… seems to have been enclosed by a wall*." All of the site was "*greatly mutilated, vast quantities of the hewn stones, and other materials, having been carried off*".

Water supply – "*There has been a channel, lined with hewn stone, to convey a supply of water to the work from the bank of the river on the south, and the water has been brought into the channel [there] by a <u>race</u>, or aqueduct, from a water-fall up the river*" (Young, 1817, 2, 762)

Access track – A forge had been operated at Smithy-holme on the opposite side of the river, "*and the road leading up from the river to the alum-garth is paved with slag*".

(43 A) Alum Making in Yorkshire – 1750 to 1830

Alum production in Yorkshire continued for about two hundred and fifty years (Kent, 1980, 40). Huge excavations of the Upper Lias 'Alum Shale' were made along the coast at Peak, Saltwick, Kettleness, and Boulby. Inland the alum workings were on a much smaller scale, along the north Cleveland scarp westwards to Osmotherly (Kent, 1980, 40).

Alkali Supplies:

Alkali was a raw material required for the manufacture of soap, glass, and saltpetre as well as alum (Clow & Clow, 1952, 65). These industries used **potash** (potassium sulphate), as did the alum industry increasingly in preference to stale urine. The alum industry had first experimented with potasium sulphate (sal enixum), produced as a waste material by chemical works making nitric acid (Clow & Clow, 1952, 82). As the price of that rose, they turned to kelp.

"*The alkalies have an acrid and urinous taste;…and have the property of rendering oils miscible in water*". "*Tincture of litmus, and litmus paper, are always rendered more intensely blue, by the addition of alkalies*" (Parkes, 1812, 147). "*When an acid is combined with an alkali, an earth, or a metallic oxide, it forms what is called a <u>salt</u>*" (ibid, 211). "modern chemists have adopted a new nomenclature…[so] every salt has a double name, one part of which indicates its acid, and the other its base…Compounds of…alkalies with the sulphuric acid are called sulphates" (ibid, 212)

Shortages of alkali at the beginning of the nineteenth century led to some misconceived experiments. "*The manufacturers of ALUM, of COPPERAS, of BLUE VITRIOL, and of all other SALTS would…do well to become chemists…Till lately the MAKERS OF ALUM bought alkalis of every description. An accurate analysis of alum has now discovered that potass* [potash] *and ammonia are the only alkalies which enter into the composition of alum; and consequently, that during a long series of years large sums have been expended by the manufacturer for an article of no use*" (Parkes, 1812, 19)

Between 1730 and 1830 kelp seaweed became the major source of alkali for the soap, glass and alum industries in Britain (Clow & Clow, 1958, 236). **Kelp ash** contained a mixture of chemicals. About three percent was potassium chloride. Mostly it was common salt (sodium chloride), sodium carbonate (soda), sodium sulphate, magnesium sulphate, and magnesium chloride. (Clow & Clow, 1952, 81).

Soap and glass works could use pot ash from burnt wood, but suppies in Britain were increasingly limited and large quantituies were imported fron northern Europe, Russia and North America (Lclow & Clow, 1952, 65). Barilla, an ash from glasswort plants, was bought from Spain, but supplies were often interrupted by hostilities or war. **Soapmakers** actually preferred kelp ash, because it provided some of the salt (sodium chloride) they needed without incurring the salt-tax. They crushed the kelp ash to powder, dissolved it in water, and added calcium hydroxide to make the caustic soda they required. The potassium remained behind, and evapourated lye was sold to the alum works as a source of potassium (Clow & Clow, 1952, 82).

Samuel Parkes noted in 1812 that "*the greatest part of the potass* [potash*] used in this country comes from Russia and America; but the kelp of our own coasts, and the* <u>*barilla*</u> *of Spain and of the islands of Teneriffe and Sicily* [using *zostera maritima*] , *furnish us with most of our mineral alkali* (Parkes, 1812, 157). In 1800-01 Britain imported 172,454 cwt Barilla, 44,401 cwt pearlash, and 135,400 cwt potash.

Glassmakers also had reasons to prefer kelp ash, because the admixture of salts served as a useful flux. Even after synthetic alkali became available, "*the common green bottle-glass is made with a large proportion of the ashes of vegetables, or soap-boilers' waste ashes, instead of pure alkali. The portion of iron, which is generally found in vegetable substances, gives it the green colour*" (Parkes, 1812, 120).

The competing markets for **kelp** drove up the price and created a very substantial industry (Beaton, 1800, 243). Payments for kelp played an important role in the development of a cash economy in the most remote parts of Scotland.

