SEASONAL SETTLEMENT

IN THE MEDIEVAL AND EARLY MODERN COUNTRYSIDE

edited by PIERS DIXON & CLAUDIA THEUNE

RURALIA XIII

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Contents

In which part of the year did iron smelting occur in the Drava valley?

Ivan Valent, Tajana Sekelj Ivančan** and Renata Šoštarić****

Abstract

During extensive field surveys conducted in one part of the Drava river valley, numerous sites of iron smelting workshops have been identified. For the past 10 years, several of these smelting workshops, dated to Late Antiquity and the early medieval period, have been excavated. It was realised that the furnaces were not isolated in the landscape, but rather that they were located in the close vicinity of settlements, always by a creek, on a small slope, and within a landscape that retains water, which enables the accumulation of bog iron ore in the soil. Due to the fact that the smelting process is highly complicated and requires good preparation as well as good execution, it is believed that it took place during summer and early autumn. The reasons for such a hypothesis lie in the fact that before the smelting process could even begin, certain necessary preparations that included the collection of ore and wood, the drying of logs, and the preparation of charcoal, essential for the process, had to have been completed. Furthermore, archaeo-botanical evidence found within the walls of one furnace, as well as within the settlement, supports the same hypothesis.

Keywords: *Drava river valley, bog iron ore, furnace, smelting, workshop, archaeo-botany.*

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Résumé

Quelle était la bonne saison pour la fonte du fer dans la vallée de la Drava?

Des recherches intensives étaient à la base de la découverte de nombreuses bas-fourneaux dans une partie de la vallée de la Drava. Plusieurs d'entre eux, datant de l'Antiquité tardive et du début du Moyen-Âge, ont été examiné de près ces dernières dix années. Il s'est averé que ces bas-fourneaux n'étaient pas isolés dans le paysage, mais toujours proches d'habitats, le long d'un ruisseau, sur une petite élévation et dans un environnement naturel favorable pour l'accumulation du minerais de fer marécageux dans le sol.

La fonte de fer est un processus très compliqué nécessitant une bonne préparation ainsi qu'une bonne exécution, on pense qu'il a eu lieu pendant l'été et au début de l'automne : en effet, avant même que le processus de fusion ne puisse commencer, certaines préparations nécessaires qui comprenaient la collecte du minerai et du bois, le séchage des bûches et la préparation du charbon de bois, qui étaient essentielles pour le processus, devaient avoir été effectuées.

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L'hypothèse est soutenue par des analyses archéobotanique des parois d'un bas fourneau et de l'habitat.

Mots-clés : *vallée de la rivière Drava, minerai de fer marécageux, bas-fourneau, la fonte, atelier, archéobotanique.*

Zusammenfassung

Zu welcher Jahreszeit wurde im Drau-Tal Eisen verhüttet?
In einem Teil des Drau-Tals wurden im Zuge von extensiven Untersuchungen an vielen Stellen Eisenrennöfen gefunden. Innerhalb der letzten 10 Jahre sind einige dieser Eisenrennöfen aus der späten Antike und frühem Mittelalter ausgegraben worden. Es wurde klar, dass diese Rennöfen nicht für sich stehend in der Landschaft gebaut, sondern dass sie stets in der Nähe von Siedlungen errichtet wurden, immer am Ufer von Bächen oder am Abhang bzw. sogar als Teil einer Landschaft, wo man Wasser stauen könnte, um Sumpfeisenerz zu gewinnen. Bezogen auf die Tatsache, dass Eisenverhüttung ein sehr komplizierter Prozess ist, der gute Vorbereitungsarbeiten erfordert, um Eisen zu produzieren, sind wir der Meinung, dass diese Arbeiten im Sommer und im frühen Herbst stattfanden. Die Gründe hierfür mögen in den nötigen Vorbereitungsarbeiten liegen: man musste Eisenerz finden und Holz trocknen um Holzkohle zu gewinnen, die beiden Hauptkomponenten bei der Eisenproduktion. Ohne diese Vorarbeiten könnte man den Prozess nicht starten. Außerdem tragen archäo-botanische Evidenzen, die in einem der Rennöfen und innerhalb einer Siedlung gefunden wurden, zu dieser Hypothese bei.

