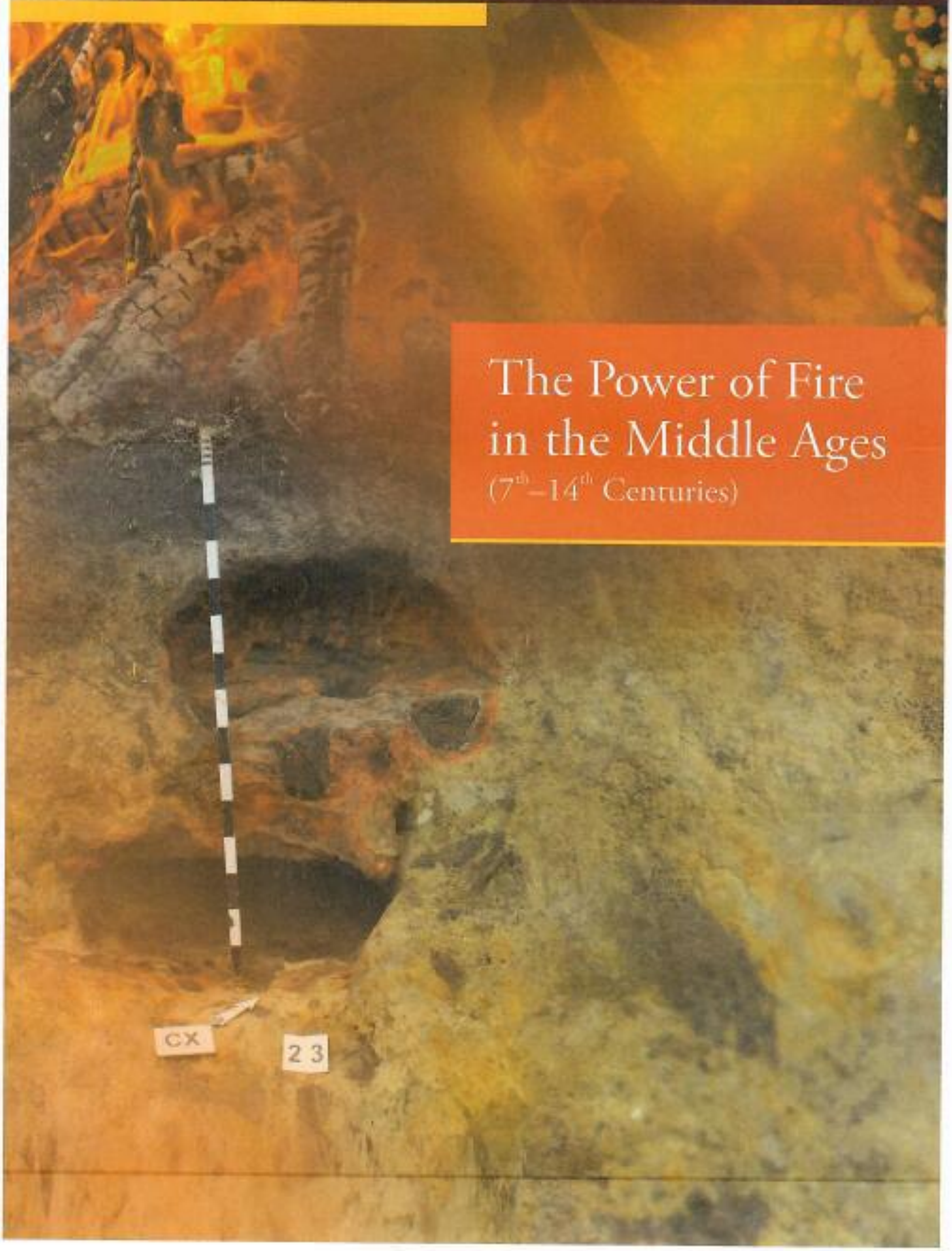
Orbis Mediaevalis

IV

The Power of Fire in the Middle Ages

(7th–14th Centuries)



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Proceedings of the International Conference
The Power of Fire in the Middle Ages
(7th – 14th Centuries)

Székesfehérvár 14th – 16th October 2022

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Archaeological Record of an Iron Production Workspace at the Draganovec Site: Contribution to the Research on Early Medieval Iron Production in Podravina, North-West Croatia[1]

Tena Karavidović, Ivan Valent

Abstract: *An early medieval iron metallurgy workspace has been unearthed at the foot of an elevation, the Draganovec site, located in the Podravina lowland, NW Croatia. The study discusses iron production, taking into account the position of the excavated workspace in relation to the surrounding landscape, the archaeological field records and the morphological and statistical analysis of the finds, as well as the process of site formation, the workspace use and technology. The characteristics of iron production are analysed in the context of other early medieval iron production sites known from the area of the Drava Basin and beyond, within the Carpathian Basin.*

Keywords: *Early Middle Ages, iron production, iron slag, bog iron ore, Drava Basin.*

Introduction – The site

The archaeological site of Draganovec is located on the southern outskirts of the town of Koprivnica, in Koprivničko-Križevačka County, northwest Croatia. It is situated on the fourth terrace of the river Drava, on the northern slopes at the foot of the Bilogora mountain, on a slight elevation, at an altitude of 160.5 m (maps 1–2).[2]

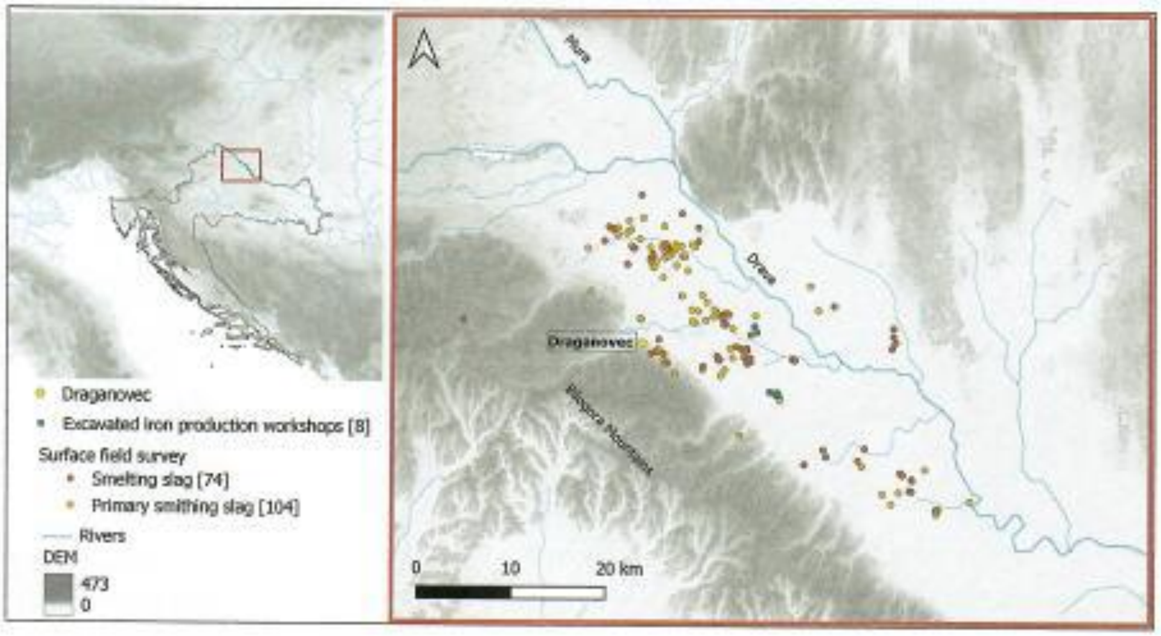
The site was discovered during a field survey carried out in 1981, that led to the first excavation campaign conducted the same year in which remains of two superimposed buildings were unearthed. The associated movable finds were mainly building and household ceramics and the structure was dated to Antiquity, i.e. the Roman period. The overall results of the campaign, as well as the position of the site, led the researchers to believe that they had identified the position of a Roman station *Piretis* (*Tab. Peut.*) i.e., *Peritur* (*Itiner. Hier.*).[3] The excavation continued the following year, but was relocated to the neighbouring parcels to the west because of agricultural crops on the lot in question. Three trenches were investigated in the second campaign.[4] Trench 1 contained some pottery and roof tiles (*imbrex*), but no other remains of structures were discovered. It

[1] The research presented is supported by the Croatian Science Foundation, project: *Cultural Landscapes of Iron Metallurgy During Antiquity and the Early Middle Ages in the Sava and Drava River Basin*– Kultur FER (IP-2022-10-1846).

[2] The site occupies cadastral lots 7071/1, 7075 and 7076 of the Koprivnica cadastral municipality. It is believed that during its occupation the site extended further west but was destroyed during the Modern Period by the construction of Radnička road and family houses west of the listed lots. This presumption is supported by the fact that a small trench investigated during the 1982 excavation campaign on the cadastral lot 7668 of Koprivnica municipality yielded some archaeological material.

[3] Demo 1982.

[4] The results of the 1982 campaign have not been published. They are known from the field journal records kept in the Koprivnica Town Museum (Marković 1978–1997, 108).



