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Socio-Economic Aspects of Early Iron Age Wood Tar Production in Scandinavia

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ABSTRACT
From being a completely unknown subject, knowledge about tar production during the Scandinavian Iron Age has increased substantially over the last couple of decades. This is due to the identification of funnel-shaped tar production pits at settlements mainly in eastern Sweden but with connections to other regions in Scandinavia. In this paper, various aspects of the tar production pits—such as size, appearance, and chronology—are presented and discussed along with their geographical distribution. Additionally, aspects related to how this early tar production was integrated into settlement organization, economy, and societal relations are analyzed and, in relation to the topic, household versus surplus production. Tar production in funnel-shaped pits appears to be highly overrepresented in eastern central Sweden. This could indicate that other contemporary methods for producing tar existed in other parts of Europe but have yet to be identified.

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Introduction

The use of tar and other resinous products can be traced back to prehistoric Scandinavia. Resins were used as glue for flint arrows in the Mesolithic, and there are several examples of birch bark tar used to seal wooden and ceramic vessels in the Bronze Age and Early Iron Age (Isaksson 2009; Nordby 2009; Svanberg 1995). Tar loaves—circular, flat discs sometimes with a hole in the middle—made from birch bark tar and dated to the Bronze Age are found in substantial numbers across Scandinavia (Nordby, Sørgaard, and Orestad 2020). Prior to the Iron Age, tar production seems to have been based on birch bark, while pine wood tar did not appear until the Early Iron Age, with the earliest examples used for boats. For instance, tar-saturated textiles were used for caulking the boards from the Halsnøy boat found in western Norway in A.D. 1896 and radiocarbon dated to A.D. 325–550 (calibrated ^{14}C age) (Fasteland 1996; Wickler 2019, 195). Thus, the use of wood tar has been known for a long time, but how tar was produced prior to the Middle Ages (11th century A.D. onwards) has remained unknown for a long time.

Tar is produced by heating almost any type of resinous wood in a low oxygen environment in a process of pyrolysis. In the Nordic countries, pine wood was commonly used. From the 11th century A.D. up to modern times, the most common production method involved tar kilns—cone-shaped pits dug into a natural hill slope. Wood was stacked in the upper part, set on fire, and covered with turf to reduce the access of oxygen. The heat from the fire caused the tar substances in the wood to condense and drip out through an outlet pipe in the bottom. Such tar kilns can be found in large numbers in the forests in northern Sweden and Finland, as well as in Norway. Several other regional types of production methods are also known. In mid-Norway, tar was produced on platforms above water-filled pits in mires, causing the tar to gather in the water below. In southern Sweden and Norway, long, narrow ditches placed on slopes were also common. Various other methods were used, particularly to produce tar from specific wood species or with specific properties (see, for example, Hennius et al. 2005, 12–18; Kurzweil and Todtenhaupt 1991, 66–70).

Up until the early 19th century A.D., tar was one of the most important export products from Sweden, including Finland at the time. A massive amount of work and long-term planning was invested in the production. Several years in advance, the trees were prepared by cutting marks in the trunks to increase the production of tar substances. The trees were felled, dried, and chopped up into sticks to later be stacked into the tar kiln. Additionally, barrels were required for transport and had to be manufactured (Villstrand 1996). Calculations based on tar production experiments indicate that 1 m^3 of pine wood yielded 28–35 L of tar (Egenberg 2003; Egenberg et al. 2002; Ravn 2016).

In 2002, a specific type of funnel-shaped pit found at a Roman Iron Age settlement (A.D. 0–400) in the region around Uppsala in eastern central Sweden was associated with the production of tar, using a method previously unknown in Scandinavia (Hennius 2006; Hennius et al. 2005; Svensson 2007). Around the same time, similar but much larger tar pits dated to the Late Iron Age (ca. A.D. 700–1000) were discovered (Hennius 2018). These pits also appeared in the province of Uppland but were situated in forested outfield areas. The discovery of the first funnel-shaped tar production pits at settlements in 2002 led to the identification of many more and subsequent reinterpretations of similar funnel-shaped features found earlier (Hennius 2006; Svensson 2007). The total number has now surpassed 160 (Supplemental Material 1), but new pits are

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constantly found. The vast majority has come to light in eastern central Sweden. A few have been found at archaeological excavations in Norway (Risbøl et al. 2021) and one in Denmark.[1] None are known from Finnish archaeology except one from the Åland islands—the autonomous region of Finland situated in the Baltic Sea between Finland and Sweden (Figure 1).

Purpose and Aim

The purpose of the present article is to summarize the state of knowledge developed over the past two decades on Scandinavian tar production pits found at settlements. This also involves identifying key research questions for the future regarding Iron Age tar production in Scandinavia and beyond. The discovery of tar production in Scandinavia has created opportunities to explore various aspects of Iron Age society. This includes all kinds of technical aspects related to the production process: how was it done? What raw materials were used? How large were the quantities produced? And so on. It also provides an opportunity to explore broader societal questions related to organization, distribution, economy, etc. These questions are interconnected and interdependent. For instance, understanding distribution and production quantities is essential for studying critical topics such as specialization and household versus surplus production.

The study presented in this paper focuses on wood tar production in Early Iron Age Scandinavia and is based on the following questions: how was tar production organized? To what extent was tar a surplus commodity? Do we observe increasing complexity in tar production throughout the Early Iron Age? As a first step, the tar production pits—their number, geographical distribution, and chronology—will be presented and discussed. This will serve as a foundation for analyzing and discussing the potential impacts on socio-economic aspects of Early Iron Age society in the studied region.

