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A BIRCH BARK TAR FIGURINE FROM THE PULLI SETTLEMENT SITE IN ESTONIA

INTRODUCTION

Art objects have been produced in the Eastern Baltic region since the beginning of the Mesolithic period, around 9000 BC, although they are not very numerous. One art-related artefact[1], probably a zoomorphic figurine, was found in 1972 at the Early Mesolithic Pulli settlement site in southwestern Estonia (Fig. 1). Its uniqueness, aside from its early age, lies in the fact that it was made from birch bark tar. Birch tar, found in the context of the Stone Age, is known primarily as the earliest adhesive for composite tools. It was already being produced and used by Neanderthals.[2] In

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1 AI 4476: 612, earlier written as No 662; stored in the Archaeological Research Collection of Tallinn University.

2 Johann Koller, Ursula Baumer, Dietrich Mania, "High-tech in the middle palaeolithic: neandertal-manufactured pitch identified", *European Journal of Archaeology*, 4 (3) (2020), 385–397; Paul Peter Anthony Mazza, Fabio Martini, Benedetto Sala, Maurizio Magi, Maria Perla Colombini, Gianna Giachi, Francesco Landucci, Cristina Lemorini, Francesca Modugno, Erika Ribechini, "A new Palaeolithic discovery: tar-hafted stone tools in a European Mid-Pleistocene bone-bearing bed", *Journal of Archaeological Science*, 33 (9) (2006), 1310–1318; Marcel J. L. Th. Niekus, Paul R. B. Kozowyk, Geeske H. J. Langejans, Dominique Ngan-Tillard, Henk van Keulen, Johannes van der Plicht, Kim M. Cohen, Willy van Wingerden, Bertil van Os, Bjørn I. Smit Luc W. S. W. Amkreutz, Lykke Johansen, Annemieke Verbaas, Gerrit L. Dusseldorp, "Middle Paleolithic complex technology and a Neandertal tar-backed tool from the Dutch North Sea", *Proceedings of the National Academy of Sciences*, 116 (44) (2019), 22081; Geeske Langejans, Alessandro Aleo, Sebastian Fajardo, and Paul Kozowyk, "Archaeological Adhesives", *Oxford Research Encyclopedia of Anthropology* (Oxford: Oxford University Press, 2022), 16.

this capacity, it was used throughout the Stone Age, and with the appearance of pottery was also employed to repair pots.[3] In addition to its excellent viscosity, sealing and adhesive properties, birch tar has a vivid black colour, which probably led to its use as a decorative material at some point – for filling engravings on bone artefacts[4] or as a paint for patterns on pottery[5]. Its use across various historical periods spans a vast geographic range, covering areas from England to China.[6]

Most individual lumps of birch tar found at various Stone Age sites initially became notable due to the presence of tooth marks on them.[7] This feature gained particular importance once ancient DNA began to be extracted from these samples and metagenomic studies

3 Petro Pesonen, "Koivutervan juurilla – koivutervan käyttö saviastian korjauksessa kivikaudella", *Tekniikan Waiheita*, 1 (1994); Petro Pesonen, "Radiocarbon dating of birch bark pitches in typical Comb Ware in Finland", *Dig it All. Papers Dedicated to Ari Siiriäinen*, ed. by Matti Huurre (Helsinki: The Finnish Antiquarian Society, The Archaeological Society of Finland, 1999), 191–197; Viktor N. Karmanov, "Remont keramicheskoj posudy v neolite i eneolite (po materialam krajnego Severo-Vostoka Evropy)", *Arheologiya Evrazijskih stepej*, (4) (2024), 228–240.

4 Tabea J. Koch, Jacek Kabaciński, Auréade Henry, Benjamin Marquebielle, Aimée Little, Rebecca Stacey, Martine Regert, "Chemical analyses reveal dual functionality of Early Mesolithic birch tar at Krzyż Wielkopolski (Poland)", *Journal of Archaeological Science: Reports*, 57 (2024), 104591, https://doi.org/10.1016/j.jasrep.2024.104591.

5 Dushka Urem-Kotsou, Mark S. Copley, Richard P. Evershed, "The use of birch bark tar on Late Neolithic pottery from Stavroupoli, North Greece", *Sostikes anaskafes sto neolithiko oiskimo Stavroupolis Thessalonikis, Meros II (1998–2003)*. Publications of the Archaeological Institute of Northern Greece 4, ed. by Dimitrios V. Grammenos, Stavros Kotsos (Thessalonikis, 2004), 339–247; Martine Regert, Isabelle Rodet-Belarbi, Arnaud Mazuy, Gaëlle Le Dantec, Rosa Maria Dessì, Stéphanie Le Briz, Auréade Henry, Maxime Rageot, "Birch-bark tar in the Roman world: The persistence of an ancient craft tradition?", *Antiquity*, 93 (372) (2019), 1553–1568, https://doi.org/10.15184/aqy.2019.167.

6 For example: Elizabeth M. Aveling, Carl Heron, "Identification of Birch Bark Tar at the Mesolithic Site of Star Carr", *Ancient Biomolecules*, 2 (1) (1998), 69–80; Huiyun Rao, Yang Yimin, Abuduresule Idelisi, Li Wenying, Xingjun Hu, Wang Changsui, "Proteomic identification of adhesive on a bone sculpture-inlaid wooden artifact from the Xiaohe Cemetery, Xinjiang, China", *Journal of Archaeological Science*, 53 (2015), 148–155; Shidong Chen, Signe Vahur, Anu Teearu, Taisi Juus, Mikhail Zhilin, Svetlana Savchenko, Svetlana Oshibkina, Vitali Asheichyk, Aliaksandr Vashanau, Evgeniia Lychagina, Ekaterina Kashina, Konstantin German, Ekaterina Dubovtseva, Aivar Kriiska, Ivo Leito, Ester Oras, "Classification of archaeological adhesives from Eastern Europe and Urals by ATR-FT-IR spectroscopy and chemometric analysis", *Archaeometry*, (64) (2022), 227–244, https://doi.org/10.1111/arcm.12686.

7 For example: Sakari Pälsi, "Kivikautista purupihkaa", *Suomen Museo*, 64 (1931–1932) (1932); Aarne Kopisto, "Vähän lisää purupihkasta", *Kotiseutu*, 6 (1963), 206.

