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Analysis of Pigments from Decorated Antler or Bone Artifacts from the Early Iron Age Princely Burial Mounds in Jalžabet (NW Croatia)

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ABSTRACT

During the Early Iron Age in Europe (EIA), the phenomenon of the Hallstatt culture enveloped a large portion of the European continent. Between the Atlantic Ocean and the River Danube, cultural groups can be roughly divided into two major regions: the Western and the Eastern Hallstatt circle. EIA finds made from organic material decorated with pigments are usually well-preserved only in specific conditions. A good example is the coloured textile found in the salt mines of the eponymous site Hallstatt (AT). Other examples are Scythian finds north and east of the Black Sea, far outside the Hallstatt culture area. This paper presents the results of the analysis of decorated artifacts made from bone or antlers from Jalžabet (NW Croatia). The artifacts were found in two princely burial mounds with incinerated remains: burial mound 1 (Gomila) and burial mound 2. The funerary monuments belong to the Eastern Hallstatt culture and date back to the middle of the 6th century BC, *i.e.*, the end of the Ha D1 period. A group of scientists from Croatia and abroad performed several series of analyses on the selected bone or antler artifacts. The motifs on the artifacts were made by incisions and were filled with black pigment, and there are faint traces of red pigment on the surface. With the help of colourant analysis performed in Brussels and Zagreb (SEM-EDX, MRS, FT-IR), zooarchaeological taxonomic identification, and archaeological determination of a selected group of findings from Jalžabet, we have tried to answer several major questions. The most important question being: are the traces of pigments on artefacts deliberate decoration? If so, can we determine the composition of the paint? What kind of raw materials were used for the production of the artifacts? These questions are important because these kinds of EIA finds are rare and even more rarely analysed. New data would considerably expand our knowledge about the funeral rites of the most prominent members of the Hallstatt nobility in the Drava River valley and Central Europe. Taxonomically, the raw material from which the finds were made was identified to be antlers, probably from red deer (*Cervus elaphus*). Using methods for colourant analysis, we have successfully proven deliberate application of black paint based on carbon black as a pigment, probably in combination with terpenoid resin. Until now, this composition was only known from much later, Roman-period finds. Also, it was confirmed that the black paint on the artifacts from both burial mounds in Jalžabet is of the same composition. The red pigment on the finds has been identified as hematite. It is highly probable that the red surfaces were deliberate, painted decoration. The probability of extracting the raw material needed for the production of the red paint in the Jalžabet micro-region was also established and requires further research (bog iron ore). The archaeological analysis of the finds supports the idea of the use of various types of decorated plates as inlays, probably on furniture or other luxury everyday items. Smaller finds could have been used as utilitarian objects, parts of attire, and jewellery.

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Figure 1. (A): position of Jalžabet in the SW Pannonian Plain; (B): 1 – present centre of Jalžabet, 2 – Carev jarek, the position of the EIA settlement, 3 – the Bistričak Stream, 4 – Gomila and presumed EIA necropolis (source: DOF-DGU/IARH).

1. Introduction

Many high-status burial contexts from the Iron Age are published and generally well known. However, the focus of the researchers has for a long time primarily been the cultural positioning of sites and chronologically-sensitive finds. In recent decades, large data sets about textile production, including the use of pigments, have been gathered thanks to specific, favourable conditions for the preservation of degradable organic finds. A great example of such finds is the organic material from Scythian kurgans (Eurasian steppes, Altai Mountains), far outside the Hallstatt culture area (Gleba *et al.*, 2020). Closer to the SW part of the Pannonian Plain, there are also finds from the salt mines in Hallstatt (Austria). Hallstatt has become synonymous with the Early Iron Age in Central Europe and beyond (Grömer, 2016; Grömer, 2013; Rauch *et al.*, 2009). Extraordinary textiles from the salt mines in the Austrian Salzkammergut, but also textile and pigment analyses in different parts of Europe have shown how spectacularly colourful everyday life was during the EIA. Analyses of blue, yellow, olive-green, red, brown, and black pigments on textiles from Hallstatt have identified various plant species as primary dying material, with the possible use of insects and metal salt mordants (Hofmann-DeKejizer *et al.*, 2013). The permanently frozen state of Scythian finds enabled the detection of a mixture of dyes of plant and animal origin (Stepanova and Pankova, 2017, pp.119–129). In contrast to these rare examples, traces of pigments on organic materials from a majority of the EIA sites in Central Europe and beyond are exceptionally rare (Gleba *et al.*, 2019). Numerous antler and bone findings decorated with incisions and what seems to be black, but also, quite surprisingly, red paint, were unearthed in the burial mounds in Jalžabet, east of Varaždin (NW Croatia). These finds motivated researchers to try to define the material used for their production and the chemical composition of pigments used for decoration. Several publications in the past decades from EIA sites like Százhalombatta (Hungary), Krölkogel in Kleinklein (Austria), or, more recently, from Regöly (Hungary) and Rovná (Czech Republic) have presented finds made from bone or antlers decorated with incisions and residues of black pigments. The finds have shown significant potential for a better understanding of the burial customs and everyday life during the EIA (Chytráček *et al.*, 2018; Grill and Wiltschke-Schrotta, 2013; Szabó and Fekete, 2015; Egg, 2013; Egg and Kramer, 2005; Holport, 1986). However, analyses of pigments found on EIA finds still remain a rarity. The most important tested hypothesis in this paper was that the remains of the black and red substance found on the bone or antler artifacts from Jalžabet are pigments, and as such elements of deliberately-applied decoration, and not a contamination or residue of any other kind[1]. The additional unanswered questions in this research project were many, certainly too numerous for one study. Which raw material was used for the production of this group of findings from Jalžabet? Can we single out the animal species? Are traces of black paint on artifacts found in burial mound 2 (excavated 1989) and on finds from Gomila (2017–2021) of similar composition? How challenging was

[1] Contamination of decorated bone and antler artifacts with charcoal from the funeral pyre or with iron oxide from metal finds during or after the funeral itself seemed possible. The complex burial rite in Jalžabet included manipulation with burned bones after the fire was extinguished and depositing scattered remains from the pyre inside the burial chamber, without containers or urns.

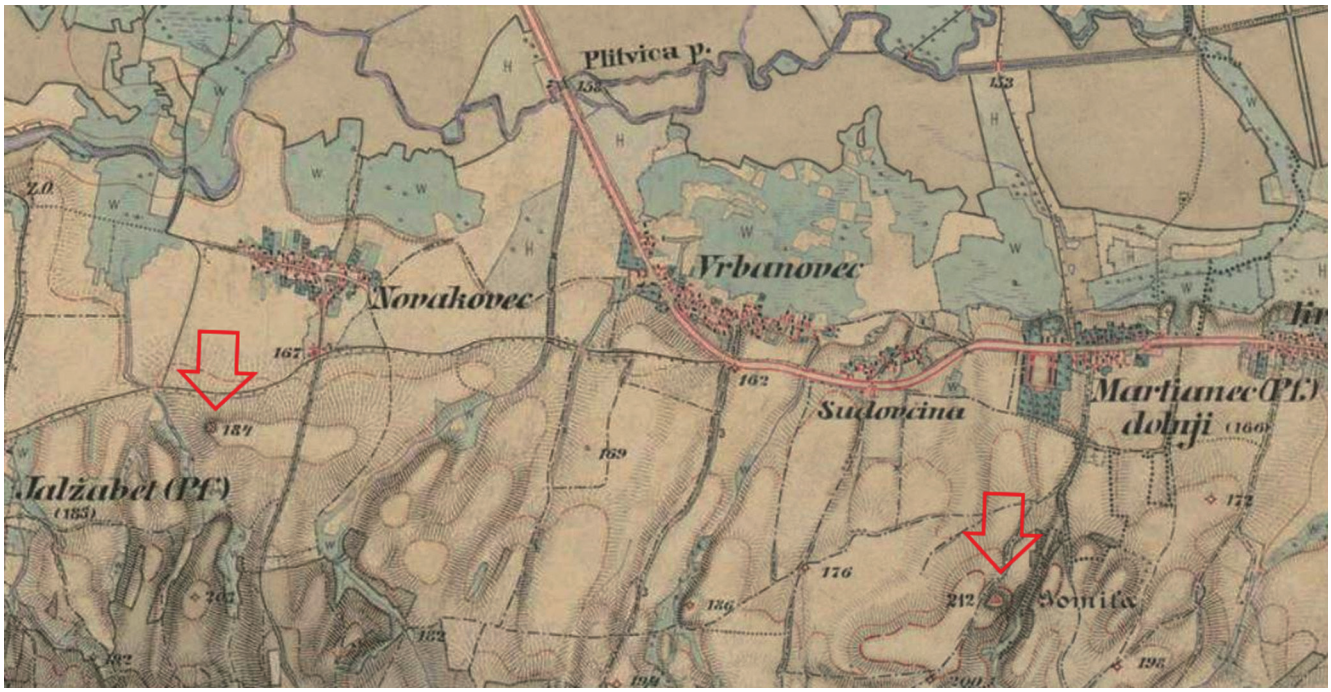

Figure 2. Map with the positions of the gigantic burial mounds in Jalžabet (left arrow) and Martijanec (right arrow) (source: www.mapire.eu, 3rd military survey, Habsburg Empire 1869–1887, March 22nd, 2021).

it for the Hallstatt community in the Drava River valley to gather the necessary raw materials? In general, how complex was the production and decoration of these types of artifacts? Some of these questions will have to stay unanswered, at least in this paper. But researchers hope to shed a little more light on some of these questions.

2. Materials and methods

2.1 Archaeological background

2.1.1 Burial mounds within the EIA landscape in the Plitvica-Bednja Rivers Basin

Jalžabet is a village in Upper Podravina, in the Plitvica-Bednja Rivers Basin. It is positioned 18 km southeast of the city of Varaždin, the seat of the Varaždin County. The area lies close to the south-eastern Alps, but throughout the past, it was strongly connected with areas north of the Drava River, as well as to the Danube region farther to the east (Feletar, 1986). Today, the Drava flows less than five kilometres to the north of Jalžabet. Thirty kilometres northeast of Jalžabet, lies the confluence of the Mura (or Mur) into the Drava River. The people on the raised southern flanks of the Drava River valley, where Jalžabet and Martijanec are situated, have lived there from the earliest times. The positions were close enough to important pathways. However, at the same time, they were far enough from the river, which was known to suddenly flood wide areas in the past. There, towards the hills in the south, Pleistocene sediments prevail. The most common sediments are clay and loess (Kurtek, 1966, p.510). This was the most important material built into the corpus of burial mounds at the position Jalžabet-Bistričak. Some key

Figure 3. A look from the east at burial mound 2 with an imprint of a wooden frame in the centre of the burial chamber (excavations in 1990). Gomila – burial mound 1 is visible in the background (source: The Archaeological Museum in Zagreb, Archive TD-AMZ, 011_JLZ).

elements of the EIA landscape in Jalžabet are still preserved. The large settlement of Carev jarek is situated on the western bank of the Bistričak Stream. The burial mounds are on the opposite bank, within the presumed Bistričak necropolis. Just five kilometres to the east of Jalžabet lies another important EIA site, Martijanec. The site features another large settlement surrounded by burial mounds, including another large mound called Gamula (Figures 2 and 3).

Today, Gomila in Jalžabet is elliptical in shape, 65×55 metres, and 8 m in height. Gamula in Martijanec is slightly smaller. In the past, the southwestern part of Gomila in Jalžabet was remodelled into a ramp and the top was flattened. Gomila originally had a rounded top and was around 12 m in height (Kovačević, 2020c). After the burial chamber was built on the prepared plateau, a huge circular ditch was dug around Gomila.[2] At the base of Gomila, on the artificially-levelled plateau, stood a monumental stone crepidoma or base, approximately 25 m in diameter. A burial chamber with a *dromos*, a long ceremonial corridor, was built in the centre of the stone base (Figure 4). The size of the chamber was 11.5 × 11.5 m, with a height of around 1.4 to 1.5 m. The burial chamber had a square layout with rounded corners and 1.7 m thick "sandwich" walls composed of several parallel wall structures made from wood, stone, and interspaces filled with charcoal and rocks. Densely-arranged thin vertical stakes were driven deep into the ground and formed the outer face of the chamber's walls. Thick layers of loose sterile charcoal were thrown on the outer side of the finished burial chamber and *dromos*. Afterward, the entire structure was covered with pebbles, stones, and, finally, a huge mound of clay and loess (Kovačević, 2019).