Schlagwörter: *Drau-Tal, Moor, Eisenerz, Rennofen, Werkstatt, Archäo-Botanik.*

Introduction

During intensive field survey conducted over the last 40 years in the area of Podravina and Prekodravlje by the staff of the Museum of the City of Koprivnica, the Institute of Archaeology, and amateur archaeologists (I. and Z. Zvijerac from Torčec, J. Cugovčan from Podravske Sesvete, M. Alečković from Hlebine, and R. Pavleš from Starigrad), hundreds of archaeological sites have been discovered dating from the Late Neolithic to the early modern period.

Standing out among the numerous new locations is the Virje site with its two positions: Volarski breg and Sušine (Fig. 1). During the systematic field surveys of the Virje area during 2007 (*Sekelj Ivančan 2007*, 73-79), a large amount of smelter slag was found at Volarski breg, on the basis of which the first rescue archaeological excavations of smelting furnaces in the Podravina area were undertaken (*Sekelj Ivančan 2009*, *2010*), which also represented the first archaeological research related to iron-ore smelting furnaces in the Republic of Croatia.

Excavations began in 2008, and soon became systematic, with several excavation campaigns conducted over the next few years at the following sites:

1) Virje-Volarski breg (2008, 2010, 2012) (*Sekelj Ivančan 2007*, *2009*, *2010*, *2011a*, *2011b*, *2013*, *2014a*, *2016*, 120, *2017b*; *Sekelj Ivančan et al. 2019*);
2) Virje-Sušine (2012, 2013, 2014) (*Sekelj Ivančan 2013*, *2014a*, 163-164, *2014b*, *2015*, *2016,* 120, *2017a*, *2019a*; *Sekelj Ivančan – Karavidović 2016*; *Sekelj Ivančan – Mušić 2014*; *Sekelj Ivančan – Tkalčec 2018*);
3) Hlebine-Velike Hlebine (2016, 2017) (*Sekelj Ivančan 2016*, 121-122, *2018*; *Sekelj Ivančan – Valent 2017*);
4) Hlebine-Dedanovice (2018) (*Sekelj Ivančan 2019b*).

Furnaces were found at these sites that can be related to the production or processing of iron, and the best known are smelting furnaces with a shaft, such as are known throughout the broader European area (*Gömöri 2000*; *Pleiner 2000*). Although investigations have confirmed this branch of economic activity in the Late Antiquity period (*Sekelj Ivančan – Mušić 2014*, 178-179, n. 8) and the early medieval period (*Sekelj Ivančan 2010,* 34-35, n. 2, 3; *Sekelj Ivančan 2017b*, 119), the surface finds of pottery along with pieces of the furnace walls, smelting slag, and nozzle sections discovered within archaeological units all indirectly indicate that this activity took place continually in the Podravina region from the period of the late Iron Age to the early modern period (*Sekelj Ivančan 2016*, 123; *Valent et al. 2017*, 22).

Several years after the first excavations, and on the basis of the results then available, the scientific research project TransFER (IP-06-2016-5047), 'The production of iron along the Drava River in the Roman and medieval periods: the creation and transfer of knowledge, technology, and goods', was begun, financed by the Croatian Science Foundation, within the same framework as the work that is presented in this chapter. One of the first tasks of the project was the creation of a database of sites where smelting activity had taken place. This database was composed on the basis of systematic field surveys carried out up to the present, survey reviews, and new field surveys (*Valent et al. 2017; Valent et al. 2018; Valent et al. 2019*), and so far it includes more than 70 sites where on the basis of surface finds of smelting slag, nozzles or furnace wall fragments this specific activity can be hypothesised (*Valent et al. 2017*; *Valent et al. 2018*; *Valent et al. 2019*). By mapping the sites where the finds of the smelting activities were identified, it was observed that their distribution follows the course of