Map 1. Iron production and processing sites in the Podravina region (NW Croatia) and the position of the Draganovec site (data: Sekelj Ivančan, Karavidović 2021; Valent et al. 2021; basemap: NASA JPL 2013) (made by: T. Karavidović).

was concluded that these were the remains of a building possibly dating from the medieval period which were removed by the "later inhabitants". Also, it is known that the land owners have cleared the site of large quantities of stone in order to make the land more fertile, during the 20th century. Trench 2 contained a layer of gravel 20 centimetres thick. The researchers suggested that these layers might have been a part of a road that passed through the settlement. Apart from fragments of pottery collected from the contact level between humus and sterile soil, no settlement structures were discovered.[5] Although no precise dating of the unearthed structures has been proposed, the changes in the organisation of the settlement, primarily in the orientation of the buildings excavated in the 1981 campaign,[6] which are comparable to similar changes in the orientation of buildings in the nearby site of Ludbreg, i.e., *Iovia*,[7] suggest that the site functioned at least until the fourth century. Although the exact position of the trenches is not known, the area of the site can be estimated on the basis of descriptive data from excavation campaigns and perambulation conducted in the following decades (map 2).[8] In the spring of 2021 a surface survey led to the discovery of traces of two large dwellings, containing Roman roof tiles and bricks on the slope of the elevation. A concentration of iron smelting slag was also found in the lowland area, scattered over a surface of some 200 square meters. A trench was dug in the area where the majority of slag pieces had been collected, and the record was excavated.[9]

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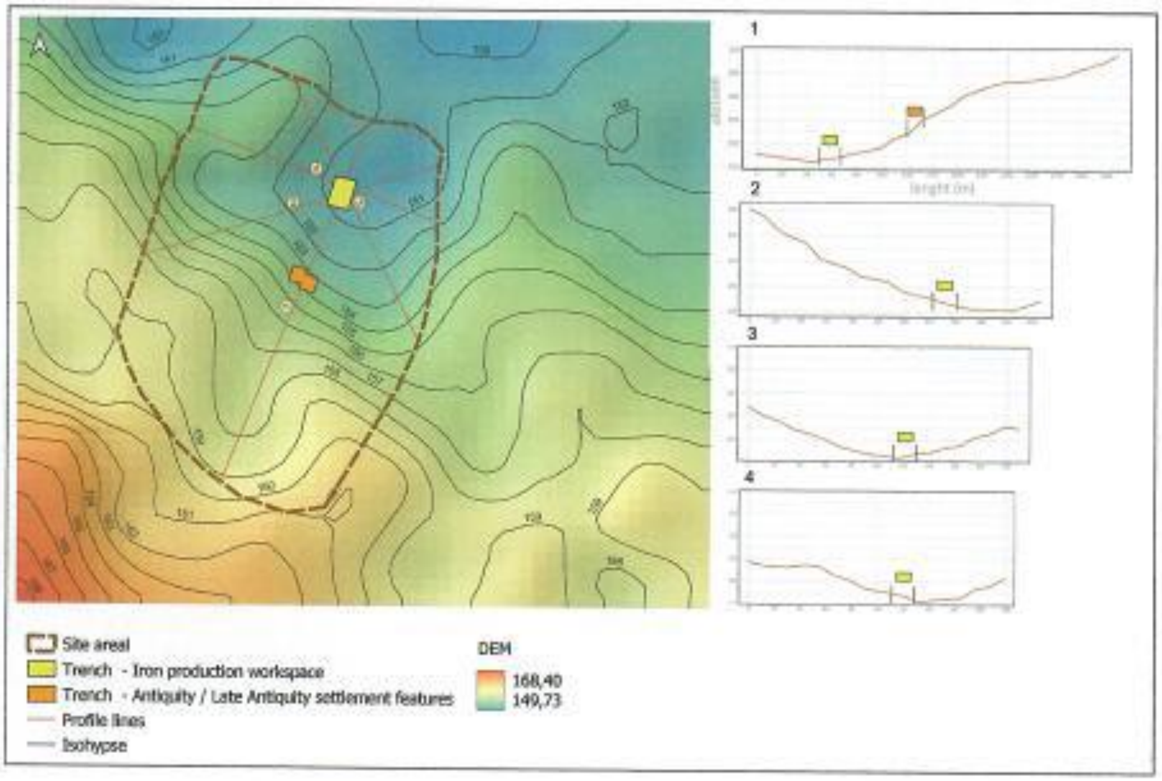
[5] Marković 1978–1997, 108.

[6] Demo 1982, 72.

[7] Vikić-Belančić 1983–1984, 161.

[8] The first two trenches, measuring 78 m², were positioned on the neighbouring parcel to the west of the former excavation area, presumably the current cadastral lot 7071/1. There is no information about the dimensions of the second trench, and the third trench (9 m²) was opened some 250 meters to the west, presumably on what is currently lot 7668.

[9] The excavation of the workshop was conducted by the Koprivnica Town Museum in the period between the 8th and 18th of March 2021 under the direction of the author, Ivan Valent. We would like to take this opportunity to thank the archaeological team who participated in the research: Ilija Cikač, *mag. archeol.*; Ivan Zvijerac; Robert Čimin, *PhD*; Saša Hrenić.



Map 2. Area of the presumed Draganovec site based on older excavation campaigns and surface field surveys with positions of the excavated trenches (2021). Digital elevation model and profile sections (1–4) showing the position of the excavated workspace in relation to the relief features (basemap made from elevation data from Google Earth pro – point interval 5-10 m) (made by: T. Karavidović).

Active iron production in the Podravina region is presumed on the basis of numerous sites defined by surface field surveys, of which only a few have been excavated and analysed in detail. The aim of the excavation at Draganovec was to gain insight into a different work space context, a site located away from the majority of excavated sites in the same region, and possibly related to settlement features. On the basis of the excavated record and analysis of finds, the process of site formation is presumed, the workspace and technology of iron production are defined. The insights are compared and interpreted in relation to data known from contemporary sites in the region.

Methodology

The presumed workspace was excavated by stratigraphic method. All archaeological finds were collected during excavation and further analysed. A basic morphological, quantitative and temporal analysis was conducted on all types of finds in relation to individual contexts. The position of the site is analysed with regards to distribution of other iron production sites in the region and natural characteristics of the area – relief, pedology and geology. The latter information is taken from available data and maps for the area of Croatia and previously published works on the location of iron production sites in the Podravina region. The processes of site formation are analysed based on the stratigraphic sequence, the representation of finds within context, and the natural properties of the area. The digital elevation model and terrain profiles were generated from point cloud obtained from Google Earth Pro satellite imagery (ca. 3–10 m point density). The data were processed, visualized and analysed via QGIS 3.22.10.

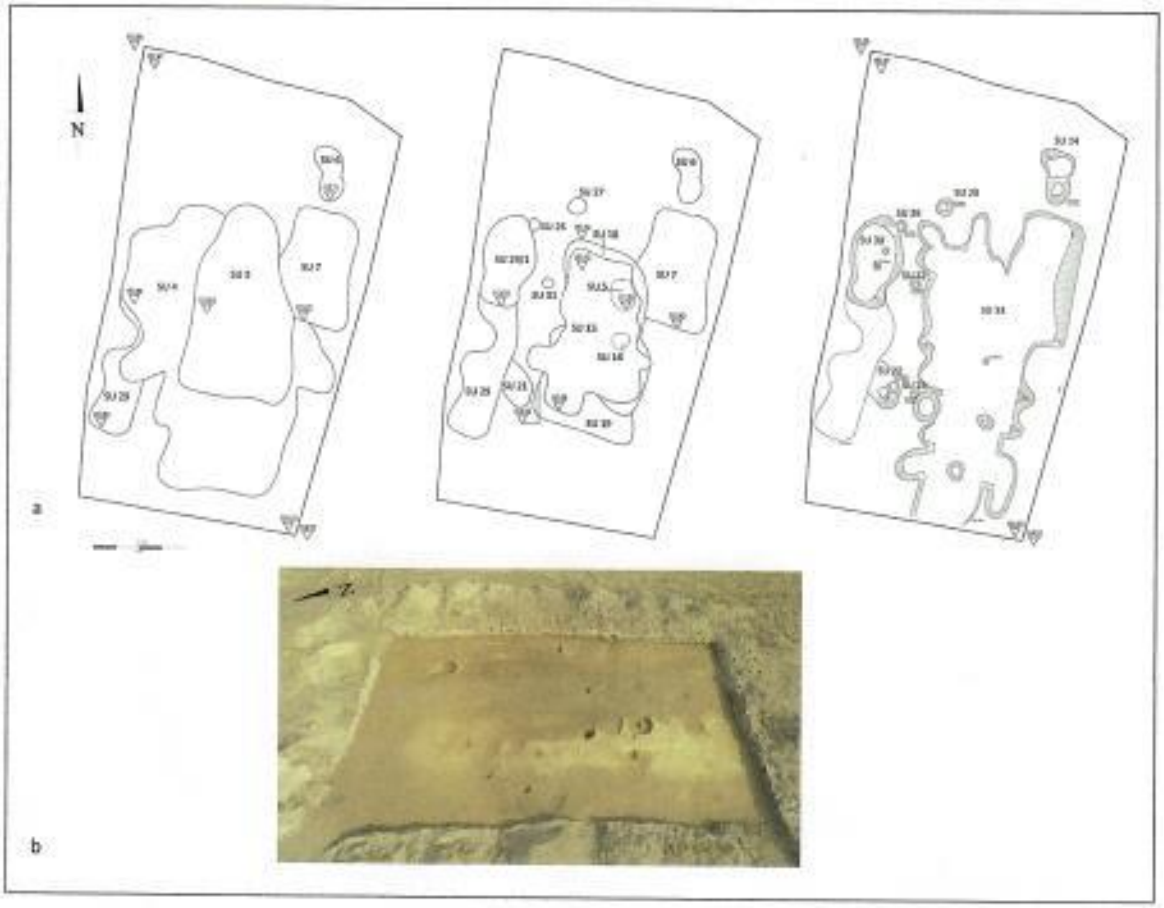


Fig. 1. Excavated area: layouts by phases of excavation (a), photograph at the end of the excavation (b).

Results

Excavated record

The excavated trench was rectangular in shape and oriented north – south. It covered an area of 214.40 square meters, and was located where the largest quantity of smelting slag pieces were collected during the surface field survey (Map 2).[10] The trench and the majority of the presumed antique and late antique site is located on an actively used agricultural field.

