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Archaeological investigation of the Kakulaane charcoal-burning site

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INTRODUCTION

Production of charcoal goes back a long time, as it has been an important source of fuel, mostly to produce, cast and forge metals, but also for heating and cooking, nowadays commonly sold in shops for grilling. Charcoal, as an energy source, is beneficial for achieving high temperatures and is easy to transport (compared with wood). To produce charcoal, wood must be burned in a low-oxygen environment. Intentional burning of charcoal in Estonia is likely linked to the start of metalwork in the Bronze Age. Ethnographical sources describe that smaller amounts of charcoal could be burned in an oven at home or in the sauna (Talve 1942). Therefore, no specific sites or constructions for getting charcoal may be needed in the time periods of small-scale metal work, e.g. in the Bronze Age.

Two overall methods and structures in landscapes are evidence for producing charcoal in more significant amounts. The oldest method is burning charcoal in a pit, where the depression was filled with wood, covered by soil and turf and thereafter burned. Pits could be rectangular or round-shaped (Hirsch *et al.* 2020). The second method was burning charcoal in kilns, in which wood was piled on the ground and covered with soil. Charcoal burning in pit kilns decreased by the end of the 13th century in Central Europe, and mound kilns were introduced (Deforce *et al.* 2021). Two types of above ground kilns are described in Estonia and Finland: those with wood stacked upright, and others with wood stacked horizontally (Talve 1942; Kangaskesti 2021). In this paper, we refer to the yet unburned stack of firewood as a *kiln*, and the burned and emptied kiln as a *mound*.

In Central Europe, historical charcoal burning sites with numerous mounds have been studied mainly in metal production areas (Rutkiewicz *et al.* 2017; Rutkiewicz *et al.* 2019; Raab *et al.* 2022; Schmidt *et al.* 2016; Schneider *et al.* 2020; Knapp *et al.* 2015). Some remains are significantly larger compared to Estonian counterparts – with diameters up to 30 m and heights up to 50 cm, on slopes even up to 1 m (Raab *et al.* 2022). The areas with charcoal

burning mounds in Latvia are also linked with iron production (Kļava *et al.* 2018; Zunde *et al.* 2023). The pits, on the other hand, have gained less attention from researchers although they have been considered to be older. In the Low Countries, the oldest pits were dated 800–57 BC (Deforce *et al.* 2021).

It is hard to estimate when the special charcoal burning sites first appeared in Estonia, as archaeological evidence on this topic is scarce. Jüri Peets (2003) summarises the previous state of archaeological research and describes four archaeological sites with evidence of charcoal burning. The oldest could be charcoal burning pits from the Olustvere settlement site near an iron smelting site. As the iron smelting site is from the Roman Iron Age, also the charcoal burning site could date from that time. Two charcoal burning pits were radiocarbon dated: Raatvere (1020–1220 AD) and Tuiu (1025–1210 AD), both of which were near the iron smelting complexes (Peets 2003). It is unknown when charcoal burning in kilns started in the territory of Estonia. Only one charcoal kiln from historical times has been excavated before this study. Even this was done by chance as it was mistaken for a barrow by Silvia Laul near Piusa in south-east Estonia. It was dated to 1630–1740 AD (Peets 2003). In addition to what is written by Peets, Harri Moora, who excavated the Viisli barrow cemetery in 1925, found a rectangular pit filled with charcoal from the top of the barrow that he interpreted to be a charcoal burning pit (Moora 1925).

The introduction of coal in the 19th century slowly started to replace the produce of local charcoal burning in Estonia (Talve 1942). However, the tradition of charcoal burning on a smaller scale continued until and during the 20th century. Ethnologist Ilmar Talve gathered responses from 98 correspondents from various regions of Estonia in 1941–1942 about charcoal burning for his master's thesis (Talve 1942). Correspondents described both burning charcoal in pits, piles and special brick kilns, giving vital information about the structures, the preferred types of trees, and about the use of charcoal afterwards. Charcoal burning legacy is also present in place names, folklore notes and landscapes. In the database of cultural heritage coordinated by the State Forest Management Centre, 42 charcoal-burning sites from all regions of Estonia were mapped until 2024 (Kivisaar 2024). As the mapping of the sites was rather non-systematic, the actual number of charcoal-burning sites is much higher. However, the topic has not received much attention from Estonian archaeologists; for example, no charcoal-burning site is under protection in the National Register of Monuments.

