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The Sulphur Trade of Iceland from the Viking Age to the End of the Hanseatic Period

In the late 19th century, archaeologists excavated a grave in Kekomäki, Kexholm county, in the Finnish part of Karelia. Buried in the 13th century, the deceased had been laid to rest with a small leather pouch containing lumps of sulphur, fragments of flint and an iron object, possibly a strike-a-light (Schwindt 1893, 197 with plate 12). To this day, it has remained one of only a few discoveries of sulphur. The flammable properties of sulphur had long been known in ancient China, the Arabic world and the eastern part of the Mediterranean and the finds from Kekomäki illustrate that by the 13th century at the latest, this knowledge had spread to the most marginal regions of Europe.

Over the course of the later Middle Ages, sulphur became an increasingly sought-after commodity in Europe. It had entered many aspects of daily life and both the ruling and the emerging merchant classes soon began to try to gain control of sulphur exploitation, processing, and trade. From the 13th century onwards, Iceland's rich sulphur deposits attracted the attention of foreign merchants who soon began to export sulphur in great quantities. Other European sulphur deposits were known and exploited at that time, e.g. in Sicily, Poland and Sweden (Nilsson 2005; Panciera 2006, 96) but by that time Iceland had entered the northern European economic area and sulphur soon became its most important export item besides stockfish and homespun.

Sulphur is a Latin word. In Middle English it was known as *brimstone*, deriving from *brinston* or *bernston*, meaning 'burning stone'. The Icelandic word *brennisteinn* and the Old Norse *brennistein* are closely related. In Old English it was called *sweft* which is closely related to the German term *Schwefel* and the Norwegian word *svovel*. Sulphur is a chemical element with the symbol S and it occurs in two forms: in its elemental form or as sulphur minerals in combination with metals and earths. In Iceland, only elemental sulphur is found (Vestdal 1943, 59, 62) which melts at a temperature of c. 115° C. It occurs in great quantities at so-called *solfatares*, openings in the earth crust that emit hydrogen sulphide and other gasses (Fig. 1). Once the gasses come in contact with oxygen, the hydrogen sulphide turns into elemental sulphur and sulphur dioxide.



Figure 1. Sulphur from the solfatares at Krýsuvík, Iceland. (Photo: ©N. Mehler)

The 18th and 19th centuries are the best-known period of sulphur mining and refining in Iceland. The earlier history, especially that of the 15th and 16th centuries which is considered to have been the heyday of the Icelandic sulphur industry, has been described by Finnsson (1783), Vestdal (1943, 64-66), Þorsteinsson (1972) and Guðmundsdóttir (2008). This period roughly coincided with a phase during which Iceland's trade was largely in the hands of German merchants, predominantly from Hamburg and Bremen, and to a lesser extent from Lübeck (e.g. Baasch 1889; Hofmeister 2000; Karlsson 2000, 123-127; Þorláksson 2003, 142-152). The merchants and their home towns were part of the Hanseatic League but from the 15th century onwards, merchants from Bremen and Hamburg acted more and more on their own accounts and had expanded their business to incorporate the North Atlantic islands of Shetland, Faroe and eventually Iceland. Iceland's connections with the Germans remained firm until Christian IV (1577-1648), King of Denmark-Norway, put an end to it in 1602 by introducing the Danish Trade Monopoly (Aðils 1971). Initially, the Germans were mainly interested in stockfish, but with the development and spread of firearms throughout northern Europe in the later medieval period the demand for gunpowder, and thus sulphur, rose rapidly. Sulphur soon became a commodity of considerable economic, political and cultural importance.

The applications of sulphur

The possible uses of sulphur are diverse and it was an essential component in many aspects of daily life. In pharmacy, sulphur was valued due to its antibacterial and stimulating properties. Sulphur was processed and added to unguents used to cure haemorrhoids and skin diseases such as psoriasis, acne vulgaris or leprosy. Because sulphur stimulates the intestinal mucosa it was also used internally as a laxative. Abbess Hildegard of Bingen (1098-1179), for example, handed down a prescription for an ointment for leprosy that contained sulphur (Lesshafft 2006, 12). The same use but a different method is known from the late 13th century. A decree issued by Burkhard von Serkem (1276-1317), Bishop of Lübeck, dated 12 June 1294 and addressed to the leper house outside the town, orders lepers to dress in sulphur-treated Icelandic woollen cloth (Lat. *watmalico*, or *vaðmál* in Icelandic): *Omnes autem simplici panno, scilicet griseo watmalico vel sulphurico vestiantur* (LUB III, no. 32). This reference is quite

remarkable as it combines two Icelandic products in one commodity, thus suggesting that the cloth was perhaps treated with sulphur in Iceland before it was exported. Above that, sulphur was also used to treat animals. A travel account dating from the late 18th century mentions the treatment of growths on cow udders in Iceland by fumigating the infected area with sulphur (Olafsen 1774, 114).

Sulphur was also used as a pigment component in a bright red colorant known as vermilion. Vermilion, originally made from the powdered mineral cinnabar, can also be produced synthetically by mixing mercury and sulphur, or Highland moss and sulphur, as done in Iceland (Jónasson 1961, 27). The first method has been known since at least the 9th century and during the Middle Ages, vermilion was particularly often used in wall paintings, manuscripts and illuminations but also to dye cloth (Struckmeier 2011, 194-195). Jónsbók, the Icelandic law codex written around 1363, for example, was illustrated with vermilion (Best et al. 1995). During excavations in Milk Street, London, remains of vermilion were found on oyster shells, interpreted as mixing palettes for manuscript illumination, and dated to the early 12th century (Pritchard 1991, 170; Loveluck 2013, 323).

Sulphur played also a great role as a preservative and disinfectant. A small amount of sulphur added to a barrel of wine stopped the fermentation process. It was common practice to place a lit sulphur fuse in an empty wine barrel, which was then closed tightly. After the fuse had gone out, the sulphur dioxide and the fumigation would then prevent the fermentation of any wine and it would disinfect the barrel and stop the wine from deteriorating (Lück and Jager 1996, 102-112). Sulphur dioxide fumigation furthermore helped to preserve hops which made it an important component (Narziss and Back 2009, 117).

But sulphur was of course greatly valued for its highly flammable properties and used to light fires, e.g. with a flint and strike-a-light (Weiner 2012). From the later medieval period onwards sulphur became increasingly important as a main ingredient in the production of gunpowder, which consisted of saltpetre (c. 74%), charcoal (c. 16%) and sulphur (c. 10%). Gunpowder made its way into Europe in the mid-13th century and the demand for it grew drastically with the development of firearms in the later Middle Ages (Gray et al. 1982).

Sulphur mining areas in Iceland

The richest sulphur deposits in Iceland lie along the Mid-Atlantic Ridge where active volcanoes are concentrated. Two areas were exploited on a large scale, one in the Mývatn district (*Mývatnssveit*) in the north and the other at Krýsuvík on the Reykjanes Peninsula in the south (Fig. 2). The sulphur mines (*brennisteinsnám*; *námur* is Icelandic for 'mine') at Mývatn were the most profitable, where the richest mine was located in the area of Reykjahlíðnámur. Other mines were at Kröflunámur and Leirhnúkur, at Fremri námur, and at Þeistareykjanámur, c. 35 km north east of Húsavík. Húsavík was the main harbour for sulphur export and sulphur was also refined here, as it was situated near the important mines of Mývatn (Vestdal 1943, 59-60, 65). The mines in the south of the country were exploited to a lesser extent. At Krýsuvík, sulphur deposits were concentrated at Brennisteinsfjall and sulphur from the south was processed near the mines and then transported on horseback to Straumur near Reykjavík (Vestdal 1943, 60).