The excavated area is situated on a slight slope that descends from south to north, at the foot of an elevation – top altitude: 154.66 (S) – 153.49 (N). The topsoil is a layer of ploughed soil, that reaches a depth of 22-32 cm, beneath which thin archaeological layers and fills are found. In the area of their absence and below, a geological layer of sandy clay was defined (Fig. 1/a–b). Traces of ploughing (strait marks of a plough) were identified sporadically within the geological, sterile sediment. The stratigraphic sequence is made up of relatively thin layers, which together reach a thickness of up to 20 cm (154.11 – 153.90 altitude) appearing within an area of around 103 m^2 (Fig. 1/a). The first layer identified beneath the topsoil wasa dark grey layer (SU 3) without any archaeological material (Fig. 1/a). At the edges of this layer, a light grey soil was identified (SU 4). Below SU 3, another layer (SU 15) and two clusters of vitrified furnace walls and slag (SU 5 and

[10] The initial trench was gradually expanded as the archaeological record implying a connection with iron production, was clearly wider than the surface concentration of finds.

16) were identified, which lay directly on SU 15. SU 5 and SU 16 could be interpreted as poor, *in situ* remains of a furnace associated with iron metallurgy. The latter is supported by a pale reddish circular trace of burned soil (SU 17), identified directly beneath SU 5, implicating the effect of heat on the ground. It can be interpreted as the remains of the hearth bottom of a smelting furnace, as poor remains of furnaces are known to exist on other sites in the same region where the same land use methods were applied (agricultural land), but with a clearer possibility for interpretation as workshops for iron production, with furnace remains.[11] The burned layer lay on a light grey layer (SU 19) that contained pieces of different types of slag, ceramic building material and shards of pottery. Layer SU 19 spread beneath layers SU 15, 16 and SU 18. After its removal, only the shallow negative (SU 33) remained. Relatively below SU 4, a fill was defined at the western part of the trench (SU 29/30). Just like all the other layers, it contained pieces of ceramic building material, pottery and different types of slag. After the removal of SU 4 and partially SU 19, several smaller, shallow cuts were defined around the described layer sequence and below it.

Archaeological finds

Ceramic building material

Based on the morphological traits, the ceramic building material can be divided into five groups: bricks, *tegulae, imbrices, tubuli*, unidentified (Tab. 1). The material can be dated to antiquity/late antiquity. All finds are fragmented, and no clusters or structure remains from ceramic building material were identified during excavation. The most represented finds are *tegulae*, followed by bricks and *imbrex* pieces. The ceramic building material fragments are present in the majority of the excavated layers and fills, dominantly represented in the layer SU 19 (66.5 % of the total, by weight). Accompanying architectural remains that could be associated with ceramic building material cannot be clearly defined within the excavated archaeological context, although the presence of building materials suggests that some Roman architectural remains should be expected, possibly in the vicinity.

Pottery

Pieces of ceramic vessels were analysed on the basis of several visually detectable traits: fabric, production technique (hand made or thrown on a potter's wheel), typology and decoration. Based on these parameters and analogous finds, they can be attributed to: 1) Antiquity, 2) Late Antiquity, 3) Early Middle Ages, 4) High Middle Ages, 5) Undetermined (Tab. 2; Fig. 2). The group of finds dated to Antiquity can be further divided into local and imported pottery, but for the purpose of this analysis the pieces of both groups have been reduced to a common nominator. All pottery was thrown on a potter's wheel and none of it is decorated. Local production has mica in the clay, while imported pottery is produced from sandy clay. Different types of Pannonian grey pottery are the best represented in the imported pottery, while local production is characterised by the coarse

[11] Remains of variously preserved smelting furnaces are known from sites dating from Late Antiquity and the Early Middle Ages: Virje-Volarski breg, Virje-Sušine, and Hlebine-Velike Hlebine (Sekelj Ivančan, Karavidović 2021). In some cases, the hearth was preserved as a shallow circular dent with burned soil on the bottom (Sekelj Ivančan, Karavidović 2021, Figs.7–8).

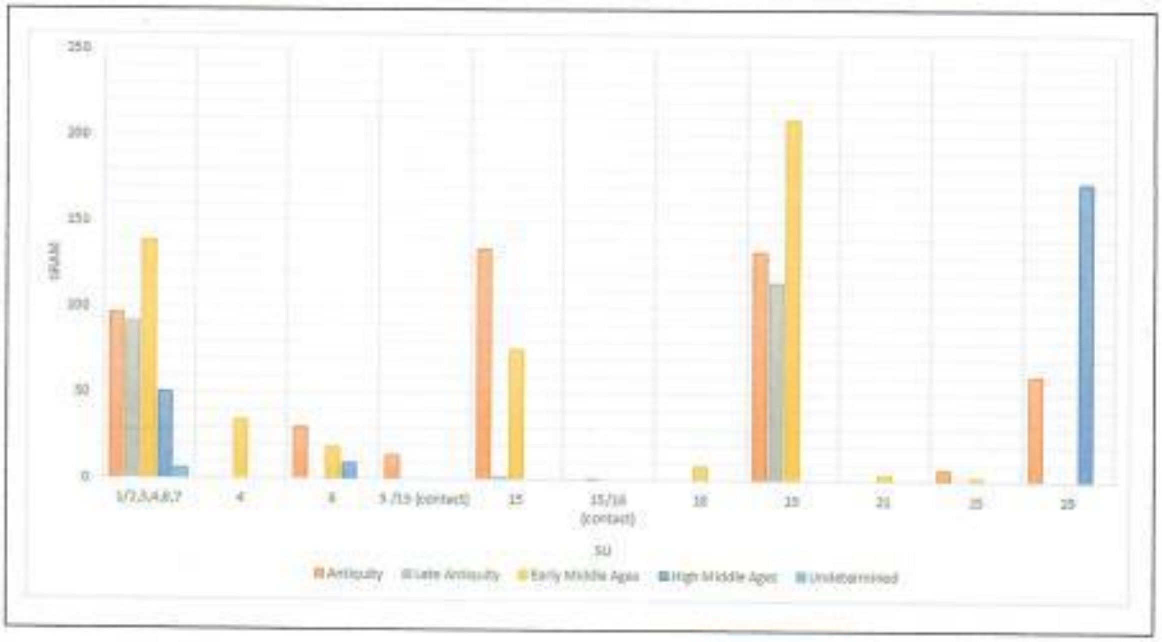


Fig. 2. Graphical representation of the quantity of pottery finds with regard to their temporal affiliation and context (SU).

ware, represented by pots with and without handles. The common characteristic of the second group, dated to Late Antiquity, is the shaping of the vessels by hand. There are two main groups of fabric, similarly represented: 1) fabrics with organic admixtures that were burned during firing, leaving the pottery with a porous structure, 2) fabrics with rare admixtures of mica or tiny stones. Decoration is absent in this group as well. The pottery of the third group is made on a slow wheel and has tiny stones of different sizes in a single fabric. Some of the pieces are decorated with rough, single or multiple waves or multiple horizontal lines. The fourth group consists of pottery dated to the High Middle Ages. All the collected pieces of that group were produced on a fast wheel and commonly decorated with single waves or single horizontal lines. Like the previous group, these pieces have tiny stones of different sizes in the fabric. The last group is made up of pieces that do not fit into any of the previous groups due to their size and fabric.

SU	Sample no.	Bricks		Tegulae		Imbrex		Tubuli		Undetermined		TOTAL	
		g	pc	g	pc	g	pc	g	pc	g	pc	g	pc
1/2-4,6,7	1, 4	537	3	4972	33	271	3	235	3	1514	80	7529	122
6	9, 15			5598	11							5598	11
8	8			612	3					106	3	718	6
15	13, 26	627	2	439	6	596	7			809	31	2471	46
18	27	85	1	237	3					191	5	513	9
19	29	2097	3	34747	115	1340	13			2540	94	40724	225
21	35	153	4							106	3	259	7
25	38					59	1			38	2	97	3
27	34			244	1					62	4	306	5
29	41			1177	12	362	5			469	27	2008	44
31	45	1013	1									1013	1
TOTAL		4512	14	48026	184	2628	29	235	3	5835	249	61236	479

Tab. 1. Ceramic building material by stratigraphic units (SU).

SU	Sample no.	Antiquity		Late Antiquity		Early Middle Ages		High Middle Ages		Undetermined		TOTAL	
		g	pc	g	pc	g	pc	g	pc	g	pc	g	pc
1/2,3,4,6,7	2, 5	96	11	91	10	138	36	50	6	6	1	381	64
4	25					34	5					34	5
6	14	30	3			18	3	9	1			57	7
21	20					3	1					3	1
5 /15 (contact)	11	14	2									14	2
15	12,21	134	6	2	1	75	16					211	23
15/16 (contact)				1	1							1	1
18	28					8	1					8	1
19	30, 47	133	24	115	18	209	40					457	82
25	37	7	2			2	1					9	3
29	40	61	11					173	22			234	33
TOTAL		475	59	209	30	487	103	232	29	6	1	1409	222

Tab. 2. Ceramic pottery finds by stratigraphic units (SU).

Most of the pieces collected are rather small and vary in size from two to four centimetres. Several larger pieces are between five and six centimetres long, and only one piece is larger.[12] Looking at the distribution of the pottery within the excavated layers and fills (Tab. 2) it is obvious that the highest number of pottery pieces was found within the lower layer SU 19, followed by pottery from the contact layer with the ploughed topsoil, and by the layer SU 15. SU 29 is also quite saturated with pottery finds, although the temporal representation differs from the previous layers by the lack of Late Antique and Early Medieval pieces, and the predominance of pieces from the High Medieval period. On the other hand, layers SU 15 and 19 do not contain any High Medieval pottery. Furthermore, it should be noted that the deepest layer in the sequence of superimposed layers, SU 19 is the most saturated overall and by individual time periods – antique, late antique and early medieval.

Finds related to iron production

Macroscopic analysis of finds related to iron metallurgy revealed four main groups (Tabs. 3–5): 1) technical ceramics, 2) slag, 3) iron bloom particles, 4) bog iron ore.