Orkney kelp sold at Newcastle Upon Tyne for £1 5s per ton before 1730 (Clow & Clow, 1952, 79). By 1764 Hebrides kelt sold there for over £2 10s per ton. During the American War of Independence (1776-83) it reached £8, falling to £ 6 10s in 1788, and then rose again to £11 12s in 1798. During the 1790s Britain was importing extra kelp from Norway, and Barilla from Alicante and Tenariffe (Clow & Clow, 1952, 80).

English merchants were seeking kelp at Anstruther in Fife by 1694, and in the Orkneys by 1722 (Clow & Clow, 1952, 70). By 1814 Scotland produced 10,000 tons of kelp ash each year, half of it from Orkney (Clow & Clow, 1952, 75). In 1822 the industry was said to provide seasonal employment to 80,000 people in Scotland, producing 20,000 tons of kelp ash each year.

The development of new chemical industries on Tyneside provided alum makers with potential new supplies of alkali. They tried using potassium sulphate (sal enixum), a waste product of nitric acid manufacturing, but that became too expensive. Then they turned increasingly to the evaporated lye from **soap-makers** for potassium (Clow & Clow, 1952, 82).

Alkaline lee made from kelp was used until 1781, when "***black ashes***" from soap-boilers lees were used as a supplement and reputedly had largely replaced the kelp by 1794. The first soap works in Newcastle was opened in 1770 by Lambe and Waldie, and was bought in 1775 by Thomas Doubleday (Clow & Clow, 1952, 125).

Kelp was still regarded as better because it also precipitated and removed any iron present, improving the quality of the alum for dyers. Scottish kelp production reached its maximum output in the first two decades of the nineteenth century (Clow & Clow, 1952, 79

The use of "***Muriate of Potash***" (potassium chloride) by alum works replaced "black ashes" within a few years of its introduction in 1801. Urine continued to be regarded as an essential ingredient until 1794, but the quantity was then gradually reduced and by 1817 very little was used. Many of these improvements in Yorkshire were instigated by **Lord Dundas** at Lofthouse alum works (Price, 1817, 2, 812)

Even in 1812 Parkes recorded that "*British* [alum] *manufacturers generally use kelp (which contains a quantity of potass* [potash] *as well as soda), or black ash … from the waste lees of the soap-boilers, and…[*this] *contains a portion of muriate* [chloride] *and sulphate of potass*" (Parkes, 1812, 157). Lord Normanby's alum works at Whitby was unusual in still using kelp in 1845 (Clow & Clow, 1952, 74).

Contemporary accounts of the Yorkshire alum works:

George Young researched the alum industry in detail for his 1817 'History of Whitby' (Young, 1817, 2, 811). He had the benefit of notes made by his friend, the late Richard Winter. He described the quarrying of shale, the calcining process, extraction of alum liquor, followed by its evaporation in lead pans, cooling and crystallization of alum (Young, 1817, 2, 812-815). His decision to compile an accurate description of the manufacturing process was probably influenced by two earlier books

Lionel Charlton, in his 1779 'History of Whitby', had emphasised the importance of the alum industry to the expansion and prosperity of the town and its port, but did not attempt to explain the technology involved.

John Graves, in his 1808 'History of Cleveland', gave a picturesque description of the clifftop alum quarries, and provided a brief but rather confused account of Baker and Jackson's alum works at Boulby, in Easington parish. There was probably growing public interest in how this impressive industry was conducted.

Richard Winter published a detailed technical description of the Yorkshire alum industry in April 1810, in volume 25 of William Nicholson's 'Journal of Natural Philopsophy, Chemistry and the Arts' (Winter, 1810, 241). This became the standard account, copied by technology textbook authors like Andrew Ure.

Torbern Bergman – Alum Manufacture in Sweden in 1764:

John Graves in 1808 almost certainly copied his description of Yorkshire alum technology from Bergman's "*Dissertation IX Of the Preparation of Alum*" , in his 'Physical and Chemical Essays', translated into English by Edmund Cullen and published in London in 1784. He had probably been loaned a copy by one of the Yorkshire alum makers. Bergman was the chemistry professor at Upsalla University, and his account provides a useful summary of the academic interpretation of the north European allum technology. It was based on Garphyttan alum works in Sweden. Surprisingly, he apparently regarded the addition of alkali during the boiling process to be an aptional extra, to maximize yield, rather than the essential component it was known to be in Yorkshire. Charles Macintosh at Hurlet alum works in Scotland found this so strange that in 18089 he sent his son George to visit Garphyttan (Macintosh, 1847, 46). George concluded that sufficient alkali was being incorporated through the quantity of wood used to calcine the 'schistus' there.