The Material

During excavation, the pits appear as round or slightly oval anomalies that are difficult to distinguish from other features dug into the ground, such as various pits and postholes. However, their funnel-shaped cross-section allows for the interpretation as tar production pits, along with their characteristic fills—typically consisting of dark soil, charcoal, burnt stones, and burnt clay (Figure 2). Before these features were identified as tar production pits, their distinct funnel shape led the excavating archaeologists to assume that they had been used for some specific but unknown purpose. In some cases, they were misinterpreted as postholes, cooking pits, or furnaces. However, through comparisons with central European tar production pits and chemical analyses of material from a few of the Swedish pits, their use for tar production was confirmed in the early 2000s (Hennius et al. 2005; Hjulström, Isaksson, and Hennius 2006).

Size, Appearance, and Production

The morphology of the pits can generally be divided into two sections: an upper part with slanting sides and a lower cylindrical section. In rare cases, the lower part has an hourglass-shaped profile. The upper section is where the raw material (sticks of dried resinous pinewood) was placed and ignited, while the tar was collected in the lower section, presumably in some kind of container (Figure 3). Unlike the upper part, the lower section does not show signs of exposure to intense heat (Berggren and Hennius 2004, 37; Åberg and Svensson 2006, 40–41). It is assumed that the pile of resinous pinewood sticks was covered with turf to limit oxygen access during combustion.

The sizes of the pits vary considerably. The average diameter is 0.76 m, ranging from 0.22–2.6 m, and the average depth is 0.58 m, with a range from 0.23–1.4 m (Table 1). The upper sections of the pits are often only partially preserved due to ploughing, which affects the recorded measurements. Despite this, significant variation in size is evident, a factor that will be discussed further below.

To estimate the amount of tar produced, the volume of the lower, cylindrical section can serve as a basis of calculation. The size of the underlying pit has been recorded in 10 cases from eight sites (Table 2) The average gross volume is approximately 60 L, but variation is substantial, ranging from 4.5–171 L. Accounting for the space needed for a container (estimated to -10%) and that the tar acid content must be subtracted (-15%),[2] the average net volume of usable tar can be calculated at approximately 45 L. Tar acid is a heavier, acidic water phase that gradually separates from the tar during storage and must be removed before use. Multiple production phases have been documented at several excavations (Eriksson 2012; Fagerlund and Hennius 2014; Göthberg, Qviström, and Åberg 2002; Larsson and Hamilton 2018; Larsson, Lingström, and Sjölin 2018; Sauvage and Østmoe 2019), and consequently we must also take into account that the tar production pits do not represent a single instance of production but apparently were used repeatedly.

To put these production figures into perspective, we can compare with tar consumption mentioned in written sources from Medieval and early modern times. The amount of tar needed to coat a stave church is reported to be between 441 and 696 L (Dybdahl 1976, 71–72; Egenberg 2003, 51),[3] while a profane building required approximately 580 L (Dybdahl 1976, 71–72). Information on the amount required for tarring a boat varies between 232 and 290 L (Bugge 1925, 306; Dybdahl 1976, 71–72). However, Ravn (2016) has estimated that constructing a large Viking Age personnel carrier required around 500 L of tar. Although retrospective comparisons across such a long time span require caution, the figures still suggest that Early Iron Age tar production was small-scale. It can also be mentioned that the tar production in the large pits in forested outfield areas from the Late Iron Age is estimated to have been at least 200–300 L in each production cycle (Hennius 2018, 1351).

Dating and Chronology

Unlike similar tar pits found in the Slavic regions (see below), Scandinavian pits rarely contain pottery or similar diagnostic findings useful for dating. Small pieces of pottery are reported to have been found in only three cases (Berggren and Hennius 2004, 38; Hallgren 2010, 46; Larsson and Hamilton 2018, 125). As a result, radiocarbon dating (^{14}C) is the primary method used for establishing their age. A total of 56 ^{14}C dates have been obtained from 52 tar production pits (Figure 4). Most pits are dated to the Roman