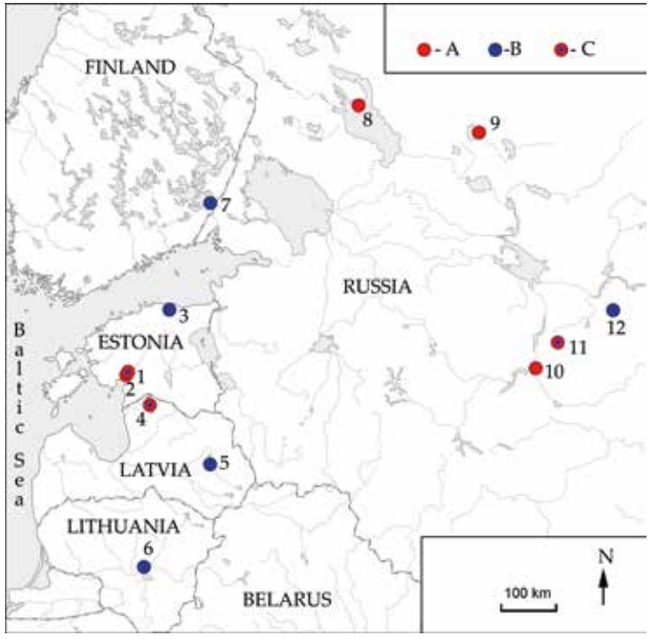

FIG. 1. MAP SHOWING THE MESOLITHIC SITES MENTIONED IN THE TEXT:
1 – PULLI; 2 – LOWER REACHES OF THE PÄRNU RIVER; 3 – KUNDA LAMMASMÄGI; 4 – ZVEJNIEKI II; 5 – SŪĻAGALS; 6 – EIGULIAI 1A; 7 – MUILAMÄKI; 8 – YUZHNY OLENIY OSTROV; 9 – VERETJE 1; 10 – ZAMOSTJE 2; 11 – IVANOVSKOE 7; 12 – STANOVOE 4. **A** – SITE WITH PORTABLE FIGURINES; **B** – SITE WITH ENGRAVED ITEMS; **C** – SITE WITH PORTABLE FIGURINES AND ENGRAVED ITEMS.

started to be conducted.[8] However, no standalone objects intentionally made of birch tar had been discovered until now. Therefore, the

8 Theis Z. T. Jensen, Jonas Niemann, Katrine Højholt Iversen, Anna K. Fotakis, Shyam Gopalakrishnan, Åshild J. Vågene, Mikkel Winther Pedersen, Mikkel-Holger S. Sinding, Martin R. Ellegaard, Morten E. Allentoft, Liam T. Lanigan, Alberto J. Taurozzi, Sofie Holtsmark Nielsen, Michael W. Dee, Martin N. Mortensen, Mads C. Christensen, Søren A. Sørensen, Matthew J. Collins, M. Thomas P. Gilbert, Martin Sikora, Simon Rasmussen, Hannes Schroeder, "A 5700 year-old human genome and oral microbiome from chewed birch pitch", *Nature Communications*, 10, (2019), 5520, https://doi.org/10.1038/s41467-019-13549-9; Natalija Kashuba, Emrah Kırdök, Hege Damlien, Mikael A. Manninen, Bengt Nordqvist, Per Persson, Anders Götherström, "Ancient DNA from mastics solidifies connection between material culture and genetics of mesolithic hunter–gatherers in Scandinavia", *Communications Biology*, 2 (2019), 185, https://doi.org/10.1038/s42003-019-0399-1; Emrah Kırdök, Natalija Kashuba, Hege Damlien, Mikael A. Manninen, Bengt Nordqvist, Anna Kjellström, Mattias Jakobsson, A. Michael Lindberg, Jan Storå, Per Persson, Björn Andersson, Andrés Aravena, Anders Götherström, "Metagenomic analysis of Mesolithic chewed pitch reveals poor oral health among stone age individuals", *Scientific Reports*, 14 (2024), 22125, https://doi.org/10.1038/s41598-023-48762-6.

uniqueness of the birch tar figurine from the Pulli settlement site is beyond question.

This article presents the results of a comprehensive analysis of the figurine, which, in addition to the previously published chemical analysis[9], includes microscopic examination of surface treatment traces, direct radiocarbon dating, 3D scanning, photogrammetry and computed tomography. The artefact is discussed within the context of finds from the Pulli settlement, as well as within the broader context of art objects, especially small figurative sculptures from the Mesolithic (9000–6000/2800 BC) period of the European forest zone.

SITE DESCRIPTION

The Pulli settlement site was discovered in 1967, when geologists found a humus layer containing animal bones beneath several meters of sand during the investigation of a gravel pit.[10] Archaeological excavations took place between 1968 and 1973 and 1975–1976 under the leadership of Lembit Jaanits. Most of the settlement area, a total of 1,159 m^2, has been thoroughly investigated.[11]

The Stone Age settlement site was located on the ancient Pärnu River bank a few kilometres away from the shoreline (of what where the Yoldia Sea and the Ancylus Lake, dating from 9700 to 8700 BC and 8700 to 7900 BC respectively)[12] that existed in the Baltic Sea basin during that time.[13] A thin cultural layer of 5 to 15 cm contained several hearths and remains of sharpen-ended wooden stakes (Fig. 2E).[14] A few

9 Signe Vahur, Aivar Kriiska, Ivo Leito, "Investigation of the adhesive residue on the flint insert and the adhesive lump found from the Pulli Early Mesolithic settlement site (Estonia) by microATR-FT-IR spectroscopy", *Estonian Journal of Archeology*, 15 (1) (2011), 3–17.

10 Lembit Jaanits, Kaarel Jaanits, "Frühmesolithische Siedlung in Pulli", *Eesti NSV Teaduste Akadeemia Toimetised. Ühiskonnateadused*, 24 (1) (1975), 65.

11 Lembit Jaanits, Kaarel Jaanits, "Ausgrabungen der frühmesolithischen Siedlung von Pulli", *Eesti NSV Teaduste Akadeemia Toimetised.* Ühiskonnateadused, 27 (1) (1978), 56.

12 Tiit Hang, Siim Veski, Jüri Vassiljev, Anneli Poska, Aivar Kriiska, Atko Heinsalu, "A new formal subdivision of the Holocene Series/Epoch in Estonia", *Estonian Journal of Earth Sciences*, 69 (4) (2020), 269–280, https://doi.org/10.3176/earth.2020.15.

13 Triine Nirgi, Alar Rosentau, Hando-Laur Habicht, Tiit Hang, Tõnno Jonuks, Argo Jõeleht, Kersti Kihno, Aivar Kriiska, Mario Mustasaar, Jan Risberg, Sten Suuroja, Peeter Talviste, Hannes Tõnisson, "Holocene relative shore-level changes and Stone Age palaeogeography of the Pärnu Bay area, eastern Baltic Sea", *The Holocene*, 30 (1) (2020), Fig. 8.

14 Jaanits, Jaanits, "Frühmesolithische Siedlung in Pulli", 67; Jaanits, Jaanits, "Ausgrabungen der frühmesolithischen Siedlung von Pulli", 56, Fig. 1.