Technical ceramics

Technical ceramics include parts of the above-ground structure of the furnace – the walls of the furnace and tuyeres (Tabs. 3–4). Fragments of furnace walls can be divided into two basic groups according to their morphological characteristics: 1) amorphous fragments with different degrees of burning, variable traces of firing atmosphere visible in the cross-section and on the surface (red – oxidative, grey – reductive), 2) amorphous, heavily burned fragments, vitrified on the inner surface, with traces of slag adhering. These basic macroscopic differences are related to the position of the remaining fragments within the above-ground structure of the furnace. Those

[12] Information on the size of individual pieces of pottery is based on visual observation. Each piece was placed next to a ruler during basic photo documentation. Measurements were not taken for each individual piece.

vitrified with traces of slag were positioned closer to the hearth, within the hottest zone, close to the tuyere where the temperatures are highest, the slag separates from the iron and a bloom is formed (Pl. 1/1–2). None of the fragments has been preserved in its full thickness, so it is not possible to unambiguously define the thickness of the furnace walls and their possible variability, but the best preserved parts of the walls reach up to 6 cm. The latter could mainly be measured on fragments that belong to group 2, and should be taken as a minimal value of the wall thickness next to the tuyeres. The possible full thickness of these is not much greater, maybe a few centimetres (around 10 cm).

The aim of the analysis of tuyeres was to record all measurable and visually separable traits, to define the morphological shape of the body, common and distinguishable traits among samples and calculate the number of possible individual tuyeres found. The data collected could serve for estimating the number of smelting events and individual smelts within the excavated record, and for defining the way tuyeres were made, as well as for illustrating their position within the furnace structure. Unfortunately, most of the tuyeres are quite fragmented, so the possibility of joining individual pieces together was rather low (only 6% of the total fragments were joined, Tab. 3) and a full scope of descriptive data could not be collected for individual fragments. The aim was to record the basic geometric shape of the body and the outer rim modelling, the diameter of the opening (A – outer, B – middle, C – inner), the length (preserved, full, estimated), the thickness of the walls (measured at the centre of the body), the colour, the fabric (visible inclusions, relative hardness) and the inclination against the furnace walls in which the tuyere was placed. The analysis revealed that there are three groups of tuyeres (Tab. 4), primarily distinguished by some of the morphological traits – fabric and way of firing, thickness of the walls and inner diameter. Two groups (Tab. 4/groups 1–2) are quite similar, with a major difference in colour after firing and in fabric. These two groups were defined as cylindrical, possibly slightly conical, while for the third group it was impossible to define differential parameters (inner diameter (A – B – C) change). All the tuyeres analysed were fired before being inserted into the furnace walls/doors, which is evident from the difference in fabric, colour and the way they break against the furnace walls.

In order to calculate the number of tuyeres found, the fragments were physically joined prior to other analyses.[13] The number of remaining fragments is referred to as the maximum number of tuyeres (tab. 3). The minimum number is estimated based on visual similarities (measured parameters and additional traits such as degree of burning on the inner rim) and the degree of preservation of individual pieces – pieces smaller than ¼ of the estimated dimensions were excluded as potential individual tuyeres. The optimum number is estimated using the same parameters as the latter, with one major difference – individual rim fragments that could not be directly joined were excluded, although they could have belonged to the same tuyere, based on the preservation of other very similar rims. The latter seems a viable option for estimation, because the rims of the tuyeres are the most exposed parts during the smelting process, they regularly have slag adhering to them and they sometimes crack and deform during the process, meaning that the possibility of direct physical joining is reduced.

[13] The few fragments that were joined came from different SUs, so the spatial context of individual fragments was not included as a defining factor in estimating the number of tuyeres. For the same reason, the data on maximum, minimum and optimum numbers were not included in the statistical analysis of the finds in relation to their context.

SU	Sample no.	Furnace walls			Tuyeres				
					group/ type	pc	Individual objects		
		g	pc	average mass per fragment (g/pc.)			max.no	min.no	opt.no
1/3,4,5,6,7,8	6,5,2	7840	428	18,32	1	12	11	3	4
1/2	1	1542	101	15,27					
5	18,17,4,68	2145	130	16,50	2	2	2	0	1
6	10	48	5	9,60					
8	3	120	5	24,00					
15	10,12,19	7514	413	18,19	1	2	2	1	1
15/16 (contact)	6	73	19	3,84	1	2	2	1	1
15/19(contact)	23,24				1	3	3	0	0
16	15	1154	54	21,37					
18	17	965	55	17,55					
19	23,27,31,33,32,39,47,18	5307	226	23,48	1,2	5	5	0	0
21	13,21	644	28	23,00					
25	24	75	3	25,00					
27	20	28	4	7,00					
29	25,42,43,44	1169	98	11,93	1,2	6	4	1	1
TOTAL		28624	1569	16,79		32	29	6	8

Tab. 3. Technical ceramics – furnace walls and tuyeres by stratigraphic units (SU).

Tuyeres													
Group	Shape - body	Shape - cross section	Shape- external rim	Diameter – A/cm	Diameter – B/cm	Diameter – C/cm	Thickness/cm	Lenght - preserved max./cm	Colour - Fabric	Inclination	Total/no.		
											max.	min.	opt.
1	cilindrical - midly conical	circular	unk.	2,6-2,9	3	unk.	0,6-0,7	6,3 (aprox. total lenght 7-10 cm)	bright red (uniform), sandy clay, hard	45	16	2	3-4
2	cilindrical	circular	unk.	2,8	2,9	unk.	0,5-1	4,6	ochar (uniform), sandy clay, hard	unk.	10	1	2
3	unk.	squarish	unk.	unk	4	unk.	1,1-1,2	3,3	ochar - pale redish (uniform), clay with some sand, soft	unk.	3	1	2

Tab. 4. Properties of tuyere groups (1–3).

Ore, slag and iron bloom particles

The slag fragments can be divided into several categories, descriptively named according to their position in relation to the smelting furnace: 1) tap slag, 2) tapped slag rod, 3) furnace slag, 4) furnace bottom slag (Tab. 5 and Pl. 1/3–6). Other types of slag may belong to multiple processes: 5) spheres and irregular prills, 6) unidentified. The tap slag (Pl. 1/5) refers to a slag that has been discharged from the furnace in the molten state and is characterised by a smooth flowy texture on the upper surface, and an uneven, narrowly indented, smooth lower surface that has been in contact with the soil. Tapped slag rod (Pl. 1/4) is a category of fragments with visible traces of a rod negative space, i.e. a slag positive of a hole punched with a rod by the base of the furnace in order to tap the slag out. The running slag filled the hole, and fragments sometimes showcase both tap slag and furnace bottom/furnace slag characteristics. Furnace slag refers to the slag from the shaft of the furnace (Pl. 1/3), which is seen from the porous texture, imprinted by the unburned charcoal pieces over which the slag has settled. Furnace bottom slag deposited on the hearth bottom (Pl. 1/6), was not discharged and solidified into a shape that illustrates a slightly concave hearth bottom. It has a rough, uneven, narrowly divided upper surface, and a similar lower surface, most commonly partially covered with burned soil on which the hearth was placed. Other slag finds are very small in size and have a regular, spherical shape or irregular elongated shape with a vertically aligned flowy surface texture. Small fragments of individual molten slag prills can appear inside the furnace shaft[14] as indicated by the analysis of slag from experimental tests,[15] although this form of slag is most often associated with post - reduction procedures.[16] Unidentified slags are amorphous fragments that are not typical in shape or structure for either category, and could not be attributed to a specific process, primarily reduction or post-reduction.

Another category worth mentioning is the heavily corroded amorphous magnetic particles that can be attributed to the compacting of the bloom, although smelting is not excluded entirely (Tab. 5). They represent slag pieces of iron bloom that have detached during compacting or unsintered bloom particles formed during smelting.

Among the finds there are several pieces of ore (Tab. 5). On the basis of their structure and colour, these can be classified as bog iron ores, characterised by visible roundish particles and brownish – yellow – grey (raw state) or dark red – grey (semi-reduced) colour. Similar ores are known from the Podravina region, found both in excavated archaeological contexts and through geoarchaeological field surveys, in areas with or without archaeological traces of iron production.[17]

SU	Slag																					TOTAL - all waste finds - slag, technical ceramics (furnace walls)			Fe object	Ore					
	Tap slag		Tap slag rod		Bottom of the furnace				Furnace slag		Spheres		Prills		Amorphous (corroded magnetic and non magnetic)		Indeterminate - amorphous		TOTAL							Raw		Semi-reduced		TOTAL	
	g	pc	g	pc	g	pc	* pieces of bloom attached (g)	* pieces of bloom attached (pc)	g	pc	g	pc	g	pc	g	pc	g	pc	g	pc	average mass per pc - g/pc	g	pc	average mass per pc - g/pc	g/pc	g	pc	g	pc	g	pc
1/3,4,6,7	15356	455	581	4	1384	16	549	7	3450	183					490	23	694	8	22504	691	32,57	30344	1119	27,12		35	1			35	1
1/2	8212	264	153	2	834	8			1016						82	7	158	5	10455	286	36,56	11997	387	31,00		30	1			30	1
5	966	33	79	1	631	1			293	26					22	2			1991	63	31,60	4136	193	21,43							
6									16	2									16	2	8,00	64	7	9,14							
8	387	9							49	49									436	58	7,52	556	63	8,83							
15	7027	262	714	6					2980	216	3	3	34	7	828	61			11549	545	21,19	19063	958	19,90		13	2	15	2	28	4
15/16	73	10							18	4									91	14	6,50	164	33	4,97							
16	116	10							90	6									206	16	12,88	1360	70	19,43							
18	588	29			93	2			342	19					57	4			1080	54	20,00	2045	109	18,76	22/1						
19	6127	425			337	5			2070	146			10	3	649	63			9183	639	14,37	14490	865	16,75							
21	304	12							362	22					59	1	120	1	845	36	23,47	1489	64	23,27							
25	348	2																	348	2	174,00	423	5	84,60							
27	23	4							24	6					14	2			61	12	5,08	89	16	5,56							
29	1602	65	186	3	132	2			745	89					185	12			2855	172	16,60	4024	270	14,90							
31									17	2									17	2	8,50	17	2	8,50							
TOTAL	41129	1581	1713	16	3416	34	549	7	11472	770	3	3	44	10	2386	175	972	14	61637	2592	27,52	90261	4161	20,94	22/1	78	4	15	2	93	6

Tab. 5. Slag, ore, iron objects and total of waste finds by stratigraphic units (SU).