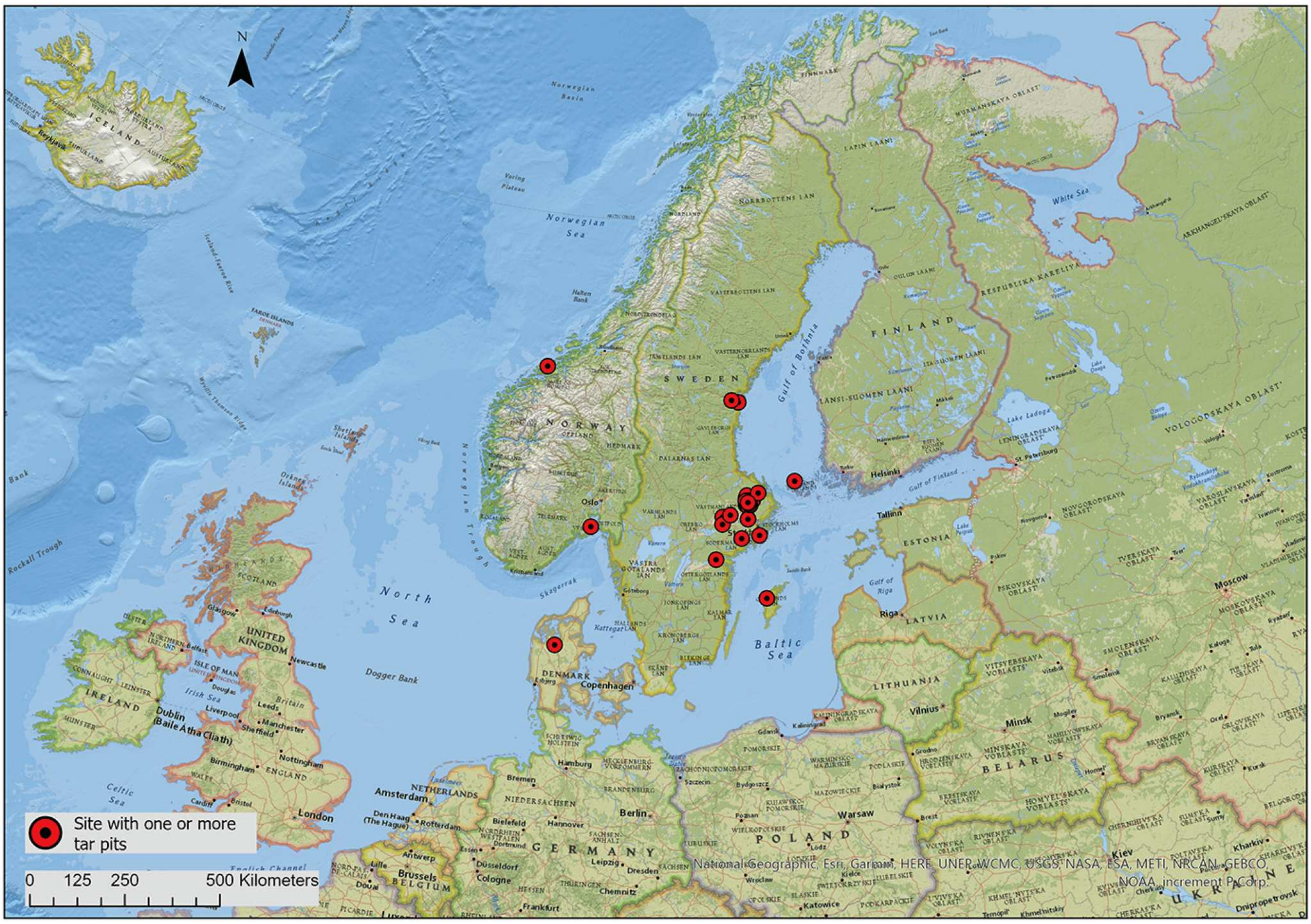

Figure 1. The geographical distribution of Iron Age tar pits found in settlements. 157 are found in Sweden, two in Norway, one in Åland (Finland), and one in Denmark.

Iron Age (A.D. 0–400), the Migration Period (A.D. 400–550), and the Merovingian Period (A.D. 550–800). A few dates deviate from this pattern: a tar production pit from Fullerö is dated to the Early Pre-Roman Iron Age (Björck and Appelgren 2006, 16), there are three dates in the Viking Age—two from Källstalöt (Andersson 2015, 91) and one from Örby (Eriksson 2012, 22)—and two pits are dated to the Early Middle Ages—Bälinge (Fagerlund 1997, 49) and Matfors (M. Lindeberg, personal communication 2024). The earliest date (from Fullerö) clearly falls outside the main pattern. We believe that this might be an example of the use of fossil wood, i.e. use of wood with a high natural age (see discussion below), or contamination of the samples from older remains in the surrounding area. The Viking Age date from Örby was based on hazel wood and might represent younger material that ended up in the pit due to later refilling or leveling. The Örby settlement had a long continuity and was also in use during the Viking Age (Eriksson 2012, 24ff). However, the second date from Örby falls within Roman times, aligning with the broader dating pattern.

The two Viking Age radiocarbon dates from Källstalöt are almost identical and appear to be reliable. Since they were found near houses of the same period, they provide strong evidence that small-scale tar production occurred within settlements during the Viking Age, alongside the large-scale production in outfield pits mentioned above. The most recent tar production pit, from Bälinge, was initially excavated in the 1990s but was only later reinterpreted as a tar production site. Unfortunately, no information on tree species was recorded during the analysis. The Bälinge pit was discovered on a small excavation site where a pile of fire-cracked stones from the Middle Ages was found lying right next to it. Additionally, approximately 100 m to the north, a settlement from the transition between the Late Roman Iron Age and Migration Period has been excavated (Fagerlund 1997, 41–45). It is possible that the tar production pit belongs to this settlement and that its fill was contaminated by later activity.

Based on the available data, we assess that tar production pits generally belong to a technological tradition that emerged during the Early Roman Iron Age and persisted into the Viking Age. After this period, there are very few recorded dates, suggesting that the small-scale production at settlements was gradually replaced by much larger funnel-shaped tar production in outlying forested areas. These large pits, with a production capacity ten times greater than their predecessors, have been dated to the 7th century A.D. and remained in use throughout the Viking Age and into the Early Middle Ages, eventually giving way to the well-documented historical tar kilns with drainage pipes (Hennius 2018). However, the small-scale production at settlements was not completely abandoned in the Late Iron Age but continued in parallel at a few settlements like Källstalöt. In that respect, it is of interest that small tar pits similar to the Scandinavian ones are found in eastern and western Slavic settlements dated to the 7th–12th century A.D. (see also below).

While the broad chronological framework appears well established, several uncertainties remain regarding the reliability of ^{14}C dating in the context of tar production.

Figure 2. Tar pits seen in profile. A) Sommaränge (S3), B) Berget (S82), C) Kvissle (S152), D) Stein (S1), E) Blåsenhus (S117), and F) Söderhällby (S103).

One major issue is the difficulty of obtaining reliable samples. Like many features in Scandinavian settlement archaeology, the dating of funnel-shaped wood tar kilns relies heavily on ^{14}C analysis. Unfortunately, the remnants of wood tar production pits do not form ideal deposits for ^{14}C sampling. If correctly interpreted, the method required that the pit be emptied at the end of the process for the wood tar to be removed. As a result, the sampled material may not always be directly related to the period of tar production. Uncertain sampling context is of course a general challenge related to many types of settlement features. Nevertheless, since wood tar making produced large quantities of charcoal, there is a high probability that charcoal relevant for dating the production was trapped in the pits, even if in a secondary fill. Despite this, sample context must always be carefully considered.