The spacious, but low-sitting chamber had a *dromos*, a ceremonial approach from the east. The passage of the *dromos* was 2.20 m wide and at least 18 m long. The entire floor of the chamber was paved with split sandstone tiles and additionally completely covered with wood. In the centre of the chamber stood a timber frame, measuring around 5×5 m. The structure rested on horizontal wooden beams placed on the floor, with vertical posts supporting the horizontal roof. Structures made from wood were found in the dromos as well, for example, traces of wooden wall lining and flooring (Figure 5). The architecture of the burial chamber (with several "outer" and "inner" burial chambers or "chambers inside other burial chambers") seems similar to, but larger and more complex than the one found in Hochdorf, in the Western Hallstatt culture area (Brestel, 2019). According to M. Egg (2019, p.339), the role models for the construction of *dromoi* in the Eastern Hallstatt culture can probably be found in tombs of Etrurian nobility[3].

The majority of burned bones inside the burial chamber in Gomila were found along the southern wall and in the southwestern corner of the burial chamber. A thick, compact layer of very fragmented bones was found, mixed with fine charcoal. We believe the bones were carefully selected from the extinguished funeral pyre, deposited in the southwestern part of the burial chamber, and then covered with the rest of the burnt material from the pyre[4]. Preliminary screening of the osteological material did not reveal any human remains, but comprehensive analyses of the whole assemblage are currently underway by both zooarchaeologists and physical

[2] This feature was the source of the immense quantity of earth built into the mound. However, it is suspected that it probably had some other function(s) as well. The ditch had a diameter of approximately 100 m, it was 15 m wide and up to 2 m deep. The ditch was detected by geophysics and confirmed by archaeological excavations beneath the northern, eastern, and western slopes of Gomila (Kovačević, 2018b; 2020c).

[3] Some other sites where we can find quite rare examples of burial mounds with *dromoi* in Central Europe are Kleinklein, Strettweg, Kaptol, Pivola, Vaskerestesz, and Süttő (Kramer, 2013, p.31). The building sequence of the burial chamber and *dromos* in Gomila is inseparably intertwined with the burial rite. Both problems are very complex and deserve much more detailed analysis than we can present in this paper.

[4] Traces of the funeral pyre have not been found in the excavated part of Gomila.

Figure 4. (A): Gomila from the south-east during excavations in 2018 (aerial photo: M. Šimek and T. Trubić); (B): the burial chamber inside Gomila at the beginning of excavations (2018): 1 – crepidoma, 2 – quadratic burial chamber, 3 – robber's trench, 4 – *dromos* (photogrammetry: M. Mađerić).

Figure 5. Photogrammetry of several interpolated stages of research of the burial chamber inside Gomila 2018–2021 (photogrammetry: M. Mađerić).

anthropologists. For now, it is really hard not to presume the remains of the ruler to be among these remains[5]. In Gomila, we did not find whole ceramic or bronze vessels or any other large object crushed *in situ*. The majority of the finds were fragmented, some completely deformed by the pyre, some not burned at all[6]. It is a complex puzzle of various high-status goods that experts will analyse in the future, after the substantial task of currently ongoing restoration and reconstruction of the numerous finds is completed. Finds from burial mound 2 (1989) are now completely restored and will be published. Preliminary interpretations indicate architectural, cultural, and chronological compatibility of the two burials. Although very different in size, both are built similarly; with square burial chambers, *dromoi* towards the east, on a carefully prepared and paved plateau (Šimek, 1998). Some movable finds from both burial mounds in Jalžabet are closely comparable as well. For example, some bronze horse equipment pieces and *lamellae* from bi-metal lamellar (scale) armour from Gomila and tumulus 2 are practically identical (Šimek, 1998, Figure 5). It would not be surprising if it were determined that the finds originated from the same workshop.

2.1.2 Just follow the rivers: Jalžabet and "the Horizon of the Last Princes"

In the EIA, the southwestern part of the Pannonian Basin, including the Upper Podravina region, belonged to the Eastern Hallstatt culture. M. Egg also described it as a conglomerate of similar, but also quite different, cultural groups

[5] A phenomenon of the disproportion of the presumed number of inhabitants of numerous settlements across Europe and the number of found corresponding graves, even on well-researched sites, has been known for some time. The phenomenon of missing human graves or human physical remains during the last millennium BC in Europe has already been recognised and analysed in archaeology (*e.g.*, Torres-Martínez *et al.*, 2021 with quoted literature). A closer look will be needed at the issue, not just to recognise beyond a doubt the presence of human remains but also to better understand the complex burial rites in Jalžabet and other EIA sites. A detailed analysis of the bones found in Jalžabet burials will be executed by Siniša Radović from the Institute for Quaternary Palaeontology and Geology, Croatian Academy of Sciences and Arts, and Mario Novak from the Institute of Anthropology in Zagreb, who also performed a preliminary screening of the bone finds.

[6] We have to emphasise that except for clear traces of a recent looting attempt (Figure 4: B3), we did not find any signs of ancient intrusion or looting in the burial chamber. The preliminary analysis of the context, arrangement, and deposition of the finds speaks in favour of a quite specific, well-defined burial rite.

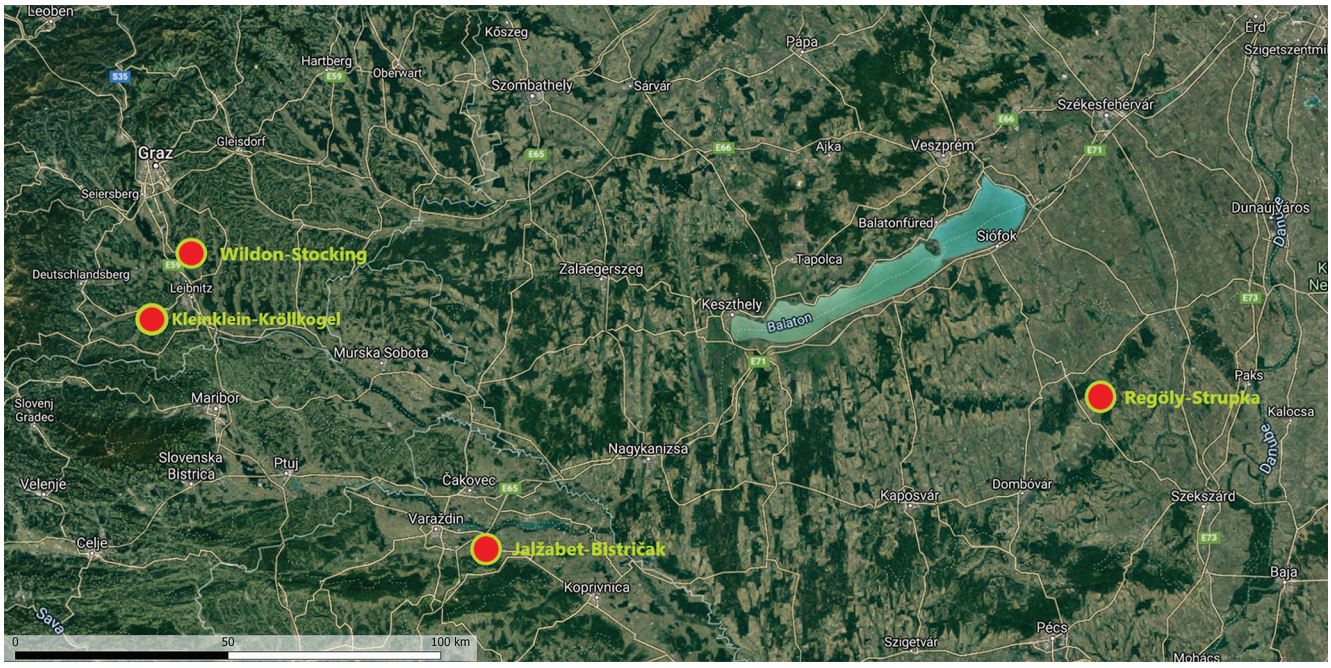

Figure 6. Map of southwestern Pannonia and select analogies for the EIA burial mounds in Jalžabet (source: https://www.google.com/maps, June 20th, 2020).

(Egg and Kramer 2005, Abb. 2). Most recent finds from the EIA princely burial mound 1 or Gomila (2017–2021) from the Jalžabet-Bistričak site, as well as select older finds from burial mound 2 (1989), will be analysed further in the text. Chronologically, both burial mounds from Jalžabet belong to the Ha D1 period, *i.e.*, to the middle of the 6th century BC. This is the final phase of the Martijanec-Kaptol group, corresponding to the time of the Serpentine Fibula phase in Dolenjska and the Styria III period (Vinski-Gasparini, 1987; Gabrovec, 1987; Teržan, 1990; Dular-Tecco-Hvala, 2007). Although there are many analogies outside the region, we will limit our discussion to a few of the most significant sites (Figure 6)[7]. Time will tell if the circular ditch with wooden posts and other structures detected during research around Gomila point to a larger ceremonial landscape. The site of Glauberg is an extraordinary example of such a landscape outside the Eastern Hallstatt culture (Hansen and Pare, 2008, p.58; Balzer, 2016, p.13)[8]. It may be that a shared source inspired the construction of the monumental burial chamber beneath Gomila. However, our short quest for analogies for the burials in Jalžabet will start outside Western Hallstatt territories. An unfortunately heavily-damaged burial mound in Regöly, at the position of Strupka-Magyar birtok, lies in the Tamási District of Tolna County. The site is located southwest of Balaton and approximately 150 km northeast of Jalžabet (Fekete and Szabó, 2017, Figure 2). It was dated to the 7th century BC, but we believe it to be slightly more recent, contemporary with Jalžabet. The type of burial mound construction and movable finds from Jalžabet and Regöly show striking similarities (Szabó and Fekete, 2012, pp.66, 78, 92–98; Szabó and Fekete, 2015, pp.26, 28–37; Szabó, 2015, p.297, Figure 6: d–g; Fekete and Szabó, 2017, p.115)[9].

The next site in the search for analogies is Grafenkogel in Wildon-Stocking, near Leibnitz, in Austrian Styria, approximately 100 km northwest of Jalžabet (Gutjahr and Mandl, 2014). It seems Grafenkogel was a large burial mound from the Ha D1 period and is separated from the nearby necropolis in Kainach by the Mura River (Gutjahr *et al.*, 2018, p.65). In Grafenkogel, like in Gomila and in Regöly, there was abundant use of loose charcoal (Guthjahr *et al.*, 2018, p.72, Figure 3)[10]. Finds made of precious metals

[7] It is quite important to emphasise that the rescue excavation of Gomila in Jalžabet ended recently, at the end of 2021. A detailed comparison of assemblages from Jalžabet and chronologically and culturally comparable funerary monuments of the EIA will be possible only after the ongoing complex restoration and detailed analysis of finds are completed.

[8] Institute of Archaeology as PP 6 participated in the project "Monumentalized Early Iron Age Landscapes in the Danube River basin" DTP1-1-248-2.2 (acronym "The Iron-Age-Danube project"), implemented under the EU Interreg Danube Transnational Cooperation Program. The project was co-funded by the European Union from the ERDF and lasted from the 1st of January 2017 until the 30th of June 2019 (Kovačević, 2019). Some of the data presented here are the results of this project, especially LiDAR and geophysical surveys. The Institute for Archaeology would like to thank our Iron-Age-Danube project partner Dr. Zoltán Czajlik from Eötvös Loránd University, Institute of Archaeological Sciences, for the joint effort.

[9] The find of an arrow made from antler or bone decorated with drilled-in concentric circles is the closest analogy inside the Eastern Hallstatt culture for the finds from burial mound 2 in Jalžabet (Šimek, 1998, p.504; Szabó and Fekete, 2012, p.78).