[14] Bayley *et al.* 2008, 22–23, Fig. 15; Dungworth 2011, 227–228, Pl. 47.

[15] Karavidović 2020.

[16] Jouttijärvi 2015.

[17] Brenko *et al.* 2020; Brenko *et al.* 2021; Karavidović 2022, 55–67, Map 3.1, Tab. 3.1, Figs. 3.1, 3.8; Karavidović, Brenko 2022.

A total of 90.261 kg of residue from processes of iron smelting and most probably compressing of the iron bloom was found on the site, 61.637 kg (68%) of which is slag and particles of detached bloom and 28.624 kg (32%) technical ceramics, mainly furnace walls. A great amount of slag and technical ceramics was collected on the contact of ploughed topsoil and level of definition of archaeological layers and fills, i.e. surface of defined layers (SU 1/ 2,3,4,5,6,7 – 69% of slag finds by weight and 33% of technical ceramics, 57% of total residue from iron production) (Tabs. 3 and 5; Fig. 3). Within the excavated layers and fills, two superimposed layers – SU 15 and 19 contained an outstanding quantity of all materials associated with iron production. The proportion and quantity of slag and furnace walls in these contexts is quite similar, pointing to a regularity in distribution of finds within them. The amount of slag in the majority of the explored contexts is greater than the amount of furnace walls, with the exception of SU 5 and 16, which are presumed to be in connection with the remains of the furnaces based on the field record (Fig. 3/a). The majority of the slag represented in individual contexts and in bulk, is the tap slag, followed by furnace slag (Fig. 3/b). The latter two are also represented in similar ratios within individual contexts. Other types of slag occur in multiple contexts, but are generally underrepresented. The data on average mass per piece (g/pc) (Tabs. 3 and 5; Fig. 4) reflect the fragmentation level of different types of finds within a single context. Fragmentation level is reciprocal to the value of mass per piece, the greater the latter value the lesser the fragmentation, i.e. individual pieces are heavier/bigger on average. Since slag and furnace walls are quite uniform types of material, as opposed to ceramics from different periods in one context, the comparison of the level of fragmentation between individual contexts can imply similarities and differences in their formation, and can consequently be an additional argument for the analysis of potential workspace use or post-depositional changes. The data show relatively similar values for the majority of contexts, but it is possible to distinguish at least three groups by natural breaks for the total fragmentation level of finds: 1) low values (SU 27, 31, 8, 6) 2) medium values (SU 21, 5, 15, 16, 18, 19, 29), 3) higher values (SU 1/ 2,3,4,5,6,7) and 4) high values (SU 25) (Fig. 4). Group 1 is composed of units that belong to fills, possibly of some construction(s) post holes found around the edges of Group 2. Group 2 consists of superimposed layers concentrated in one area, where remains of furnaces have been identified. Group 3 refers to the surface of layers in contact with the ploughed zone and the last single context (Group 4) is located close to the layer sequence of Group 2, and consists of a single find of slag and three pieces of furnace walls within a shallow fill.

Discussion

Technology of iron production – raw material use, reduction and post-reduction activities

The types of slag, technical ceramics and the archaeological field record (burned bottom) testify to the design of the furnace and the way it was operated. They were freestanding shaft furnaces, with relatively thin walls from which the slag was partially discharged. The ratio between tap slag and furnace slag testifies to the management of individual smelts – the majority of the slag formed in a single smelt was discharged. The slag was tapped at the bottom of the furnace, with a tool measuring approx. 2 cm in diameter, which is known from the remains of the tap slag rod (Pl.1/4 and Tab. 5). This type of basic iron production, and analogous types of furnaces are known from the Podravina region[18] as well as the wider scope of the Carpathian

[18] Sekelj Ivančan, Karavidović 2021; Karavidović 2022.

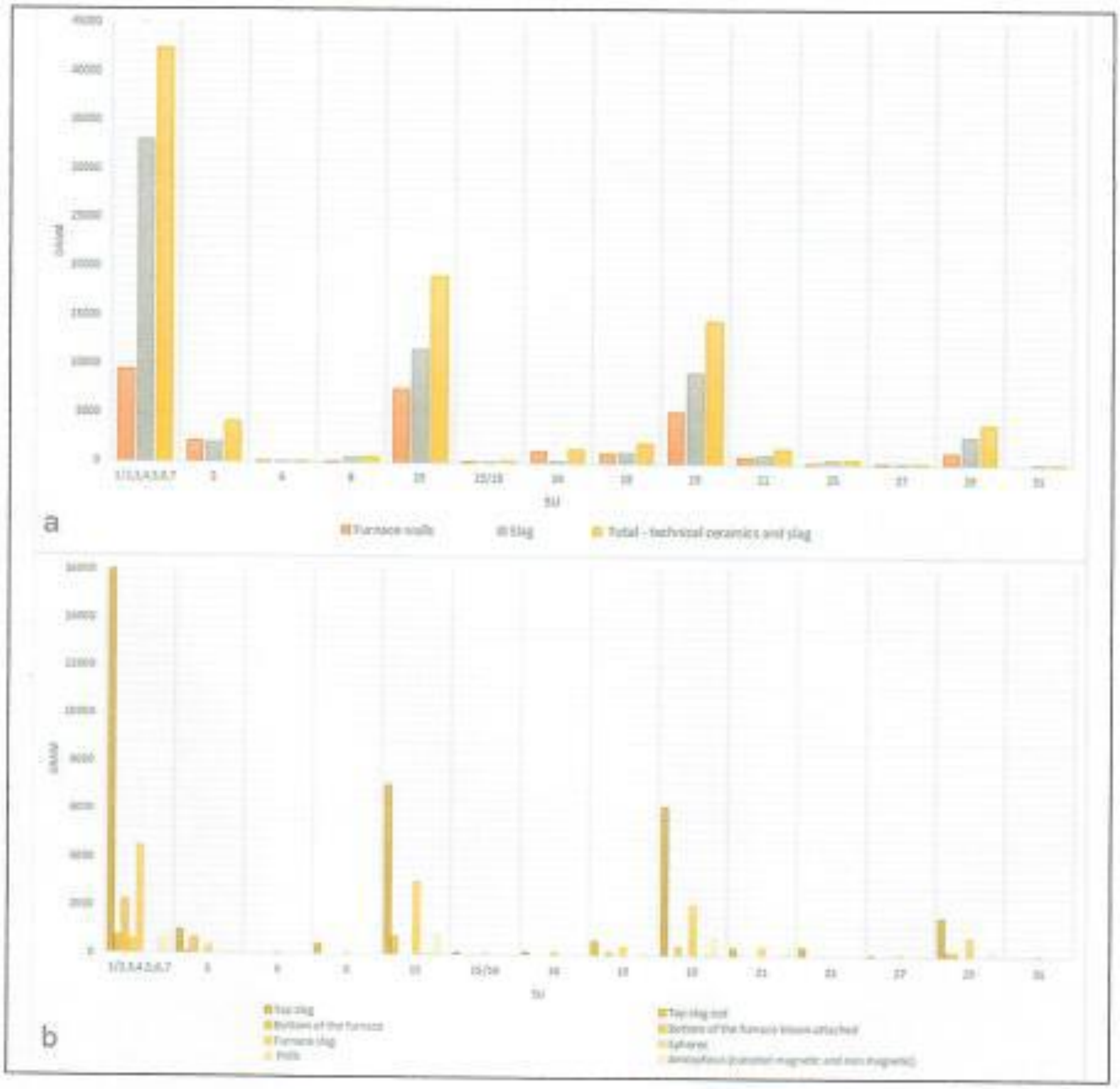


Fig. 3. Graphical representation of the quantity of iron production finds (technical ceramics and slag) in relation to context (SU).

Basin[19] and beyond. They date from Late Antiquity and are most common in the Early Middle Ages. The material finds from the Draganovac site are quite fragmented and the record is poorly preserved, so that details about the furnaces (height, diameter of the hearth, the existence of a movable plate/door) are not known. Based on the analogous types of furnaces found in the same region in the early Middle Ages (from the end of the 6th/7th – ¾ 8th centuries), the diameter of the hearth was between 28-40 cm (possibly even larger) and the furnaces had a removable plate at the front in which the tuyere was placed. This plate was removed at the end of the process to extract the iron bloom, suggesting that the furnaces were built to be used several times.

Some of the post reduction procedures such as the compressing of the bloom immediately after its removal from the smelting furnace, may have been carried out on the site. These could be represented by amorphous fragments of magnetic (iron bloom particles) and non-magnetic slag

[19] Bielenin 1977; Pleiner 2000, 172–188; Gömöri 2000a and 2000b; Gömöri, Török 2002; Gallina 2002; Gallina *et al.* 2007a and 2007b; Török *et al.* 2015.

(unknown category), spheres and prills. There are no features in the archaeological record that could be connected to this process, which could be entirely due to the simplicity of the setup, for instance, a wooden segment of a tree trunk could have been used as a surface for compression.