Fig. 1. *View of the Kakulaane charcoal mounds.*
Jn 1. *Vaade Kakulaane metsas olevatele söepõletuskuhjadele.*
Photo / Foto: Pikne Kama

KAKULAANE CHARCOAL-BURNING SITE

The Kakulaane research area with numerous charcoal-burning pits and mounds is situated in south-east Estonia, in Karula parish, Antsla rural municipality, near the surroundings of Perajärve farms. The nearest villages at the time of the use of the charcoal-burning site are approximately 3 km away. Nowadays, the area is primarily a sandy pine forest (Fig. 1), with a relatively flat relief (Mets 2025). As the soil is not suitable for agriculture, the remains of the burning site are in general well preserved. Kakulaane site was discovered by Pille Tomson in 2018,

and the first radiocarbon date from one of the charcoal burning pits (E3) gave a surprising result: 1284–1410 AD (Table: 7). This attracted the attention of archaeologists. Additional fieldwork in the following years has resulted in mapping 88 pits and 57 mounds over the territory of 1,16 km² (Fig. 2), though including terrains that are not suitable for kilns and pits (e.g. swamps). Most of these features are visible on the Estonian Land and Spatial Development Board LiDAR map and on the landscape.

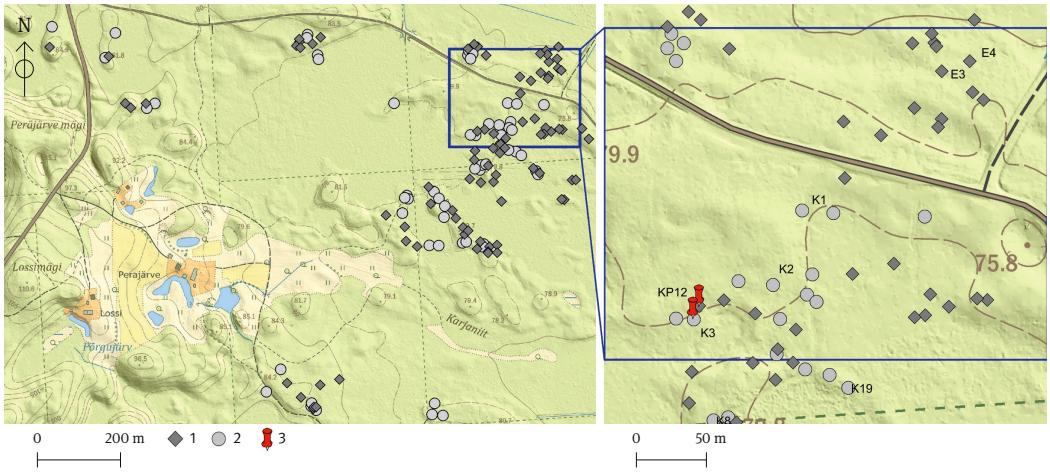

Fig. 2. *Map of the Kakulaane charcoal burning site: 1 – pits, 2 – mounds, 3 – archaeologically investigated remains.*
Jn 2. *Kakulaane söepõletuskoht: 1 – miiliaugud, 2 – miilikuhjad, 3 – arheoloogiliselt uuritud söepõletusjäänused.*
Figure / Joonis: Pille Tomson

However, others are not so well detectable. Firstly, the remains are affected by how well the wood was burned and how carefully the charcoal was taken out. Secondly, different activities in later times, such as forest harvesting and planting trees, have damaged the burning sites. Soil samples were taken with an auger to confirm the character of mounds and pits, as other human activities can also leave behind visually similar structures. Although most of the charcoal was dug out after the burning, there is also a considerable amount of charcoal left in the soil.

In Kakulaane, the charcoal mounds have an average diameter of 6–7 m and a height of 0.5 m. The pits' average diameter is 1.5 m with a depth of 0.7 m. Shallow trenches around kilns can also be detected because of the soil dug to cover the wood before burning. Based on the appearance, two additional types of kilns can be distinguished.