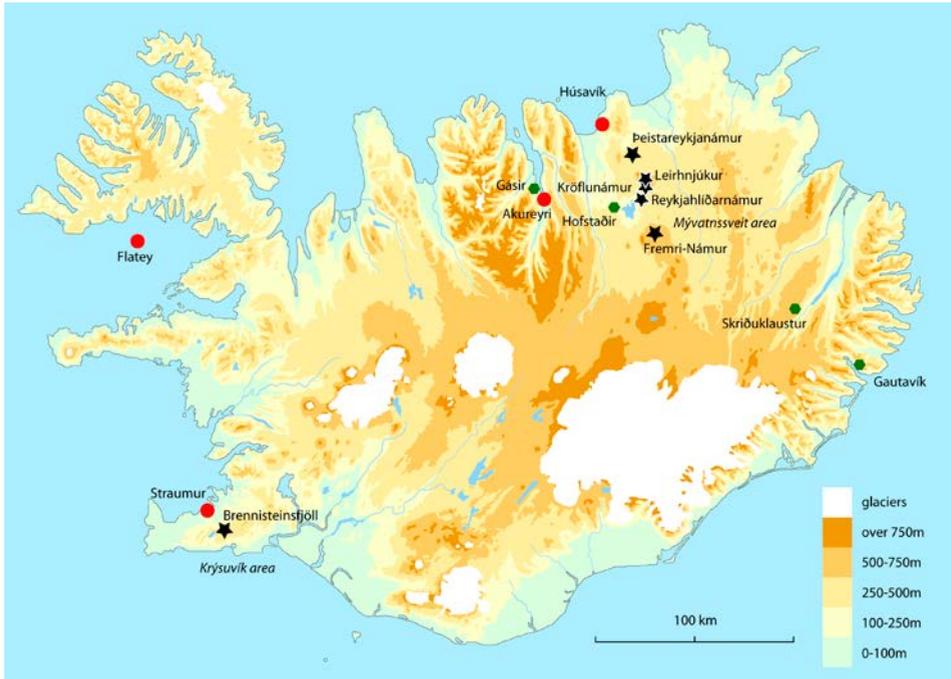


Figure 2. Map of Iceland with the sulphur mining areas of Mývatn and Krýsuvík (black stars), the main export harbours (red dots) and the sites where sulphur was discovered during archaeological excavations (green hexagons). ©Natascha Mehler.

Bringing together the evidence: written, archaeological and pictorial sources

First attempts to summarize the early history of the sulphur trade were made in the late 18th century. Hannes Finnsson (1783) gave a detailed historical account focussing on the 16th century while Pál Vídalín concentrated on the 17th century (Vidalin 1768). Jóhanna Guðmundsdóttir has recently analysed the sulphur history of the 15th and 16th centuries on the basis of written records from that time (Guðmundsdóttir 2008). Documents such as letters and decrees exist in Old Icelandic, Middle Low German and Old Danish and mostly deal with the political regulation of the trade, but also offer an insight into how it was organized. However, aspects of mining, exploitation or refining are hardly ever mentioned in this kind of record and we need to turn to 18th century travel accounts for a description of how sulphur was refined. Although these accounts postdate the medieval processes by about two centuries they give a clearer idea of how things were done, at least in the 18th century. Passages of earlier documents show that the 15th and 16th century methods would have been largely the same (see below).

Of great importance is the description of the sulphur mines and refinery at Húsavík in northern Iceland written by Ole Christian Henchel (1750-1824), in 1776 (published in 1780). Henchel (sometimes spelled Henckel) was an expert on mining industries (Berg 2003). In 1775, he travelled around Iceland to study the sulphur mining areas in general and the

sulphur refinery at Húsavík in particular which had been built in 1761. His detailed account *Underretning om den Islandske Svovel-Miiner samt Svovel-Raffinering sammesteds* (Statements regarding the Icelandic sulphur mines and the refining of sulphur) is a first-hand account that not only describes in detail how sulphur was processed but also includes suggestions as to how the methods could be improved and the profit increased (Henchel 1780). Other travel accounts focus on geological and topographical aspects of the sulphur areas. Examples are the accounts by Johan Anderson (1746) or the Icelandic scholars Eggert Ólafsson and Bjarni Pálsson who travelled through Iceland during 1752 and 1757 and published their descriptions of the sulphur areas in a series of books in the early 1770s (Olafsen 1774).

As an archaeological source, sulphur is very elusive and most of it has long disintegrated into smoke or dust. Therefore, the archaeological evidence is quite scarce but significant for our understanding of the history of medieval sulphur trade. The finds that have come to light so far are described in detail in this paper.

Lastly, there is one illustration predating the 18th century that shows processed sulphur ready for export. This schematic and not very precise illustration can be found on the *Carta Marina*, an early map of northern Europe created by the Swedish bishop and cartographer Olaus Magnus (1490-1557), printed in 1539. The map includes what is considered to be one of the earliest depictions of Iceland (Sigurðsson 1978). A barrel labelled SULVUR is drawn on the southern coast, roughly in the area of Krýsuvík (Fig. 3). A pile of stockfish and the tents



Figure 3. Detail of the *Carta Marina* (1539) depicting the southern coastline of Iceland and a barrel labelled SULVUR (image from Wikipedia, http://upload.wikimedia.org/wikipedia/commons/f/f6/Carta_Marina_Edited.jpg?uselang=de).

of a trading post are shown nearby. Four sturdily built round structures with frontal annexes can be seen behind the sulphur barrel. According to the map legend, these symbols represent four types of springs: drinking and thermal water springs, carbonated springs, and finally sulphur springs (Erkes 1929-1930, 79). In his *Historia de gentibus septentrionalibus*, which was published in 1555 and describes the geography and history of the Nordic countries, Olaus Magnus talks about 'sulphur veins', probably sulphuric streams (Magnus 1996, book 2, chap. 1). The *Historia* is presumed to have served as a detailed commentary on the *Carta Marina*. A second map by Abraham Ortelius, printed in c. 1585, mentions sulphur in the north near Mývatn but does not depict it in any form.

Olaus Magnus never visited Iceland but he may have learned about the Icelandic sulphur sources during his years in Lübeck, Hamburg and Bremen, and also in Gdansk, where he started working on his map (Miekkavaara 2008). He may have received the information from the Hanseatic traders who carried on an extensive sulphur trade with Iceland at that time. Magnus' work was largely based on the works of earlier scholars, particularly of the Danish historiographer Saxo Grammaticus (c. 1140 - c. 1220) and his *Gesta Danorum*, a history of the Danish kingdom, written around 1200 (Hadfield 2009, 15), which could have been another one of Magnus' sources on sulphur. The types of springs that Magnus depicts and describes in the *Carta Marina* are already mentioned in the *Gesta Danorum* (Erkes 1929-1930, 79). Indeed, Saxo Grammaticus mentions Icelandic sulphur springs but his description expresses surprise at the nature of these rather than an explanation as to what they could be and the potential uses of sulphur. In fact, smoking and steaming waters are mentioned, but the word 'sulphur' does not actually occur (Dan 0.2.7).

Sulphur processing

There are basically two methods of refining sulphur, both of which are based on heating or melting in order to extract or purify it. Sulphur minerals that occur in metals are roasted in order to extract the element. As sulphur in Iceland occurs only in its elemental form, this method will not be further explained here. Unfortunately, there are no contemporary sources that describe the method of refining elemental sulphur in Iceland during the Middle Ages. The earliest description available is the 1776 report by Henchel mentioned above, which specifies in detail the working methods and techniques that were employed at the sulphur refinery in Húsavík (Henchel 1780).

As Henchel describes, the sulphur was brought from the Mývatn mines to the refinery near the harbour in Húsavík. This refinery consisted of the melting works, two storage houses – one for raw and one for refined sulphur, and a third building which contained a living room and a kitchen. The complex was erected *paa Islandsk Maade av Torv*, using the Icelandic construction technique of building with turf. The refinery is described as a building of c. 6.25 m in length and c. 3.75 m in width.¹ It contained a platform with two built-in iron pans, the smaller one with a capacity of a metric hundredweight of melted sulphur and the larger one with a capacity of 3 metric hundredweights of unrefined sulphur. A wooden board with a hole in each end was built into the wall above the pans. A stick was fitted into each hole to stir the sulphur, thus making the task easier for the workers to carry out (Henchel 1780, 710-711).