Another potential issue is the "old wood" or "inherited age" problem. Pine wood is highly resistant to decay and can be utilized for centuries. Historical sources from early modern Scandinavia suggest that the preferred raw material for pine tar was old stumps and roots, which are naturally rich in resin (Egenberg 2003, 60). Since these stumps can remain intact for hundreds of years, samples taken from such material may produce radiocarbon dates that are significantly older than the actual production period. If subfossil pine stumps and roots were the primary raw material in early tar production, radiocarbon dating would be ineffective in establishing a reliable chronology.

There are, however, reasons to question the importance of pine stumps in prehistoric wood tar production, since this notion is based primarily on early 20th century A.D. sources. The use of stumps is mainly related to early modern times

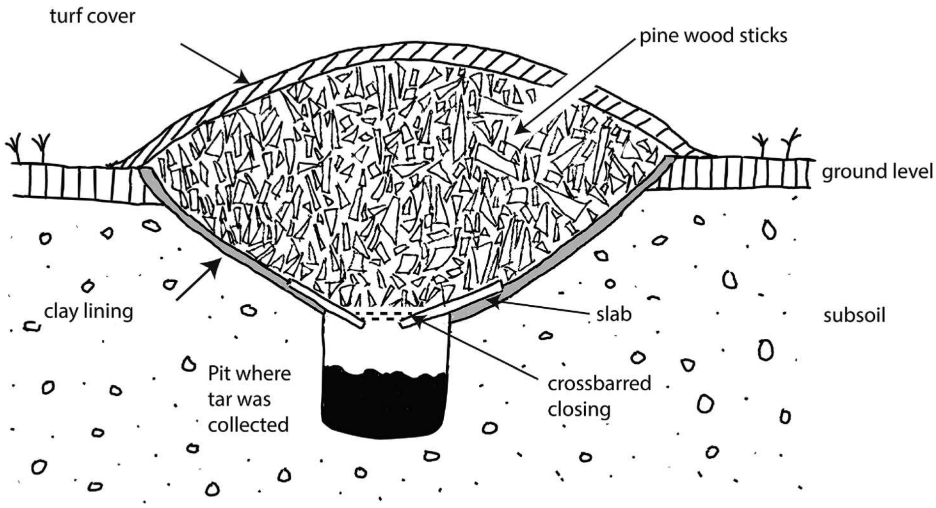

Figure 3. Drawing of a reconstructed tar production pit. Illustration: Raymond Sauvage; NTNU University Museum, Trondheim, Norway.

when timber became a commercial article of great economic value for trade and export (Holmberg 2005). Stumps and roots were readily available after logging and thus became a convenient resource for tar production. Pine stumps may be rich in resin but are also very labor-intensive to extract from the ground and split into manageable pieces. Also, we know from written sources that tar production was not exclusively based on stumps and roots as a resource. Tar producers of the 18th century A.D. with fewer opportunities to ship bulky timbers overseas used their best timber logs to save time (Juvelius 1747, 13 ff). Naturally-grown pine forests were also rich in other sources of resinous wood, such as trees affected by wildfires, lightning strikes, and fungal infections (Juvelius 1747, 10; Köhler 1907, 3; Petrini 1928, 1344). Consequently, tar production was not solely based on stumps and roots but a variety of pine wood resources.[4] A few analyses of charred wood from tar pits indicate that the situation might have been similar in the Iron Age, with the presence of roots proved in two cases (Hamilton and Lindberg 2020, 66; Åberg and Svensson 2006, 81) and a trunk in another example (Berggren and Hennius 2004, 66). However, the majority of analyzed wood samples show no signs of decay or root usage, suggesting that prehistoric tar production was not predominantly dependent on old wood.

To complicate things further, another source-critical factor concerns the risk of "tar contamination" of the sample material. Deciduous wood, well-suited for ^{14}C dating due to its low inherited age, might be contaminated during the production process by tar from resin-rich wood with a high inherent age. This can thereby eliminate the advantage of using tree species with low inherent ages for dating. Several studies have identified this issue as a potential explanation for unexpected ^{14}C dates in tar production sites where low inherent age wood species were used (Amundsen 2007, 291, 302; Bergstøl 1997, 44; Gundersen and Wenn 2011, 262; Martens and Paasche 2002, 192).

The problem can be illustrated with dating results from an excavation in eastern Norway where four tar production kilns from the Middle Ages or early modern times were investigated. In one case, a date based on birch bark without the old wood problem turned out to be far too old for this known type of tar production kiln. A second birch bark sample was dated, but this time the sample was cleaned of tar residues before the dating was conducted, resulting in a new date that was consistent with what one would expect. The birch bark had apparently been contaminated by tar from pine wood, which was the actual raw material used (Amundsen 2007, 290–291). In another case, the bottom of a kiln was sealed with tar paper, an industrially produced, bituminous product, which dated the kiln to the 20th century A.D. A radiocarbon date from a carbonized pine wood stick from the kiln gave a date approximately 400 years older than the actual use (Amundsen 2007, 298–299).