[10] Use of charcoal, although not in such excessive quantities as in the case of Gomila in Jalžabet, has been noted on other EIA sites in Croatia, like Budinjak and Kaptol. A rectangular ditch filled with charcoal in Kaptol as well as a burned wooden "ring" under a burial mound in Budinjak were discovered during excavations. In Budinjak, the use of sterile charcoal was detected already in flat graves, below and above the urn at the very end of the Late Bronze Age (Vejvoda and Mirnik, 1971, pp.187, 190, Figure 2;

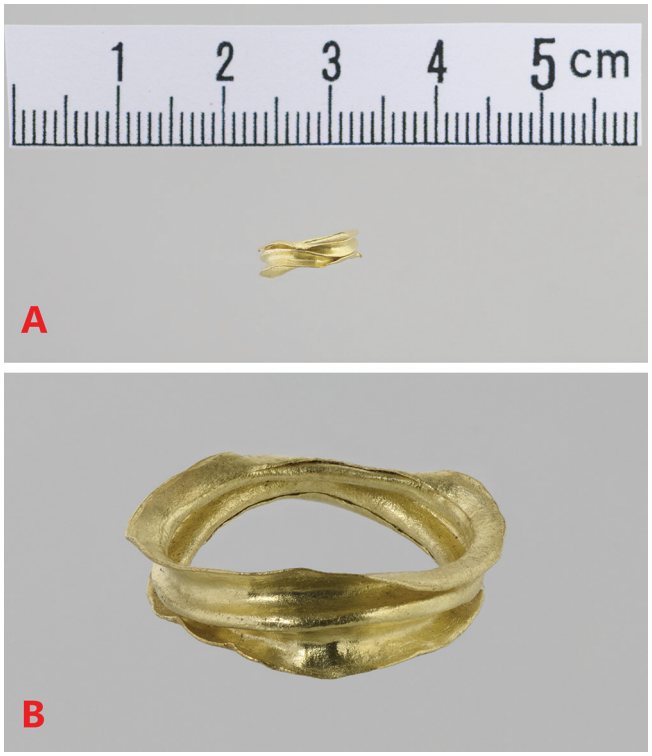

Figure 7. One of the golden rings from Gomila during restoration (SU 091 ZAP, SF 1001, 2019, the western part of the burial chamber) (photo: Lj. Gamulin/CCI).

were also discovered on all three sites (Figure 7)[11].

The final analogy also comes from Austrian Styria. Kleinklein is 30 km south of Graz and around ten kilometres west of the confluence of the Sulm and Mura rivers. The Kröllkogel, Tschoeneggerfranzl 2, and Kürbischhansl tumuli represent the final phase of Kleinklein. All three had large burial chambers made from wood and stone with *dromoi* (Kramer, 2013; Egg and Kramer, 2005; Dobiat, 1980, pp.307–316, Figure 5). They share a similar funerary architecture with the tumuli in Jalžabet, similar groups of movable finds, as well as burial rites. In so-called "*brandflächengräber*" (Dobiat, 1980, p.52), remains of the deceased were separated from the rest of the burned material from the pyre with great care, simply spread out on the surface of the floor inside the burial chamber, without any recipient serving as an urn. Practically identical burial rites are present in both princely tumuli from Jalžabet. Between the

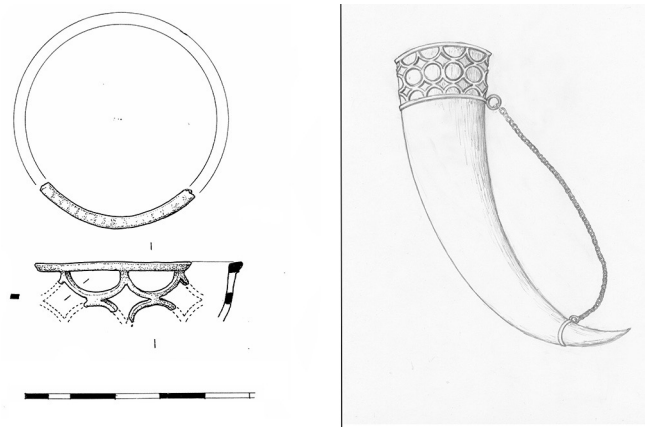

Figure 8. An ideal reconstruction of the bronze mount from burial mound 2 in Jalžabet (Author: M. Galić).

three mentioned burial mounds from Kleinklein, Kröllkogel is probably the most well-known. It had a similar layout to Gomila, with an 8×8 m square burial chamber made from wood and dry-stone wall and a 12 m long *dromos* (Kramer, 2013, p.31)[12]. It is estimated that Kröllkogel was originally around 12 m high, with a 40 m diameter (Egg and Kramer, 2005, p.9). Large quantities of cereals and cultivated plants, as well as remains of different animals (horses, pigs, goats, and sheep), were found in both Kröllkogel and Gomila (Grill and Wiltschke-Schrotta, 2013, p.33; König, 2013, p.69)[13]. When it comes to Kleinklein, a century and a half long line of succession was determined, with one ruler in each generation (Egg, 2019, p.346, Figure 9). After Kröllkogel, there are no later burials under the burial mounds, while intense habitation of the Burgstall settlement also reached an end (Smolnik, 1994, p.36). Similar patterns can be traced to a wider area, with the causes still unknown (Teržan, 1998; Egg, 2013, pp.473–483). All signs indicate that something similar happened to Jalžabet, which features the youngest royal burials of the Ha D1 horizon discovered so far, and to areas south of the Drava River.

The mentioned EIA sites seem to be connected with a network of pathways and communication routes. The rivers Drava and Mura were probably the backbone of the network in the southwestern Pannonian Plain. The network was extended towards salt mines, amber, and the Western Hallstatt world in the north, as well as riches and ores of the south-eastern Alps in the west. Alpine passages connected the region to the Etruscan, Greek, and Phoenician societies

Škoberne, 1999, p.27, Figure 15). In Gomila, huge quantities of loose, light, and brittle charcoal probably have apotropaic meaning. It is really hard to find a reasonable explanation for using charcoal as a building material. So much burned wood was probably a very important and precious, perhaps even indispensable sacrifice?

[11] As a rule, with just a few exceptions, these are rarely seen in Eastern Hallstatt culture burials (Gabrovec, 1964-65, Table 8; Gabrovec *et al.*, 2006, Table 37/1; Potrebica, 2009, p.136; Egg and Munir, 2013, pp.157–159, Table 18/6–7; Tiefengarber *et al.*, 2014, p.52; Szabó and Fekete, 2015, p.295, Plate 4/r–t; 19; Gutjahr *et al.*, 2018, p.73). Similarities can be detected between Gomila in Jalžabet and the famous grave of the Stična Princess in the Dolenjska region in Slovenia (Gabrovec and Teržan, 2008, p.291). However, more details about these finds from Jalžabet will be available after the restoration work is completed.

[12] There are more similarities. Kröllkogel had a stone structure on the floor in the centre of the burial chamber, which supported the wooden frame and the roof (Kramer, 2013, p.31). Gomila in Jalžabet had a wooden frame resting on horizontal beams that supported the roof, also without postholes. Also, burial mound 2 (1989) had a wooden frame in the centre of the burial chamber, but it rested on dug-in posts.

[13] For the preliminary analysis of flora and fauna samples, we would like to express our gratitude to Siniša Radović from the Institute for Quaternary Palaeontology and Geology, Croatian Academy of Sciences and Arts, and Renata Šoštarić from the Department of Biology, Faculty of Science, University of Zagreb.

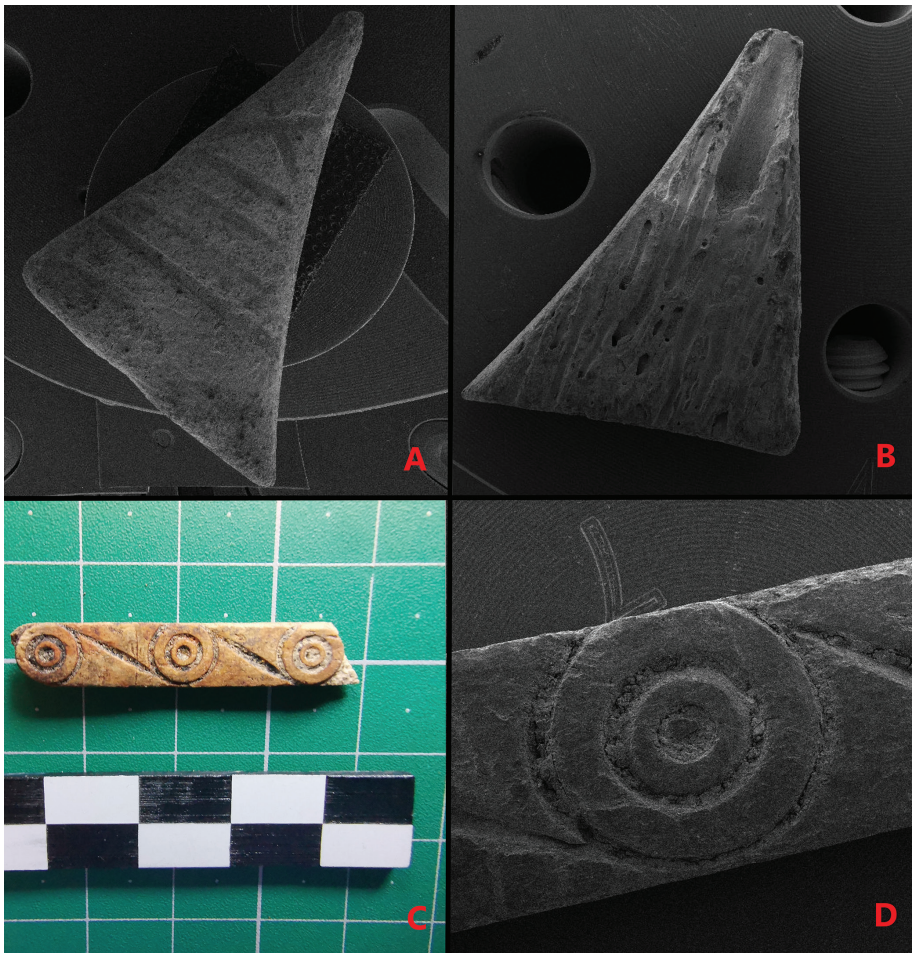

Figure 9. Selected finds from Gomila in Jalžabet; (A)–(B): anthropomorphic triangular bead from antler or bone, in the form of a woman; (C)–(D): decorated rectangular plate made from bone or antler (photo by SEM: Marin Petrović; photo C: Saša Kovačević).

and sophisticated artisans of the Apennine Peninsula and the Mediterranean World in the south. Across and along the Danube, the region was opened up to influences from farther east and southeast. On a second, local level, the Plitvica-Bednja, Kapos, Kainach, and Sulm rivers certainly played their role in communication between communities. This relatively short period of approximately fifty years, "the Horizon of the Last Princes", could be considered the peak of development that started a couple of centuries earlier. During this period, one by one, the royals of Regöly, Wildon, Kleinklein, Strettweg and in the end, Jalžabet, died. Soon afterward, the life of different groups of people from the Danube River in the east to deep inside the Alps to the west would have been dramatically impacted or irreversibly changed (Egg, 1996; Kovačević, 2019; Teržan 1998; Teržan, 2019; Teifengraber *et al.* 2014).