1 10 ells long and 6-7 ells wide; a Danish ell corresponds to c. 0.625m (Krüger 1830, 272).

The sulphur was processed in the following manner: approximately two pounds of sulphur were heated in the iron pan while stirring gently and consistently. The purpose of this process was to dry the sulphur rather than to melt it right away. Once the sulphur started to melt, train or fish oil was added while the stirring continued. The soil and impurities adhering to the train oil eventually formed a mass floating on top while the refined sulphur sank to the bottom. The impurities were skimmed, new sulphur and train oil added and the process repeated until the pan was full and the refined sulphur was transferred into wooden moulds using iron sieves. The moulds consisted of four oak planks and were c. 94 cm long and 31 cm wide. More wooden planks were inserted in the moulds, effectively cutting the cooling sulphur into thin slices. Before the hot sulphur could be poured into the moulds, these had to be dipped in cold water which ensured that the sulphur slices could be taken out of the moulds more easily (Henchel 1780, 711-712). Unfortunately, Henchel did not include a drawing of the building but a plate shows some of the tools and technical equipment that he saw at the sulphur refinery in Húsavík (Fig. 4); these include an iron shovel with holes to skim off the impurities floating on top of the sulphur melt.

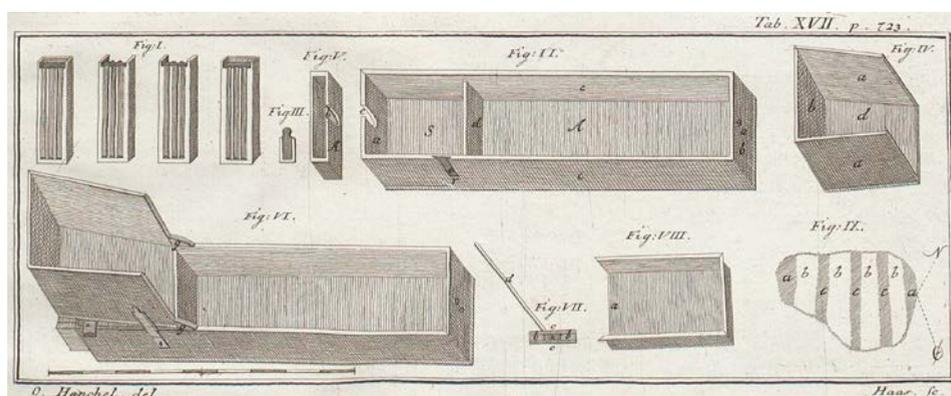


Figure 4. Tools and technical equipment from the sulphur refinery at Húsavík, northern Iceland. I = wooden moulds for the sulphur melt; II = sieving plant, IV = wooden construction fitted above the sieving plant, VI = Sieving plant assembled, VII = oak wood rake, VIII = metal pan to dry the sulphur (after Henchel 1780, fig. p. 722).²

In a country with limited access to fuel, the melting process must have been a delicate business. In fact Henchel reports that the melting was not done daily but only at certain times. While each year about 9m³ of beech wood were sent from Denmark to Húsavík for use in the refinery, turf was also burnt (Henchel 1780, 710-712).

Henchel also critically evaluated the working processes at the sulphur refinery and concluded that train oil consumption was far too high, making the production process almost unviable. He also reported that the refined sulphur was contaminated by the train oil which later affected the granularity of the gunpowder, making it too sticky and of bad quality, as claimed by powder mill owners in Copenhagen (Henchel 1780, 714-715). Henchel therefore suggested that the sulphur should be washed and floated with water in Iceland before it was melted, an idea objected to by the director of the Húsavík refinery, arguing that this had previously been done, and had not been satisfactory. While there had indeed been a reduction in the

2 Not all instruments illustrated here are explained in Ole Henchel's text.

amounts of train oil used it had also resulted in a significant loss of sulphur which dissolves in water (Henchel 1780, 717). In an attempt to avoid this, Henchel subsequently designed a wooden sieving plant (*Slæm-Drum*) which was intended to reduce the loss of sulphur (Fig. 4 nos. II and VI). It consisted of two basins separated by a partition wall, where the water could overflow from one basin into the other. A wooden construction could be placed on top of the basin (Fig. 4 nos. IV and VI) into which the impurities that were skimmed off could be placed. The water for this construction was brought in via wooden pipes from a reservoir. Humidity was another problem in storing the refined sulphur. Henchel proposed drying the sulphur in a metal pan (Fig. 4 no. VIII) before melting it. The refinery, which employed a director and four workers, would then have operated thus: floating would have taken place in the spring after the farmers had brought the raw sulphur to the refinery. The floating process required two people: one to watch the settling basin, the other to skim off the impurities. In the meantime, the other two workers would cut turf for fuel. The melting then took place once all the raw sulphur had been washed (Henchel 1780, 718-720, 725-726, 728).

It is unclear when sulphur processing began in Iceland. The oldest surviving record that mentions 'melted' (*smelltan*) sulphur dates from 1506 (DI 8, no. 98; Guðmundsdóttir 2008, 24). The document does not indicate how it was done but other sources clearly state that train oil was also used in the processing of sulphur at that time. One record dating from 1589 mentions that the sulphur was refined using water, as was also stated in the late 18th century by the director of the Húsavík refinery. South of the farm Garður at Mývatn there is, in fact, a pond called Brennisteinstjörn which means 'sulphur pond' and this suggests that its water was used to wash sulphur (Guðmundsdóttir 2008, 25-26).

The archaeological evidence shows that sulphur was already processed in Iceland prior to the early 16th century. In 2002, excavations at the medieval trading site of Gásir in northern Iceland uncovered a pit of about 3 x 3 m in size which contained layers of peat ash, charcoal and sulphur (Roberts 2003, 10, 17; Adderley et al. 2003). The fuel deposits and the composition of the sulphur indicate that the pit was actually used to process sulphur (pers. comm. Ian Simpson and Howell Roberts). It is, however, difficult to date the feature. Gásir had been a trading site until the late 14th or early 15th century. In 2002, more sulphur lumps were found, one associated with a Rhenish stoneware fragment dating from the period between the late 13th to the early 15th centuries (Mehler 2004, 61, 70) and more sulphur came to light during subsequent excavations which were completed in 2006 (e.g. Roberts 2004).

Sulphur was processed in Iceland until 1562, after which the operation was transferred to Copenhagen and not resumed until modern times. In March 1562, Frederik II commanded two ships, each with a minimum capacity of 100 last (*thuo gode skibbe. huertt paa ett hundritt lester oc ick mindre*) (1 last is approx. 2 tons), to sail to Iceland and buy train oil and sulphur; he also had a building erected in Copenhagen where the sulphur could be refined: *att the ther wdj wor köbsted Köbnehaffn skulle lade lutre all thend suouell* (DI 13, no. 521). Two ships of the same size had already been sent to Iceland in the previous year to collect sulphur (DI 13, no. 424). The king obviously felt that refining sulphur in Iceland was too difficult and costly. In 1562, he commissioned Admiral Herluf Trolle (1516-1565) to build a sulphur house at Stranden Plads, which at that time was a small island at Kalvebod strand near the royal castle. Two windmills were erected next to it (Nielsen 1885, 211, 313; Fleischer 1985 s. v. Kongens Bryghus) and a 1555 record indicates that they could have been powder mills (*krvd mølle*)

(DN 11, no. 690). Indeed, the sulphur house can be seen on an engraving entitled *Hafnia vulgo Kopenhagen* printed in 1587. It shows a frontal view of the sulphur house, a framework building located between two windmills (Fig. 5). During an archaeological survey carried out in Copenhagen in 2012, indistinct remains of the sulphur house were recorded in a section of a new line trench (Rohden Olesen 2012, 31-33). This first sulphur house did not survive very long. In the early 17th century, the island was incorporated into the bastion and a new sulphur house was built (Nielsen 1885, 211, 313; Fleischer 1985 s. v. Kongens Bryghus).