"*The aluminous schist is nothing more than an argillaceous schist impregnated with a dried petroleum, and thereby rendered black…During the roasting* [calcining], *the bituminous part is expelled, and the pyritous decomposed, so that a part of the acid adheres to the iron, and the rest to the pure clay; hence are produced at once an alum and green vitriol* [copperas], *and if there is present any calcareous earth, or magnesia, they are vitriolated"* (Bergman, 1784, 1, 350)

Tests showed that no alum salt could be extracted from the so-called 'schist' before roasting, "**nor can the taste discover any vestiges of a saline matter** [on the 'schist']; *hence also it appears to be generated during the* [calcining] *operation, and for that purpose nothing seems to be necessary but the presence of a* ***pyrites****; this* [pyrite*] sometimes shows visible nuclei of various sizes, but is generally dispersed through the whole mass, in the form of very minute particles : the goodness therefore of the ore, is to be estimated by the suitable quantity and equal disttribution of the pyrites*" (Bergman, 1784, 1, 350).

"*That* [shale] *which contains the pyrite so conspicuously that it is visible is rejected, there being too much iron in it – it the mean time the most dense and ponderous* [shale] *is the most esteemed; the weight manifestly discovering* [indicating] *a pyrites, without which no alum is obtained*…[So] *a stratum adjoining one of the best kind, is often of little or no value…Sometimes this ore produces salts without the application of fire; but…in this case it is never found, but* [unless it] *has undergone more or less of a spontaneous calcination*" (Bergman, 1784, 1, 350). Bergman seems to have meant that these "salts" were alum, not aluminium sulphate.

Bergman described all the manufacturing processes at an alum-works, beginning with the spring season re-opening of a works closed through the winter. Consequently, on the first processing run there were no liquids to recycle from a previous run.

The first stage was to achieve a suitably concentrated solution of **'lixivium'** from the calcined ore. Manipulating the liquid to achieve that concentration was important, to minimize the fuel costs for the next process, which was boiling it to increase the concentration. Initial concentration was measured using a glass bottle: "*the weight of* [pure] *water which fills a small glass bottle is divided into 64 parts, each of which is* *called a panning*" {Bergman, 1784, 1, 362). "*The quantity* [weight] *by which the same bottle, full of lixivium, exceeds it…is supposed to indicate the quantity of salt dissolved". "The cold lixivium ought to be made no richer than when the superpondium* [extra weight*] is equal to 45 pannings, which, according to our computation, shows the water to be loaded with 1/5.7 of its own weight*". The lixivium inevitably contained some impurities, including "*vitriol of iron,…vitriolated magnesia, and more subtile* [suspended] *earthy particles"* (Bergman, 1784, 1, 364).

Before boiling, 'lixivium' of the correct strength was brought through 'canals' to a **leaden boiler** in the alum house, and another receptacle nearby was similarly filled ready to replenish losses from the boiler during evaporation. Thus the lead boiler was kept filled "*at the same height*" throughout the boiling. Bergman made no reference to alkali being added at this stage, which it would have been in Yorkshire to convert the aluminium sulphate to alum. "*Some take the floating of a newly laid egg as a token of boiling being finished – The specific gravity of such an egg is about 1,081*" (Bergman, 1784, 1, 365). Others used the glass-bottle method instead, and regarded 20 pannings as correct, representing an increase of 1/1.69 above the water's weight when pure.

The liquor then "*flows through channels into **coolers"***, where it was left for about an hour to deposit the "*grosser hetrogenous particles*" of impurities. "*It is then put into either **stone or wooden receptacles**. In eight or ten days the [residual] lixivium, commonly called **magistral water**, flows into another vessel , leaving behind a number* [quantity] *of **crystals**, generally small and impure, which incrust the bottom and sides of the vessel. These are collected, and washed from the impurities which adhere externally, with* [using*] cold water: impurities remaining in the reservoir after washing, are kept by themselves*" [possibly for recycling] (Bergman, 1784, 1, 365).

"*The washed crystals are put into the* [special] *boiler used for **depuration***". They were then dissolved in a minimum amount of heated water, before being poured into a "***great tub***" holding the same volume. According to Bergman, **alkali** was only added at the 'depuration' stage, if at all. "*In order to obtain the alum more pure at the second crystallization, in some places additions are employed, such as alkalis, lime or urine; for the experience of many years has shewn, that the lixivium sometimes acquires such a consistence, that it both crystallizes with difficulty, and produces impure crystals: pot-ashes, particularly, were used to prevent this inconvenience, because the acid is superabundant".*

"*After 16 or 18 days the hoops of the* [**great**] ***tub** are loosed, and the aluminous mass is bound with an iron ring: after 28 days the residuum of the solution* [remaining liquid] *is let out through a hole, and collected in a trench"* (Bergman, 1784, 1, 365). The solid purified alum, when dried, was called **depurated alum**. At Garphyttan alum works each batch of purified alum weighed 26 tons.