3. Bone and antler artifacts from princely burial mounds in Jalžabet

Evaluation and finer classification of the decorated bone or antler artifacts will be possible after the currently ongoing process of restoration and reconstruction of the finds from Gomila is completed. However, even at this stage, some preliminary postulates can be formed. At first glance, the group of artifacts made from bone or antler from both burial mounds in Jalžabet forms a uniform ensemble. The major discrepancy between Gomila (2017–2021) and burial mound 2 (1989) is the quantity and diversity of the finds. In Gomila, the most common are items decorated with drilled-in motifs, incision, dyeing with one or two pigments, openwork décor, and oblique grooves. In burial mound 2, only incision and drilled-in motifs filled with black pigment are present. Various linear motifs, circles with dots in the middle, concentric circles, circles connected via tangents, oblique groves, and mesh motifs appear inside Gomila. As a large-scale excavation of the settlement across Bistričak stream is yet to be conducted, we can only presume that these objects were produced inside households or even in a workshop somewhere inside the spacious settlement. In the process of production, we can presume that the raw material would have been well chosen and prepared, and rough and uneven surfaces discarded or smoothed out. The material was then cut into smaller shapes, plates, or other forms and decorated. The plates from Gomila have a smooth face, and carefully-cut vertical edges. The backs of the plates are usually a bit rough and undecorated, and feature no holes[14]. It

[14] Some analysis of the rear parts of the decorated objects from Jalžabet was done with Raman and FTIR at the School of Medicine, the University of Zagreb. Comparing the results with measurements of undecorated

is possible that the raw material was steamed or heat-treated and straightened, probably under some weight. However, we can hardly expect physical evidence of this process[15]. Although it is not a chronological or cultural analogy, the find of the Early Byzantine trident tool from Caričin grad forms an excellent methodological analogy for these EIA finds. A simple tool was found inside a workshop for products made of horn, dated to the time of Justinian I (6th century AD) (Marković and Stamenković, 2016, p.223). After motifs were made by incision or drilling, the items from Jalžabet were decorated with pigments. Some finds had grooves filled with a relatively well-preserved, greasy black pigment. On others, only sparse residues of the black incrustation were preserved. A third sub-group of finds featured only empty incision motifs. We can only presume that the non-occurrence of paint in these cases is probably connected with a poorer state of preservation. On rarer occasions, faint or more vivid traces of a semi-transparent red colour have been preserved on the surface of the bone or antler artifacts. These red surfaces were always clearly framed or set within the incised lines, in some methodical, contrasting manner. This initially made researchers consider deliberate decoration as the most probable explanation.

Decorated animal bone or antler objects from Jalžabet come in several basic categories, which will be described in more detail in the next section.

3.1 Main types of bone and antler artifacts from Jalžabet

3.1.1 Type 1: Objects of cylindrical shape

The function of these decorated objects of cylindrical shape (Figure 11) is still not clear. This is the case in Jalžabet and also other EIA sites as well (Egg, 2013, pp.293–298). It is thought they could have belonged to cylindrical containers, serving as handles or collars on metal objects, or even utensils for textile production. Pieces of cylindrical items were found in Tschoeneggerfranzl 2 and Kröllkogel, with drilled-in circles connected by tangents, which was also one of the favourite motifs in Gomila (Egg, 2013, Figure 127, Figure 129; Dobiat, 1980, Table 59). Similar finds were discovered in Regöly and Százhalombatta in Hungary (Szabo and Fekete, 2012, Figure 28/11–12, 33/1; Holport, 1986, Table 8/3; Holport, 1985, Figure 5/15). The specimen from burial mound 117 in Százhalombatta had a decoration of drilled-in concentric circles in combination with linear incisions, inlaid with black pigment. The pigment was identified more than three decades ago as bitumen (Holport, 1986, p.96). Not only horn and bone, but also the tusks of different animals were used in different ways during the EIA. For example, in burial mound 114 in Százhalombatta, horse iron bits with wild boar tusks as cheek pieces were discovered (Holport, 1986, pp.94 and 356, Table 8/3). It is possible that one of the bronze mounts with openwork décor from burial mound 2 in Jalžabet was used as decoration on the rim (4.8 cm in diameter) of a smaller drinking horn (Figure 8). But, it may also have been a cheek piece from horse headgear similar to the mentioned exemplar found in burial mound 114 at Százhalombatta.

3.1.2 Type 2: Parts of larger objects and unidentifiable smaller fragments

As expected, the majority of decorated bone or antler finds from Gomila fall into this category. Some of the finds are only a few millimetres long. Small cylindrical beads made from animal bone or antler were frequently found in Gomila. We can presume that cylindrical pieces like the one analysed later in the text (Figure 12-a, Figure 14), decorated with drilled-in concentric circles with a dot in the middle, connected with tangents and dyed with black pigment in the grooves and red pigment on the surface, were probably larger tricolour beads. They could have been a part of a necklace or a hair ornament. Together with amber beads of various sizes, bronze and gold beads, rings, and rivets found in Gomila, simple white or coloured bone beads surely could have formed impressive-looking ornaments. In Gomila, researchers found at least two triangular plates, decorated with incisions, with a vertical hole on the back, without visible traces of pigments, both thoroughly burned (Figure 9A–B). These anthropomorphic beads or *appliqués* represent stylized women in long triangular skirts and could have been used as part of elaborate necklaces or pectorals. Furthermore, they could have been sewn onto cloth or leather (*e.g.*, veil, diadem, dress, or cape)[16] along with very small amber and bone beads or delicate bronze and gold buttons, similar to the famous Stična princess (Gabrovec and Teržan 2008; Gabrovec *et al.* 2006). These luxurious finds probably represent parting or funeral gifts from women of higher status, which were put on the pyre after the fire was extinguished.

3.1.3 Type 3: Decorated plates

This group of finds consists of small cut-out plates, without holes, richly decorated with incisions, drilled-in decorations, and with traces of pigments. The decorated plates could have been used as inlays on highly-decorated, high-status

animal bones, we did not detect any clear traces of residue that could point to adhesive. However, there is no reason to believe that organic glues or compounds like birch bark tar were not used during the EIA in Podravina. Richly-decorated pots with conned necks from Gamulica in Martijanec or burial mound 6 in Kaptol, have tin meanders and spirals applied probably with some kind of glue (Šimek, 2004, pp.118–119; Potrebica, 2019, Figure 5). Certainly, other analytic procedures would be more successful in detecting this kind of residue as now we are certain neither Raman nor FTIR are techniques sensitive enough to identify low quantities of adhesive (Vinciguerra *et al.*, 2019; Morandi *et al.*, 2018; Fremout, 2014).

[15] We would like to thank the only Croatian traditional comb maker, Mr. Antun Penezić for his valuable information. Until recently, Mr. Penezić made combs and various other items by hand from the horn and bone of animals. In the process of treatment of raw cow or ox horn, an important part is played by the complicated procedure of making flat plates, which includes boiling/heating and pressing the raw-material. Bone, in contrast to horn, cannot be straightened in such a way, because the material is too brittle (See: https://www.youtube.com/watch?v=g0AiBkd_agk, April 9th, 2021).

[16] Interestingly, both of these *appliqués* have been burnt at a high temperature. It could be possible that they were sewn onto dresses of sacrificed women.

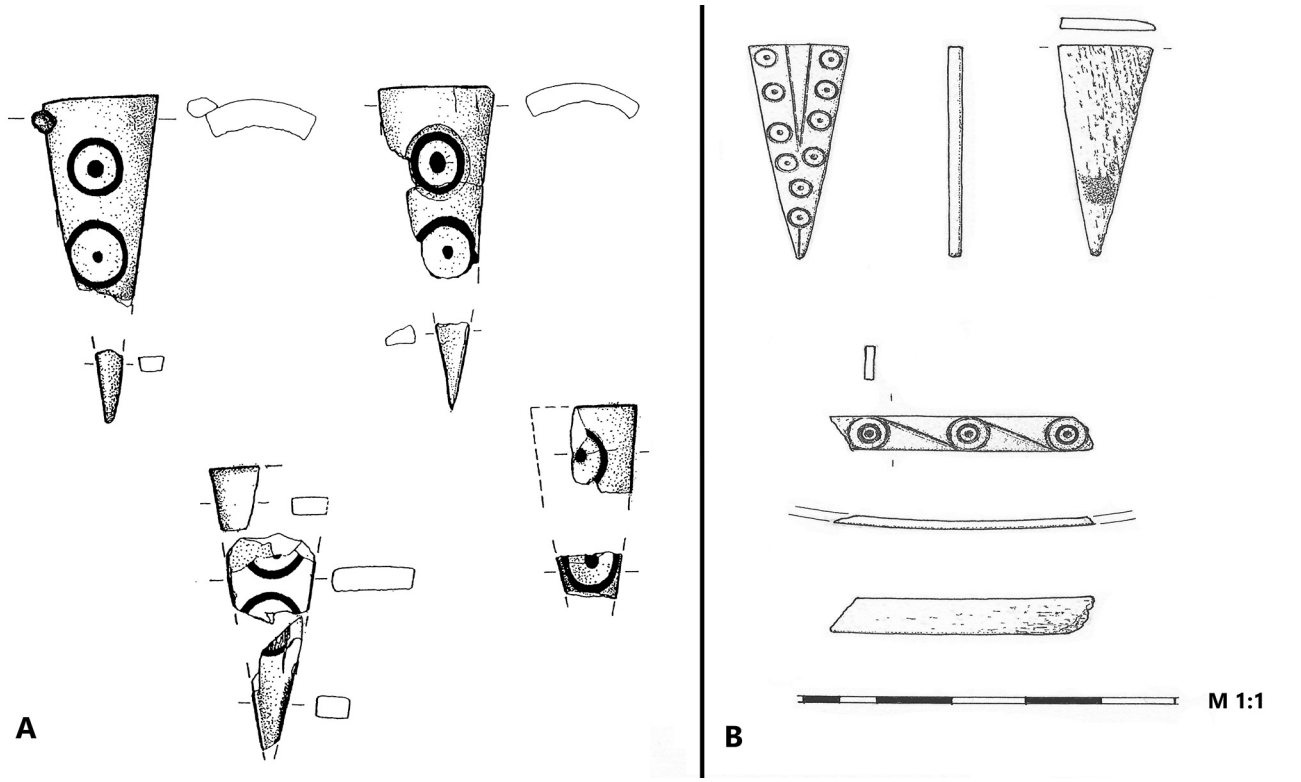

Figure 10. (A): decorated triangles made from animal bone or antler from Kröllkogel (source: Egg, 2013, p.295); (B): triangles from Gomila in Jalžabet, drawing: M. Galić).

items made from metal or organic materials such as wood. In burial mound 2 (1989) in Jalžabet, decorated animal bone or antler arrows were found inside the burial chamber. Two major types of arrows can be discerned. Type A features a drilled-in decoration consisting of three concentric circles in the middle and smaller concentric circles above and below. Type B is decorated with single or even double vertical rows of circles of the same size, sometimes with straight incised lines (Šimek, 1998, p.504, Figure 12; Šimek, 2004, p.113, Figure 27). Just from the shape and size of the circles, it can be presumed that several different instruments were used to decorate the arrows (maybe with 2, 3, and 4 prongs)[17]. In Gomila, no arrows were found. Two major types of decorated items from Gomila are triangles and strips. Strips were usually decorated with drilled-in circles in a row connected with incised tangents (Figure 9C–D). Several dozens of decorated, elongated triangles were also found. The majority of this type of object from Gomila was not burned. This is the reason for the good preservation of pigments, especially the black pigment inside the grooves[18]. Almost all triangles from Gomila adhere to two decor patterns. When it comes to the more frequent variant 1, incised lines are parallel with the lateral edges of the elongated triangles and accompanied by parallel rows of circles. (Figure 10-b, Figure 12-b). This variation is similar to type B arrows from burial mound 2. The second variant is less frequent (Figure 11-7) and was decorated with several larger concentric circles at the base in combination with smaller circles on the top of the triangles, with no linear incisions. Black dye was frequently preserved in the grooves of both variants of triangles and arrows.

3.2 The function of decorated bone or antler plates from Jalžabet

In Kröllkogel, triangles were probably made from antler and resemble Gomila's variant 2, decorated only by drilled-in circles. The triangles from Kröllkogel are between 1.3 and 1.5 cm wide and approximately 4.2 cm long (Figure 10-a) (Egg, 2013, pp.283 and 295, Figure 127). The triangles from Gomila seem to be of a roughly similar size; 1.0 to 1.3 cm

[17] The specimen from Regöly, which is the closest analogy for the arrows from Jalžabet, has a completely different decoration layout. It consists of larger triple drilled-in concentric circles and smaller circles with dots around them (Szabó and Fekete, 2012, p.78, Table 14/1).