Figure 5. The sulphur house built by Frederik II in Copenhagen in 1562, as depicted on the engraving *'Hafnia vulgo Kopenhagen vrbs Daniæ primaria qua se terra mariqve conspiciendam exhibit Anno Salutis M.D.LXXXVII'* printed in 1587 (illustration by the Museum of Copenhagen).

Sulphur mining and trade up to the end of the 16th century

The history of the Icelandic sulphur trade up to c. 1600 is characterized by periods of foreign interest in and control of Iceland, first by the Norwegian kings, then by English fishermen and traders, followed by German merchants, predominantly from Bremen and Hamburg, and finally the Danish-Norwegian kings. A very early reference to sulphur trade can be found in the *Colloquy*, written by the English abbot Ælfric shortly before c. 1010 but it does not say where in Europe the sulphur was purchased (Loveluck 2013, 319). The first clear written evidence for sulphur stemming from Iceland dates to the second half of the 12th century and at that time, Bergen was the main port for distribution (Guðmundsdóttir 2008, 7). When Iceland was taken over by the Norwegian crown in 1262, the bishop's see at Nidaros already had the right to acquire sulphur (DI II, no. 71; Þorsteinsson 1972). Over the course of the 14th century, when the demand for gunpowder was rapidly increasing, the interest in Icelandic sulphur rose accordingly. The Norwegian kings had a strong interest in keeping control of the sulphur trade and the imposition of tolls and taxes is mentioned in several records (Þorsteinsson 1972). At that time, sulphur was also frequently mentioned in English customs accounts. Shipments of sulphur came from Bergen to Ravensere (1306, 1308) and Boston (1309, 1333), for instance, and, although it was not specifically mentioned, it is highly likely that the sulphur had originated in Iceland (Guðmundsdóttir 2008, 8; Nedkvitne 2014, 58, 610, 612). In the 15th century, the sulphur trade fell largely into English hands. English fishing vessels, first recorded in Icelandic sources in 1412, were now increasingly often operating around Iceland, and they appear to have also brought home sulphur. As early as 1419, no fewer than 25 English ships are said to have sailed to Iceland. Records of that time

tell of sulphur mining in Fremri-Námur, from where it was transported across the mountains to the harbour at Straumur (near Reykjavík) and to Flatey, a small island in Breiðafjörður (see Fig. 2); from there, the sulphur was sold on to merchants from Bristol (Þorsteinsson 1972; Karlsson 2000, 118-122).

Although German merchants are first mentioned around the same time as the English the Germans only gained a foothold in Iceland in the late 15th century, after a Danish prefect had been killed by an Englishman in 1467, prompting the Danish king to begin promoting German merchants in Iceland. A Hamburg vessel was the first to be recorded in 1423, followed by a ship from Bremen in 1469 (Hofmeister 2000, 20-21; Hill 2004, 201-202). Merchants from other Hanseatic towns such as Gdansk and Lübeck also travelled to Iceland but less frequently. The Dutch too had begun to sail to Iceland to take part in the sulphur trade but could not compete with the dominant Germans at that time (Baasch 1889, 79). The Hanseatic period in Iceland gradually came to an end when the Danish king introduced the Danish Trade Monopoly in 1602. The implementation of the Trade Monopoly, however, was a lengthy process and German merchants continued to sail to Iceland until the 1620s (Baasch 1889; Hofmeister 2000; Karlsson 2000, 122-127; Mehler 2009, 95; Hofmeister, in press; Lorenzen-Schmidt, in press).

Sulphur trade in the first decades of the 16th century was largely in the hands of Bremen and Hamburg merchants and sulphur had become a commodity that was almost as important as fish (Baasch 1889, 78). Until 1560, Hamburg, for example, sent two or three ships annually to Húsavík and a location called Eyjafjörður, which probably corresponds to present-day Akureyri, most likely to collect sulphur (DI 13, no. 436 p. 583; DI 14, no. 112; Baasch 1889, 79), but the number of ships could have been higher (Baasch 1889, 80). Guðmundsdóttir (2008, 17) has calculated that some 320 tons of sulphur were exported every year, which suggests that enormous profit was to be made. Baasch (1889, 79) has calculated that gross profit from the sale of sulphur in Hamburg was 1600%. Ships from Lübeck are also frequently mentioned, e. g. in 1557, when Gert Ruther, Jorgen Koninck and Cordt Kroene sailed to an unspecified port in northern Iceland to pick up sulphur (DI 13, no. 196). Hamburg merchants not only brought the sulphur to their home port but also sold it to the Danish king for a high price (DI 13, no. 430; Slangen 1759, 379; Finsson 1783, 5 footnote 10; Baasch 1889, 79-80).

Naturally, King Christian III (1537-1559) repeatedly tried to gain control of the sulphur trade but it remained free until the mid-16th century. Only his successor Frederick II (1559-1588) managed to gain full control of it (Þorsteinsson 1972). In 1561, he monopolized the sulphur trade and from then on foreign merchants were officially excluded from the business. In January of that year, Frederik instructed the royal governor of Iceland, Páll Stígsson, to prohibit foreigners, particularly merchants from Hamburg, Bremen and Lübeck, from exporting sulphur (DI 13, nos. 426-427; Aðils 1971, 509; Guðmundsdóttir 2008, 14). A few weeks later, he also wrote an open letter to the inhabitants of northern Iceland commanding them not to sell sulphur to any foreigners. Indeed, after 1561, hardly any records refer to the export of sulphur from Iceland to Hamburg (or to other German towns) anymore. It is highly likely that sulphur was traded illegally but naturally this was only officially recorded when a ship was caught in the act. In 1562, the king had all Hamburg ships intercepted in Skagerrak strait and searched for illegal goods, including sulphur (Slangen 1759, 379).

However, the monopoly seems to have been difficult to enforce. On May 4th 1562, Frederik once again instructed Hamburg merchants not to export any more sulphur (DI 14, no. 6; Guðmundsdóttir 2008, 15). He awarded the sulphur trade privileges to Danish merchants and officials, who now bought it directly from the collecting farmers (Nielsen 1885, 211).

Once the king had gained control of the sulphur trade, he also needed full access to train oil in order to refine the sulphur. In March 1562, he introduced a train oil monopoly to ensure the success of his newly erected sulphur smelting works in Copenhagen (DI 13, no. 531; Aðils 1971, 42). The documents do not specify the kind of train oil used but at that time Icelanders were usually extracting it from (stranded) whales, seals, shark and cod (Guðmundsdóttir 2008, 25). In the same year, Frederik II sent a letter to Erik Rosenkrans in Bergen, instructing him to bring all the train oil from the fiefs of Bergenhus and Vårdhus to Copenhagen (DI 13, no. 565) which indicates that Icelandic train oil was not enough to refine the sulphur brought to Copenhagen and that also Norwegian train oil was needed.

The operation of the sulphur trade: collection, transport, and harbours

Prior to the king's sulphur monopoly, sulphur mines were in the hands of powerful dynasties or bishops. From the late 14th to the mid-16th centuries, all sulphur mines in the north of Iceland belonged to the clan of Finnbogi Jónsson (c. 1440 - c. 1513), the local governor (Norw./Dan. *sysselemann*) of northern Iceland (Thoroddsen 1883-1884, 98). This changed when the king introduced the sulphur monopoly and began to buy up all sulphur mines. In a document dated 15 August 1563, Vigfús and Nikulás Þorsteinsson, Finnbogi Jónsson's grandsons, sold all their sulphur areas to the king (DI 14, no. 113). By the end of the 16th century, some of the sulphur mines seem to have become overexploited. A 1589 record states that a considerable amount of sulphur had been exported over the previous 40 years or more but that the amount was now decreasing (Guðmundsdóttir 2008, 19).