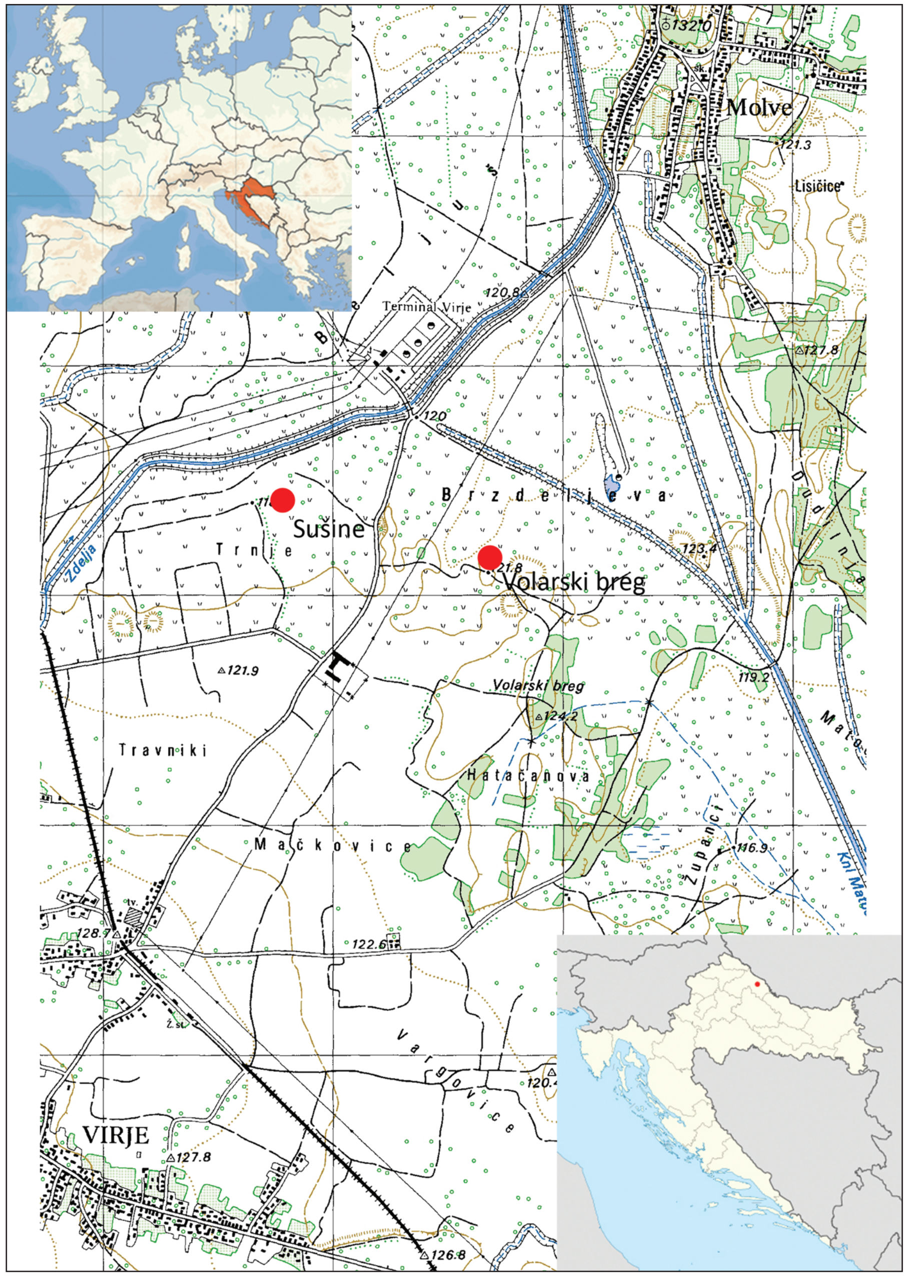

Fig. 1. Locations of the archaeological sites Virje-Volarski breg and Virje-Sušine (© Tajana Sekelj Ivančan and Ivan Valent).

the Drava river (northwest to southeast) and that most of them are located in the lowland area along the river, *i.e.* in the Drava floodplain and Drava terraces (*Valent et al. 2017*, 6-7, Fig. 1). The data obtained were compared with the results of field surveys carried out in the Hungarian region of Berzence, Somogy District, which showed similar or identical patterns of spatial occupation for this type of site (*Zatyko 2013*).