In 2024, fieldwork was limited to the Kakulaane area, where three mounds (K1, K2 and K3) were sampled using soil probe and dated, the results confirmed their use in Late Medieval and Early Modern Period (Table: 1–3). However, LiDAR imagery showed that charcoal-burning sites extend across a much wider area within the territory of the former Vana-Antsla manor. South of Kakulaane (700–800 m), eight larger kilns were discovered, each 10–11 m in diameter, with pits adjacent to the kiln edges. One charcoal pit was sampled near Lossi farm, 1.3 km south-west of Kakulaane, and dated to 1660–1908 AD (Table: 10). Near historical Aruküla (~3 km from Kakulaane), wider (8–9 m in diameter) and lower kilns were discovered in 2024. One kiln was sampled using a soil probe, and the charcoal was dated to 1679–1941 AD (Table: 9).

Table. *^{14}C dates from Kakulaane, Perajärve and Aruküla charcoal-burning sites*
Tabel. *^{14}C dateeringud Kakulaane, Perajärve ja Aruküla söepõletuskohtadest*
Compiled by / Koostanud: Ragnar Saage & Pille Tomson

No. / Nr	Site / Objekt	Context / Kontekst	Lab. no. / Laborinr	^{14}C Age (BP) / ^{14}C vanus (BP)	95.4% cal AD
1	Kakulaane	Mound K1	Poz-176010	360±30	1456–1529 (45.5%), 1540–1635 (50.0%)
2	Kakulaane	Mound K2	Poz-173102	300±30	1495–1602 (69.4%), 1610–1656 (26%)
3	Kakulaane	Mound K3	Poz-176011	445±30	1416–1490
4	Kakulaane	Pit KP12	Poz-189812	310±30	1490–1649
5	Kakulaane	Pit KP12	Poz-176009	60±30	1694–1726 (26.8%), 1811–1918 (68.6%)
6	Kakulaane	Pit E4	Poz-189813	75±30	1691–1728 (26.4%), 1809–1920 (69%)
7	Kakulaane	Pit E3	IHME-4299	620±50	1284–1410
8	Kakulaane	Pit E3	Poz-176014	235±30	1528–1550 (3.5%), 1634–1684 (48.4%), 1735–1804 (39.7%), 1929–...(38%)
9	Aruküla	Mound 1	Poz-189814	120±30	1679–1741 (26.0%), 1752–1764 (2.4%), 1800–1941 (67.1%)
10	Perajärve	Pit	Poz-176001	170±30	1660–1700 (17.4%), 1721–1816 (46.4%), 1833–1889 (12.2%), 1908...(19.5%)

ARCHAEOLOGICAL FIELDWORK

Archaeological fieldwork took place during five days in July 2024. Two trenches were opened: for Trench 1, a charcoal burning pit (KP12) was selected, and for Trench 2, a mound (K3) was partly dug (Fig. 2). The soil from the excavations was sieved on a 5 × 5 mm mesh. The charcoal burning remains and the area around it were checked with a metal detector, but no artefacts were recovered from the trenches nor the areas surrounding them. The excavation was documented using a Trimble S5 total station and photogrammetry using a Canon 800D SLR camera and a DJI Mavic 3 Pro drone.

Trench 1

The trench measured 2.5 × 2 m and it targeted half of the charcoal burning pit in order to get a good profile view of the pit. Four main units could be distinguished (Fig. 3). From the top, Unit 1 was the layer of topsoil, which was very poor, consisting of about 10 cm of moss, roots and forest floor litter. Under that, we found a burned layer with leached sand and smaller charcoal pieces, which could have originated also from a forest fire (Unit 2). Looking at the cross section of the trench, it looks like at least two different charcoal burning events took place in that pit. The excavated lower log was dated 1490–1649 AD (Table: 4). The later one (Unit 3) was dug into the remains of the older charcoal production event (Unit 4). The upper layer was sampled using a soil probe before excavations and was dated 1694–1918 (Table: 5). A similar date (1691–1920 AD) was recorded from the nearby pit E4 (Table: 6).