The sulphur was collected by farmers in the spring time, after the snow had melted, but before they were occupied with summer activities such as hay making (Henchel 1780, 727; Guðmundsdóttir 2008, 27). A mine was a location where elemental sulphur protruded from the ground and could be collected by digging it up. On Henchel's map created during his 1775 visit each mine is marked with the chemical symbol for sulphur, a triangle with a cross below. This symbol combined with the capital letter A, marks the mines with the best quality sulphur (Fig. 6). Some sulphur areas such as Þeistareykjanámur in the north were quite isolated and inhospitable and it is possible that simple buildings were erected to offer shelter in bad weather conditions. Archaeological surveys have been carried out in recent years in some of the mining areas both in the north and south (e.g. Einarsson 1998; Vésteinsson 2001; Bergsteinsson 2008; Kristjónudóttir 2008; Stefánsdóttir 2008). In the northern mining area at Mývatnssveit, four ruined stone buildings were recorded at Ketildyngju at Fremri-Námur, one of which was interpreted as a shelter for sulphur collectors. The dating remains uncertain because no archaeological excavations have been carried out so far (Fig. 7) (Kristjónudóttir 2008).

Once it was dug up, the sulphur was brought to the farms. A document dating from 1550 states that unrefined sulphur was kept at the farms of Arnarvatn and Saltvík near Húsavík, both near the Mývatnssveit mining areas (DI 11, no. 688, p. 877). From there it was transported

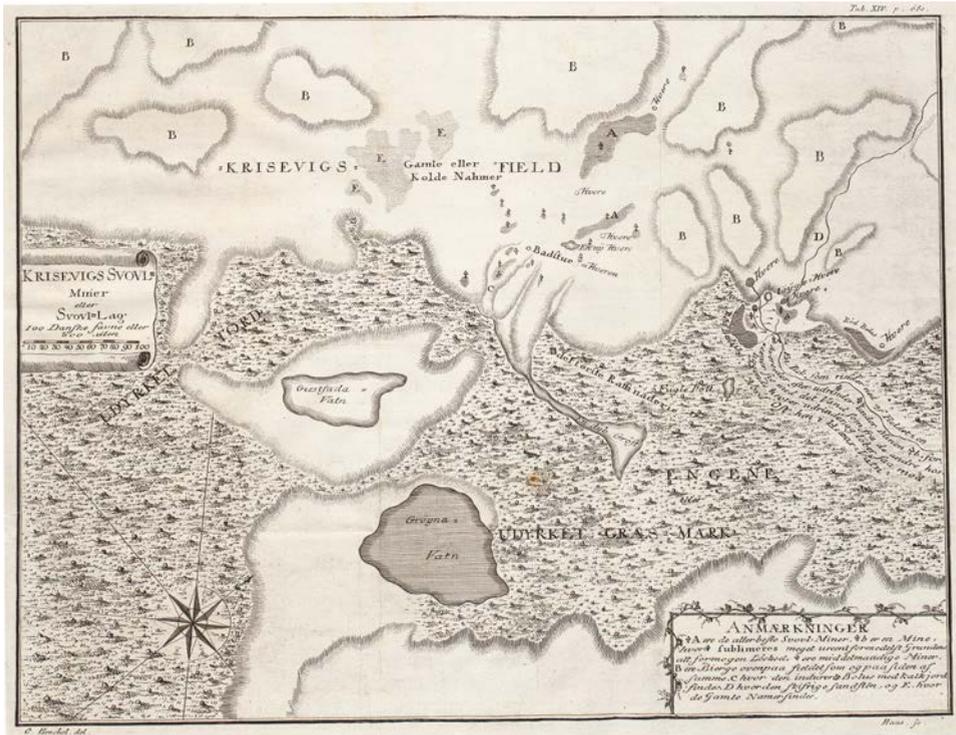


Figure 6. Map of the sulphur mines at Krýsvík on the Reykjanes Peninsula, published by Ole Henchel in 1780. A rectangular building labelled “det første Raffinaderie” (the first refinery) is marked in the centre. Each mine is labelled with the alchemy symbol for sulphur, a triangle with a cross below (after Henchel 1780, map p. 680).



Figure 7. The ruin of a stone building at Ketildyngju at Fremri-Námur, possibly the remains of a shelter for sulphur collectors. (Photo: Inga Sóley Kristjónudóttir, taken in 2008).

by horse to the various harbours (DI 13, no. 524). From 1561 onwards, the sulphur was collected by Danish officials who then gave it to the king (DI 13, no. 430; no. 524). One such Danish official was Hans Nielsen who in 1560 was charged with overseeing the sulphur trade for the following 10 years (DI 13, no. 363). Prior to 1561, when German merchants were still permitted to buy sulphur, the substance was barrelled in Iceland. Barrels varied in size, with weights ranging from 300 to 490 pounds. Once the ships arrived e.g. in Hamburg, the barrels were transported to the weigh house and inspected by a member of the city council (Baasch 1889, 80).

After 1561, sulphur was sold to the Danish king in its raw form, i.e. unrefined, and then processed in Copenhagen. Prior to that, sulphur had been exported to Hamburg in both forms, i.e. raw and refined. This is indicated by a price difference depending on the quality of the sulphur. Some Hamburg records describe the sulphur as *lutteren* (DI 13, nos. 521 and 565; Baasch 1889, 80) meaning refined. The sulphur that was exported in its raw state must have either been refined in Hamburg or sold on.

During the second half of the 16th century, especially after the introduction of the Danish sulphur monopoly which had come into force in 1561, two ships had sailed from Hamburg to Iceland every year to pick up sulphur (e.g. DI 11, no. 328). They generally headed for Húsavík but sometimes also for an unspecified port in Eyjafjörður, most likely Akureyri, as was the case e.g. in 1562 (DI 13, no. 529). Prior to the period of German trade domination, the trading site of Gásir had also been used to ship sulphur, as clearly shown by the archaeological evidence discussed above. Gásir is located very near Akureyri and in all likelihood was its predecessor (see Fig. 2). Later, during the Danish Trade Monopoly (1602-1789) Húsavík was the only harbour used by sulphur traders (Aðils 1971, 42, 260).

The introduction of the sulphur monopoly naturally resulted in intensive smuggling. There were not that many Danish officials in Iceland and the vast swathes of land were difficult to monitor. Because Húsavík was firmly in the hands of Danish officials sulphur was smuggled to other harbours. In August 1562, Kolbeinn Þorgrímsson was accused of having brought sulphur from the mines at Fremri-Námur to the harbour on the island of Flatey and to Straumur near Reykjavík (DI 14, no 9.); he must have transported the sulphur across the mountains on horseback (see Fig. 2). In 1566, a ship with illegal goods including five lasts of sulphur stranded in the Thy district in Jutland, Denmark. Because the sulphur was regarded as the king's property it was seized by the authorities and transported to Thisted (DI 14, no. 393).

The importance of sulphur for the Hanseatic League

The Hanseatic expansion towards Iceland coincided with the spread of firearms in Northern Europe. In the 15th century, firearms were commonly used, both in land and sea battles. By around 1500, artillery had become the norm on warships (Unger 1981, 245, 248; McLachlan 2010, 8). Having a firm grip on Icelandic sulphur from the end of the 15th century at the latest, German merchants were able to provide sulphur for gunpowder production. Around the same time that Hamburg merchants were first mentioned in Iceland (1423), a powder mill stood on the outskirts of the city (Piezonka & Schlottau 1985, 55). The League also made good use of sulphur in its own naval conflicts such as the Anglo-Hanseatic War (1469-1474) (Dollinger 1998, 390-392).