The geological background

In order to define the reasons why the smelting workshops were located precisely in the area of the Drava floodplain and terraces, it is necessary to understand the complete process of smelting activity. As in the case for any other activity, it cannot take place unless the basic prerequisites for it exist, in this case a source of the raw material – iron ore – but also the other natural resources necessary for successful completion of the entire process: clay, water, and wood. For this reason, it is necessary to consider the geological, pedological, and hydrographic background of the area in which such activity takes place.

The Drava river, together with numerous meanders, small streams, and tributaries, has always been the main component forming the region of Podravina and Prekodravlje (the lowlands on both the southern and northern banks of the river), and the most significant feature of its floodplain and terraces is marshy land. These wetlands within the otherwise low-lying area are intersected by small crests and aeolian-fluvial deposits, which together with river terraces and small terraced 'cliffs' compose the main relief components (*Feletar – Feletar 2008*, 178-179; *Valent et al. 2017*, 10). Analysing the soil composition in the vicinity of iron-ore smelting workshops at the sites of Virje-Volarski breg and Virje-Sušine, which are located on the second Drava terrace, it was determined that this area, due to the geological composition of the soil, the hydrographic network, and the groundwater regime, is extremely favourable for the creation of bog iron, which could have been exploited during the operation of the workshops (*Sekelj Ivančan – Marković 2017*). This recognition is possible, as was the case under analysis, on the basis of soil discoloration caused by the presence of iron oxides in the soil, as well as stagnant water. These two elements are the most recognisable visual markers of the presence of dissolved iron in water and the presumed presence of iron oxides in soil (*Weronska 2009*). Such areas of stagnant standing water, like the position of the toponym Sušine, in the Đurđevec area are called *pajn* (*Sekelj Ivančan et al. 2019,* 63*)*. To confirm the first results suggesting the possibility of the formation of bog ores in the area of the Drava basin (*Sekelj Ivančan – Marković 2017)*, an additional 44 soil profiles were sampled at other locations where during systematic field survey indicative finds had been gathered indicating smelting activities. Of the sampled profiles, six were analysed in detail, and mineralogical analysis confirmed the presence of iron oxyhydroxides. The selection of samples for more-detailed analysis was made on the basis of visual observations regarding the highest concentration of iron oxides in the profiles, where it was determined that the geochemical content of iron varied in each, but was always elevated. Differences in the content of iron and other elements in each soil sample are conditioned by changes caused by groundwater levels (*Brenko 2018*; *Brenko et al. in press*). These analyses have made it possible to conclude that the area of Podravina and Prekodravlje was indeed a suitable place for the creation of bog ore, which was certainly exploited for the workshops for smelting iron ore. In addition, it should be emphasised that the area in the broader vicinity of Virje, as far as is now known, had the highest values in terms of the presence of iron oxides in the soil (*Brenko et al. in press*).

The selection of the sites where the smelting workshops were located was certainly not coincidental, as can be seen from the preceding discussion. However, the characteristics of the environment, which favour the creation of ore in marshy surroundings, in fact raise questions about when during the calendar year this activity could have taken place, considering the capriciousness of the Drava river and its tributaries and the variations in underground water, as well as the retention of precipitation in the ground during certain parts of the year. An answer to this question can perhaps be given by one find from the site of Virje-Sušine.