It must be said that after the burning, digging into the pit of charcoal is part of the process of recovering the charcoal, so it is not that easy to distinguish between different charcoal burning events and the messy process of recovering the charcoal.

The charred remains at the bottom of the pit enable us to make some conclusions about the way the logs were stacked in the pit. The deepest charred log pieces were crosswise to the pit, and the longer logs were stacked on top of them. This way, there would be some ventilation and charring all the way to the lowest level logs (Fig. 4). The original pit measured 2 × 0.9 m at the bottom, and it was 1.2 m deep.

Fig. 3. *The cross section of the charcoal pit in Trench 1 (1–4 mark the units). The scale marks metres above sea level.*
Jn 3. *Profiil 1. kaevandis, mis näitlikustab söepõletusaugu läbilõiget (numbrid 1–4 tähistavad üksusi). Skaala märgib absoluutkõrgusi meetrites.*
Figure / Joonis: Ragnar Saage

Trench 2

Trench 2, measuring 4 × 3.5 metres, targeted a charcoal burning mound about 10 m southwest of Trench 1. The mound was roughly 6.5 m in diameter and about 0.5 m higher than the surrounding ground. A shallow ditch was visible around the mound. The area of the trench covered one quarter of the mound. The excavation revealed the following stratigraphy on the mound: the top 10 cm were moss, roots and litter (Unit 1). The following 25 cm was pyrogenic soil, where leached sand was mixed with pieces of charcoal (Unit 2). Then, we unearthed the charred log remains, which were surprisingly intact (Unit 3). The remaining logs were preserved in two crosswise rows with the bottom consisting of only one log, onto which the second row was supported on. Under the logs, there was another layer of leached sand (Unit 4) and then the undisturbed sand. It also became clear that the mound was artificial, and before the stacking of the wood for the kiln, the ground had been level. The edge of the kiln was visible where sand had been piled against the logs (Fig. 5: 5). The ditch that surrounded the mound where most of the material for covering the kiln was dug was also evident (Fig. 5: 6).

Fig. 4. *The lowest level of the charred logs in Trench 1. The arrow marks the crosswise log.*
Jn 4. *Alumine söestunud tukkide kiht Kaevandis 1. Nool märgib ristipidist tukki.*
Photo / Foto: Ragnar Saage

The mound was dated to 1416–1490 CE prior to the excavation using charcoal from a soil probe (Table: 3). During the excavations, no evidence could be obtained that this mound had been used more than once. It would also not make sense to reuse a mound, because more soil would have to be used to cover the kiln.

Fig. 5. *South-western profile of Trench 2. 1 – litter (Unit 1), 2 – pyrogenic soil (Unit 2), 3 – log remains (Unit 3), 4 – leached soil (Unit 4), 5 – edge of the kiln, 6 – a ditch. The scale marks metres above sea level.*
Jn 5. *Kaevand 2 edelaprofiil: 1 – kõdu, 2 – pürogeenne pinnas, 3 – palkide jäänused, 4 – leetunud muld, 5 – riida serv, 6 – kraav. Skaala märgib absoluutkõrgusi meetrites.*
Figure / Joonis: Ragnar Saage

BOTANICAL ANALYSES

Charcoal fragments were selected from different depths to identify the burned tree species. The taxonomic identification was carried out using a Zeiss Stemi 508 optical microscope (reflected light, magnification up to ×500), reference material (Veermets 1962), online identification keys (Schoch *et al.* 2004), and a reference collection.

The minimal diameter of burned trees was measured using stencils (see Nelle 2002) with a step of 2.5 cm up to 30 cm in diameter. In thicker trees, the curvature of the annual rings is no longer discernible with a stencil as they seem parallel. As none of the measured pieces were covered by bark, the real diameter could be much bigger.

In the investigated pit (KP12) in Trench 1 the number of identified pieces of charcoal was 53. These included pine (*Pinus sylvestris*) with 29 fragments, eight fragments from spruce (*Picea abies)*, seven from birch (*Betula* sp.), six from unidentified coniferous wood, two fragments from unidentified deciduous wood, and two pieces of non-wood charcoal. For 39 pieces the average length of the longest side was 1.35 cm (ranging from 0.7–3.7cm). 11 pieces were large enough to measure the diameter. The average minimum diameter of burned trees was 13 cm (ranging from 2.5–22.5 cm).