The use of bog iron ore is attested at all of the region's sites with traces of iron production, and deposits are presumed to be located all over the region, presumably in the close vicinity of some of the sites.[20] The preconditions for the formation of bog ores have been studied for the area of the second terrace of the Drava river,[21] lying closer to the river than the Draganovec site, which is on the fourth terrace. Data on the geological possibility of bog ore formation near the Draganovec site have not been studied in detail, so it is not possible to make a definite assumption about the location of deposits. Although the preconditions for iron ore formation are numerous,[22] a predictive model made for a site in the Podravina region[23] shows that some of these may have been met, in an area just north of the excavated workspace (Map 2) – a low - lying depression, where water occasionally stagnates during the hydrological year. Pedological research[24] shows that the soil composition is similar to other parts of the region where susceptibility to bog iron ore development has been proven, suggesting the possibility of deposits close by.

Site formation processes and workspace use

The spatial distribution and sequence of the layers (Fig. 1), as well as the quantitative distribution of finds related to iron production within layers (Figs. 3–4), can be interpreted in connection to the manner, intensity and/or duration of the workspace use. From the horizontal and vertical distribution of the layers it is evident that a central area of about 35 m² (layers SU 15, 5, 16, 18, 19) (Fig. 1/a) was involved in a more intense and continuous layer formation, while the surrounding area was not exposed to such depositing.[25] This could be due to a more active workspace use for iron production activities (preparation of raw material, smelting, compacting) and consequently more intense layer formation, translated into the archaeological field record as individual, thin layers of different colour and consistency, all saturated with iron production waste. The formation of layers and saturation with finds can be attributed to traces of structural needs of the smelting process – furnace remains (layers SU 5, 16, 17), but it could also be induced by side processes, like charcoal and ore storage, preparation and use, workspace maintenance – waste cleaning and continuous trampling. In comparison to other workshop environments in the Podravina region, there seems to be no designated dumping ground for larger quantities of slag. Instead, it seems that only an active workspace, with minor quantities of waste has been excavated. The latter could be provisionally argued by: 1) the uniform spatial distribution of the layer sequence, 2) the comparison of the frequency of occurrence of waste finds within layers, 3) the comparison of the degree of fragmentation of slag and technical ceramics in individual contexts on site and with other excavated workshops in the region, where the full scope of the workspace has been excavated and analysed,[26]

[20] Karavidović, Brenko 2022.

[21] Sekelj Ivančan, Marković 2017; Brenko *et al.* 2020.

[22] Brenko *et al.* 2020 and literature therein; Karavidović, Brenko 2022 and literature therein.

[23] Karavidović, Brenko 2022.

[24] DPK 2018; 2021

[25] If we include the spatial scope of single layers and fills around the central area, the total area measures 58 m² (layers SU 15, 5, 16, 18, 19, 7, 28, 32, 24), and the widest scope where iron production related finds were found is around 102.89 m². The latter includes the spatial scope of all excavated features in the trench.

[26] The full scope was estimated on the basis of systematic research that involved surface surveys and geophysical investigation prior to the opening of the excavation trench. (Mušič, Horn 2021).

4) the potential number of individual smelts and campaigns based on the data on tuyeres. The layers (SU 15,18,19) form on top of each other in an almost identical spatial scope (Fig. 1/a), indicating continuous deposition, which could be the result of active work, leaving residues of the process in a spatially restricted, designated workspace. The regularity of saturation with technical ceramics and slag types within two major superimposed layers (SU 15 and 19) (Figs. 3–4), indicates a similarity in the way the space was used, with a temporal difference in smelting events (SU 18). The similar quantity of different types of slag within the layers could be understood as a regularity in the quantity of the bloom iron produced, i.e. the number of smelts in a single smelting event and the way that the processes were carried out. This means that the space may have been used occasionally, perhaps seasonally in a preconceived way. This kind of workspace use could be driven by economical needs, availability of the raw materials or simply other characteristics of work organisation. The data on tuyeres can indicate two or three separate smelting events, with possible multiple individual smelts in a time framed event (Tabs. 3–4). The furnaces known from better preserved, relatively contemporary workshops in the Podravina region, had a removable door/plate in which a tuyere was inserted, so a single tuyere was used for a single smelting. The primary difference between groups of tuyeres is the way they were modelled (fabric, shape and dimensions) and fired before smelting (colour). These types of similarities within a group suggest that multiple tuyeres were made under the same conditions. It can be presumed that several tuyeres were made in the same manner and were fired under the same conditions from a single batch of raw material, and these were used for multiple smelts on an occasional or seasonal basis. The optimum number of tuyeres calculated suggests that there were 2-4 tuyeres in each of the three groups, possibly representing the number of smelting events and of smelts per campaign. Taking into account the groups of fragmentation level (Fig. 4), and the quantity and distribution of finds within contexts (Fig. 3), we can presume that these regularities correlate with the similarity in the use of space and/or secondary, post-depositional changes. The fragmentation groups also reflect spatial and structural characteristics of the contexts (type of archaeological unit), which would imply that the data show similarities in the workspace use rather than post-depositional changes. At the Hlebine Velike–Hlebine site, where a complete workshop has been excavated, there is a clear difference in the frequency and fragmentation level of slag and technical ceramics between areas used with different intensity depending on the type of activities practised.[27] The most intensely used areas (smelting, compacting/primary forging) have fewer waste finds both within a single context and in bulk, and a higher level of fragmentation of slag and technical ceramics, interpreted as a consequence of intense trampling and cleaning/maintenance due to active use. In relative terms, comparable to the available data from the Draganovec site record, this would mean that no whole pieces of tapped slag or larger pieces of furnace walls with tuyeres were found in the layers surrounding the remains of the furnaces,[28] as opposed to the designated dump site. The average mass per piece of slag and technical ceramics within a single context is a measure that reflects the level of fragmentation. The comparison of such data recorded at Draganovac (Tab. 5) and Velike Hlebine site shows that the figures correlate more closely with the area of intense activity where fragmentation levels are higher than with the designated dump site. The only context with a lower fragmentation level (greater mass per pc) is an isolated piece of slag found in a context beyond the presumed main, layered

[27] Karavidović 2022, 253–255.

[28] At the Hlebine–Velike Hlebine site, the exceptions are the *in situ* slag masses (within the remains of the furnace hearth) and small quantities of furnace walls and tuyeres, interpreted as the remains of the last smelting episodes at the site (Karavidović 2022; Sekelj Ivančan, Karavidović 2021, 67–71, Fig. 24).

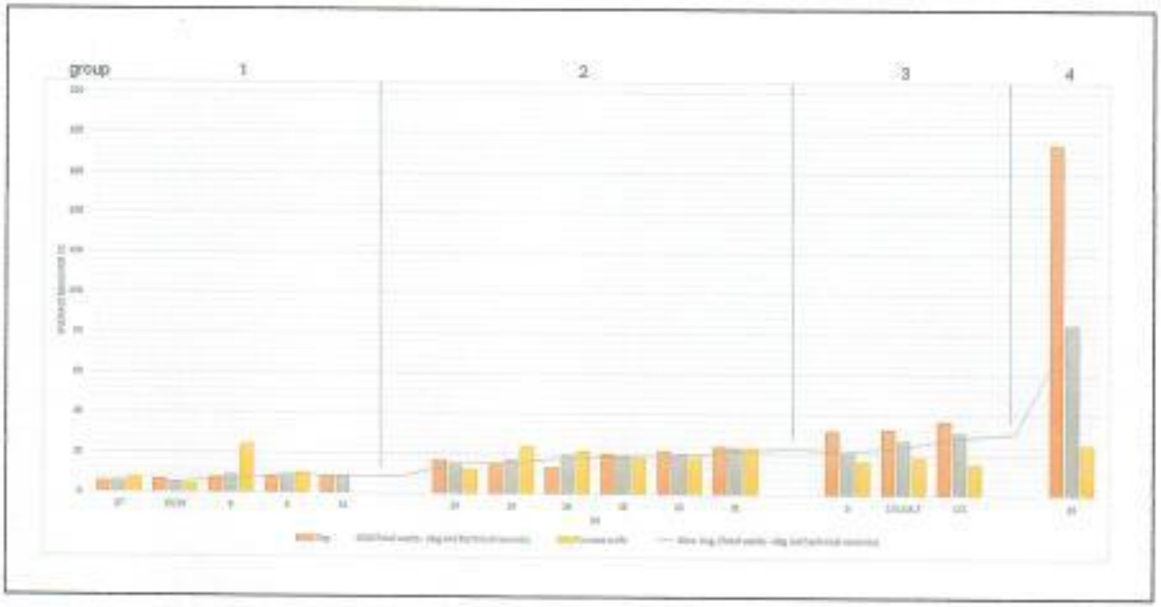


Fig. 4. Graphical representation of the mass per pc values (fragmentation level, groups 1-4) of iron production finds in relationto contexts (SU).

workspace (Tab. 5/SU 25; Figs. 1 and 3). In the excavated part of the Draganovac site there is no designated dump site, indirectly indicating a reduced need for major workspace organisation, that could be in connection with the amount of iron produced. Calculating the amount of bloom iron produced is some what ambiguous, but the state of research allows for some assumptions. From experimental testing of bog iron ore smelts, we can assume that the output of iron bloom to slag is between 0.15/20–0.5.[29] This would mean that the production of 18-45 kg of iron bloom could result in the slag quantity found on the site. Dividing this by the optimum number of tuyeres (7-8), a bloom would weigh between 2.5 and 5.6 kg. Experimental tests have shown that these kinds of blooms could easily be made in furnaces with a hearth dimension of 30-40 cm, known from the Podravina region in the 7th and 8th centuries.