[18] The objects were scattered around the burial chamber, in different layers, seemingly without any pattern. Whenever possible, we took the precise position of every find inside the burial chamber. Detailed mapping of the finds found *in situ* will be made and analysed on a different occasion. It is worth mentioning, that all archaeological layers from the monumental burial chamber and *dromos*, including the soil from the robber's trenches, were put through dry or wet sieving. Wet sieving was predominantly used because we wanted to save fragile movable finds, especially burned bones from further damage. Although a huge task, especially in the context of rescue excavations, the results of the sieving were excellent. We presume that the amount of not found or lost material during research is very low. Even the smallest amber beads or fragments of metal vessels, as well as small bones and archaeobotanical remains, were singled out and will be included in the final analysis.

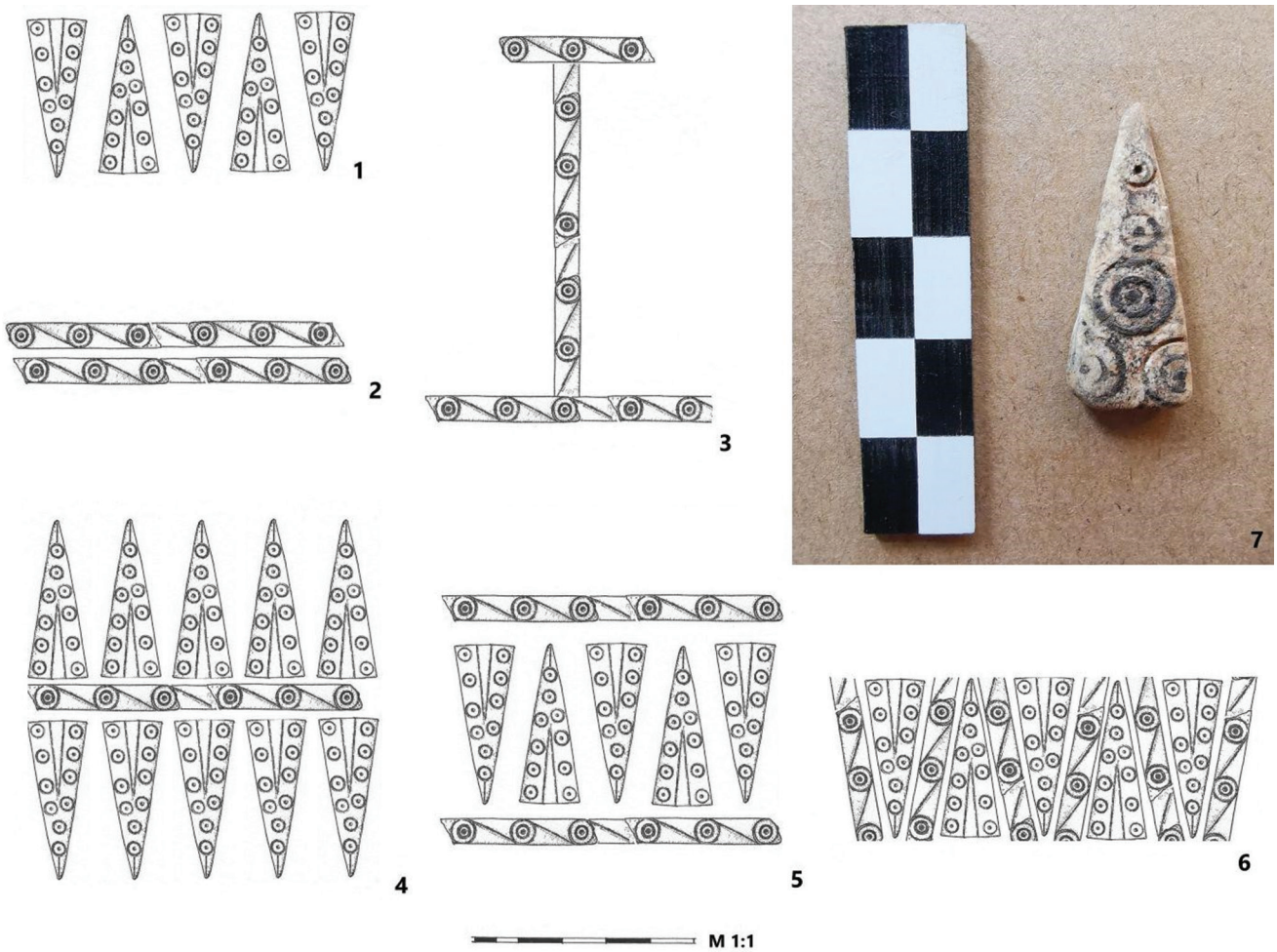

Figure 11. 1–6: several possible patterns regarding the finds from Gomila; 7 – the second type of triangular plates from Gomila (drawing: M. Galić and S. Kovačević).

wide, and 2.5 to 3.8 cm long[19]. Although at first glance the triangles from Gomila and Kröllkogel look similar, both groups diligently follow their decoration pattern. They probably came from one larger object, perhaps a luxurious piece of furniture. In South Bohemia, close to the confluence of the Otava and Volyňka Rivers, the Rovná site is situated (Chytráček *et al*. 2019, Figure 11; Egg and John, 2018, p.302, Figure 16). Although the site dates back to the end of the EIA (Ha D2/3-LtA) and is thus more recent than Jalžabet, Regöly and Kröllkogel, finds from the burial mound 1 in Rovná revealed not only ties with the Western Hallstatt culture and Apennine Peninsula but also analogies for finds from Jalžabet made of animal bone or antler (Chytráček *et al.*, 2018, p.289). Among the finds from the burial chamber, a small wagon or cart (100×70 cm) on two wheels was discovered (Chytráček *et al.*, 2018, p.299). The luxurious movable table perhaps had a ritual purpose. It was decorated with openwork antler plates with cut-out anthropomorphic figures and other elements such as bone or antler plates decorated with rows of drilled-in concentric circles (Egg and John, 2018, pp.298–301 and 310, Figure 13/1–8). Some analogies for such decorated wagons were found by M. Egg in northern Italy and Tuscany, while decorated open-work plates have analogies made of bronze in Wildon-Kainach (Egg, 2013, p.291, Figure 125; Guthjahr *et al.*, 2018, p.62, Figure 4)[20].

With regard to all the examples mentioned in this paper, it can be presumed that decorated items made of bone or antler had a strong symbolic meaning. They offer a glimpse into the lavish interiors and ceremonial attire, utilitarian and/or ceremonial goods, probably even from the ruler's household, which could have also played an important role during the burial. Some of them should be considered parts of clothing

[19] As some of the material is already in the restoration process and unavailable for further analysis, these measurements were taken on material available during the writing of this paper. Accordingly, this data should not be considered final.

[20] As in Jalžabet, Kleinklein, and Rovná, it is almost certain at least some of the huge number of decorated bone or antler objects found in the burial mound in Regöly published by Szabó and Fekete (2012) could have been parts of richly-decorated furniture. Bone or antler plates found there are shaped like wetland birds with prongs for installation in grooves mimicking similar metal pieces probably from bronze vessels found there (or on a similar ceramic vessel from Dvorišće in Međimurje, Vinski-Gasparini, 1987, Table XXV/1). Interesting are also rods decorated with spiral grooves and flat cut-outs with holes at the end. Decorated plates, some even with bronze rivets, are described by authors as parts of scale armour (Szabó and Fekete, 2012, Figures 28/1-9, Figure 21/2–6, 10, 15–16, Figure 29/34, Figures 30–31 and 33/44–47).

for high-status individuals. These types of finds, as well as objects made of precious metals, should be expected in the future in the richest burials belonging to the Ha D1 phase of the Eastern Hallstatt culture.

4. Description and taxonomic identification of the worked bone and antler assemblage

Numerous decorated bones and/or antler objects were found during the archaeological excavations of princely burial mounds 1 and 2 in Jalžabet. Part of this exceptional assemblage has been archaeozoologically studied to determine the raw material used while decorations (motifs, incisions, and pigments) are described elsewhere in this paper. Typologically, as seen earlier, the analysed material can be sorted into three categories: type 1, type 2, and type 3. Concerning taphonomic identification, special attention has been given to curved, square, tricolour plate (type 1, Figure 14), an anthropomorphic triangular bead or pendant in the form of a woman (type 2, Figure 9A–B), and – triangular (Figure 10B, above, Figure 11-7), rectangular (Figure 9C–D, Figure 10B, below) and arrowhead-shaped plates (Figure 12C, all type 3). Except for the decorated arrows, all other items are relatively small in size.

Some of the analysed objects are completely burnt – in particular, an anthropomorphic pendant and a few triangular and rectangular plates. They are white, some chalky in appearance and others with visible cracks and some distortion. All of it results from rapid dehydration and shrinkage typical of exposure to extremely high temperatures (Lyman, 1994, p.386). Others appear to be unburnt.

Putting aside the arrowhead-shaped plates, for now, we turn our attention to the other items. In addition to a single anthropomorphic pendant and a single curved, square plate, a total of eight different decorated, triangular and two rectangular plates were examined. Specimens were macroscopically studied with the use of a hand lens (magnification 10×). Most of them are smooth and shiny, finely abraded/polished on both large sides, but without macroscopically-visible clear traces of abrasion direction. All have in common that they are elongated, straight, and very thin in cross-section. Each of these objects is decorated with incised motifs on one side (front), while the other side (back) was only abraded/polished with perhaps some traces of use. It seems that all except the anthropomorphic pendant and curved, square tricolour plate most likely formed together a composite ornament inlaid into the larger luxury object(s), possibly made of wood (see Čerškov *et al.*, 2016).

Analysed decorated plates, as well as an anthropomorphic pendant and curved, square tricolour plate show characteristic cancellous structure lacking a clear trabecular pattern typical of bones (Sisson *et al.*, 1975). This is especially visible on the undecorated backside of these items. This suggests that as a raw material for the production of these objects, antler was used, most likely belonging to red deer (*Cervus elaphus*) since it is the dominant cervid species of appropriate size that was confirmed to have inhabited the wider area at the time (Trebsche, 2013). Nevertheless, the possibility that some of it (if any) may have belonged to a much rarer elk cannot be completely ruled out (see Bartosiewicz, 2005). The cortical portion of the antler is partially visible on the decorated front side, suggesting that the natural composition of antler may have played an important role in the selection of raw material in the production of these artifacts. This may be especially true of a thin, curved, square plate, the morphology of which favoured its presumed use as an inlaid part of a composite cylindrical decorative object possibly made of wood, perhaps a handle or a large decorated bead.

Considering arrowhead-shaped plates – present only in the assemblage recovered in the burial mound 2 (Šimek, 1998, p.504; Šimek 2001, 315; Šimek, 2004, p.113, Figure 27) – a total of five were analysed here. It is unlikely that these objects were ever used as real arrows, that is, they were not functional as weapons. All their side edges are blunt and generally, they give the impression of very fragile objects. Their function was rather decorative, as is the case with the above-mentioned other decorated plates, or perhaps ceremonial/symbolic. Generally, they are naturally light-brown, although some mottling is present. This discolouration may suggest partial exposure to fire either during their manufacture, or later, but none of them came from a pyre. Although these objects could also have been made of antler, at the moment, unfortunately, it is not possible to determine with certainty, given the unfortunate fact that they were covered with a protective layer of varnish during their conservation.

Several representative bone fragments were selected for a detailed analysis. Their optical images are shown in the Figure 12. All fragments contain geometric incisions filled with a black substance/paint, and some of them (Fragments 1 and 4) also exhibit reddish-brown colouration on certain parts.