In the mound (K3) in Trench 2 the number of identified pieces of charcoal was 70. These included pine (*Pinus sylvestris*) with 50 fragments, 19 from spruce (*Picea abies*), and one fragment of non-wood charcoal. The average length of the longest side was 3.65 cm (ranging from 0.7–7.8 cm). The average minimal burned tree diameter from 65 fragments was 20 cm.

The results demonstrate that the kiln contained wood from an old-growth forest where trees with a diameter of more than 30 cm grew. The pit had two different layers. In the bottom layer there was pine charcoal, while the upper layers also contained deciduous trees, that refer to a secondary forest composition. The charcoal in the pit was more fragmented than that in the kiln, possibly due to different harvesting methods.

DISCUSSION

Trench 2 gave us a unique insight into the charcoal burning process in the Late Medieval period. Initially, the kiln ground was cleared of most of the organic matter. Then, at least two logs were set as the base. There might have been a third one in the middle, which we just missed with the excavation. Then a second row of logs was set crosswise on top of the

base logs (Figs 6, 7). The height of the kiln is complicated to reconstruct, but it was probably only a few layers of logs. Then the kiln was covered with soil that was dug around the heap. A very high kiln would have needed a lot of soil to cover (especially on the sides of it), and we have no evidence of extra material on the edges. There were definitely some openings where the kiln was lit and the fire was controlled. It is said that in Estonia, charcoal burning in pits took three days (Talve 1942). However, in a recent charcoal burning carried out by local inhabitant Endel Meriste in 2025 in Karula, the pit burned for three weeks (oral information). In kilns, the charcoal burning lasted about 10–14 days, depending on the size, burned tree species and moisture content of wood, and weather conditions (Raab *et al.* 2022). Then the kiln was extinguished and left to cool down. Eventually, the kiln was opened, and the fully charred logs were taken out. The excavated log remains in Trench 2 were probably only partly charred, which explains why they were not picked out.

The majority of the studied above ground kilns have been round-shaped, where the wood was stacked vertically (Raab *et al.* 2022). Less attention has been paid to the rectangular kilns with a horizontal stack. Every description of a rectangular kiln in the Swedish Charcoal Burning Handbook (Bergström 1922, 168) includes a dense horizontal and parallel stacking.

Ethnographical records from the neighbouring municipality of Varstu describe that dry wood was stacked parallel and raw wood crosswise (Pettäi 1941). According to found remains, the Kakulaane kiln was a rectangular horizontal kiln, but the method of stacking cannot be determined with certainty. In the light of current knowledge, it seems that charcoal-burning pits in the Kakulaane site are from a wider time range, starting from the 13th to the 14th century and lasting possibly up until the 20th century. Burning charcoal

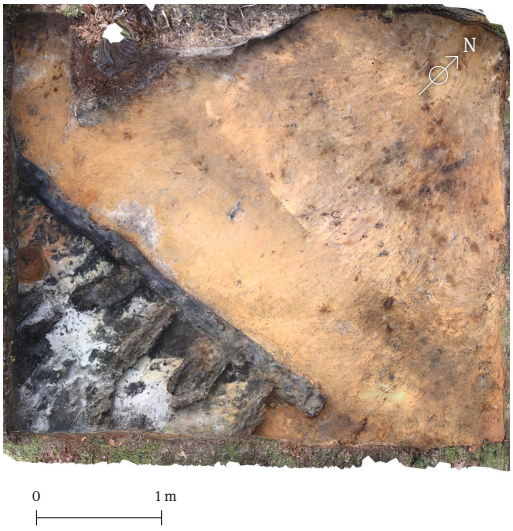

Fig. 6. *Charred log remains in Trench 2.*
Jn 6. *Söestunud palgijäänused Kaevandis 2.*
Figure / Joonis: Ragnar Saage