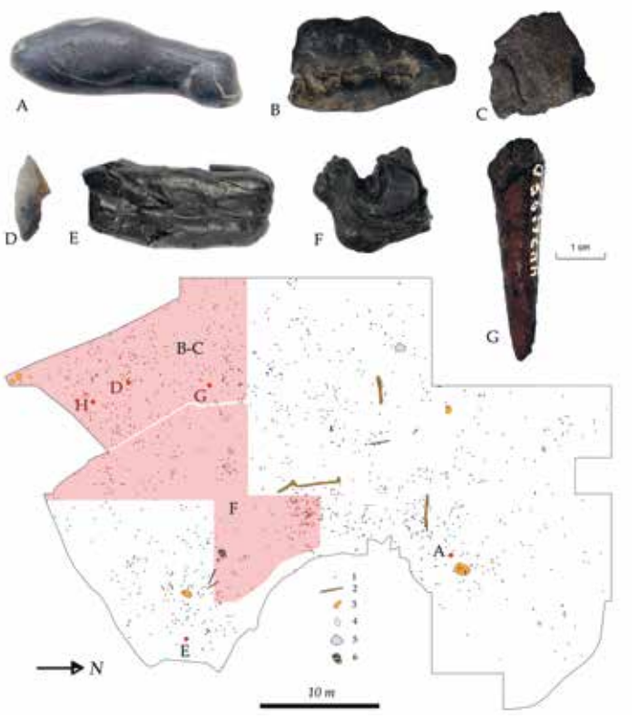

FIG. 2. FINDS DISCUSSED IN THE TEXT AND PLAN OF THE PULLI SETTLEMENT SITE WITH FINDS OF TAR AND ART OBJECTS MARKED BY LETTERS. THE EXACT LOCATIONS OF FINDS B, C, AND F ARE UNKNOWN; THEREFORE, THE AREAS OF THEIR ORIGIN ARE MARKED WITH A PINK COLOUR. **A** – BIRCH BARK TAR FIGURINE (AI 4476: 612); **B – C** – BIRCH BARK TAR LUMPS WITH TOOTH MARKS (NO NUMBERS); **D** – FLINT INSERT WITH REMAINS OF BIRCH BARK TAR (AI 4476: 1042); **E** – BIRCH BARK TAR LUMP WITH TOOTH MARKS (AI 4441: 14); **F** – BIRCH BARK TAR LUMP (NO NUMBER); **G** – BROKEN BONE TOOL WITH REMAINS OF BIRCH BARK TAR IN THE LOWER PART (AI 4476: 920); **H** – FRAGMENT OF ENGRAVED ARROWHEAD (SEE FIG. 9); 1 – FIND; 2 – REMAINS OF WOODEN STAKES; 3 – HEARTH WITHOUT STONES; 4 – PIT; 5 – STONE; 6 – HEARTH WITH STONES. CONSOLIDATION OF PLANS PUBLISHED IN DIFFERENT PUBLICATIONS, TECHNICAL EXECUTION BY KRISTEL ROOG, IRINA KHRUSTALEVA. PHOTOS: KRISTEL ROOG, IRINA KHRUSTALEVA.

thousands artefacts and ecofacts were relatively sparsely dispersed in the former living zone of the site.[15] The most common finds were small flint items, such as scrapers, knives, drills and arrowheads, along with tool blanks – blades and flakes – and stone processing

15 Lembit Jaanits, Silvia Laul, Vello Lõugas, Evald Tõnisson, *Eesti esiajalugu* (Tallinn: Eesti Raamat, 1982), Fig. 14.

waste.[16] Bone and antler artefacts such as adzes, arrowheads, spear and harpoon tips, pendants made of animal teeth, etc., were also relatively numerous, although mainly preserved in fragments.[17] Four birch bark tar lumps, three of which are with tooth imprints, and one figurine made of tar were found at the settlement site (Fig. 2A–C, E–F). The tar figurine was found in the northwestern part of the site, 1 m southwest of the hearth without stones (Fig. 2).[18] Tar is also present in the groove of a bone arrowhead, securing a flint insert inside, as well as on the surface of another flint insert and a broken bone tool (Fig. 2D and G).[19] The intense use of birch bark tar by the inhabitants of Pulli can be supposed due to numerous flint inserts used in composite points, which constitute nearly 30% of the secondary processed flint artefacts.[20]

Pulli was probably a repeatedly used seasonal campsite. It was flooded during the culmination of the Ancylus Lake transgression around 8200 cal. BC[21], causing the cultural layer to be buried under several metres of sandy sediment.[22] Sixteen radiocarbon dates

16 Ibid., 27–30; Aivar Kriiska, Lembi Lõugas, "Stone Age settlement sites on an environmentally sensitive coastal area along the lower reaches of the River Pärnu (southwestern Estonia), as indicators of changing settlement patterns, technologies and economies", *Mesolithic Horizons. Papers Presented at the Seventh International Conference on the Mesolithic in Europe*, ed. by Sinéad McCartan, Rick Schulting, Graeme Warren, Peter Woodman (Oxford: Oxbow Books 2009), 72.

17 Jaanits, Laul, Lõugas, Tõnisson, *Eesti esiajalugu*, 30; Eva David, "Preliminary results on a recent technological study of the Early Mesolithic bone and antler industry of Estonia, with special emphasis on the Pulli site", *From Hooves to Horns, from Mollusc to Mammoth. Manufacture and Use of Bone Artefacts from Prehistoric Times to the Present*. Proceedings of the 4th meeting of the ICAZ Worked Bone Research Group at Tallinn, 26th–31st of August 2003. Muinasaja teadus, 15, ed. by Heidi Luik, Alice M. Choyke, Colleen E. Batey, Lembi Lõugas (Tartu: Tartu Ülikooli kirjastus; Tallinn: Tallinna Ülikool, 2005), 67–74.

18 Jaanits, Laul, Lõugas, Tõnisson, *Eesti esiajalugu*, Fig. 14.

19 Ibid., 30; Vahur, Kriiska, Leito, "Investigation of the adhesive residue on the flint insert and the adhesive lump found from the Pulli Early Mesolithic settlement site (Estonia) by micro-ATR-FT-IR spectroscopy", 3–17; Chen, Vahur, Teearu, Juus, Zhilin, Savchenko, Oshibkina, Asheichyk, Vashanau, Lychagina, Kashina, German, Dubovtseva, Kriiska, Leito, Oras, "Classification of archaeological adhesives from Eastern Europe and Urals by ATR-FT-IR spectroscopy and chemometric analysis", 227–244.