The functional and temporal diversity of other finds in layers attributed to the workspace could imply other formation mechanisms of the stratigraphic sequence seen at the Draganovec site, such as long-term post-deposition environmental formation processes. These can be attributed mainly to naturally and anthropogenically induced erosion and potentially, flooding. The lowland area of the Drava River terraces generally has low erosion potential/risk, but the Draganovac site is located on the edge of the alluvial plain, just beneath the slopes of the Bilogora Mountain, where the risk is more pronounced.[30] Erosion as an exodynamic process includes the separation, movement and transport of particles by different agents, such as wind, water or ice.[31] The way that agents can affect erosion depends on a number of factors – primarily climate conditions, rock or soil type, relief, land use and vegetation cover. Identifying susceptibility for erosion and predicting spatial patterning of the eroded material/sediment in an area[32] and consequently the potential influence on formation of archaeological record is a complex question that involves various environmental data. Variables that are common in predictive modelling account for the factors of influence on erosion

[29] Karavidović 2022, 229-230, Tab. 5.2, 5.3 and reference therein.
[30] PFRA 2019.
[31] Benac 2013.
[32] Howland *et al.* 2018; Bezak *et al.* 2024.

potential.[33] None of the erosion models acquired through the use of GIS are applied here due to the lack of data required, and importance of elemental variables that are hard to conceive for the erosion of archaeological layers.[34] Nevertheless, the available geomorphological, pedological and hydrological data, as well as the analysis of archaeological artefacts can provide a relative, positive implication for the environmental formation processes at the site. The position of the excavated part of the site in relation to the relief features and the position of the excavated and surveyed parts of the antique/late antique site[35] with identified dwelling spaces gives a clear indication of a high relief inclination (slope) for a short length (direction south-north), directly on the excavated site with settlement features, towards the area of the workspace and a mild long slope further north, towards a deeper part of the depression, a swampy area (Map 2). The steeper the slope in relation to its length, the greater the risk of erosion.[36] In this case, the steepest slope (between 5-7.8%) is south of the excavated area (map 2/profile line 1), where antique/late antique structures were found, suggesting the greatest potential for erosion in the area observed. The terrain where the presumed workshop remains were found is lower with a very slight change in altitude over a greater length. This area presents a lower risk of erosion and is more prone to sediment accumulation (map 2/profile line 1-4). The geomorphological data for the area suggest past erosion and fluvial processes. Colluvial sedimentation[37] has been defined in the wider area of the Draganovec site by pedological research,[38] and the geological substrate consists of Holocene eolian sands and silty sands and other Pleistocene fluvial deposits.[39] The latter types of deposits are quite erodible,[40] and

[33] Geographical information systems have been applied to some archaeological sites in order to predict the erosion potential/risk, and hence the distribution of archaeological material (Howland *et al.* 2018 and reference therein). These predictions use pre-defined variables to describe the type of erosion, such as rain-induced erosion (RUSTLE – (Revised Universal Soil Loss Equation) (Renard *et al.* 1997)) or a variety of water-driven erosion processes (EPM – Erosion potential model), to which an area of interest is susceptible (Bezak *et al.* 2024 and reference therein). The latter use various factors for modelling such as rainfall erosivity factor (a measure of the degree to which local conditions of precipitation cause erosion), the soil erodibility factor (the potential of the soil to erode according to the type of soil), the length-slope factor (the influence of topography), and cropping and conservation practice factors (the effects of vegetation and slope).

[34] Commonly used environmental variables are described in the fn. 20. In the case of sediments presumed to have been eroded in the past, the prediction of erosion of archaeological layers lacks elementary data such as the structure of original sediments and presumed soil erodibility, data on vegetation cover and precipitation in the periods under research.

[35] Traces of early and high medieval occupation were not identified during the excavations, which does not exclude their existence in the wider area. Given the interpretation of layer formation provided in this work, complete erosion of previously existing archaeological layers cannot be ruled out either and would explain their absence from the archaeological record excavated south of the workspace. The earlier research of Draganovec–Piretis site (see introduction), mentions the use of construction material from the Roman period by "later inhabitants in the medieval period".

[36] Ganasri, Ramesh 2016.

[37] Other soil types defined for the area of the Bilogora Mountain slopes are loess, pseudeogley and gley soils, which have different erodibility coefficients (Bezak *et al* 2024, Tab. 1).

[38] DPK 2018; 2021.

[39] Aeolian sediments are represented by fine and medium-grained sand and silty sands. These are Holocene fluvial deposits of the Drava and Mura rivers. Due to the action of strong northern winds, the sand fraction of these unconsolidated fluvial deposits was transferred and accumulated in today's areas, among them the south-eastern slopes of the Bilogora Mountains where the Draganovec site is located. The fluvial deposits formed during the Pleistocene in the area of the Kalnik-Bilogora Mountains consist of gravel and sand with interlayers and lenses of silt and clay and constitute the fourth terrace of the Drava River (Velić, Vlahović 2009, 97, 99; HGI 2009).

[40] Posarić 2018, 13–14, Fig. 3/2, Tab. 3/1: 1, 5.

have the highest soil erodibility coefficient.[41] They are defined as loose soils. The structure of the archaeological layers that would possibly erode onto the excavated area is unknown, but we can assume that there are differences between the saturation with archaeological finds and organic residues, which implies a variable structure and looseness of the sediment.

Accompanying post-depositional disturbance of the record in recent times could be related to the agricultural land use, primarily ploughing, evident through traces of plough at the level of the archaeological layers (although not recorded as a direct cut into the archaeological record) and the high representation of a full variety of archaeological finds on the surface and within the topsoil layer (tab. 1-5/SU 1; Figs. 2–3). Ploughing can redistribute near-surface artifacts, eventually destroying the spatial context and the integrity of archaeological finds. It can also level out differences in relief to some extent and systematic agricultural land use impacts the vegetation cover.[42] Both factors could increase erosion possibility, in more recent times. The arable, ploughed lands have generally low vegetation protection which, if not managed, increases the risk of erosion.[43] Some influence on the all location of finds could also be attributed to flooding processes that should be expected in the excavated area, due to the shallow depression just north of the excavated trench, an evidently swampy area (observed vegetation cover, relative moisture of the area) and seasonal flooding (ground water table regime fluctuations and accumulation of stagnant water through rainfall) known through the lowland Podravina region. The first layers below the ploughed topsoil (SU 4, 3), characterised by grey soil with few or no archaeological finds may indicate the effects of flooding on the substrate and on the archaeological layers. The strongest argument in favour of the layers being part of the workspace related to iron production, rather than part of a layer exclusively formed by environmental factors, are the few, presumably *in situ* remains of furnaces and several small regular pits (probably remains of a wooden post) seen in the record. The finds unrelated to iron production in these layers maybe the result of gradual long term post-depositional environmental processes of layer formation. Continuous use and cleaning of the workspace may also have disturbed the record of earlier activities or layer formation processes. The post-depositional relocation by erosion of finds older than the iron production workshop could be attested by the dimensions of the ceramic finds (high degree of fragmentation) and the low possibility of joining the pieces found within layers. The high number of individual vessel shards within a single context suggests a possible secondary influence on the formation of the archaeological record.

Finds from different time frames occur in most of the layers that are a part of the presumed iron production workspace, but a regularity in representation with respect to the stratigraphic sequence can still be observed (Fig. 2). The representation of finds from individual periods in layers is some what proportional to the stratigraphic sequence, especially when comparing two major superimposed layers. Finds from individual periods are more strongly represented in the deeper layer (SU 19), while their representation decreases in the upper level of the excavated record (SU 15), although these layers are of similar spatial distribution and thickness. This would imply an intensive erosion prior to the use of the workspace and more intense primary deposition due to the workshop use. Since the workspace could have been used occasionally, erosion could have continued throughout the period of use. The pottery fragments dated to the High Middle Ages occur within the topsoil layer and two contexts (SU 29, 25). They do not appear within the layers that

[41] Bezak *et al.* 2024, Tab. 1.
[42] Huisman *et al.* 2019.
[43] Bezak *et al.* 2024, Tab. 2.

were probably formed under multiple influences, and were associated with the most active work area. The spatial distribution of this ceramic material (Figs. 1–2) suggests that the erosion process which carried with it archaeological material from preceding periods and the sedimentation at the base of the elevation may have been predominantly triggered before the High Middle Ages. Based on the stratigraphic sequence, the recognised flooding event(s) (SU 4 and 3) would have occurred after the occupation phase or erosion event from the High Middle Ages. Continuous or long term erosion can also be presumed, as the fillings of the mentioned pits also contain material dated to Antiquity and Early Middle Ages, suggesting that they were filled after the abandonment of these structures. On the other hand, this may have also been caused by the flood-induced collapse of the eroded layers into which the pits were cut, after their abandonment.

The timeframe of workspace use and temporal and spatial context of iron production in the Podravina region

The ceramic material from the presumed occupation levels and structures interpreted as furnace remains is quite variable (Tab. 2 and Fig. 2). The only piece of pottery found in connection with the structure SU 16 is dated to Late Antiquity. Two pieces associated with structure SU 5 are dated to Antiquity, while the main occupation level with which the two structures were associated, contained pottery from Antiquity, Late Antiquity and the Early Middle Ages (SU 15). The same is the case with the layer below the SU 15 (SU 19). The relative dating of ceramic material overlaps with the period when other excavated iron workshops functioned on the territory of the Drava River Basin – Late Antiquity and the Early Medieval Period.[44] Relative dating by macroscopic slag analysis is not possible, because the basic technology for the production of bloom iron, and thus the main types of slag, are quite similar at the Late Antique and Early Medieval sites in this area,[45] although there are differences that suggest a gradual evolution of iron production.[46] In order to better define the date of the workshop's operation, a piece of charcoal, found in the debris of the *in situ* record – remains of the furnace (SU 5) – was sent to Queens University Belfast for analysis.[47] The results indicate that the iron production activity should be dated to the Early Middle Ages, the earliest date being the last quarter of the 7th century and the latest the last quarter of the 8th century, with a median probability of the end of the first quarter of the 8th century (AD 723) and highest probability in the timeframe AD 711 to 774. The relative dating of the Early Medieval ceramic material found within the excavated layers, gives a wide potential timeframe. Parallels for decorated pieces can be found at numerous sites in the Podravina region. While some of these decorations occur over a longer period, others have a narrower dating range. Based on the different types of decoration in closed archaeological contexts, the earliest presumed date could be set at the end of the 7th and beginning of the 8th century, while the latest possible date could be set within the second half of the 9th century, i.e. between Torčec II to Torčec IIIa phase.[48] Unfortunately, such a wide timeframe does not allow for a clear presumption about the temporal relationship between the use of the workspace and a potential settlement/habitation in the near vicinity. As the ceramic

[44] Sekelj Ivančan, Karavidović 2021, 81–83; Botić 2021.