The '**maistral water'** (lixivium residue) left over from the coolers, went back into the leaden boilers in the alum house, until they were two thirds full. It was then reheated to boiling-point and fresh lixivium (made with the calcined ore) was added to fill the leaden boilers. More was added as evaporation continued. Once this reached the appropriate strength (of 20 pannings) the lixivium was sent to the coolers, and then through the subsequent processes, as before.

"*Alum, as it is commonly made, although depurated by a second crystallization, yet is almost always found to be contaminated with dephlogisticated vitriol; hence it yellows with age, and when dissolved in water deposits ochre. This, in many of the arts, is equally* [just as] *useful with* [as] *pure alum; it is even so in dying, when dark colours are wanted, which frequently require green vitriol* [copperas]; *but when the more lively colours are sought, every thing marshal must be avoided, as it always obscures them, more or less. In such cases the Roman alum is employed"* (Bergman, 1784, 1, 386).

Richard Winters' account of Yorkshire alum production in 1810:

(a) Site geology - "*The stratum of **aluminous schistus***[shale] *bordering upon the sea, presents cliffs that are in general precipitous. Their height is from 100 to 750 feet*." (Winter, 1810, 241).

Coastal locations were best for alum works because "*the immense quantity of refuse schistus and rubbish (as the covering strata of the aluminous schistus are called) to be removed*" then had to be dumped nearby. The overburden included "*alluvial soil, sandstone, ironstone, shale and clay*". Transport costs for coal fuel "*brought by sea from the ports of Sunderland and Shields*" were also lower at coastal sites.

"*The aluminous schistus is generally found disposed in horizontal laminae. Sometimes it exists in the form and appearance of indurated clay; in fact the whole of the upper part of the stratum resembles indurated clay, when first wrought; but by exposure to the atmosphere it suffers decomposition, and crumbles into thin layers.*

The upper part of the rock is abundant in sulphur, and the deeper they work into it, the quantity of sulphur decreases, and the bituminous substance increases, and the rock becomes more hard and slaty; so that a cubic yard of rock taken from the top of the stratum, is as valuable as 5 cubic yards taken at the depth of 100 feet.

When a quantity of the schistus is laid in a heap, moistened with sea water , it will take fire spontaneously, and will continue to burn until the whole of the combustible matter is exhausted.

The colour of the aluminous schistus is a bluish grey. Its hardness differs: at the top part of the strata it may be crumbled in pieces between the fingers, [but] at a considerable depth it becomes as hard as roof slate*"* (Winter, 1810, 246).

"The *covering strata are removed previous to working the **alum rock** (as it is generally called)"* (Winter, 1810, 248)

(b) Wheelbarrow ironways - "*The hewing of the rock is performed with **picks and javelins*** [marlinspikes?]; *and it is conveyed to the calcining place in **barrows**, so contrived* [designed*], that the centre of gravity of the weight, is in erpendicular line with the wheel; by this means the men have nothing more to do, than to keep the barrow steady, throw the weight of the substance* [shale*] upon the wheel, by raising the handles, and throw the barrow upon the way"* (Winter, 1810, 248).

The wheelbarrow ironway "*is formed of **cast-iron plates, 6 feet in length**, 6 inches in breadth, and half an inch thick; these plates arre fastened into cross pieces of wood fized into the ground at the end of each plate.*

Ten of these barrows contain one solid yard of rock.

The expences of working the rock vary according to the facility [ease] *with which it can be hewn. When the distance the rock is to be barrowed* [to the calcining heap] *is about 200 yards, the rate for removing and hewing one cubic yard is about 6 ½ d. It is unecessary to state, that the price must maintain a corresponding ratio with the distance to be conveyed.*

The men earn about 2s 6d per day in the winter season, and 3s in the summer" (Winter, 1810, 248).

(c) Calcining the Shale -

"*The rock is poured out of the barrows upon a bed of fuel, composed of underwood, furze &c.*

The dimensions of this pile of faggots is about four or five yards in breadth, and two in height; as the rock is deposited upon the fuel, it is necessary that it should be broken into small fragments, [so] *that the combustion may take place with greater facility.*

When *they have got about four feet in height of the rock upon the faggots, fire is set to the bottom, and fresh rock* [then] *continually poured upon the pile; other piles of wood are then placed alongside the first, and they proceed as before, adding more rock, firing the fuel, &c.*

*This they continue until the calcined heap is raised to the height of 90 to 100 feet, and from 150 to 200 feet in length and breadth. Some of these heaps of calcined **mine** (as it is now called) will contain 100,000 solid yards of schitus or rock*" (Winter, 1810, 248).