20 Kaarel Jaanits, Mati Ilomets, "Umbusi mesoliitilise asula vanusest ja kohast Eesti keskmise kiviaja kronoloogias", *Loodusteaduslikud meetodid Eesti arheoloogias*, (Tallinn: Eesti NSV Teaduste Akadeemia Ajaloo Instituut, 1988), 54–64.

21 Hang, Veski, Vassiljev, Poska, Kriiska, Heinsalu, "A new formal subdivision of the Holocene Series/Epoch in Estonia", 269–280.

22 Siim Veski, Atko Heinsalu, Veiko Klassen, Aivar Kriiska, Lembi Lõugas, Anneli Poska, Ulla Saluäär, "Early Holocene coastal settlements and palaeoenvironment on the shore of the Baltic Sea at Pärnu, southwestern Estonia", *Quaternary International*, 130 (2005), 83, Fig. 1.

obtained from organic matter from soil, charcoal, bones, seeds, and birch bark tar found in the cultural layer range in the median spans from approximately 8950[23] (9620±120 BP, Hel-2206A) to 8300 (9095±90 BP, Ua-13352) cal. BC.[24]

THE SUBJECT OF THE STUDY

This artefact immediately drew attention; however, it was initially interpreted as a zoomorphic figurine made of bone that may have been used as a pendant (Fig. 3A).[25] As a bone figurine it was also displayed for a long time as part of the exhibition at the Tallinn University Museum. In 2007, material from several locations on the surface of the figurine was collected for chemical analysis performed by attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy. This determined that the artefact is, in fact, not bone, but birch bark tar (Fig. 3B).[26] Traces of some fat, and pine or fir resin were interpreted as an admixture to the birch tar.

Due to the absence of tooth marks – which are typically the primary feature that sparks interest in birch tar – the artefact somewhat lost its appeal, and the topic of the figurine was no longer discussed. However, our attention has now returned to this item, and closer examination under a microscope revealed traces of scraping or planing, indicating that its shape is the result of intentional surface modification.

23 All dates in the article are calibrated using the OxCal 4.4.4 programme with the IntCal 20 atmospheric curve and are given with a 95.4% probability; Paula J. Reimer, William E.N. Austin, Edouard Bard, Alex Bayliss, Paul G. Blackwell, Christopher Bronk Ramsey, Martin Butzin, Hai Cheng, R. Lawrence Edwards, Michael Friedrich, Pieter M. Grootes, Thomas P. Guilderson, Irka Hajdas, Timothy J. Heaton, Alan G. Hogg, Konrad A. Hughen, Bernd Kromer, Sturt W. Manning, Raimund Muscheler, Jonathan G. Palmer, Charlotte Pearson, Johannes van der Plicht, Ron W. Reimer, David A. Richards, E. Marian Scott, John R. Southon, Christian S.M. Turney, Lukas Wacker, Florian Adolphi, Ulf Büntgen, Manuela Capano, Simon M. Fahrni, Alexandra Fogtmann-Schulz, Ronny Friedrich, Peter Köhler, Sabrina Kudsk, Fusa Miyake, Jesper Olsen, Frederick Reinig, Minoru Sakamoto, Adam Sookdeo, Sahra Talamo, "The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP)", *Radiocarbon*, 62 (4) (2020), 725–757; Christopher Bronk Ramsey, *OxCal 4.4 manual* (2021), https://c14.arch.ox.ac.uk/oxcal/OxCal.html [accessed December 15, 2024].

24 Partially published dates see Veski, Heinsalu, Klassen, Kriiska, Lõugas, Poska, Saluäär, "Early Holocene coastal settlements and palaeoenvironment on the shore of the Baltic Sea at Pärnu, southwestern Estonia", Tab. 2 and publications cited therein.

25 Jaanits, Laul, Lõugas, Tõnisson, *Eesti esiajalugu*, 30, Fig. 17:3.

26 For details see Vahur, Kriiska, Leito, "Investigation of the adhesive residue on the flint insert and the adhesive lump found from the Pulli Early Mesolithic settlement site (Estonia) by microATR-FT-IR spectroscopy", 3–17.

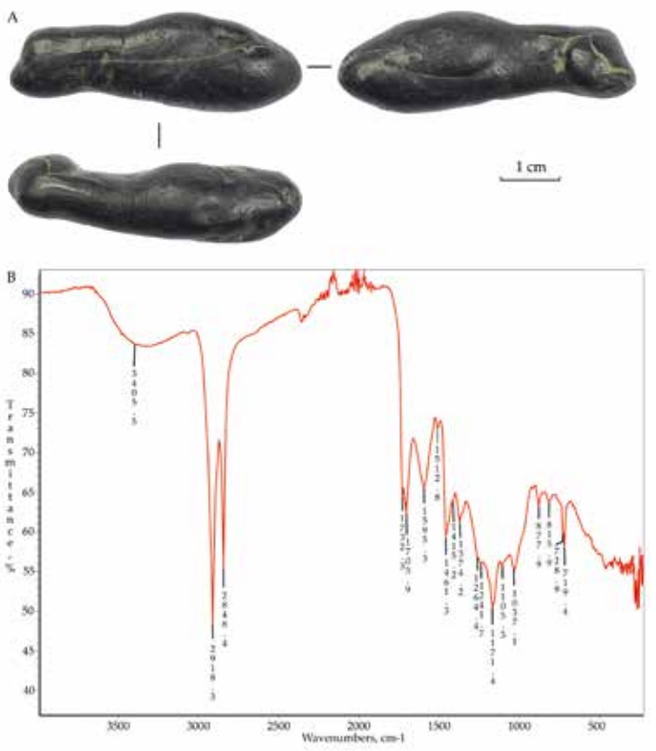

FIG. 3. **A** – BIRCH BARK TAR FIGURINE. PHOTOS: IRINA KHRUSTALEVA. **B** – IR SPECTRUM OF THE TAR FIGURINE: VAHUR, KRIISKA, LEITO, "INVESTIGATION OF THE ADHESIVE RESIDUE ON THE FLINT INSERT AND THE ADHESIVE LUMP FOUND FROM THE PULLI EARLY MESOLITHIC SETTLEMENT SITE (ESTONIA) BY MICRO-ATR-FT-IR SPECTROSCOPY", FIG. 5.

The figurine has an elongated oval shape with a narrowed central section (neck), an end that thickens into a head-like shape with an elongated nose, and the opposite end (body) is an elongated oval with a thickened middle part. The figurine is 4.8 cm long, with a width of 1.6 cm at the centre, a thickness of 1.2 cm, and a weight of 5.3 g. The colour is black and it has a smooth surface and deep longitudinal cracks. In some areas, there are slight delaminations of the surface layer, but overall, the structure is dense with no visible pores.