Virje-Sušine

During the archaeological excavations of the multi-strata site of Virje-Sušine in 2013, in Trench 7, along with the remains of a furnace for smelting iron ore, part of a workshop was also investigated where smelting waste had been deposited, which consisted of a large quantity of smelting slag, broken pieces of the furnace walls, and fragments of pottery nozzles (*Sekelj Ivančan 2014b*). The remains of the discarded material included a piece of furnace wall with a negative impression of a leaf. In order to determine the period when the waste was discarded, and hence also when the smelting workshop was in operation, a sample of charcoal gathered from the same

Fig. 2. Impression of a leaf fragment preserved in the remains of a furnace for smelting iron ore dating to Late Antiquity (© Tajana Sekelj Ivančan).

material was sent for radiocarbon analysis at Beta Analytic Inc., in Miami, Florida, USA (Beta 374149). The analysis dated the sample (U-190) to the period 1620±30 years before the present (Conventional Radiocarbon Age). The calibrated date would place the sample in the year AD 420, while other calibrated results (1 sigma calibrated result, 68%) place the sample in the period between AD 400 and 425, *i.e.* in the period between AD 385-475 and 485-535 (2 sigma calibrated result, 95%). CalPal (Online Radiocarbon Calibration) suggests a calendar year of Cal AD 456±51.

The discovered leaf impression was preserved during the construction of the furnace. The leaf fell by chance from a nearby tree onto the fresh clay and remained attached. In the course of time, the leaf disappeared, and only its impression remained, showing the main and lateral veins of the leaf, so that their arrangement could be clearly seen. Unfortunately, neither the edge of the leaf nor its petiole were preserved, which made identifying such a small fragment difficult (Fig. 2). Because the Virje-Sušine site is located in the continental lowland area of Croatia, with hills rising to a height of only a hundred meters, comparative material was collected to aid in the most precise possible identification of the sample – in the form of leaves of various plant species that represent an integral part of the natural forest vegetation of this area. A preliminary comparison of the comparative material with the preserved leaf impression was carried out by Prof. Renata Šoštarić (Faculty of Science, Department of Biology, Botanical Institute), a co-author of this text, and given the arrangement of the leaf veins, three deciduous trees were identified with which the negative leaf impression could be associated – European hornbeam (*Carpinus betulus*), wild cherry (*Prunus avium*), and black alder (*Alnus glutinosa*).

An experiment was carried out to determine more accurately which kind of deciduous tree provided the leaf. The leaves of the selected species were impressed into moist prepared clay, and after drying, the clay was fired in a muffle furnace at 600°C. In this manner impressions were gathered of the leaves in clay (Fig. 3) in order to make comparisons to the leaf impression of the wall of the iron-ore smelting furnace. It was established that all three species have a very similar arrangement of leaf veins, and none of them could be singled out merely on the basis of such structures. However, it was obvious that the alder leaves left a much deeper and clearer impression in the clay, like the clear and fairly deep impression of the leaf of the furnace wall, while the impressions of the hornbeam and cherry were barely visible. On the basis of the above, it was concluded that the leaf fragment that remained preserved via the impression on the remnants of the iron-ore smelting furnace from Late Antiquity most probably came from a black alder (*Alnus glutinosa*). The preserved