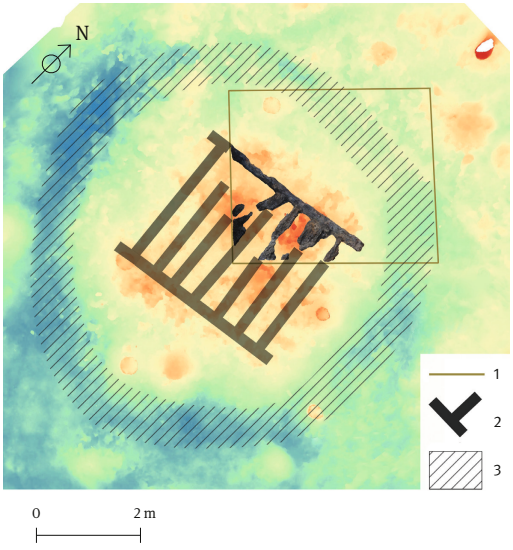

Fig. 7. *Reconstruction of the kiln base based on the remains in Trench 2 and the surrounding ground level. 1 – Trench 2, 2 – reconstructed log positions, 3 – the ditch. The height map was based on the 3D model of the mound.*
Jn 7. *Miilikuhja alumiste palkide ladumisviisi rekonstruktsioon Kaevand 2 ja kõrgusandmete põhjal. 1 – kaevand 2, 2 – kuhja aluspalkide asend, 3 – kuhja ümbritsev kraav. Kõrgusandmed pärinevad kuhja 3D-mudelist.*
Figure / Joonis: Ragnar Saage

in kilns seem to be rather limited in time, taking place in the 15th–17th centuries. Kilns made it possible to burn more wood in one event. There is no record of a nearby metalworking site, so charcoal was probably not used locally, but was rather sold elsewhere. How far and to which centre the charcoal was transported is unknown. It is possible that the charcoal burning was organised by the Vana-Antsla manor as the kilns seem to correspond with the area owned by the manor.

Historical documents from medieval and early modern towns record that charcoal was imported to urban centres in large quantities. The regulations of the guild of smiths of Riga, dating from 1382 stipulated that charcoal had to be bought packaged into barrels (Stieda and Mettig 1896, 458). The most common quantities in which charcoal was sold were the barrel and wagonload or sleighload. The regulations of the guild of smiths of Tallinn, dating from 1415, inform that the price of charcoal in the towns was highest during spring and autumn, more specifically at those times in the year when roads were so wet and muddy that they were unsuitable for transport with wagons and sleighs (TLA.190.2.554). Similarly to other goods imported to towns, the smiths of Tallinn were required to purchase their charcoal in the town market or at least within the area of the walled town. Smiths were forbidden from buying charcoal outside the town (TLA.190.2.554). The penalty for breaking this regulation was one barrel of beer in Tallinn in 1415. The Riga regulations do not contain such a clause. Instead, they forbade smiths from purchasing unpackaged and unmeasured charcoal (Stieda and Mettig 1896, 458). This might mean that charcoal was brought into town unpacked and barrelled in the town before it was sold.

The importance of charcoal for urban smithies is illustrated in the regulations of the smith's guilds of both towns by stipulations which mandated smiths to sell at least one barrel (in Riga) or one quarter of a wagonload/sleighload (in Tallinn) to a fellow smith in times when charcoal was scarce (Stieda and Mettig 1896, 458; TLA.190.2.554). The Tallinn regulations had one very specific clause, which stated that if charcoal was brought and left behind the door of a smith, and when another smith (or their servant) came to the house, saw the charcoal and wanted to buy it, he had the right to purchase the said charcoal himself, provided that he entered the house and found nobody home (TLA.190.2.554). This stipulation is so bizarrely specific that it seems to record a real-life event in early 15th-century Tallinn. Apparently, charcoal in towns was a seasonal commodity, which was not always available in sufficient quantities required by town smiths. It was brought to the towns from the countryside with sleighs or wagons, depending on the season.

CONCLUSIONS

This research highlights the archaeological potential of peripheral areas and a possible usage of lands not suitable for agriculture. Charcoal burning leaves very specific remains, which can be easily detected using a soil probe. This also means that these monuments are very easy to date using radiocarbon analysis. The Kakulaane charcoal-burning site demonstrates a long temporal range of activity, with charcoal pits dated from the 13th to possibly the 20th century, and mound kilns primarily dated to the 15th–19th centuries. This reveals sustained and evolving use of charcoal production technologies in south-east Estonia over several centuries.