However, armed conflict was not the only reason why sulphur was such an important commodity for the Hanseatic League. It was also required to keep the beer brewing business going. Sulphur was used to preserve the hops and disinfect all the barrels used to transport the beer. The export of beer was one of the main pillars of the economy, especially for Bremen and Hamburg from where large quantities were shipped to Scandinavia and also to Iceland (von Blanckenburg 2001). Other commodities such as fish, flour and wine were transported in barrels which all needed to be cleaned and disinfected regularly, and towns such as Hamburg produced great quantities of barrels (Holbach 2006).

Bergen's role in the Hanseatic sulphur trade

Starting at the time when Iceland came under Norwegian rule in 1262 up to the second half of the 15th century, when all direct trade with the North Atlantic islands was prohibited, Bergen was the main trading hub for goods coming from and going to Shetland, Faroe, Iceland and the Norwegian areas north of Bergen. During this period, prior to the time when German merchants traded freely with Iceland, most of the sulphur was channelled via Bergen. Initially, it would have been brought there by Norwegian merchants and then later, also by the English who not only had begun to sail to Iceland but were also regularly trading with Bergen at that time. By about 1360, one of four Hanseatic *kontors* was established there and from then on, trade was dominated by merchants from Lübeck. Between September 1379 and July 1380, four ships from Lübeck arrived in Hull on the east coast of England carrying sulphur (DN 19, no. 598) which must have been acquired in Bergen. Sulphur was also part of the Lübeck-Bergen-Boston trade as attested to by three German merchants bringing sulphur to Boston in 1333 (DN 19, no. 536).

In the later Middle Ages, Bergen's trade was dominated by Hanseatic merchants (Helle 1995, 378). Once the first Hanseatic commercial settlement had been established there in 1343, the town remained a major Hanseatic base for the North Atlantic and trade was dominated by Lübeck merchants (Helle 1995, 773-788; Dollinger 1998, 136-137). This supremacy was largely based on the royal trade ban mentioned above which prohibited foreign merchants from trading with other places north and west of Bergen, including Iceland. The ban lasted for over 100 years, coming into force in 1294 and ending in the second half of the 15th century (Friedland 1973, 69; Dollinger 1998, 318). By limiting the sulphur trade to Bergen during the period of the ban a sulphur monopoly was effectively created for the city. The tax that was due upon arrival of the sulphur in Bergen raised revenue for the king.

Around the mid-14th century, a ship sank off the Darss coast in the German State of Mecklenburg-Western Pomerania. Oak planks were dendrochronologically dated to 1298-1313 (Daly 2007, 70) and the cargo included, amongst other things, schist from Eidsborg in Norway, reindeer antler and a barrel of sulphur (Fig. 8). Staves from the sulphur barrel were dendrochronologically dated to 1335 (Förster 2003, 88). The ship must have picked up the reindeer antler, the schist and sulphur in Bergen, the latter having been brought there from Iceland by Norwegian or English merchants; the ship then sank on its way home after having crossed the Skagerrak strait (Mehler 2009, 101).



Figure 8. Oak barrel containing sulphur, discovered in the wreck of the so-called Dars Cog which sank off the German coast around the mid-14th century. (Photo: Roland Obst)

Other archaeological finds

In order to shed light on the early history of sulphur mining in Iceland, three more archaeological discoveries shall be discussed. The first is a small sulphur deposit discovered at the Viking Age hall at Hofstaðir in Mývatnssveit. The sulphur (find no. 00-120) was discovered in the fill of a barrel pit in annex building A2 to the east of the large hall (context 254b) (Lucas 2009, 122, 305). The pit had a diameter of c. 1.64 m and, after the barrel had been removed, was backfilled with manufacture debris from smithing activities which included slag, fragments of hearth lining, charcoal, ash, turf and sulfur. A hearth was discovered just southeast of the barrel pit. The use of the building and pit was dated to the late 10th and early 11th centuries (Lucas 2009, 122, 305). The feature is remarkable because of its early date, making it probably the oldest sulphur find of northern Europe so far. The context of a smithy and the deposition alongside charcoal indicates that the sulphur was used as an inflammable matter in the process of lighting fires.

From 2002 to 2011, extensive archaeological excavations took place in eastern Iceland at the monastery of Skriðuklaustur. Founded in 1493, it was run by Augustinian monks and it was dissolved in 1554. The monastery included a church with a cemetery, a building complex with cells and a kitchen, a cloister garden and a well and it also served as a hospital. The remains of eight skeletons were found in a separate part of the cemetery. Analyses revealed that the individuals had suffered from syphilis (Kristjánsdóttir 2008; 2012; Kristjánsdóttir &

Collins 2011). A lump of sulphur associated with two fireplaces was found in a small room at the north-western end of the building complex (Fig. 9). No food remains were found in the room, and this has made its interpretation rather difficult. The sulphur, however, has opened up a new possibility. In medieval times, most of the medication used in hospitals was produced in their own laboratories or alchemy kitchens. The sulphur could indeed indicate that medications such as ointments or even sulphur-treated cloth were made in this room at Skriðuklaustur. Given the monastic context it is also possible that vermilion was produced here for manuscript illuminations.

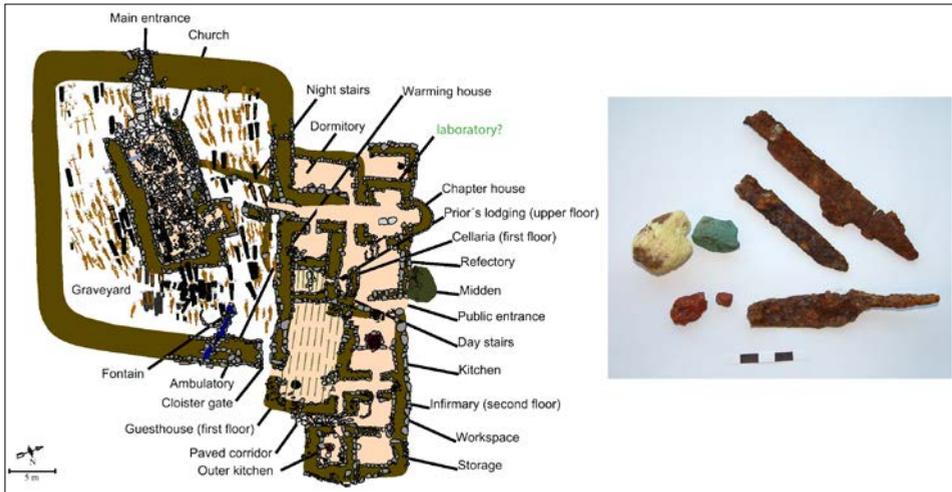


Figure 9. Excavation plan of the monastery at Skriðuklaustur, eastern Iceland. A small room, which may have been used as a laboratory, was discovered in the north-western part of the building complex. Finds from the room included a fragment of sulphur. (Illustrations: Steinunn Kristjánsdóttir)

The final discovery to be mentioned here was a round brick-built structure excavated in the late 1970s at the medieval trading site of Gautavík in eastern Iceland (Fig. 10). The structure had a diameter of c. 2.10 m and was dated stratigraphically to the late 15th or early 16th centuries. This date corresponds well with the imported bricks which on the basis of their format (c. 29 x 16 x 8cm) can be dated to the same period (Schäfer 1995, 8; Bertelsen 2010). The interpretation of the structure has so far proved difficult. While one of the excavators suggested that the structure might have been a drying kiln (Capelle 1982, 56-58), this interpretation has not found favour amongst other archaeologists. Others have suggested that it was perhaps a kiln to produce train oil (Ólafsson 2005, 16) or a construction used to process sulphur (Mehler 2007, 239); the latter idea was based on an unidentified whitish substance (Capelle 1982, 45, 52) which had been found between the bricks during the excavations. Although both interpretations are plausible no firm conclusions can be drawn without further analysis and a re-excavation of the *in-situ* structure. Gautavík was a trading site until the end of the 16th century and also supplied the monastery at Skriðuklaustur. It is reasonable to assume that either sulphur or train oil, the latter an important component in the sulphur production process, were processed at the site.