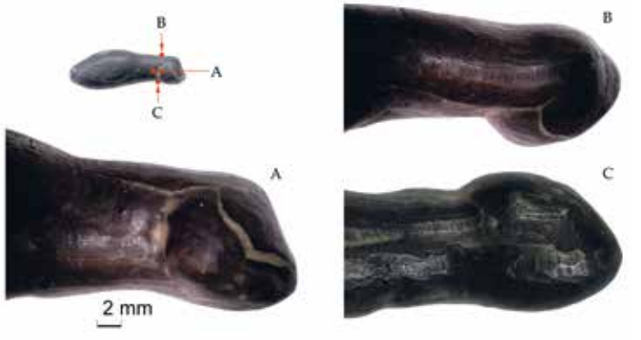

FIG. 4. SCRAPING OR PLANING MARKS ON THE FIGURINE'S NECK AND HEAD. RED DOTS MARK PLACES OF TAKEN PICTURES. **A–C** – MAGNIFICATION: 14.8 X. PHOTOS: IRINA KHRUSTALEVA.

METHODS AND RESULTS

Microscopic analysis. Traces of surface treatment are visible to the naked eye; however, they become more distinct when viewed under a microscope. A Dino-Lite Edge digital microscope was used for this purpose. The artefact was investigated under a magnification of 14.6 to 81.9 times. Distinct scraping or planing marks in the form of longitudinal stripes 1–2 mm wide cover the entire surface of the figurine's neck and part of the head, with only isolated marks on the back (Fig. 4). Thin linear traces can also be observed in some places.

To investigate how such marks on the surface of the figurine could have been created, experiments were conducted. A small lump of tar,

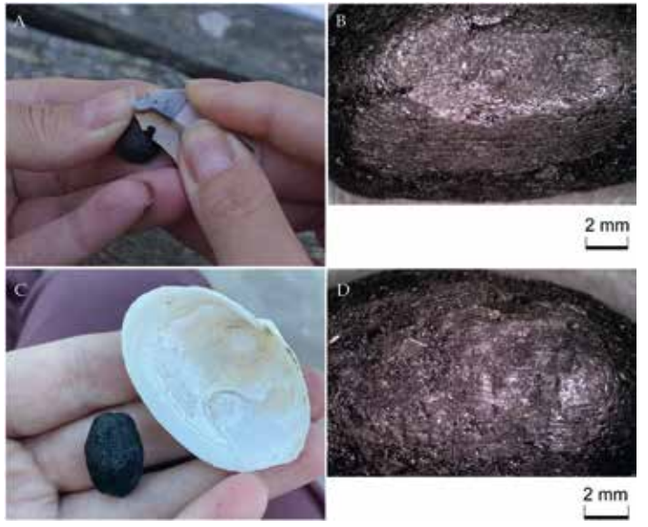

FIG. 5. EXPERIMENTAL STUDY OF SCRAPING AND PLANNING MARKS ON THE BIRCH BARK TAR LUMP. **A** – USING A FLINT FLAKE. **B** – TRACES OF SCRAPING AND PLANING AFTER USING A FLINT FLAKE, MAGNIFICATION: 26.6 X. **C** – USING A MYA ARENARIA SHELL. **D** – TRACES OF SCRAPING AFTER USING OF A SHELL, MAGNIFICATION: 28.4 ×. PHOTOS: IRINA KHRUSTALEVA, AIJA MACĀNE.

produced through the dry distillation method[27], was used as the raw material. This sample had been left to cure for about a month after being collected, otherwise its surface would have remained sticky. For scraping, a flint flake and a *Mya arenaria* seashell were used – materials that would have been available to Stone Age people (Fig. 5A, C). The study of the experimental sample showed that scraping the dried surface of tar with a flint flake produces marks in the form of

27 About the methods of tar production see e.g. Grzegorz Osipowicz, "A method of wood tar production, without the use of ceramics. In (RE)construction and experiment in archaeology", *European Platform*, 2 (2005), 11–17; Paul R. B. Kozowyk, Marie Soressi, Diederik Pomstra, Geeske H. J. Langejans, "Experimental methods for the Palaeolithic dry distillation of birch bark: implications for the origin and development of Neandertal adhesive technology", *Scientific Reports*, 7 (2017), 8033, https://doi.org/10.1038/s41598-017-08106-7; Maxime Rageot, Isabelle Théry-Parisot , Sylvie Beyries, Cédric Lepère, Alain Carré, Arnaud Mazuy, Jean-Jacques Filippi, Xavier Fernandez, Didier Binder, Martine Regert, "Birch Bark Tar Production: Experimental and Biomolecular Approaches to the Study of a Common and Widely Used Prehistoric Adhesive", *Journal of Archaeological Method and Theory*, 26 (1) (2018), 276–312, https://doi.org/10.1007/s10816-018-9372-4.

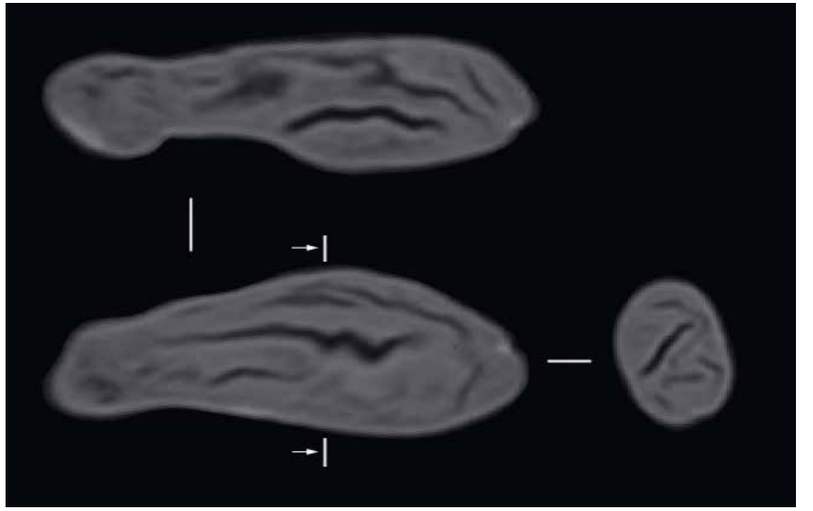

FIG. 6. COMPUTED TOMOGRAPHY OF BIRCH BARK TAR FIGURINE SHOWING DEEP CRACKS INSIDE THE ITEM.

longitudinal stripes and some linear traces, similar to those observed on the archaeological artefact (Fig. 5B). The seashell, however, does not leave clear longitudinal stripes because it tends to break, but it does leave many linear traces (Fig. 5D, C). Thus, the experiment demonstrated that a flint flake is much better suited for scraping and planing, as the seashell crumbles easily when interacting with the dense and viscous material of tar. We did not test whether similar marks could be made using a bone tool as they are supposedly too soft to scrape dry tar. The main conclusion is that these marks can only result from intentional actions. This confirms the initial hypothesis that the artefact from Pulli is a deliberately crafted piece of art.