5. Colourant identification of decorated bone fragments

Detailed optical images were taken with a digital microscope Hirox KH 8700. The elemental composition of the black and red paint, as well as the surface characteristics of both the painted areas and “bare” bone was determined non-invasively by scanning electron microscopy (SEM) coupled to an energy dispersive X-ray detection (EDX) system. SEM-EDX analysis has been performed in two systems: (i) Zeiss EVO LS15 microscope in combination with EDX detector from Oxford Instruments, located in Brussels, and (ii) Tescan Vega 3 microscope in conjunction with Bruker Quantax 200 XFlash 6 spectrometer, located in Zagreb. The bone fragments as such could be introduced into the sample compartment of the electron microscope. The analysis was performed under a beam of primary electrons created by an accelerating voltage of 15 kV (Brussels) and 20 kV (Zagreb). In order not to contaminate the bone fragment, the SEM analysis is done without coating the sample. SEM images are acquired by collecting secondary electrons

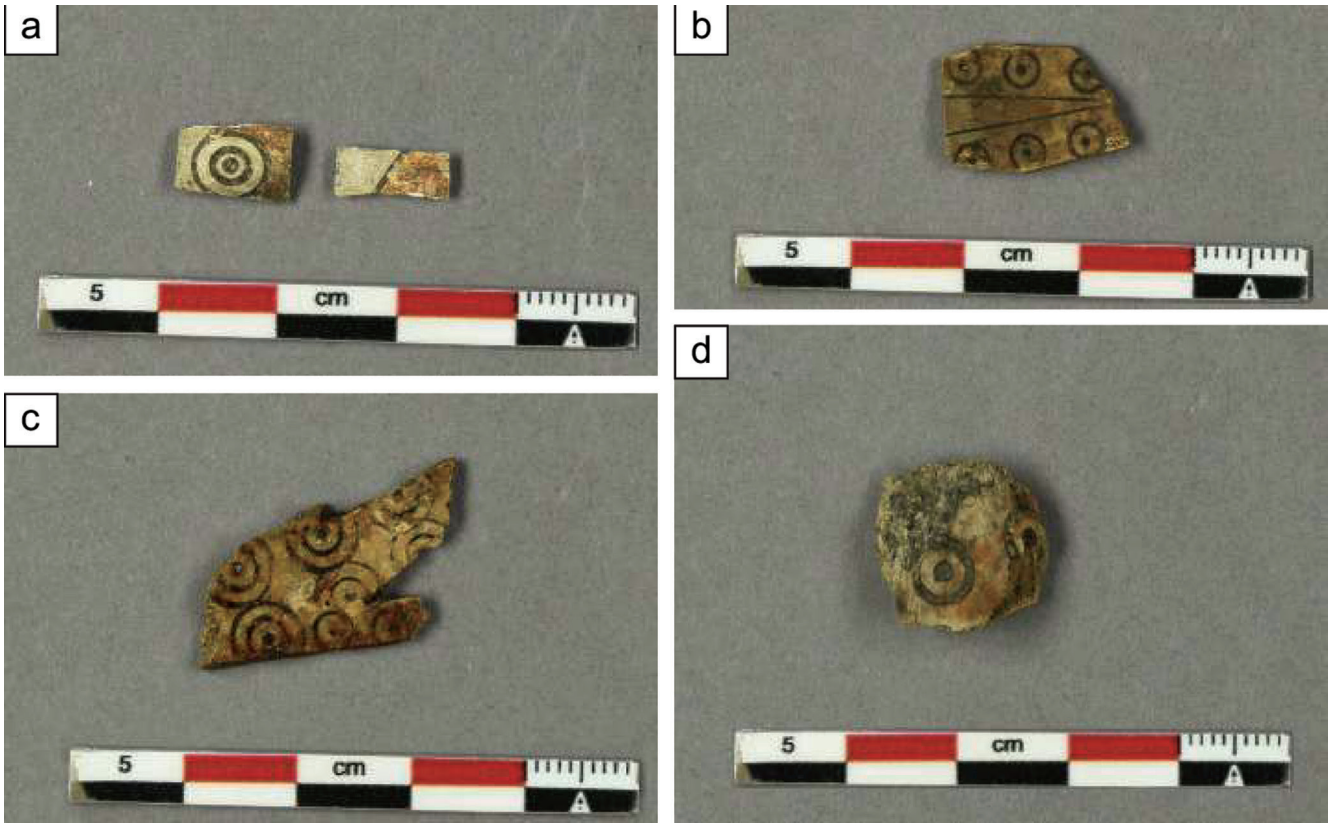

Figure 12. Photographs (Nikon D810 with AF-S 60 mm f2.8 lens) of fragments (a) 1, (b) 2, (c) 3 and (d) 4. For Fragment 1, only the left-hand piece was analysed further.

(SEM-SE) and backscattered electrons (SEM-BSE). Point measurement, as well as area mappings, are performed with SEM-EDX. For the Micro Raman analyses (MRS), a Renishaw InVia spectrometer with a 785 nm laser in combination with a 1200 l/mm grating was used. The laser power is reduced to values between 0.5 and 1 mW over a wavelength range of 100 – 2500 cm^{-1}, with a 30 s exposure time and 5 accumulations per analysis. The bone fragments could fit under the 5× objective of the Raman microscope allowing the analyses to be performed on the bone surface without any sample removal. The obtained spectra are compared to spectra of a built in-house reference library. FT-IR analyses were carried out using two systems: (i) Hyperion 3000 microscope with a 15× IR objective and MCT detector, coupled to a Vertex 70 spectrometer (both from Bruker), located in Brussels, and (ii) PerkinElmer Spectrum GX spectrometer equipped with DTGS and MCT detectors, located in Zagreb. For the measurements done in Brussels, a microscopic amount of the red paint was removed using a needle, then crushed between two diamond windows of a compression cell (SpectraTech) to obtain a transparent film of the sample to be analysed. In Zagreb, a small amount of the black paint was carefully removed with a needle and gently pressed on commercially-available silicon-carbide abrasive pads. The spectra in Brussels were recorded in transmission mode, in a 4000 – 650 cm^{-1} range with 64 scans and 4 cm^{-1} resolution, while the spectra in Zagreb were recorded averaging 100 scans with 4 cm^{-1} resolution in the region 4000–400 cm^{-1}, in diffuse reflection mode. The spectra were obtained concerning the background, previously recorded on a clean diamond window (Brussels) or clean abrasive pads (Zagreb) under the same measurement conditions. Spectra have not been baseline-corrected or normalised. Due to the samples being extremely valuable, the authors tried to preserve them as much as possible: hence there was no black paint sampled in Brussels and no red paint sampled in Zagreb, *i.e.*, measurements that did any damage to the samples were not repeated at the different locations.

6. Results

The black material present in the incised motifs in all fragments shows either a granular aspect or a rather smooth and shiny surface when viewed in the digital microscope (Figure 13 a–c). A more detailed view of the black material is visible in SEM-SE images shown in the Figure 13 d–e. Individual grains of the material can be resolved on Fragment 1, while black material appears smooth on Fragment 2.

The chemical composition of Fragments 1, 2, and 3 was further studied by SEM-EDX analysis. The corresponding elemental distributions of aluminium, silicon, iron, phosphorus, and calcium within Fragment 1 are shown in the false-colour images in Figure 14. The maps of calcium and phosphorous are identical and point to the inorganic fraction of bone, hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$]. In maps in

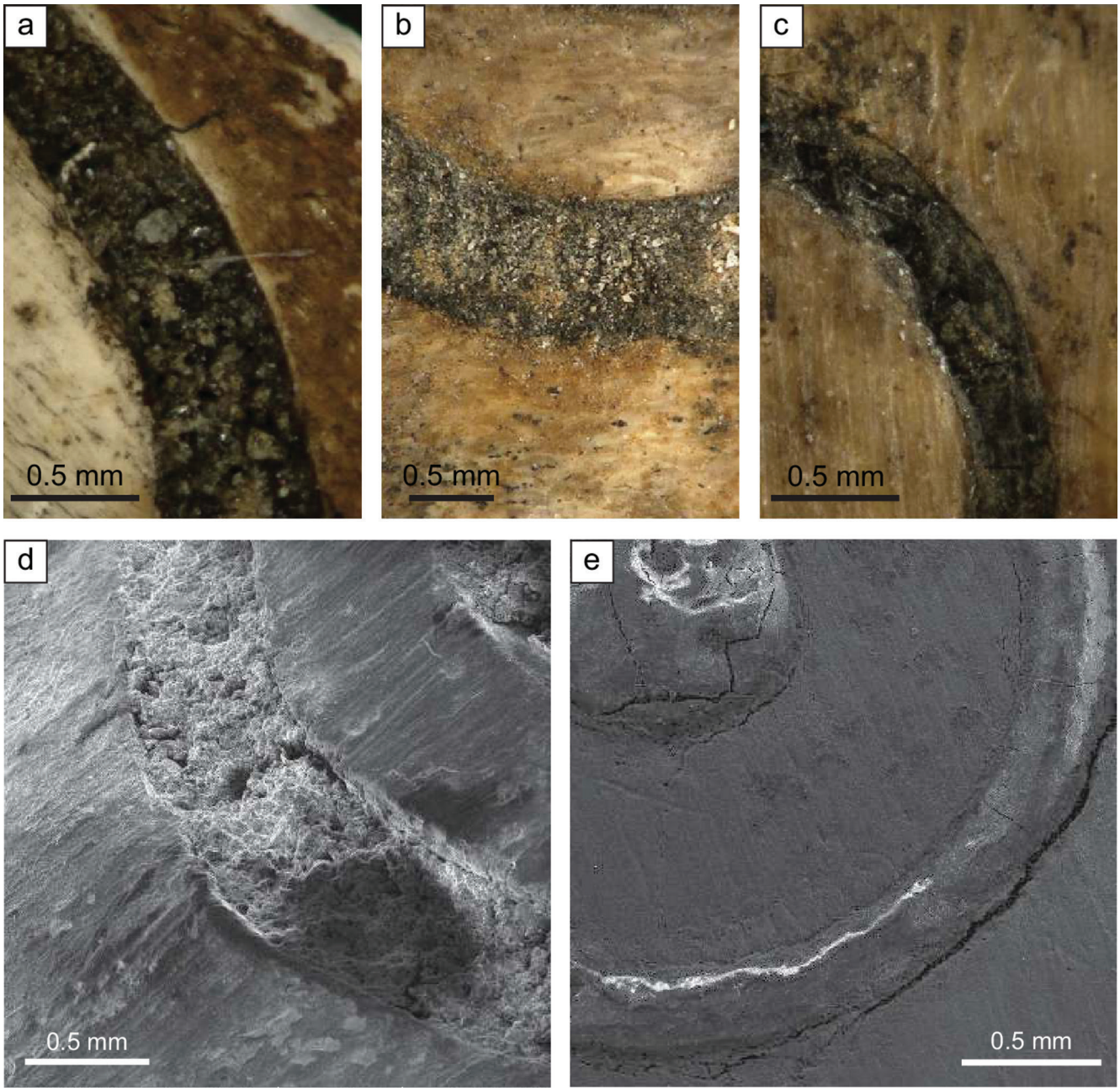

Figure 13. Digital microscope images showing the black paint with a granular aspect of (a) bone Fragment 1 and (b) bone Fragment 4 (b), or as a smooth surface of (c) bone Fragment 2. SEM-SE images of sections of (d) Fragment 1 and (e) Fragment 2, where granular and smooth aspects of the black material morphology are also evident.

Figure 14, both calcium and phosphorous are not evidenced in the incisions. As the incision is filled with black paint, the response of calcium and phosphorous towards the SEM-detector is lowered because of the longer "working distance". Hence, although both chemical elements are "present", their signal is low in the incisions. The black granular material is composed mainly of silicon and aluminium, and also carbon and potassium, as can be seen from the point spectra shown in Figure 15. Iron could be identified in both the black and the red-painted areas but the response for iron is significantly higher in the red-coloured part of the bone fragment. Hence, a firm relationship between the red paint and the presence of iron on the bone Fragment 1 can be established (*cf.* Figure 14 a and d).