With this in mind, we will now look more closely at the ^{14}C dates of tar pit kilns. As many as 41 dates were from pine, three from spruce, two from both birch and hazel, and one each from oak and alder, while the wood species of the remaining eight is unknown. Given the overwhelming dominance of pine, the issue of high inherent age raises concerns about the reliability of many dates. Charcoal from species other than pine, such as hazel, oak, alder, birch, and spruce, have been found in small quantities in the tar pits, mixed with the dominating pine. These samples have been chosen for ^{14}C analysis in a number of cases to avoid the presumed old wood problem. Of nine samples of wood other than pine, seven roughly cover the time span of the 2nd–6th century A.D., while one sample of alder covers the 8th–10th century A.D. These results closely align with the dates obtained from pine samples, reinforcing the credibility of the overall ^{14}C dataset (Figure 5).

True stratigraphical relations are rare, but in some few fortunate cases, wood tar production pits were found to be cut by later settlement features. At the site Berget, three pits were stratigraphically older than three buildings. These buildings were dated typologically and with ^{14}C. The buildings did not belong to the same period, but the ^{14}C dates roughly covered the mid-3rd–early 6th century A.D. Wood tar production pits were also found to be younger than two other buildings, covering the same period. One building was stratigraphically locked between an older and a younger wood tar production pit. Unfortunately, in this case, neither the building nor the tar pits could be dated through ^{14}C

Table 1. Average diameter and depth of the pits based on measurements from 52 pits. The third column highlights the considerable variation in pit sizes.

N = 52	Pit dimensions	Range
Average diam.	0.76 m	0.22–2.6 m
Average depth	0.58 m	0.23–1.4 m

Table 2. Amount of tar produced based on measurements from the lower section of the pits where the tar was collected. The calculations are given in both gross and net figures. The net figures account for a container that was most likely placed in the lower section of the pit. They also consider the presence of tar acids in the produced tar, which must be subtracted to give a clearer picture of the actual amount of usable tar.

N = 10	Tar amount	Range
Average (gross)	60.69 L	4.54–170.97 L
Average (net)	45.52 L	3.4–128.22 L

analysis, but the building typologically belongs to the period from the 1st–early 6th century A.D. (Göthberg, Frölund, and Fagerlund 2014, 42).

Approximately one-third of the pits have been dated using ^{14}C. This is an unusually high percentage within Scandinavian settlement archaeology and should provide a solid ground for a trustworthy chronology. One problem, however, is that sites with many tar pits have a lower percentage of dates than sites with one or a few tar pits. Since sites with many tar pits in general seem to belong to the older part of the spectrum, this might skew the overall ^{14}C results. To check if this is the case, we have examined the relative dates suggested in the excavation reports for nearly every tar pit (Figure 6). These dates are of varying quality, stretching from rigid stratigraphical relations to more vague chronological relations with other features at the sites.

This graph corresponds quite well with the graph based solely on ^{14}C results (see Figure 4). Both graphs suggest that the method came into use during the 1st or 2nd centuries A.D., when production was modest, and was then followed by a boom from about A.D. 200 that lasted a couple of centuries. From about A.D. 400, production seems to have decreased by about half compared to the previous centuries but then remained stable over 250 years. At about A.D. 650, production dropped sharply to a very low level. The tradition of making wood tar within settlements did not disappear completely, though, but persisted as a craft over the following centuries well into the high Middle Ages.

Regional Outlook/Distribution

After the first identification of pits for tar production in eastern Sweden in the early 21st century A.D., one might have expected similar pits to be discovered elsewhere in Sweden and Scandinavia. However, this has not been the case. So far, 161 pits have been identified from 43 different archaeological sites, with the overwhelming majority located in the Uppsala region, primarily in the agrarian landscape surrounding what is now the city of Uppsala (see Figure 1). Tar production pits have also been found in the Lake Mälaren area and as far south as Norrköping. A few tar pits have also been identified in Västernorrland county approximately 300 km north of the Uppsala region. Additionally, the Baltic Sea islands Gotland and Åland each have one documented feature (see Supplemental Material 1 for an overview). Two pits found in Norway and one in Denmark suggest that this production method was not exclusive to eastern Sweden. However, 63% of the known settlements with tar pits and 84% of all recorded tar pits are located within a 20 km radius of Uppsala.

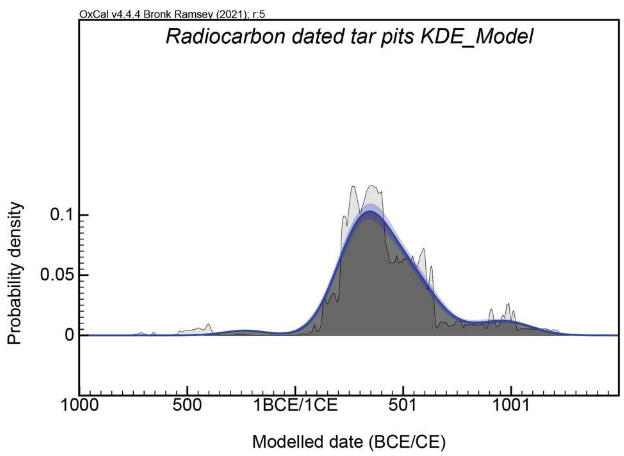

Figure 4. A graphical representation of all calibrated radiocarbon samples from funnel-shaped tar pits used for the discussion in this paper. Included in the graph are the 49 dates currently available. The light grey curve in the background represents the summarized diagram. The dark curve represents a Kernel Density Estimation curve (KDE Model) which better shows the statistically significant chronology. Calibration in OxCal 4.4.4 (Bronk Ramsey 2021).

Being a commodity with many areas of utilization, it is reasonable to assume that it was a widely needed and valuable commodity throughout Scandinavia. One would therefore expect a much broader and more even, larger geographical distribution. Their scattered occurrence and the utter absence of tar production in large parts of Scandinavia in the Early Iron Age could partly be attributed to variations in archaeological activity. However, this alone does not fully explain the pattern. While the current distribution may be somewhat influenced by the high level of archaeological work in the Uppsala area due to infrastructure and urban development projects, the concentration of tar pits in this region appears to be a genuine phenomenon that warrants further investigation.