When the whole heap is in a state of combustion, a considerable quantity of sulphureous acid gas is disengaged, [and] *this they endevour to prevent , by moistening small schistus, and forming a kind of clay; with this they plaster the outside of the heap; this however does not prevent the escape of the gas in any degree, but it prevents the wind from penetrating, and assists in preventing the calcined mine from falling* [collapsing], *by forming a kind of [*baked clay] *crust all over the heap*; [but] *this crust is soon decomposed by the action of rain, &c."* (Winter, 1810, 249).

"*130 tons of calcined mine will produce 1 ton of alum. I have deduced this number from an average of 150,000 tons of calcined mine consumed*" (Winter, 1810, 250).

(d) Dissolving the Aluminium Sulphate-

"*The calcined mine is **steeped in water**, contained in **pits,** that usually hold about 60 cubic yards.*

*The water thus impregnated with sulphate of alumine, called **alum liquor*** [though actually aluminium sulphate solution*], is drawn off into cisterns, and afterwards pumped up again upon fresh calcined mine.*

*This is repeated until the liquor becomes concentrated to the **specific gravity of 1.15; or 12 pennyweights** by the alum maker's weight.*

The half exhausted mine [calcined shale] *is then covered with water, successively, to take up the whole of the sulphate of alumine* [into solution]; *these liquors, thus impregnated, are denominated **strong liquor**, **seconds**, and **thirds*** [of progressively lower strength, from three dowsings of calcined shale]" (Winter, 1810, 250).

(e) Removal of Insoluble Impurities -

*"The strong liquor is drawn off into **cisterns** to deposit* [sediment out] *the sulphate of lime, iron, and earth* [impurities] *suspended in it.*

In order to free the liquor from these substances, [at some works] *they **clarify** it **by boiling** for a short time, which enables the sulphuric acid to exert its affinities with greater energy* [becoming neutralized by reaction with the iron].

After running it from the pans, and suffering it to cool, the whole of the sulphate of lime, iron, and superfluous alumine, and earth, are deposited; and the alum liquor is nearly pure.

Where this precaution is used, the alum is much better in quality, and almost entirely divested of [admixture with] *the sulphate of iron* [copperas*]. This method is only practised at some of the works, owing to the additional quantity of fuel required, and* [the*] consequently increased expense*" (Winter, 1810, 250).

(f) Mothers Liquor in the Boiling Pans –

"*The liquor in this state* [from the settling cisterns] *is carried by means of pipes, or wooden gutters, into **lead pans.***

These pansare made of sheet lead (cast by the workmen in the alum house) 10 feet long, 4 feet 9 inches wide, 2 feet 2 inches deep at the hinder part, and 2 feet 8 inches at the front end : this difference is allowed to give a rapid current in running off.

A quantity of mothers [liquor*] is pumped into the* **[boiling]** ***pans** every morning; and, as this evaporates, the deficiency is supplied* [replaced] *with fresh alum liquor* [aluminium-sulphate liquor], *every two hours, or, as* [when*] the liquor in the pans becomes more concentrated, the additions are made more frequently.*

It is necessary to keep the pans continually boiling, otherwise the superfluous alumine and sulphate of alumine, deprived of its water of crystallization, would be precipitated, and the pans melted, from [because of] ***the crust** formed between the liquid and the lead* [which would prevent the heat dissipating into the liquor fast enough to avoid damage]" (Winter, 1810, 251).

"*Each pan will produce upon an average* [concentrated liquor for*] 4 cwt of alum daily, and the consumption of coals will be about 18 bushels Winchester measure"* (Winter, 1810, 251). Winchester measure was a legal standard of volume, based on the bushel and introduced in 1496 by Henry VII of England. In 1824 the volume of one gallon was redefined, and the new bushel contained eight new gallons of liquid, which was about three percent more liquid than a Winchester bushel.

(g) Adding the Alkali –

"The liquor contained in the whole of the pans is run off every morning intro a vessel called the ***settler***, [and] *at the same time a quantity of* ***alkaline lee*** [liquid] *is brought along with the boiling liquor,* [having been] *prepared either from* ***kelp****, soapers lees, (generally called* ***black ashes****) or* ***muriate*** **[chloride] of potash**, [this liquid being] *of a specific gravity from 1.037 to 1.075.*

The alum maker having previously ascertained the specific gravity of the liquid in his [boiling*] pans, estimates the quantity of alkaline lees* [liquid] *to be added, necessary* [sufficient] *to reduce the liquor from the pans from the specific gravity of sometimes 1.45 or 1.5, to* [the required combined density of] *1.35 "* (Winter, 1810, 251).