The presence of both pits and mounds reflects a dual technological approach: pits likely associated with older, small-scale or dispersed burning, and kilns associated with more intensive, organised production. Botanical analysis revealed the use of mature forest wood,

especially pine and spruce, with trees exceeding 30 cm in diameter. Charcoal from the pits included deciduous species as well, suggesting later forest regeneration.

Historical guild regulations from Riga and Tallinn confirm that charcoal was a controlled and valued commodity in towns, supporting the hypothesis that the Kakulaane site was part of a broader rural-to-urban supply chain.

Despite their historical and archaeological value, charcoal-burning sites in Estonia are underrepresented among scheduled heritage sites. Kakulaane illustrates how such sites can yield important insights into local economies, land use and technology, and deserve increased attention and protection.

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ARHEOLOOGILISED VÄLITÖÖD KAKULAANE SÖEPÕLETUSKOHAS

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Kakulaane söepõletuskoht, mis paikneb Lõuna-Eestis Antsla vallas, kujutab endast olulist arheoloogilist leiukohta, kus on hästi säilinud mitmekesised söepõletusjäänused. Uurimisalal, mis paikneb liivasel männikul (jn 1) ja mis ei ole olnud intensiivse põllumajandusliku kasutuse all, kaardistati kokku 88 põletusauku ja 57 kuhilat (jn 2). Varaseimad radiosüsiniku dateeringud paigutavad söepõletuse 13.–15. sajandisse, sütt põletati seal piirkonnas 20. sajandini (tabel). 2024. aasta suvel läbi viidud arheoloogilised kaevamised võimaldasid saada uusi teadmisi hiliskeskaegsest ja varauusaegsest söepõletustehnoloogiast ning maastikukasutusest.

Söe tootmist ehk miilimist tehti kahte tüüpi struktuurides: maasse kaevatud miiliaukudes ning maapealsetes miilikuhjades. 2024. aastal uuriti kahte objekti: miiliauku KP12 ja kuhja K3. Miiliaugus tuvastati vähemalt kahest miilimisetapist jäänud jälgi ning alumise kihina säilinud puusöetükid viitasid risti asetatud alumistele palkidele (jn 3–4). Analüüsid miiliaugu puidust osutasid ajas muutunud metsakooslustele – alumistes kihtides leidus valdavalt männipuitu, ülemistes aga ka lehtpuud.

Miilikuhi koosnes horisontaalselt paigutatud palkidest ning selle serva ümber oli kraav, kust saadi pinnas kuhja katmiseks (jn 5–7). Leitud puusöe fragmentide taksonoomiline analüüs näitas valdavalt vana metsa puuliikide – männi ja kuuse – kasutamist, mis viitab toormaterjali päritolule metsadest, kus kasvasid üle 30 cm läbimõõduga puud. Kaevanditest ega ümbrusest esemeid ei leitud.

Töö tulemused viitavad, et kuhjades miilimine võimaldas suuremahulist söetootmist ning oli ajaliselt piiratud pigem 15.–17. sajandiga, samas kui põletusaugud esindavad pikemat ajavahemikku. Sütt ei kasutatud kohapeal – lähimad asulad olid 3 km kaugusel – ning seda võidi müüa või transportida kaugemale, arvatavasti Vana-Antsla mõisakompleksi kaudu. Keskja varauusaegsed allikad Riiast ja Tallinnast kinnitavad, et linnade sepad pidid sütt ostma tünnides või koormates ning turg oli tugevalt reguleeritud. Näiteks Tallinna seppadel oli keelatud sütt väljaspool linnamüüri osta.

Kuigi söepõletusel oli oluline roll Eesti ajaloolises majanduses ning maastikukasutuses, on sellised paigad Eesti kultuuripärandis seni alahinnatud – ükski söepõletuskoht ei ole seni muinsuskaitse all. Kakulaane tulemused rõhutavad vajadust süstemaatilise dokumenteerimise, teadusliku uurimise ja kaitse järele.