In our view, the uneven distribution indicates that funnel-shaped pits represent one distinct, primarily eastern Swedish, method of producing tar in Early Iron Age Scandinavia, while other production techniques must have existed in parallel elsewhere. In other regions, the mode of tar production is yet to be discovered. So far, we have no knowledge about potential alternative production methods in this period of time. If tar was produced using surface installations without pits, posts, or poles set into the ground, such sites would be extremely difficult to detect, particularly in arable land where ploughing may have erased any traces. The absence of charcoal production related to iron production in the Early Iron Age can serve as a parallel to the missing tar production features in large parts of Iron Age Scandinavia. In iron production, charcoal is a prerequisite in order to obtain the required high temperatures, but no traces of charcoal production are known from the Early Iron Age in spite of extensive iron production in this time period.[5] This contrasts with the Late Iron Age, where charcoal pits are found in considerable numbers.

Organization/Specialization

All identified tar production pits are located on or very close to settlements, but the number of pits and their distribution on each site vary, calling for further investigation. In most cases, only one single tar production pit is found per settlement (Table 3). This pattern applies to as many as 25 sites (58%), while four and five sites hold two or three pits each. At a few settlements, 5–11 pits have been found, and one settlement stands out with as many as 56 pits.[6]

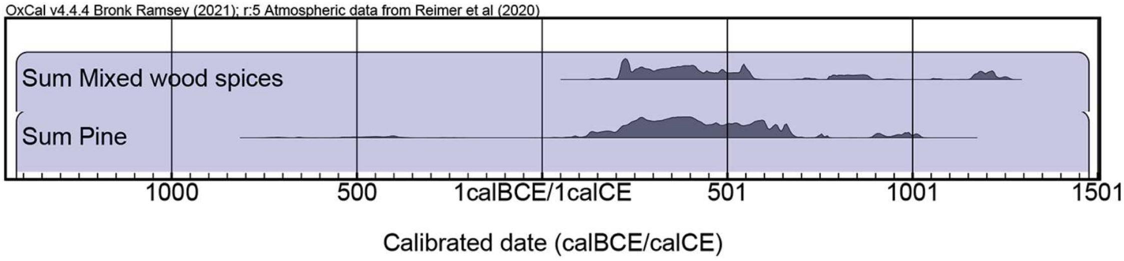

Figure 5. Graph comparing the dating conducted on pine wood and deciduous wood. It is evident that no differences related to wood species can be established.

The significant proportion of settlements with only one pit indicates that tar production was primarily intended for household use, supplying the farm where it was located. In most cases, the pits are situated near houses, typically on the outskirts of the settlement. At sites with multiple pits, their distribution varies considerably (see Table 3). While many appear as isolated features or in small groups of two or three, some settlements contain distinct clusters of pits—five, six, seven, 11, and even approximately 50 pits grouped within a restricted area within the settlement. Whether these clusters represent communal tar production areas shared among all farms on the settlement and neighboring farms or whether they were managed by a single specialized producer remains uncertain.

It is interesting to note that, in many cases, houses with adjacent tar production pits are found at settlements with other contemporary farms without traces of tar production. The clusters may indicate a level of production exceeding the needs of a single household, potentially supplying the entire settlement or even neighboring farms with tar. It is possible that a designated part of the settlement was dedicated to tar production and used collectively by multiple farmers. To fully understand the complex organization of production, it is essential to examine not only the number of pits, scale of production, and internal site distribution at settlements with proven tar production but also to include the neighboring farms and settlements without tar production. Given the widespread need for tar—for waterproofing boats, impregnating structural timber in post-built houses, and preserving wooden objects—it is plausible that certain farms specialized in tar production, supplying others in exchange for goods. This suggests a system of local economic cooperation, where individual farms engaged in specialized production that fed into a settlement-based exchange network (Hennius 2012, 179). Indications of specialization during the Early Iron Age have been observed in eastern Sweden in connection with iron production (Larsson, Lingström, and Sjölin 2018, 71), food production (Frölund and Schütz 2007, 239, 253; Göthberg, Frölund, and Fagerlund 2014, 285–286), pottery and metalworking (Hennius 2012, 249), and textiles (Larsson, Lingström, and Sjölin 2018, 99). Although self-sufficient, independent farms were the dominant form of settlement in Early Iron Age Scandinavia, there are also clear indications of cooperation and some degree of specialization and exchange.

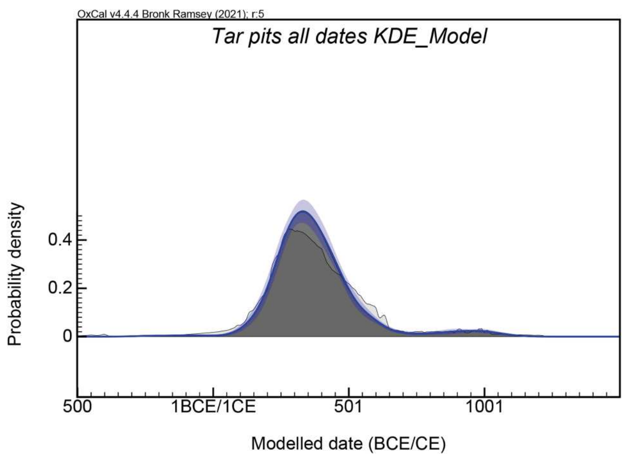

Figure 6. Combined graph of 154 suggested relative dates from a total of 157 tar pits (cf. Figure 4 of dates based exclusively on 48 ^{14}C dates).