It was crucial to reduce the **specific gravity** to **1.35** during this stage.

(h) First Crystallization of Alum –

"*The liquor then stands in the settler* [for] *about two hours* [so] *that it may deposit the sediment* [solid impurities*] it may contain, when* [and then] *it is run off into the vessels (or* ***coolers****) to crystallize.*

If the alum maker should [have correctly made liquor to] *be below, or equal to the specific gravity of 1.35, in mixing the alkaline lee and liquor,* [then] *there is nothing more to be done.*

If he [accidentally] *exceed this specific gravity, he then* ***adds urine*** *to the coolers, until the liquor* [density*] is reduced to 1.35. It is then agitated* [stirred] *to combine the heavy and light liquids, and then left to crystallize.*

It must be observed [noted*], that at a greater specific gravity than 1.35, the liquor, instead of crystallizing, would present us with a solid magma* [gunge] *resembling grease.*

After standing four days [in the cooler], *the mothers* [residual liquors] *are drained off, to be pumped* [recycled] *into the pans again the succeeding day* [mixing with fresh mother liquor]" (Winter, 1810, 251).

(i) Washing Alum Crystals –

The crystals of alum [precipitated in the cooler] *are conveyed to* ***a tub****, where they are* ***washed in water****, and put into* ***a bin, with holes*** *in the bottom, to allow of he water draining off from the alum*" (Winter, 1810, 251).

(j) Second Crystallization of Alum (Roaching)-

"**They** [the alum crystals] *are then removed into* ***a pan*** *(twice as large as the common leaden [boiling] pans), and as much water added as is found requisite to dissolve the whole of the alum when in a boiling state; the moment this is effected* [achieved], *the* ***saturated boiling solution*** *is run off* ***into casks.*** [During the boiling, "*Sometimes bullocks blood is added to clarify the solution*" by precipitating suspended impurities, according to Nicholson (1808, 'alum')]

These casks should stand about sixteen days; as [because] *they require this time to become perfectly cool in the summer season.*

The casks are then taken to pieces, and a hollow cask of alum is produced; it [the cask-shaped alum] *is then broken into, and the whole of the saturated solution of alum (called* ***the tun water****)* [from the central cavity] *is removed* [recycled] *back into the pans, to go through the process anew*. {Nicholson in 1808 added that "*the staves and hoops of*...[the casks] *are numbered, that they may be more readily put together*" (Nicholson, 1808, 'alum'; Croker, 1764, 'alum')]

This last process is called ***roaching.***

The outside of the cask [shaped mass] *of alum is now cleaned from* [of] *dirt, and* [of] *the sediment which is deposited at the bottom. It is then broken into masses ready for the market*." (Winter, 1810, 252). [Nicholson, possibly referring to manufacturers in continental europe, added that "*Lastly, the crystals are dried in a stove, and packed up in crates for sale*" (Nicholson, 1808, 'alum')].

(k) Measuring Liquor Concentration --

"*The method persued by the alum makers to find the specific gravity of any liquid is capable of considerable accuracy.*

A bottle is procured, that will contain about ½ of a pint. The narrower the neck, the more accurate will be the rsults obtained by it.

This bottle is balanced in a pair of sensible [sensitive] *scales,* [and] *we will suppose it to weigh 1000 grains; it is then filled with distilled water, and carefully dried with a cloth:*

now allowing [supposing] *the water to weigh 2400 grains, this last number is divided into 80 parts or* ***pennyweights****, and* [so] *we have 30 grains corresponding to one penny-weight; this they subdivide into ½ and ¼. Hence we may ascertain the relative specific gravity* [density or concentraion relative to pure water] *of any liquid.*

1 pennyweight is equivalent to 1.0125 [sp. gr.], *and 80 pennyweights to 2.0* [sp. gr.]

Care however is necessary, to have a counterweight of [exactly] *3400 grains, equal in weight to the* [original volume of distilled] water and [empty] *bottle together, which must always be put in the scale, along with the other weights* [on the opposide side of the balance to the bottle filled with liquor], *in operating.*

This was formerly a great secret among the alum makers, and they sold [details of] *the method at a high price, or handed it down to their children as an hereditary possession*" (Winter, 1810, 252).