Computed tomography. The computed tomography conducted at the Estonian Forensic Science Institute revealed that the material of the figurine is quite dense and non-porous. There are relatively large longitudinal cracks inside (Fig. 6), which could either be traces of the material being joined during the figurine's moulding process

FIG. 7. RESULTS OF 3D MODELLING. **A** – DIFFERENT LIGHT ANGLES BRING OUT FINE DETAIL, YELLOW LIGHT RAYS VISUALISE THE LIGHT DIRECTION. **B** – TEXTURED 3D MODEL WITH A HIGH DETAIL LEVEL, TO THE SIDE IS A SET OF USED DEPTH MAPS. **C** – WIREFRAME, ALTOGETHER 5.4M POINTS ARE CONNECTED DURING THE PROCESSING.

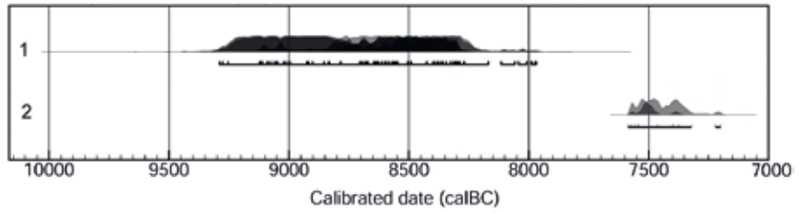

FIG. 8. RADIOCARBON DATES, PULLI SITE: 1 – BULK OF DATES FROM THE SITE; 2 – COMBINATION OF TWO DATES OBTAINED FROM TAR FIGURINE. 95.4% PROBABILITY.

or the result of the material drying out. Some of these cracks are also visible on the figurine's surface.

3D scanning and photogrammetry. Although the shape and material characteristics of the figurine were difficult, it was possible to document it with high-resolution photogrammetry using a special light solution, a full-frame DSLR camera, a macro lens, and a polarisation filter. To ensure the capture of fine detail like tool marks Nikon ModelMaker MMDx50 was also used. Detailed analysis of the dense 3D model, enabled by adjusting the lighting angle, reveals different markings and offers numerous benefits, including scalability and remote study (Fig. 7).

AMS-dating. Direct accelerator mass spectrometry (AMS) dating of the tar was conducted at the Poznań Radiocarbon Laboratory. The sample for dating was extracted from the inner part of the artefact by drilling, following the prior removal of the surface layer coated with

preservatives. The resulting date was 7600–7200 cal. BC (8370±50 BP, Poz-170407). This does seem to be late for the site, so another sample was taken from the same hole, but from a deeper layer of the artefact. However, the second sample gave a similar result – 7586–7376 cal. BC (8440±40 BP, Poz-182456).

The dating of the figurine differs significantly from other radiocarbon dates obtained from organic materials collected at the Pulli settlement site (Fig. 8); it is also inconsistent with the known environmental history of the area. During the final centuries of the 9th millennium BC, the Ancylus Lake, located in the Baltic Sea basin, flooded the territory of the settlement site, depositing several metres of sandy sediments over the cultural layer.[28] It is unlikely that the figurine was buried under sand in the middle of the 8th millennium BC. The date is more plausibly explained by the presence of modern radioactive carbon in the preservative applied to the figurine. Residues of this preservative are visible on the figurine's surface in several areas, appearing as a whitish substance within the cracks. Since it was assumed after the excavation that the figurine was made of bone, the item was conserved in the 1970s using one of methods typically applied to bone artefacts in Estonia. It was impregnated with shellac or a mixture containing silver fir resin and beeswax. There is essentially no difference between the two materials used in principle, as both introduce contamination with new radiocarbon. However, using resin and wax for conservation can explain the presence of traces of fat and pine or fir resin as revealed by ATR-FTIR spectroscopy, which are not inherent admixtures to the birch bark tar.

28 Veski, Heinsalu, Klassen, Kriiska, Lõugas, Poska, Saluäär, "Early Holocene coastal settlements and palaeoenvironment on the shore of the Baltic Sea at Pärnu, southwestern Estonia", 83; Nirgi, Rosentau, Habicht, Hang, Jonuks, Jõeleht, Kihno, Kriiska, Mustasaar, Risberg, Suuroja, Talviste, Tõnisson, "Holocene relative shore-level changes and Stone Age palaeogeography of the Pärnu Bay area, eastern Baltic Sea", Figs. 7–8.

FIG. 9. FRAGMENT OF ENGRAVED BONE ARROWHEAD, PULLI SETTLEMENT SITE (AI 4476: 1087). PHOTO: MONIKA REPPO.

DISCUSSION

In both Estonia and throughout the Eastern Baltic region, the oldest art objects are dated to the Mesolithic period.[29] Only few early Mesolithic settlement sites have been discovered so far, and even those have been insufficiently excavated. Therefore, generalisations and the current understanding of Mesolithic art are certainly premature in many respects. Nevertheless, according to the accumulated data, some changes were apparent in the art in the interval from approximately 9000 to 5500 BC, before the introduction of pottery.

Only bone and antler objects with geometric decorations are currently known from the oldest sites. In Estonia, the only securely dated engraved bone artefact from the 9th millennium BC is a fragment of an arrowhead decorated with notches, found at the Pulli settlement site (Fig. 2 and 9).[30] It is possible that some of the ornamented bone and antler items found at the Kunda Lammasmägi settlement site in northern Estonia and the stray finds from the lower reaches of the Pärnu River in southwestern Estonia are also from the Early Mesolithic period (Fig. 1). However, since the dating of finds at both locations varies by thousands of years, it is not possible to state this with certainty without dating each specific item individually.[31]

Fragments of bone items with notched ornamentation from the 9th millennium BC have also been found at the Sūļagals[32] and Zvejnieki II[33] settlement sites in Latvia. In Latvia and Lithuania, there are

29 Exceptions include a few items, such as a slate pebble with linear carvings on both sides, found at the Eiguliai 1A site in Lithuania. While this object might date back to the Paleolithic and could be considered an art piece, its classification as art remains reasonably debated; see Rimute K. Rimantene, *Paleolit i mezolit Litvy* (Vilnius: Mintis, 1971), 40, Fig. 24; Gabrielė Gudaitinė, *The first inhabitants in the western part of the Neris river basin in Lithuania*. Doctoral dissertation. Humanitarian Sciences, History, 05H (Vilnius: Vilnius University, 2018), 229–235, Fig. 113.