The SEM-EDX results of Fragment 2 are shown in Figure 15 (c–d) (point spectra) and Figure 16 (chemical maps). The distribution pattern of calcium and phosphorous illustrate nicely the bone material, just as for Fragment 1. The black areas are rich in carbon content but unlike Fragment 1, contain only low amounts of aluminium or silicon. As can be seen in the iron SEM-distribution map in Figure 16 (f), iron, albeit in low quantity, is detected over the entire bone surface; there is no noticeable distinction between decorated or non-decorated parts. This might rather point to contamination and not a deliberate finishing. SEM-EDX analysis of the black paint from Fragment 3 (not shown) yields qualitatively the same results as Fragment 2,

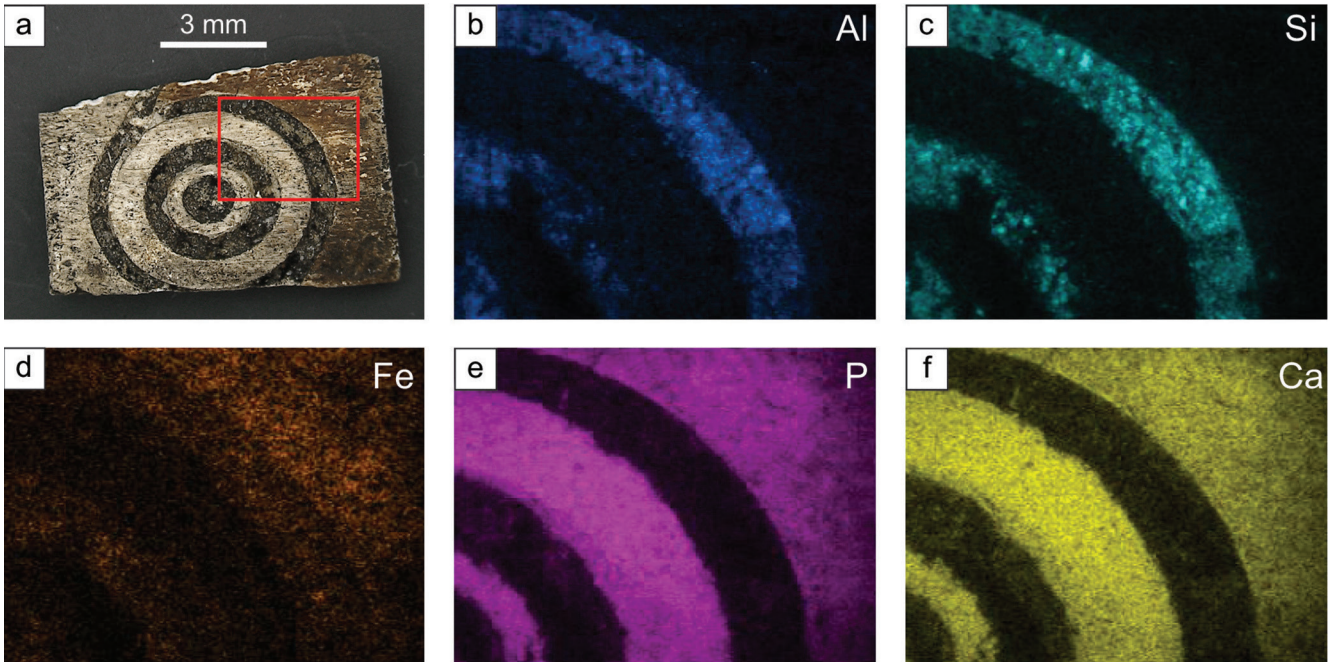

Figure 14. (a): Digital microscope image of Fragment 1; (b)–(f): SEM-EDX false-colour images showing the distribution of Al, Si, Fe, P, and Ca.

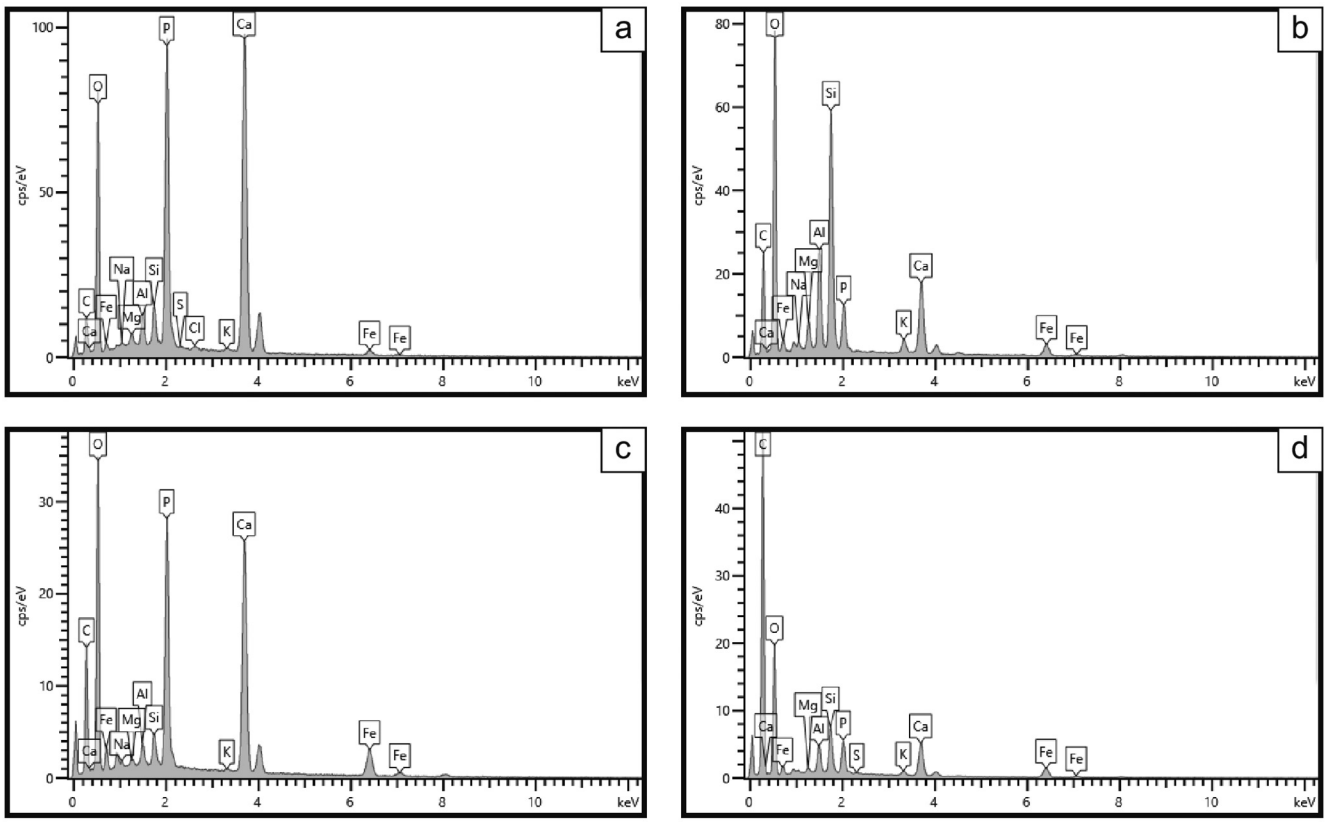

Figure 15. SEM-EDX point analysis of (a) an undecorated bone area from Fragment 1; (b) an area decorated by the black granular paint on Fragment 1; (c) an undecorated bone area from Fragment 2; (d) an area decorated by smooth black paint on Fragment 2.

pointing to the same chemical composition of the paint material from the two fragments.

The Raman spectrum of the black paint material is characterised by two broad peaks between 1300 and 1600 cm^{-1}, both for the decorations with granular or a smooth surface (Figure 18a). Analysis of the red paint, which is very clearly present on the first fragment, results in a spectrum with peaks at 223, 291, 408, and 610 cm^{-1}

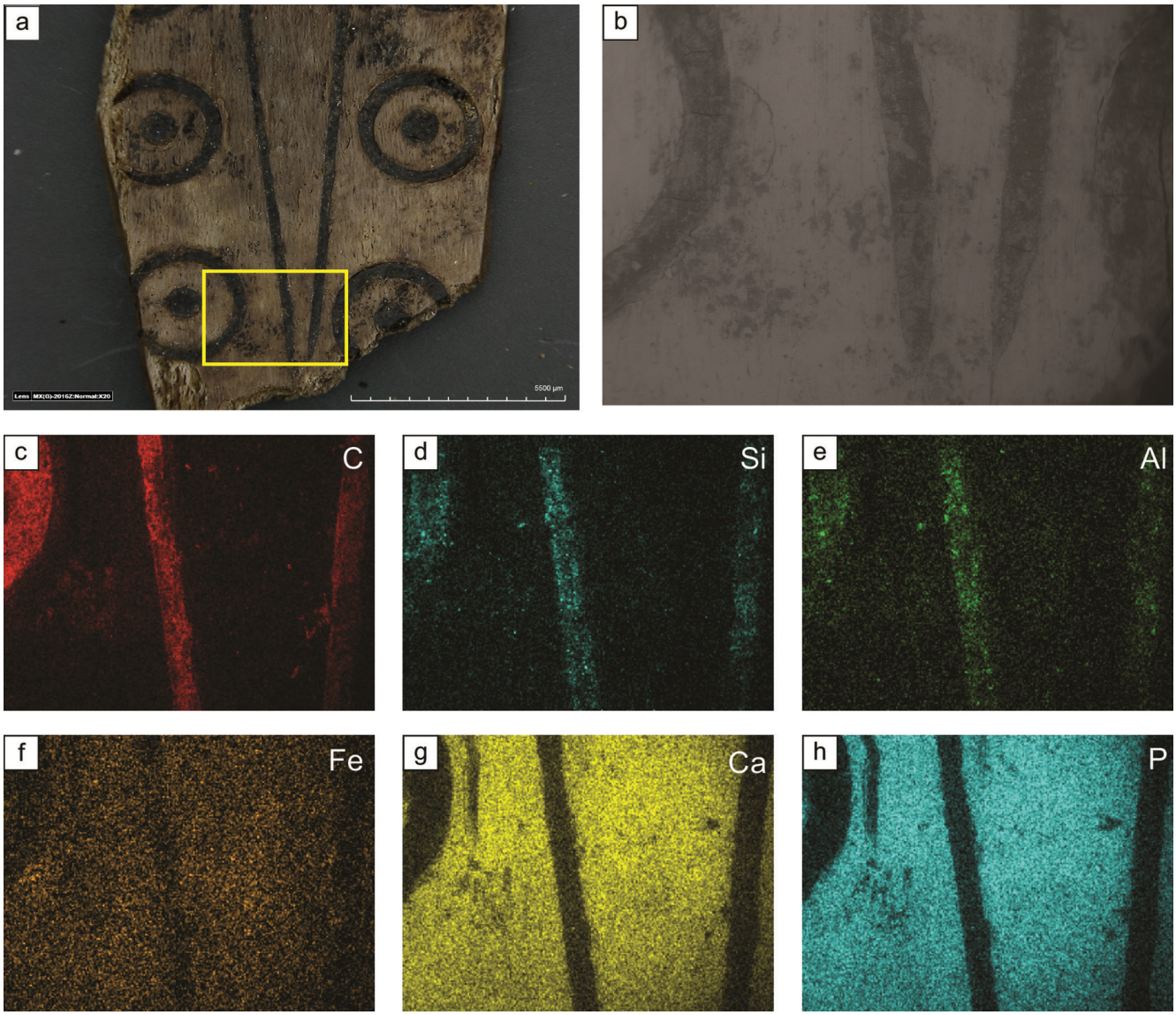

Figure 16. (a): digital microscope image of Fragment 2 (magnification 20×, top left); (b): backscattered electron image (detail; top right); (c)–(h): SEM-EDX false-colour images showing the distribution of C, Si, Al, Fe, Ca, and P.

(Figure 18b). These peaks are characteristic of hematite (iron III-oxide).

Unlike the SEM and/or Raman analysis, the FT-IR analysis is not possible in a non-destructive manner. A small sample, withdrawn with a needle, is needed. To keep the bone fragments as intact as possible even after analysis, sampling was extremely limited. The resulting FT-IR spectra of the red samples are noisy. A broad absorption band in the 1100–900 cm^{-1} range can be observed, both for the red samples of bone fragment 1 and for the slightly red sample of bone fragment 4 (data not shown).