The variation in the number of tar pits per settlement does not appear to be linked to chronology or geography. There is no evidence of a gradual increase from single pits to larger clusters over time, nor does the geographical distribution reveal any clear patterns at the local or regional level. The size of the pits varies significantly, with no standardized production capacity. On the other hand, when examining the size of tar production pits over time, a general increase is evident throughout the Iron Age, likely reflecting a growing demand for tar (Figure 7). This trend culminates in the Viking Age, when exceptionally large tar pits were constructed in outfield areas.

The estimated amount of tar produced per cycle was limited by the size of the cylindrical compartment in the bottom. Hennius (2018) argues that the major shift in the Late Iron Age, when tar production moved into forested areas and was conducted in large pits, marks an upscaling of production to an almost proto-industrial level. He further suggests that the increased demand for tar was driven by the expansion of maritime transport, advances in shipbuilding, and the introduction of sails, which required tar for waterproofing. Additionally, tar became a trade commodity in supra-regional networks during the Late Iron Age.

The small-scale production at settlements, as discussed in this paper, most likely reflects the household need for tar, such as treating boats and structural timber in post-built houses, as well as other objects made from wood. Actually, in a few cases, a smell of tar was observed from postholes during excavation at settlements where tar production pits were found (Eklund 2005, 115; Larsson, Lingström, and Sjölin 2018, app. 2, 100; Onsten-Molander and Wikborg 2006, 64). Still, as mentioned earlier, we cannot exclude the possibility that a certain specialization existed in Early Iron Age farming communities based on a local exchange of goods. This seems at least to be the case in certain parts of eastern Sweden (Beronius Jörpeland et al. 2017, 177ff; Larsson, Lingström, and Sjölin 2018, 67ff) and at Ørland in Central Norway (Ystgaard 2023, 151ff). It is commonly argued that

Table 3. Number of pits at each of the 43 sites and how they are distributed within the settlements. The number of pits and their distribution are important for understanding whether the production was household-based or surplus-oriented. Furthermore, it sheds light on how the production was organized: whether individual farms produced their own tar or whether the production was concentrated in dedicated areas of the settlements.

Number of pits	Number of sites	% of total sites	Pit distribution
1	25	58	25 single pits
2	4	9	3 sites with pits in pairs
			1 site with 2 single pits
3	5	12	3 sites with 3 pits in a group
			2 sites with pits in pairs and 1 single pit
5	2	5	1 site with 5 pits in a group
			1 site with pits in pairs and 3 single pits
6	1	2	1 site with 6 pits in a group
7	2	5	1 site with 7 pits in a group
			1 site with pits in pairs and 5 single pits
8	2	5	1 site with 3 pits in a group, 2 pairs, and 1 single pit
			1 site with 3 pairs and 2 single pits
11	1	2	1 site with 11 pits in a group
56	1	2	1 site with 56 pits in a group
Total: 161	43	100	Total: 161 pits

specialization and exchange of commodities requires a hierarchical organization with a magnate at a central farm who controlled the exchange. In terms of tar production, Berget with its 56 pits has been widely discussed within an organizational and economical frame. Frölund (2023) interprets Berget as a site subordinated to the nearby religious, economic, and political center of Gamla Uppsala, suggesting that tar production may have been part of a tribute to the local chief. However, a key weakness of this theory is the chronological mismatch: Gamla Uppsala emerged as a central site in the mid-6th century A.D., whereas ^{14}C dating indicates that tar production at Berget occurred between the 3rd and 5th centuries A.D. Frölund attributes this discrepancy to gaps in our knowledge about Gamla Uppsala's earlier history (Frölund 2023, 166).

Alternative explanations should also be considered. Berget is situated in a very densely populated area with several large settlement concentrations in the surrounding area, most of which show no evidence of tar production. This raises the possibility that Berget's tar production was integrated into a localized exchange system, supplying nearby farms and settlements that specialized in other goods. Such a system would not necessarily require a hierarchical structure with a central magnate but could have functioned as a decentralized, cooperative network among farms (Holst 2010, 2014; Ystgaard 2023, 152–153). Such bottom-up peasant modes of organization might have existed in parallel with a top-down elitist mode of organization (Holst 2010, 157–158), and the many indications of cooperation with regard to cultivation, animal husbandry, and other forms of production in the Uppland farming communities in the Early Iron Age makes a certain degree of exchange of tar probable. Still, this was most likely the exception, while small-scale, self-supporting household production seems to be prevalent.

The tar production sites discussed in this paper differ significantly from the large-scale Viking Age pits, primarily because they are found within settlements and are considerably smaller. The Late Iron Age tar pits found in the forests could probably produce several hundreds of liters of tar in every burn, necessitating transportation to locations where it could be used or sold. This large-scale production required long-term planning, including preparing wood supplies and manufacturing transportation vessels. Compared to the smaller settlement-based pits, this later production system demanded entirely different logistical arrangements. While repeated burning in small pits could yield significant amounts of tar over time, the scale of production was fundamentally different from the large-scale operations that followed.