30 Jaanits, Jaanits, "Ausgrabungen der frühmesolithischen Siedlung von Pulli", 57, Fig. 2.

31 Kristjan Sander, Aivar Kriiska, "New archaeological data and paleolandscape reconstructions of the basin of an Early and Middle Holocene lake near Kunda, North-Eastern Estonia", *Fennoscandia Archaeologica*, XXXV (2018), 65–85; Tõnno Jonuks, Shidong Chen, Aivar Kriiska, Ester Oras, Samantha Presslee, Andres Ueni, "Stone Age Imitation of a Slotted Bone Point from Pärnu River (south-western Estonia)", *Estonian Journal of Archaeology*, 27 (1) (2023), 54–79.

32 Ilze A. Loze, *Poseleniya kamennogo veka Lubanskoj niziny: Mezolit, rannij i srednij neolit* (Riga: Zinatne, 1988), 17, Tab. II: 9.

33 Ilga Zagorska, "The Early Mesolithic bone and antler industry in Latvia, eastern Baltic", *Working at the Sharp End: From Bone and Antler to Early Mesolithic Life in Northern Europe*. Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein und im Ostseeraum, 10, ed. by Daniel Groß, Harald Lübke, John Meadows, Detlef Jantzen (Kiel-Hamburg: Wachholtz, 2019), 310, Fig. 5.

more decorated bone artefacts, such as points, arrowheads, harpoons, daggers, and knives, although these are stray finds without clear chronological determination.[34] In Finland, where bone preservation is very poor, only one fragment of a notched point has been found at the Muilamäki settlement site so far, dating back to the second half of the 9th millennium BC.[35] The same is true in Scandinavia, where the presence of decorated items among early Mesolithic bone artefacts is also modest.[36] In the western part of Russia, decorated bone artefacts reliably dated to the 9th millennium BC are found at only a few settlement sites, such as Ivanovskoe 7[37] and Stanovoe 4[38]. Meanwhile, in general, the tradition of engraving bone and antler artefacts persisted throughout the observed area for millennia.

The oldest portable figurines in the Eastern Baltic region are dated to the second half of the 7th millennium BC and first half of 6th millennium BC. There are two figurines from Estonia that belong to this time period: a human figurine carved from antler that has a direct radiocarbon date, and a probable waterfowl figurine. Both are stray finds from the lower reaches of the Pärnu River.[39] From Latvia, additions include a bird, an elk, and abstract zoomorphic bone figurines from the Zvejnieki cemetery.[40] Figurines of the same age have also been found at some sites in the European part of Russia,

34 Lūcija Vankina, *The collection of Stone Age bone and antler artefacts from lake Lubāna*. Latvijas vēstures muzeja raksti, 4 (Rīga: Latvijas Vēstures muzejs, 1999); Rimutė Rimantienė, *Akmens amžius Lietuvoje: Žiburio leidykla* (Vilnius: Žiburio leidykla, 1996), 92.

35 Kerkko Nordqvist, Tapani Rostedt, Aivar Kriiska, "Kivikauden maailma (9000–1800 eKr.)", *Rajamaa. Etelä-Karjalan historia I*, ed. by Jyrki Paasikoski, Anu Talka (Helsinki: Edita, 2018), 96.

36 Lars Larsson, "Human figurines in Eastern-Baltic Prehistoric art", *Prehistoric Art in the Baltic Region*, ed. by Adomas Butrimas (Vilnius: Vilnius Academy of Fine Art, 2000), 35.

37 Mihail G. Zhilin, Elena L. Kostyleva, Aleksandr V. Utkin, Asya V. Engovatova, *Mezoliticheskie i neoliticheskie kul'tury Verhnego Povolzhya* (Moskva: Nauka, 2002), 69, 132, 137.

38 Ibid., 69; Mihail G. Zhilin, "Traditsii i innovatsii v razvitii kostyanoj industrii butovskoj kul'tury", *Stratum Plus*, 1 (2013), Fig. 5–6.

39 Tõnno Jonuks, "An antler object from the Pärnu River – an axe, a god, or a decoy?", *Man, his time, artefacts, and places. Collection of articles dedicated to Richard Indreko*. Muinasaja teadus, 19 (Tartu: Tartu Ülikooli kirjastus; Tallinn: Tallinna Ülikool, 2013), 225–246; Tõnno Jonuks, "A Mesolithic human figurine from River Pärnu, South-West Estonia: a century old puzzle of idols, goddesses and ancestral symbols", *Estonian Journal of Archaeology*, 20 (2) (2016), 111–127, https://doi.org/10.3176/arch.2016.2.01.

40 Ilga Zagorska, John Meadows, Marius Iršėnas, "New dates from Zvejnieki burial ground graves with anthropomorphic and zoomorphic figurines", *Archaeologia Baltica*, 25, 100–124.

for example the Yuzhny Oleniy Ostrov burial site[41] and the Zamostje 2 settlement site.[42] The oldest Mesolithic portable figurines there, however, date back to at least the 8th millennium BC and were found for example at the Ivanovskoe 7[43] and Veretje 1[44] settlement sites. These figurines, made of bone, antler, or wood, depict zoomorphic creatures such as elks, waterfowl and snakes rendered in a stylised manner. Thus, the birch bark tar figurine from Pulli is remarkable not only in Estonia but also more broadly in the Eastern Baltic region and even across the entire European forest zone in Stone Age hunter-fisher-gatherer art.

The Pulli figurine most likely depicts a zoomorphic creature. The figure's stout body, slightly tapering neck, rounded earless head, and rounded snout most closely resemble a seal. Among the animal bones found at the Pulli settlement site, numerous species are represented (in descending order of abundance: beaver, elk, wild boar, brown bear and wolf), but the seal is absent.[45] Although the collected animal bones do not completely rule out the possibility that the inhabitants of the settlement also hunted seals, since the excavations did not encompass the entire cultural layer, it is evident that seals, if hunted at all, were not a significant game animal for them. The more extensive exploitation of marine animals in the territory of present-day Estonia only began in the early 7th millennium BC.[46] However, evidence that seals were hunted to some extent even during the earlier part of the Mesolithic is provided by a single ringed seal bone discovered

41 Nina N. Gurina, *Oleneostrovskij mogil'nik*. Materialy i issledovaniya po arheologii SSSR, 47 (Moskva, Leningrad: Izdat. Akad. Nauk SSSR, 1956), 213–227.

42 Olga V. Lozovskaya, "Osnovnye formy izobrazitel'noj deyatel'nosti v pozdnem mezolite i rannem neolite Volgo-Okskogo mezhdurech'ya po materialam stoyanki Zamostje 2", *Problemy istorii, filologii, kul'tury*, 2 (60) (2018), 213–215.