(l) Alkali Types and Quality –

"*In using black ashes* [from soapmakers], *or* ***kelp****, a considerable quantity of charcoal is* [present] *dissolved in the alkaline lee; this charcoal is precipitated on* [by] *adding a small quantity of the solution of sulphate of alumine* [mother liquor*], but* [it] *redissolved again by adding the solution in exc*ess [by mistake, before removing the precipitate]

This charcoal contaminates the alum, and decomposes a quantity of the sulphuric acid…

Whatever alum is made with ***muriate [chloride] of potash*** *alone will be far superior in quality, while the produce will be greater in quantity.*

It might be supposed, that ***urine*** *was a necessary ingredient in the making of alum; but the fact is, it merely hides the ignorance of the alum maker. Having no determinate rule to guide him* [regarding the quantity of alkali solution to add], *in reducing the* [concentration of*] the liquor from the pans, should he by chance* [misjudgement] *exceed the specific gravity of 1.35, he adds urine, or some such light* [low density] *fluid, to bring the liquor as near as possible to this density.*

The alum works that approach the nearest to the true chemical principles [in competence] *are those of the Right Hon.* ***Lord Dundas****, and Messrs* ***Baker and Co.***

They use no urine in these works – the alum liquor is always clarified [removing suspended contaminants] *previous to being used* [processed] *– they use no* [other*] alkali generally, but* [only] *crystallized muriate* [chloride] *of potash – greater economy is observed in the consumption of fuel; and the result is a product* [output] *of alum consistently larger in a given time, and of better quality, than can be produced by the works on the old plan*" (Winter, 1810, 253).

Kelp Alkali – "*The kelp used is obtained by burning the sea wrack in kilns, at a great number of places upon the coast of England, Scotland, &c.*

It is a very inferior alkali in an alum manufactory.

It contains about 47 [percent] *of soluble salt, and 58* [percent] *of charcoal, sand and earth. The salts are muriate of soda, soda* [sodium carbonate], *and sulphate of soda* [sodium sulphate]" (Winter, 1810, 253).

Black Ashes Alkali - " *The refuse of the soap boilers' lees are burnt in a kind of oven, and sold under the name of black ashes.*

The composition of these is about 90 [percent] *of soluble salts, and 10* [percent] *of charcoal and earth,* [and] *the salts contain muriates* [chlorides] *of soda and potash, sulphate of potash, and muriates of lime and magnesia.*

I have always found great difficulty in producing alum by the [use of] *muriate of soda, and never could form alum in any* [way*] by means of* [using*] pure soda.*

The muriate and sulphate of potash are the only alkali that can be used to advantage in the composition of alum.

I have made comparative experiments to ascertain the quantity of the different alkalis it would require to produce 100 tuns of alum" (Winter, 1810, 254). The amounts were 22 tons of 'muriate of potash', or 31 tons of 'black ashes', or 73 tons of 'kelp'. "*The alkalis are considered* [here] *as in the state in which they are found in commerce".*

Andrew Ure, who copied Winter's account of alum technology for his 'Dictionary of Chemistry', revealed that the alum chemists in Scotland had studied the essay: "*Mr. Winter first mentioned, that another variety of alum can be made with soda, instead of potash. This salt, which crystallizes in octahedrons, has been also made with pure muriate of soda, and bisulphate of alumina, at the laboratory of Hurlet* [alum works] *by Mr. W. Wilson. It is extremely difficult to form, and effloresces like the sulphate of soda. On the subject od soda-alum, I published a short paper in the Journal of Science for July 1822*" (Ure, 1828, 138).

Similarly, Thomas Thomson, the professor of chemistry at Glasgow University, was informed of soda-alum by John Wilson at Hurlet: "*Soda-sulphate of alumina, or soda-alum. This species of alum has been hitherto over-looked by chemists, in consequence if its great solubility, and the consequent difficulty of obtaining it in regular crystals. I have been informed by my friend, Charles Macintosh Esq. of Glasgow, that he made it more than twenty years ago* [supposedly before 1805]. *For the specimen which I examined, I am indebted to Mr. John Wilson of Hurlet, who drew my attention to it, and furnished me with very rare specimens.*

The salt was noticed in 1810 by Mr. Winter, in his account of the Whitby alum process. In appearance, soda-alum cannot be distinguished from common alum; the crystals are regular octahedrons…the taste is the same as that of common alum…The great solubility of this alum is its characteristic property. It is more than thirty times more soluble in cold water than ammoniacal alum, and more than twenty times more soluble than potash alum…This great solubility would make soda-alum more convenient for the use of dyers and printers than the common alum, if it could be procured with the same facility" (Thomson, 1825, 1, 447)

The vague statement made by Charles Macintosh to Thomson may be the only basis for a confident account in the Encyclopaedia Britannica of 1842, that Macintosh had made soda-alum before Richard Winter (Enc.Brit,., 1842, 2, 252). William Wilson at Hurlet alum works "*afterwards made it in considerable quantities*" (Enc.Brit., 1842, 2, 252).

By 1842 natural sources of soda-alum had been discovered in South America, at 30 deg. south in St. Juan province on the east side of the Andes (Enc.Brit, 1842, 2, 574).