Both silicates and phosphate ions give rise to strong absorption bands in this range, making the correct attribution difficult. An attribution to silicate groups would match with hematite being present together with minerals such as quartz or clay (meaning red earth). On the other hand, an attribution to phosphates might indicate that the analysed sample was the bone material itself, meaning that either only hematite was present (no accompanying clay minerals), or that no real red layer' is present. Regarding the FTIR spectra of the black paint taken from the carved incisions, we compared the spectra recorded from Fragments 2 and 3 (Figure 17). Although the interpretation of the spectra is not straightforward due to the large number of peaks, several characteristic features of organic compounds, such as hydrocarbon chains (peaks at approximately 2926, 2856, 1455, 1373, and 728 cm^{-1}), and carbonyls from carboxylic acids and esters (peaks at approximately 1730, 1245 and 1037 cm^{-1}), are visible.

7. Discussion

The combined analysis results of the black-coloured, incised decoration on the bone fragments point to the presence of

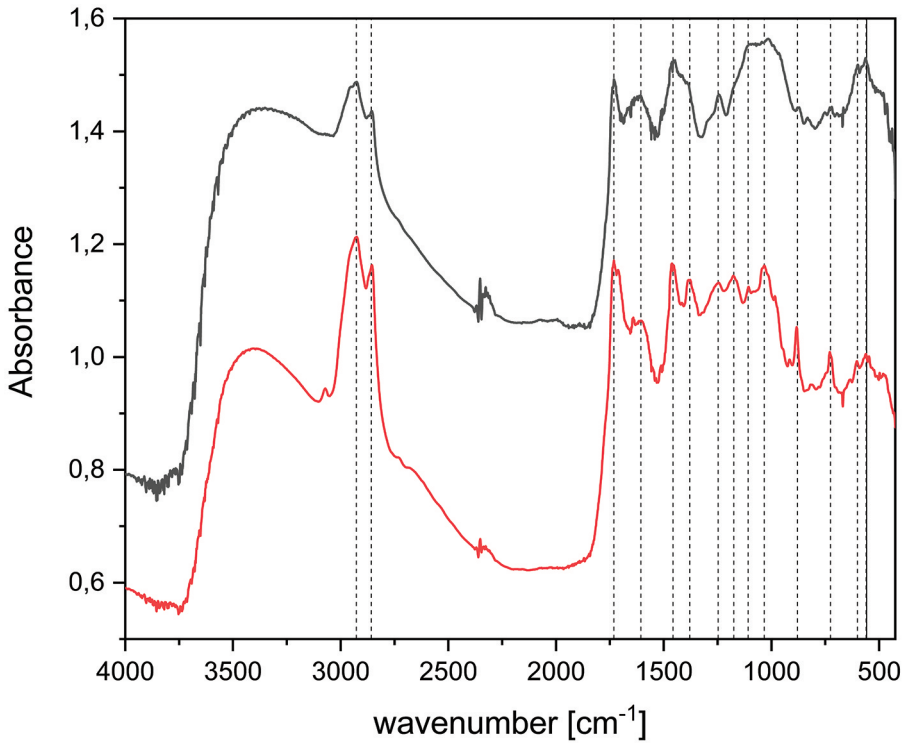

Figure 17. FT-IR spectra of black paint from bone fragments 2 (black) and 3 (red). Vertical dashed lines connect peaks found in both spectra. The spectra are offset for clarity.

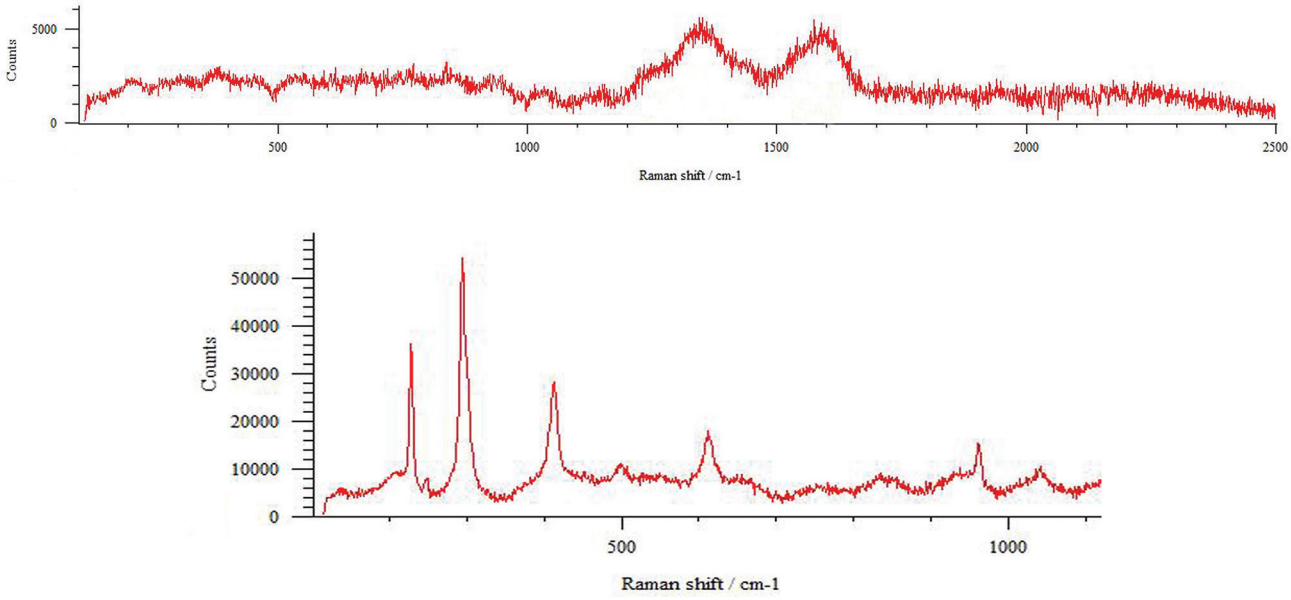

Figure 18. (a): the Raman spectrum of the black paint; (b): the Raman spectrum of the red paint.

carbon black. Carbon black is a general name given to black pigments originating from the partial burning of organic material such as fruit stones or vine stalks or the soot of burned oil, tar, or resin (Schramm, 1995; Eastaugh, 2004). It has been used as a pigment from the earliest times. On bone fragments 1 and 4, the black material had a granular structure. Apart from carbon black, it contains silicon, aluminium, and potassium. Literature sources comment on black chalk as a carbon-containing clay, hence containing quartz and/or clay minerals. Black chalk, black earth, or black stone are all names given to this material, which was certainly known since ancient times but not mentioned in ancient written sources (Howard, 2003). The black material on Fragments 1 and 4, which is coarsely ground, seems to be a deposit of black chalk rather than a black paint containing black chalk.

On the other hand, the black decorations on bone Fragments 2 and 3, with their shiny and smooth surfaces, together with the qualitative agreement of the elemental

composition, are without a doubt a deliberately-applied paint based on carbon black as a pigment. Moreover, FTIR results point to terpenoid resin being a binder and carbon black as a pigment. This result is almost comparable to a material identification of the black material present in the incised decoration of one of the Xanten bone finds from the Roman city of *Colonia Ulpia Traiana* ((Vanden Berghe and Van Bos, 2013). A red decoration could easily be discerned on bone Fragment 1: a brownish-red matte layer, containing hematite as a colouring component, is applied onto the bone surface. Hematite, together with minerals such as quartz or clay, is known as red earth. The presence of a deliberately-applied red layer is questionable for bone Fragment 2. Neither SEM, Raman, nor FT-IR could confirm that such a decorative layer is painted on this bone fragment. Although bone Fragment 4 shows only a very slight discoloration on the bone surface as compared to the surface layer on bone Fragment 1, it is likely to be an "on purpose" applied finishing containing red earth. Black and red paint, based on carbon black and hematite respectively, on objects dating from the first half of the 6th century BC are not surprising. These black and reds were the colours used by prehistoric painters to decorate their caves (Colinart *et al.*, 2001; Barnett *et al.*, 2006). Tracing the origin of the hematite and ochres, in general, is not straightforward (Siddall, 2018). By the end of the Neolithic, several iron oxide prehistoric mines were known in central and south-eastern Europe, including the Lovas mine in Hungary located at the northern end of Lake Balaton less than 200 km from Jalžabet, and the rich deposits of iron ore in the Dolenjska region in Slovenia, and in Bosnia (Levato, 2016). A comparative study of the present hematite structures found in the Jalžabet finds and the iron ores from surrounding iron oxide mines may be the next step to identifying the specific origin of the red pigment used. A recent study of the so-called bog and roasted iron ore in the Drava River Valley Region identified the very first possible point of extraction of the bog iron ore in the region, quite close to Jalžabet. In 2021, thanks to the Iron-Age-Danube project's LiDAR data, Dražen Japundžić and a crew from the Croatian Natural History Museum in Zagreb have confirmed a bog iron ore (possible limonite concretions) extraction point in the form of an open-pit mine approximately just 8 km from Jalžabet. For now, the researchers do not have any data about when the extraction point was used in the past. But the potential use of the local resource during the EIA should not be quickly dismissed[21]. This type of iron ore is easy to obtain, although not in sufficient quantities to meet a community's entire need for iron. Nevertheless, bog iron might have been used as an additional, convenient local source of iron ore even in the Iron Age. Further research may reveal whether bog or roasted iron ore was used for the production of the red colorant found on the decorated Early Iron Age antler or bone finds at Jalžabet.

8. Conclusions

Rescue excavations of one of the biggest burial mounds of the Eastern Hallstatt culture, Gomila in Jalžabet, have resulted in a large quantity of data. Archaeological analysis has shown chronological and cultural analogies between both excavated princely burial mounds in Jalžabet, and strong affiliation with other similar monuments of the Ha D1 period. Considering that the rescue excavations in Jalžabet were finished just recently (December 2021), a huge undertaking of restoration, analysis, and understanding of the finds will not be finished in the foreseeable future. However, some groups of finds have already offered the possibility of a closer look and analysis. One example is the analysis of selected decorated bone or antler artifacts from Jalžabet as presented in this paper. Closer examination has shown the strong possibility of the use of deer antlers as raw material for different types of items decorated with a combination of incisions and paint, and dismissed the use of animal bones as raw material. For a colourant analysis, SEM-EDX, MRS, and FT-IR methods were used in Zagreb and Brussels. These methods confirmed the use of a carbon-black pigment combined with some kind of resin on the finds from Jalžabet. The combination is surprisingly similar to several-centuries-younger finds from the Roman site of Xanten (Germany). In addition, the same black pigment has been confirmed in the grooves of decorated antler plates from both the Jalžabet princely burial mounds. Red paint detected on the decorated finds made of antler from Gomila was determined to be hematite, with the high probability of it having been deliberately used as a pigment. This data has expanded our knowledge about the technology, skill, and production of these finds during the EIA. Also, it has filled in some gaps when it came to the identity and burial rites of the highest classes. Using geology and LiDAR, we have determined the likely possibility that iron ore for the red pigment was sourced locally. The decorated arrows from burial mound 2 and decorated triangles and rectangular plates from Gomila were probably used as inlays, perhaps on luxurious pieces of furniture. Some of the decorated finds could have been used as beads and parts of their attire. Others were probably objects such as containers, mounts, or handles. All the currently analysed data confirms the cultural and chronological association of both the princely burial mounds from Jalžabet to be at the end of Ha D1. It can be concluded, that tumuli from Jalžabet are at the moment the last in the line of monumental royal burials of the Eastern Hallstatt culture, the youngest in "the Horizon of the Last Princes".

[21] A local source of the iron oxide in so-called bog iron ore deposits is proved to have existed and been exploited in the past in the Podravina region, for example, during The Early Middle Ages (Brenko *et al.*, 2020; Brenko *et al.*, 2021, both with quoted literature). The authors would like to thank Dražen Japundžić from the Croatian Natural History Museum in Zagreb for their help in determining the bog iron ore extraction point, as well as Michael Doneus and Martin Fera from the Department of Prehistoric and Historical Archaeology, the University of Vienna, for their immense help with processing LiDAR data within the framework of the Iron-Age Danube project.

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