[45] Sekelj Ivančan, Karavidović 2021, 83.

[46] Karavidović 2022.

[47] The piece was collected at the contact of SU 15 and SU 5, Sample U-8; UBANo 46636. The results are: Radiocarbon Age BP 1282 +/- 19; 68.3 (1 sigma): cal AD 678–706 (0.491); cal AD 726–731 (0.070); cal AD 736- 750 (0.216); cal AD 758–773 (0.223); 95.4 (2 sigma): cal AD 672–709 (0.409); cal AD 711–774 (0.591); Median probability: 723.

[48] Sekelj Ivančan 2010, 119–123, 126, 152–153.

fragments were found in layers that formed under the probable influence of erosion, flooding and iron production activity, as well as more recent disturbance by intrusive land management, it is possible that the finds indicate the existence of the settlement prior to the establishment of the workspace, at the same time, and after the workspace was abandoned.

In the Podravina area, there are two excavated iron production sites, Virje–Sušine (S-7 and 8) and Volarski breg (S-2b), dating from the period ²/₂ of the 7th century and mid or ¾ of the 8th centuries.[49] At these sites, activities of primary production (smelting and compacting), but also secondary, post-reduction processes on semi-finished products, i.e. forging, have been defined. Both sites are closely associated with settlement areas, that is, elements understood as more permanent habitation markers – pottery fragments and waste disposal features. At the Volarski breg site, reduction and post-reduction slags were found in the pit filling in association with ceramic material, relatively dated to the broader period ²/₂ 7th century – 8th century with a higher tendency towards the 8th century.[50] Smelting furnaces were not visible in the archaeological field record, and it seems that it is a matter of depositing different types of waste, considering the association[51] with other archaeological finds in fills, which indicate the habitational character of the record. In this period, the association of settlement areas with different stages of iron production is visible in the preparation of raw materials (poor quality ore, i.e. discriminated parts of ore conglomerates), reduction and post-reduction procedures, which may suggest a change or variability compared to the earlier or later periods, when areas where smelting activities were carried out were separated from the contemporaneous settlements.[52] In the case of Draganovac, we can also assume a more intense spatial connection between the settlement and the workspace.

The Draganovac site is located on the fourth terrace of the Drava River,[53] whereas the majority of the smelting sites in the Drava basin are concentrated in the area of the second terrace.[54] Nevertheless, the Draganovec workshop is not spatially isolated, as are other sites with presumed smelting activities Bakovčice–Nađbarice 1, Bakovčice–Velike livade and Glogovac–Selište, located on the edges of the Drava alluvial plain (Map 1).[55] The dating of these sites is ambiguous, as they have been defined only by field surveys, and the accompanying time sensitive material such as pottery fragments cannot be taken as irrefutable markers. Bakovčice–Nađbarice 1 is the only site with surface finds datable to Antiquity and the Early Middle Ages,[56] which opens up the possibility of dating the remains of iron production to the Early Middle Ages, assuming that they could be directly spatially associated with the iron production workspaces.

[49] For archaeological field record see Sekelj Ivančan, Karavidović 2021. For dating: Botić 2021. For overall interpretation of the finds and contexts see Karavidović 2022.
[50] Sekelj Ivančan 2021, 158–163, Figs. 11–12.
[51] Sekelj Ivančan 2021, Tab. 1/ SJ 107 and 111.
[52] As suggested by the example of the earlier: Hlebine –Velika Hlebine (S-1,2) and Virje Sušine (S-5) site, and the later Virje Volarski breg S-1 site (Karavidović 2022, 267–273).
[53] Valent *et al* 2021, Map 1.
[54] Sekelj Ivančan, Karavidović, 2021, 46–47, 66, 81; Valent *et al.* 2021, 5, Map 1.
[55] Valent *et al.* 2021.
[56] Valent *et al.* 2021, Map 1, Table 1: 1, 3, 29.

Conclusion

The analysis of the archaeological record of the excavated part of the Draganovec site and its topographical position show a high probability of several processes of site formation– those of active space use for smelting and compacting activities and post-depositional, environmental and anthropogenic sedimentation. The latter is supported by the analysis of the known natural preconditions for erosion and flooding and the more recent influence of tillage, as well as the stratigraphic sequence, the analysis of finds within individual contexts and the spatial distribution of recorded stratigraphic units and finds. The presumed workspace was used for smelting and compacting, while activities such as reheating were not confirmed in the archaeological field record or slag finds. The stratigraphic sequence and the analysis of the finds suggest that the workspace was used intermittently – occasionally or seasonally in at least two smelting campaigns, with possibly quite similar amounts of waste i.e. quantity of iron produced. The period of use has been defined by radiocarbon dating, the earliest suggested date being the last quarter of the 7th century and the latest the last quarter of the 8th century. The basic technology for smelting consisted of freestanding shaft furnaces with a shallow hearth, from which the majority of slag was tapped out, a technology known to have been used in the wider Podravina region and parts of the Carpathian Basin in Late Antiquity and most commonly, in the early Middle Ages. The production of iron at the Draganovac site could be described as small scale, although the total quantity of iron calculated from the finds should be considered very relative. The workspace was located close to or within (possibly onthe edge of) the contemporary settlement, which is in line with the data on work organisation from contemporary sites in the Podravina region, Virje Sušine (S–7, 8) and Volarski breg (S–2b). The Draganovec site is located at the far end of the Drava alluvial plain, on the edge of the slopes of Bilogora Mountain, while the majority of the known traces of iron production in the region are concentrated on the second terrace of the Drava, closer to the river. Their location testifies to a spatially wider network of iron production sites known in the region in the Early Middle Ages.

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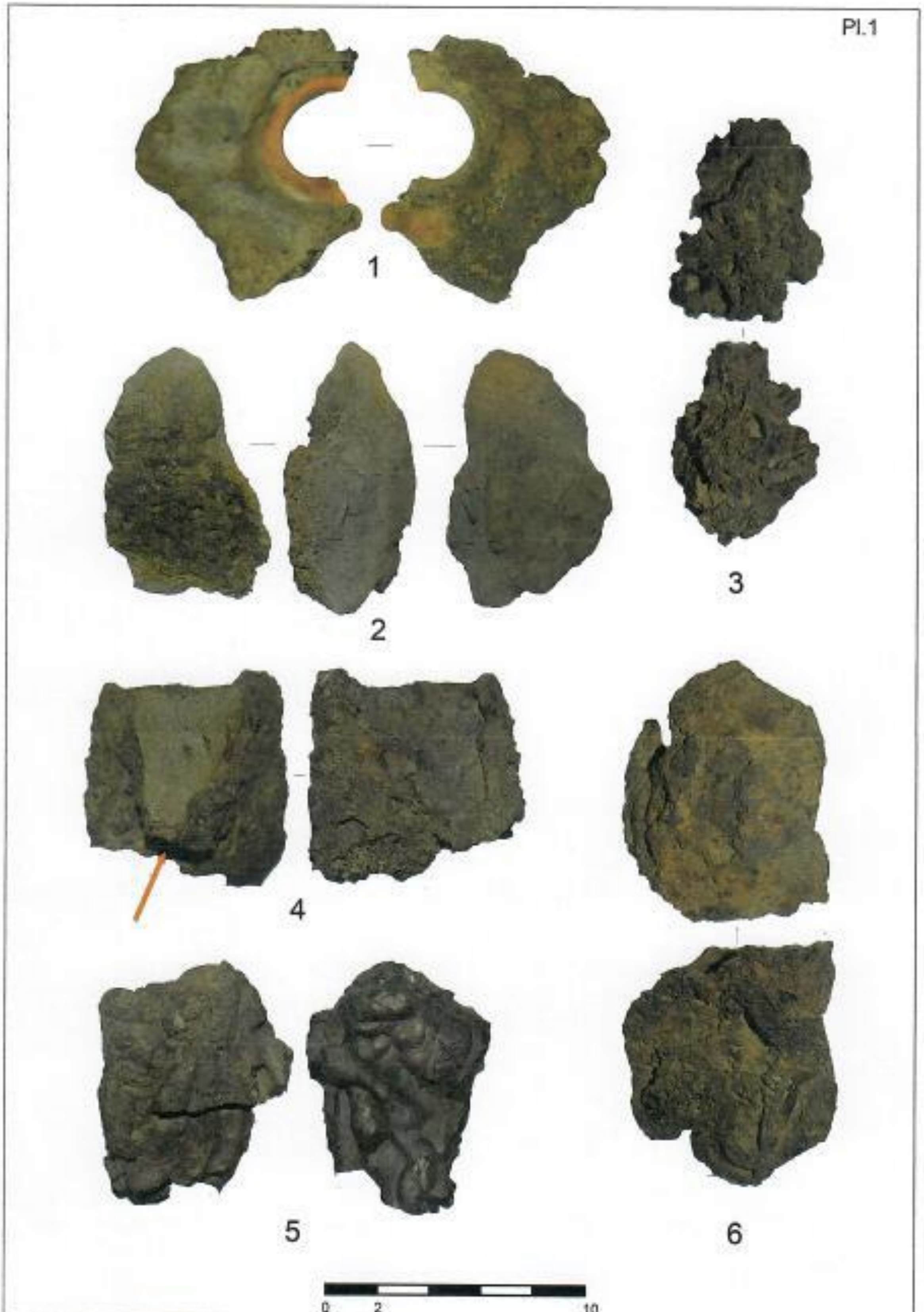

Pl. 1. Technical ceramics: tuyere (1); furnace walls (2); slag (3); tapped slag rod (4); tap slag (5); furnace bottom slag (6).