(m) Criticism of Alum Manufacturers –

Richard Winter was very critical of the approach taken by many alum manufacturers. They remained in thrall to traditional rule-of-thumb techniques, and had not embraced the new chemical knowledge and technological expertise which had been sweeping through Europe since the end of the eighteenth century. He claimed that most alum works could have easily made consideable cost savings.

"*Every suggested improvement is considered as an innovation by the illiterate, and it may be truly said, to be more easy to move mountains than* [remove] *long established prejudices; the anxious manufacturer is seldom sufficiently master of his* [own] *works, so as to be able to* [overcome] *turn the scale of long established custom: and the most enlightened and scientific methods are entirely defeated, when entrusted to the hands of workmen to carry them into execution.*

How little melioration [improvement] *can be expected among a class of* [ill educated*] people, where reason has never made any impression upon the mind! I would hail as a true patriot, who*[ever] *shall endeavour to disperse this cloud of darkness* [ignorance] *from the human race*." (Winter, 1810, 249).

Winter claimed that most alum works could make considerable cost savings by making simple improvements.

The 'mother liquor' derived from washing calcined shale, was inadequately concentrated before being sent to the boiling pans. "*The alum liquor is frequently brought into the pans as low as 1.09* [specific gravity]; *when* [whereas] *by repeatedly bringing the liquor over fresh calcined mine* [shale] *it might be concentrated to 1.25, or more* [without heating].

*I will mention an instance where the expenditure in evaporating liquor was more than £3 10s daily; when at the same time this liquor might have been concentrated to an equal degree, by repeatedly pumping the liquor upon fresh calcined mine, at an expense of not more than 9 s. in the s*ame [amount of time]; *here there was a loss of £3 1 s. daily*" (Winter, 1810, 253)

"*A very material error is committed, by concentrating the liquor in the pans to near the specific gravity of 1.5 and then reducing it again to 1.35 : this method obliges them to evaporate a very unnecessary quantity of water*" (Winter, 1810, 253).

Winter suggested that better furnaces for working the boiling pans would improve fuel economy: "*by reducing the size of the fire places, and erecting iron doors, to prevent a current of air passing over the fire, instead of entering by the ash pit* [as it should" (Winter, 1810, 253).

(n) Richard Winter – biography

Richard Winter seems to have been a well known intellectual in Whitby. He had published a poem "The Harp of St. Hilda' praising Commodore Phipps (later Lord Mulgrave) for fortitude when his ship, the 'Carcase' became trapped in polar ice in 1773 (Groombridge, 1845, 117).

He was well educated in science, a regular reader of 'Nicholson's Journal', and in 1814 contibuted a six page article on "The Propogation of Sound, according to the Newtonian Theory" to Tilloch's 'Philosophical Magazine' (Winter, 1814, 201).

He had planned to publish a History of Whitby. He "*collected, with great labour, a considerable stock of materials; issued a prospectus for the intended publication, for which subscriptions were received; wrote a number of detached pieces…and prepared for the press twenty-one pages of a General History*". George Young and Mr. Bird acted as proof readers, and went on to complete the book "*which had at least accelerated his premature death"* (Young, 1817, 1, iv).

John Graves' 1808 account of Boulby alum works:

Boulby alum works had been operated by Nicholas Conyers, and was inherited by his son Thomas, the child of his third wife Margaret nee Freville, of Hardwick in County Durham. It was later sold to John and William ward, the brothers of Ralph ward of Guisborough, and later passed by marriage to the Jackson family (Graves, 1808, 332). In 1808 the works were owned by William Ward Jackson and Mr. Baker.

"These works are situated on the ***verge of a stupendous cliff*** *; and the rock, cut down by an almost herculean labour, discovers the different strata in the bowels of the earth, and affords a spectacle at once pleasing, awful and magnificent.*

As the ***alum rock lies at a considerable depth*** *below the surface of the ground, the labour of removing it is attended with much labour and expence; but this part of the business is attended with such order and regularity, as not only to equalize the labour to the strength of the different workmen, but also to enforce it in proportion to their wages. For this purpose, they have* ***wheel-barrows*** *of various sizes , denominated <u>barrows, half barrows,</u> and <u>quarter barrows</u>; for which wages are paid in proportion to their size.*[Footnote *The construction of barrows used in the allum works, is the best imagineable, and worthy of particular notice: for, although they contain a considerable quantity of earth* [rock], *the weight is so judiciously poised upon the axle of the wheel or <u>trundle</u>, that little force is required to lift them; and in wheeling, so little weight rests upon the arms, that the labour is less fatiguing than what is required in canal work, though the* [canal] *barrows do not contain half the quantity*].