43 Zhilin, Kostyleva, Utkin, Engovatova, *Mezoliticheskie i neoliticheskie kul'tury Verhnego Povolzhya*, 156–157; Zhilin, "Traditsii i innovatsii v razvitii kostyanoj industrii butovskoj kul'tury", Fig. 9: 20; Mihail G. Zhilin, "Mezoliticheskie izdeliya iz kosti i roga iz nizhnego sloya stoyanki Ivanovskoe 7 v sobranii MAE RAN", *Camera praehistorica*, 1(1) (2018), 92.

44 Svetlana V. Oshibkina, *Veretje 1. Poselenie epohi mezolita na Severe Vostochnoj Evropy* (Moskva: Nauka, 1997), 142–143.

45 Lembi Lõugas, *Post-glacial Development of Vertebrate Fauna in Estonian Water Bodies: A Palaeozoological Study*. Dissertationes biologicae Universitatis Tartuensis 32 (Tartu: Tartu Ülikool, 1997), Appendix I.

46 Kriiska, Lõugas, "Stone Age settlement sites on an environmentally sensitive coastal area along the lower reaches of the River Pärnu (south-western Estonia), as indicators of changing settlement patterns, technologies and economies", Fig. 26.8; Aivar Kriiska, "Merelise asustuse sünd kiviajal (9000–1800 eKr)", *Eesti merenduse ajalugu I. Eesti randade asustamisest kuni Teise maailmasõja alguseni* (Tallinn: Varrak, 2023), 2324.

at the Kunda Lammasmägi settlement site, where such finds are exceedingly rare. The stable carbon isotope ($\delta^{13}C$) value suggests that the seal lived in a freshwater environment, probably in the Ancylus Lake, the predecessor of the Baltic Sea.[47] The Ancylus Lake probably hosted only the ringed seal, which evolved from individuals that had migrated from the Arctic Ocean into the Yoldia Sea[48] or even during the Baltic Ice Lake period (14000–9700 BC).[49] All the oldest seal bones found in geological and archaeological contexts belong to the ringed seal.[50] This suggests that if the figurine at Pulli was intended to depict a seal, it probably represents a ringed seal. Assuming that the lifestyle of ringed seals has not significantly changed over time, it is reasonable to infer that, like their modern counterparts, they occasionally ventured into river estuaries.[51] Even if the inhabitants of Pulli did not hunt seals, it is highly unlikely that they would not have encountered them during their travels.

To date, only one Stone Age seal figurine has been discovered in the Eastern Baltic region, a sculpture carved from pine bark at the Silinupe settlement site in northwestern Latvia, dated to the 4th millennium BC.[52] This offers very little as a basis for drawing analogies or exploring deeper meanings or connections related to the Pulli figurine. Consequently, while there is no reason to doubt the aesthetic value of the Pulli figurine, any other potential purposes – whether profane or sacred – remain beyond the reach of current scientific methodologies.

47 Lembi Lõugas, Kerstin Lidén, D. Erle Nelson, "Resource utilization along the Estonian coast during the Stone Age", *Coastal Estonia. Recent Advances in Enviromental and Cultural History*, PACT 52, ed. by Tony Hackens, Dheila Hicks, Valter Lang, Urve Miller, Leili Saarse (Rixensart: PACT Belgium, 1996), 399–420.

48 Pirkko Ukkonen, Kristiina Mannermaa, *Jääkauten jälkeläiset. Suomen nisäkkäiden ja lintujen histooria*. Museoviraston julkaisuja, 8 (Helsinki: Museovirasto, 2017), 63–65.

49 Lõugas, "Post-glacial Development of Vertebrate Fauna in Estonian Water Bodies: A Palaeozoological Study", 52–53.

50 Ukkonen, Mannermaa, "Jääkauten jälkeläiset. Suomen nisäkkäiden ja lintujen histooria", 63–65.

51 Julius Aul, Harry Ling, Kalju Paaver, *Eesti NSV imetajad* (Tallinn: Eesti Riiklik Kirjastus, 1957), 267.

52 Ilga Zagorska, "Sea mammal hunting strategy in the Eastern Baltic", *Lietuvos archeologija*, 19. (Vilnius: Diemedžio, 2000), 282.

CONCLUSION

1. A unique birch bark tar figurine was discovered in 1972 at the Pulli settlement site dating back to the early Mesolithic (9th millennium BC). The extensive use of birch tar in the production of slotted bone tools at the site is evident from the remains of such tools with tar traces, chewed lumps of tar, and a significant number of flint inserts. Art objects, however, are rare at Pulli. In addition to the tar figurine, only one engraved slotted bone arrowhead has been found at the site.

2. A detailed study of the figurine included microscopic examination of surface treatment traces, 3D scanning, photogrammetry, and computed tomography. The analysis revealed that the figurine's shape was achieved by scraping or planing a dried lump of tar. Experimental studies demonstrated that flint flakes are particularly well-suited for such manipulations.

3. The preservatives used influenced the results of ATR-FTIR spectroscopy, which revealed traces of fat and pine or fir resin in the birch bark tar. These substances also affected the radiocarbon dating, yielding a much younger date than that of the site.

4. The Pulli figurine is believed to represent a seal, characterised by its robust body, a slightly tapering neck, a rounded, earless head, and a rounded snout. It has no known analogues among Mesolithic art objects, from either the Eastern Baltic region or the European forest zone.

5. The Pulli figurine appears to be one of the oldest figurines in the European forest zone. At sites dating to the 9th millennium BC, only bone and antler objects with geometric engravings are known. The earliest portable figurines in this region are dated to the 8th millennium BC, while in the Eastern Baltic region, they appear only in the second half of the 7th millennium BC.

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Irina Khrustaleva, Andres Ueni, Mait Metspalu, Aivar Kriiska: A Birch Bark Tar Figurine from the Pulli Settlement Site in Estonia

Keywords: Mesolithic; birch bark tar; figurine; Stone Age Art; Pulli settlement site; Baltic States

SUMMARY

The oldest art objects in the Eastern Baltic region date back to the Mesolithic period, while portable figurines are only known from the second half of the 7th millennium BC. These figurines, made of bone or antler, are rare. Our article focuses on a unique zoomorphic birch bark tar figurine discovered at the Pulli settlement site (8950–8300 BC). A comprehensive analysis was conducted, complementing previously published chemical analyses. The methods included microscopic examination of surface treatment traces, direct radiocarbon dating, 3D scanning, photogrammetry, and computed tomography. The results indicate that the figurine's shape was deliberately formed through intentional scraping or planing, particularly in the neck and head areas. Preservatives used on the figurine penetrated through deep cracks, influencing the outcomes of chemical and radiocarbon analyses. This artefact, probably representing a seal, has no known analogues among the hunter-fisher-gatherer art of the Mesolithic period (9000–6000/2800 BC) in the European forest zone. It is probably the oldest portable figurine from the Eastern Baltic region.

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