Summary

Knowledge about tar production in Iron Age Scandinavia has been established for over 20 years. The first features were identified and understood during the Sommaränge excavation in eastern Sweden in 2002, leading to the discovery of many more and even prompting the re-interpretation of similar funnel-shaped features found prior to the turn of the millennium. This progression from interpreting a hitherto unexplained feature to realizing that it is not a

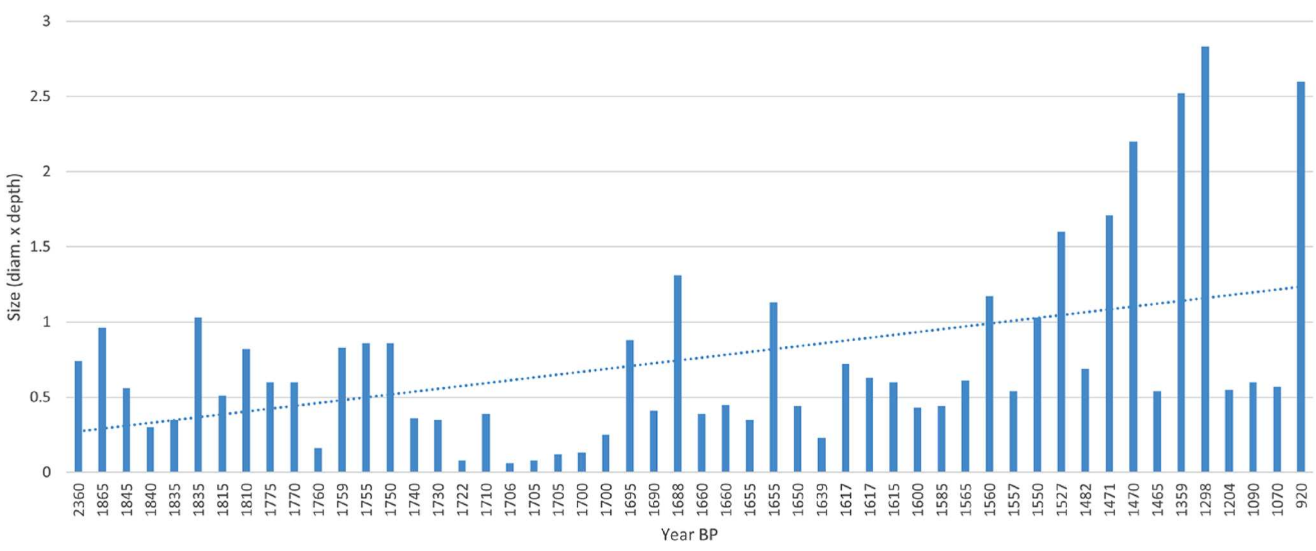

Figure 7. Graph showing a general increase in tar production pit size throughout the Iron Age.

unique example, but instead a rather common feature, is a familiar phenomenon within archaeological practice. Thus, after the initial discovery of the Iron Age tar production pits, it was anticipated that similar pits would appear at subsequent excavations across Sweden and in neighboring countries. This seems not to be the case, and the clear concentration in the Uppsala area endures two decades after the first discoveries. Provided that tar was a sought-after commodity all over Scandinavia, there is still the question of how tar was produced in regions outside eastern Sweden. The scarcity of funnel-shaped tar production features in Norway and Denmark, far from eastern Sweden, is difficult to explain. Perhaps these isolated finds reflect personal contacts and the movement of people across Scandinavia during the Roman Iron Age, bringing their knowledge about tar production with them. Regardless, the small tar production pits found almost exclusively at settlements in eastern Sweden represent one distinct way of producing tar in this period, while contemporary production techniques in other parts of Scandinavia remain unknown.

To sum up, the settlement structure in Scandinavia in the Early Iron Age was characterized by independent self-supporting farms, and tar production enters into this picture as being at the level of household production. Still, there are indications of a limited degree of specialization and exchange organized between farmers themselves within a peasant mode of organization that was not dependent on a central farm with a magnate controlling the exchange. Beyond Scandinavia, similar pits are known from the western Slavic region, primarily at settlements dating from the 7th–12th centuries A.D. (Biermann 1998, 2021). Thus, it seems that producing tar in funnel-shaped pits started five or six centuries later in the western Slavic area than in Scandinavia. Further research is needed to explore the relationship between tar production in these two regions on opposite sides of the Baltic Sea. Similar pits have also been found along Russian rivers in the eastern Slavic area, where they are associated with settlements containing finds from the Vikings (Fetisov and Muraševa 2008; Puškina, Muraševa, and Eniosova 2017, 262, with further references). This further strengthens a possible connection to tar production in eastern Sweden. The study of tar and other forest-derived products—such as potash, charcoal, and resin—is a growing area of research, particularly within the EU Cost Action PoTaRCh (Potash Tar Resin Charcoal) initiative.[7] In the coming years, new studies with a trans-European perspective are expected to shed further light on these important aspects of resource use in the past.

Endnotes

1. The Danish tar pit was initially interpreted as a well (see Terkildsen 2014) but has been re-interpreted by the authors of this paper. Thanks to Katrine Vestergaard and her colleagues at Viborg Museum in Denmark for kindly sharing the primary documentation from the Kærgaard site, excavated in the years 2007–2009.
2. 10–20% according to Egenberg (2001, 47).
3. The figures have been converted from barrels, a former volumetric measurement unit, to liters.
4. In the 17th–18th century A.D., when Sweden was the main supplier of tar, most of the production was based on using tree trunks in Finnish forests (Starlander 2023; Åström 1988). At this time, Finland was a part of the Swedish kingdom.
5. A theory has been suggested that charcoal was produced in iron production furnaces in the Early Iron Age, but this has not been proven (Larsen 2009, 32).
6. This number is based on the results from two excavations where four and 52 tar production pits were found (Fagerlund and Åberg 2005; Göthberg, Frölund, and Fagerlund 2014). According to the latter report (Göthberg, Frölund, and Fagerlund 2014, 27), the number should be 60, but the appendix (Göthberg, Frölund, and Fagerlund 2014, 393–403) mentions only 59. We have also decided to exclude the seven features that were not examined further during the excavation, where they were defined as tar pits based on their visual appearance.
7. https://www.cost.eu/actions/CA22155/.

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Disclosure Statement

The authors report there are no competing interests to declare.

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