Figure 10. Brick-built structure excavated at the medieval trading site of Gautavik, eastern Iceland (After Capelle 1982).

Conclusion

This first attempt at summarizing the historical and archaeological evidence of medieval sulphur mining and trading in Iceland has hopefully demonstrated the wide-ranging economic, political and cultural importance that sulphur had at that time. By the later Middle Ages, sulphur had become an immensely powerful trade commodity which rulers were eager to control. It has been argued that in the 15th and 16th centuries, the role of sulphur as an export article was almost as important as that of fish, especially for the Hanseatic League. Iceland's rich sulphur deposits attracted foreign merchants, resulting in the island having the competitive edge over other Northern European areas. In the 14th and early 15th centuries, Bergen virtually had a sulphur monopoly secured by a ban on trade with Iceland. The later sulphur monopoly imposed on Iceland by King Frederik II in 1561 may have been a prelude to the subsequent Danish Trade Monopoly that was in force between 1602 and 1787.

Archaeological evidence relating to sulphur mining and trade is still scarce but nonetheless important when it comes to dating the use of sulphur and the knowledge regarding its properties, which obviously began considerably earlier than the written records seem to suggest. Finds from the trading site of Gásir have shown that sulphur was processed in Iceland from the 14th century onwards at the latest. The finds also show that Gásir was used as an export harbour at that time (Roberts 2002, 27; Harrison et al. 2008, 103).

Many aspects of the early history of Icelandic sulphur mining undoubtedly still lie in the dark and numerous questions remain unanswered. One important question to address in the future is whether the economic power of the sulphur trade had anything to do with the lifting

of the Bergen ban of trade in the second half of the 15th century. Equally important would be a systematic study of the amounts of sulphur traded, the development of prices and the economic forces in this sulphur business of Northern Europe.

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References

- Anderson, J. 1746. *Nachrichten von Island, Groenland und der Straße Davis, zum wahren Nutzen der Wissenschaften und der Handlung*. Georg Christian Grund, Hamburg.
- Aðils, J. 1971. *Einokunarverslun Dana á Íslandi 1602-1787*. Heimskringla, Reykjavík.
- Baasch, E. 1889. *Die Islandfahrt der Deutschen, namentlich der Hamburger, vom 15. bis 17. Jahrhundert*. Forschungen zur Hamburgischen Handelsgeschichte 1. Herold, Hamburg.
- Berg, B. I. 2003. Bergseminaret på Kongsberg. Kunnskaper og teknologiske læretradisjoner i Bergverkhistorien. *Det norske Videnskaps-Akademi Årbok* 2003, 316-331.
- Bergsteinsson, S. 2008. *Þeistareykir. Fornleifaskráning*. Rit Fornleifavernd ríkisins 2008, 13. Fornleifavernd ríkisins, Reykjavík.
- Bertelsen, T. 2010. Teglstensformater og forbandter i Danmarks middelalder og renæssance. *Årskrift Museum Sønderjylland* 2010, 58-65.
- Best, S., Clark, R., Daniels, M., Porter, C. & Withnall, R. 1995. Identification by Raman microscopy and visible reflectance spectroscopy of pigments on an Icelandic manuscript. *Studies in conservation* 40, 31-40.
- von Blanckenburg, C. 2001. *Die Hanse und ihr Bier. Brauwesen und Bierhandel im hansischen Verkehrsgebiet*. Quellen und Darstellungen zur hansischen Geschichte, N. F. 51. Böhlau, Köln.
- Capelle, T. 1982. *Untersuchungen auf dem mittelalterlichen Handelsplatz Gautavik, Island*. Zeitschrift für Archäologie des Mittelalters, Beiheft 1. Habelt Verlag, Bonn.
- Dan = Gesta Danorum, by Saxo Grammaticus (c. 1140-1220). Webedition, Det Kongelige Bibliotek. <http://wayback-01.kb.dk/wayback/20101103143222/http://www2.kb.dk/elib/lit/dan/saxo/lat/or.dsr/index.htm> (last accessed April 2014).
- DI = Diplomatarium Islandicum. Íslenzkt fornbréfasafn, 16 volumes, 1857-1972. Félagsprentsmiðju, Reykjavík, and S. L. Möllers, København.
- DN = Diplomatarium Norvegicum, 22 volumes, 1847-2004. Mallings forlagshandel, Christiania, and others.
- Dollinger, P. 1998. *Die Hanse*. Kröner, Stuttgart (5th edition).
- Einarsson, B. 1998. *Krisuvík. Fornleifar og umbverfi*. Fornleifafræðistofan, Reykjavík.
- Erkes, H. 1929-1930. Island im Lebenswerke des Olaus Magnus. *Mitteilungen der Islandfreunde* 17, 74-87.
- Finnsson, H. 1783. Um brennusteins nám og kaupverðlan á Íslandi í tíð Friðriks Annars Dana kóngs. *Rit þess íslenska Lærdómslistafélags* 4, 1-48.
- Fleischer, J. 1985. *København. Kulturhistorisk opslagsbog med turforslag*. København.
- Friedland, K. 1973. *Der hansische Sjetlandhandel*. In K. Friedland (Ed.), *Stadt und Land in der Geschichte des Ostseeraumes*, 66-79. Schmidt-Römhild Verlag, Lübeck.

- Gray, E., Marsh, H. & McLaren, M. 1982. A short history of gunpowder and the role of charcoal in its manufacture. *Journal of Materials Science* 17, 3385-3400.
- Guðmundsdóttir, J. 2008. *Í þágu ríkisins. Um brennisteinsnám á Íslandi fram að aldamótum 1600*. Unpublished BA-thesis, Háskola Íslands, Reykjavík.
- Hadfield, A. 2009. The Idea of North. *Journal of the Northern Renaissance* 1, 1-18.
- Harrison, R., Roberts, H. M., Adderley, W. P. 2008. Gásir in Eyjafjörður. International Exchange and Local Economy in Medieval Iceland. *Journal of the North Atlantic, Special Vol. 1*, 99-119.
- Helle, K. 1995. *Bergen Bys Historie 1. Kongssete og kjøpstad fra opphavet til 1536*. Alma Mater Forlag, Bergen.
- Henchel, O. 1780. Underretning om de Islandske Svovel-Miiner samt Svovel-Raffinering sammesteds. In Olavius, O. *Oekonomisk Reise igjennem de nordvestlige, nordlige, og nordostlige Kanter af Island, vol. II*, 665-734. Gyldendal, Copenhagen.
- Hill, T. 2004. *Die Stadt und ihr Markt. Bremens Umlands- und Außenbeziehungen im Mittelalter (12.-15. Jahrhundert)*. Franz Steiner, Stuttgart.
- Hofmeister, A. 2000. Hansische Kaufleute auf Island im 15. und 16. Jahrhundert. In Hofmeister, A. & Löhner, A. (Eds.) *Kirche – Kaufmann – Kabeljau: 1000 Jahre Bremer Islandfahrt*, 47-54. Staatsarchiv Bremen, Bremen.
- Hofmeister, A. (in press), Bremen's trade with the North Atlantic, c. 1400-1700. In Mehler, N. & Gardiner, M., *German Trade in the North Atlantic, 1400-1700. Interdisciplinary Perspectives*. The Northern World Series, Brill, Leiden.
- Holbach, R. 2006. Produktion für den Export: Tischlerei und Böttcherei. In Bracker, J., Henn, V. & Postel, R. (Eds.) *Die Hanse. Lebenswirklichkeit und Mythos*, 656-658. Römhild Verlag, Lübeck (4th edition).
- Jónasson, J. 1961. *Íslenzkir Þjóðhættir*. Ísafoldaprentsmiðja, Reykjavík.
- Karlsson, G. 2000. *Iceland's 1100 Years. History of a Marginal Society*. Mál og menning, Reykjavík.
- Kristjánsdóttir, S. 2008. Skriðuklaustur monastery. Medical centre of medieval east Iceland. *Acta Archaeologica* 79, 208-215.
- Kristjánsdóttir, S. 2012. Gjöf Sesselju og klaustrið á Skriðu. *Árbók hins íslenska fornleifafélags* 2012, 27-45.
- Kristjánsdóttir, S. & Collins, C. 2010. Cases of Hydatid Disease in Medieval Iceland. *International Journal of Osteoarchaeology* 2010 (no pages).
- Kristjónudóttir, I. S. 2008. *Fremrinámur. Fornleifaskráning*. Rit Fornleifavernd ríkisins 2008, 10. Nón og Leturprent, Reykjavík.
- Krüger, J. F. 1830. *Vollständiges Handbuch der Münzen, Maße und Gewichte aller Länder der Erde*. Gottfried Basse, Leipzig.
- Lesshafft, H. 2006. Krankheits- und Therapiekonzepte der Lepra im mittelalterlichen Deutschland. *Die Klapper* 14, 11-13.
- Lorenzen-Schmidt, K.-J. (in press), The North Atlantic Trade of Hamburg (1400-1650). In Mehler, N. & Gardiner, M., *German Trade in the North Atlantic, 1400-1700. Interdisciplinary Perspectives*. The Northern World Series, Brill, Leiden.
- Loveluck, Chr. 2013. *Northwest Europe in the Early Middle Ages, c. AD 600-1150. A Comparative Archaeology*. Cambridge University Press, Cambridge.
- LUB = Lübecker Urkundenbuch. Codex Diplomaticus Lubecensis, 11 volumes, 1843-1905. Friedrich Aschenfeldt, Lübeck, and Lübcke & Nöhring, Lübeck.
- Lucas, G. 2009. *Hofstaðir. Excavations of a Viking Age Feasting Hall in North-East Iceland*. Institute of Archaeology Monograph Series 1. Fornleifastofnun Íslands, Reykjavík.
- Lück, E. & Jäger, M. 1996. *Antimicrobial food additives. Characteristics, uses, effects*. Springer, Berlin.
- Magnus, O. 1996. *A Description of the Northern Peoples Vol. 1*. Hakluyt Society, London.
- McLachlan, S. 2010. *Medieval Handgonnes. The first black powder infantry weapons*. Osprey, Oxford.
- Mehler, N. 2004. Medieval Ceramics from Gásir, 2002 and 2003. In Roberts, H. M. *Excavations at Gásir 2003. An Interim Report*, 61-72. Fornleifastofnun Norðurlands, FS238-01075, Akureyri.
- Mehler, N. 2007. Viking age and medieval craft in Iceland: adaptation to extraordinary living conditions on the edge of the Old World. In Klapste, J. (Ed.) *Arts and Crafts in Medieval Rural Environment*. Ruralia VI, 227-244. Brepols, Turnhout.

- Mehler, N. 2009. The perception and identification of hanseatic material culture in the North Atlantic: problems and suggestions. *Journal of the North Atlantic, Special Vol. 1*, 2009, 261-281.
- Miekkavaara, L. 2008. Unknown Europe: The mapping of the Northern countries by Olaus Magnus in 1539. *Belgian Journal of Geography* 3-4, 307-324.
- Narziss, L. & Back, W. 2009. *Die Bierbrauerei. Vol. 2: Die Technologie der Würzbereitung*. Wiley, Weinheim (8th edition).
- Nedkvitne, A. 2014. *The German Hansa and Bergen 1100-1600*. Quellen und Darstellungen zur hansischen Geschichte 70. Böhlau, Köln.
- Nielsen, O. 1885. *København i Aarene 1536-1660. Kjøbenhavnns Historie og Beskrivelse IV*. G. E. C. Gad, København.
- Nilsson, S. 2005. *Från Svavelbruk till Vattenbruk. Berättelser ur Dylta bruks historia*. Dyltabruk.
- Olafsen, E. 1774. *Reise durch Island vol. 1*. Heinecke und Faber, Leipzig.
- Pancieria, W. 2006. Venetian Gunpowder in the Second Half of the Sixteenth Century: Production, Storage, Use. In Buchanan, B. (Ed.) *Gunpowder, explosives and the state: a technological history*, 93-123. Ashgate, Aldershot.
- Piezonka, B. & Schlottau, K. 1985. Die Hamburger Mühlen und ihr Einfluß auf den Wirtschaftsraum der Stadt. *Beiträge zur Deutschen Volks- und Altertumskunde* 24, 49-91.
- Pritchard, F. A. 1991. Small Finds. In A. Vince (ed.), *Aspects of Saxo-Norman London, vol. 2, Finds and Environmental Evidence*. London and Middlesex Archaeology Society, London, 120-278.
- Roberts, H. M. 2002. *Fornleifarannsókn á Gásam. Archaeological Research at Gásir, 2001. An Interim Report*. Fornleifastofnun Íslands, FS163-01071, Reykjavík.
- Roberts, H. M. 2003. *Gásir 2002. An Interim Report*. Fornleifastofnun Íslands, FS194-01073, Reykjavík.
- Roberts, H. M. 2004. *Excavations at Gásir. An Interim Report*. Fornleifastofnun Norðurlands, FS238-01075, Akureyri.
- Rohden Olesen, C. 2012. *Kongens Bryghus*. Københavns Museum Archaeological Report. København.
- Schäffe, W. 1995. *Mittelalterliche Backsteinarchitektur von Lübeck bis zur Marienburg*. DuMont, Köln.
- Schwindt, T. 1893. Tietoja karjalan rautakaudesta ja sita seuraavilta ajoilta. *Finska Fornminnesföreningens Tidskrift* 13, 1-206.
- Sigurðsson, H. 1978. *Kortasaga Íslands frá lokum 16. aldar til 1848*. Bókaútgáfa Menningarsjóðs og Þjóðvinafélagsins.
- Slangen, N. 1759. *Geschichte Christian des Vierten Königs in Dännemark, Vol. II*. Friedrich Christian Pelt, Leipzig.
- SNL = Store Norske Leksikon. Kunnskapsforlag, Oslo (4th edition).
- Stefánsdóttir, A. 2008. *Brennisteinsfjöll. Fornleifaskráning*. Fornleifavernd ríkisins 2008, 4. Fornleifavernd ríkisins, Reykjavík.
- Struckmeier, S. 2011. *Die Textilfärberei vom Spätmittelalter bis zur Frühen Neuzeit. Eine naturwissenschaftlich-technische Analyse deutschsprachiger Quellen*. Cottbuser Studien zur Geschichte von Technik, Arbeit und Umwelt 35. Waxman, Neumünster.
- Thoroddsen, T. 1883-1884. En Undersøgelse 1882 i det østlige Island. *Geografisk Tidsskrift* 7, 95-112.
- Unger, R. W. 1981. Warships and Cargo Ships in Medieval Europe. *Technology and Culture* 22/2, 233-252.
- Vestdal, J. 1943. Brennisteinsnám. In Finnbogason, G. (Ed.) *Iðnsaga Íslands II*, 59-73. Iðnaðarmannafélagið, Reykjavík.
- Vésteinsson, O. 2001. *Peistareykjir í Suður Þingeyjarsýslu. Fornleifakönnun*. Fornleifastofnun Íslands FS152-01161, Reykjavík.
- Vidalin, P. 1768. *Afhandling om Islands Opkomst*. Jonas Lindgren, Sorø.
- Weiner, J. 2012. Feuerschlagsteine und Feuererzeugung. In Floss, H. (Ed.) *Steinartefakte vom Altpaläolithikum bis in die Neuzeit*, 943-961. Tübingen Publications in Prehistory. Kerns Verlag, Tübingen.
- Þorláksson, H. 2003. *Frá kirkjuvaldi til ríkisvalds. Saga Íslands VI*. Sögufélag, Reykjavík.
- Þorsteinsson, B. 1972. Svövl. *Kulturhistorisk Leksikon for Nordisk Middelalder XVII*, col. 589-591. Gyldendal, København.