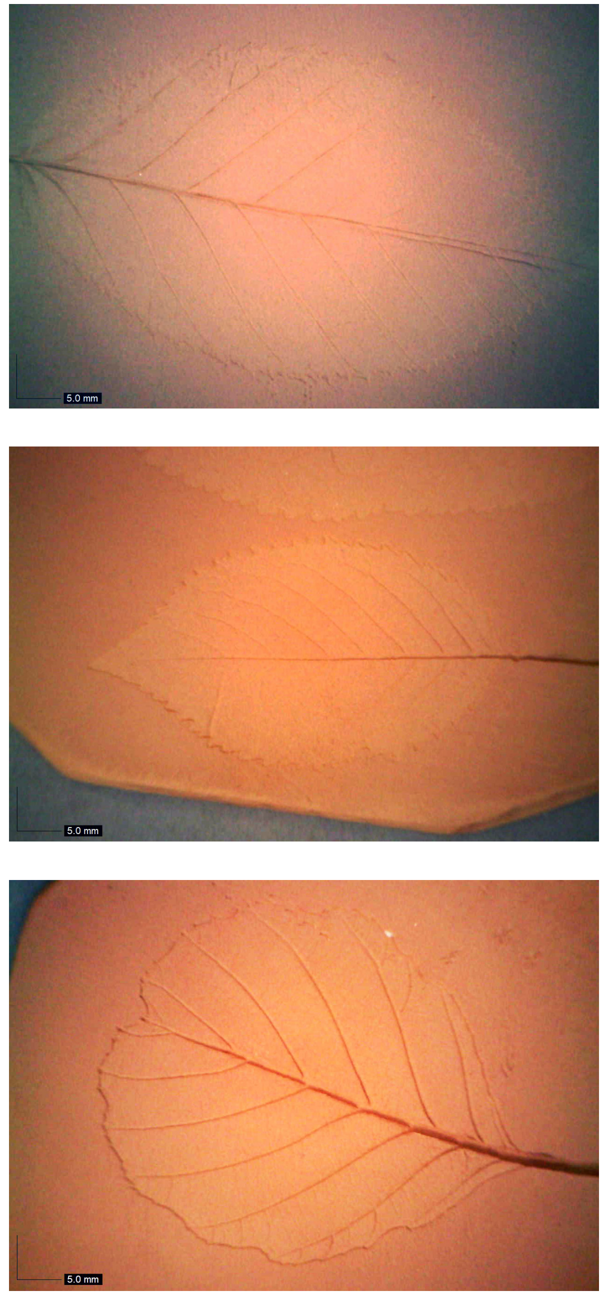

Fig. 3. Impressions of recent leaves of a) European hornbeam (Carpinus betulus), b) wild cherry (Prunus avium), and c) black alder (Alnus glutinosa) on fired clay (© Renata Šoštarić).

negative of the leaf has relatively small dimensions for the species to which it belongs, which might indicate a young springtime leaf. However, plants can produce new leaves on their outer branches throughout the growing season, from spring to late summer.

During the analyses performed to date related to the determination of the species of wood within the closed archaeological structures and units, carried out by the retired expert Dr. Sc. Metka Culiberg from the Biological

No.	Site	Trench	US	Interpretation	Smelting context (Yes/No)	Tipe of wood	No. of sam-ples	Datation	Bibliography -datation	Bibliography - wood samples
1	Virje - Volarski breg 2008.	S - 1	14a	fence	Yes	**Alder (Lat. *Alnus glutinosa*)**	3	Late 8th - late 9th century	*Sekelj Ivančan 2010*, 33-35, n. 2,3, plate 3	*Sekelj Ivančan et all 2019*, 55
2	Virje - Volarski breg 2008.	S - 1	95	well	No	Common Hornbeam (Lat. *Carpinus betulus*)	2	2nd - 1st century BC	*Sekelj Ivančan 2009*, 69; *Sekelj Ivančan 2010*, 35, n. 4	/
3	Virje - Volarski breg 2010.	S - 2	111	object	No	Alder (Lat. *Alnus glutinosa*)	3	Second half of 8th - beginning of the 9th century	*Sekelj Ivančan 2017b*, 119	*Sekelj Ivančan et all 2019*, 55, 60
4	Virje - Volarski breg 2012.	S-3	201	feature	Yes	**Common Hornbeam (Lat. *Carpinus betulus*)**	2	Late Antiquity context	*Sekelj Ivančan 2013*, 50-51, n. 3	/
5	Virje - Volarski breg 2012.	S - 3	201	feature	Yes	**Alder (Lat. *Alnus glutinosa*)**	2	Late Antiquity context	*Sekelj Ivančan 2013*, 50-51, n. 3	*Sekelj Ivančan et all 2019*, 55
6	Virje - Sušine 2012.	S - 5	240	feature	Yes	**Alder (Lat. *Alnus glutinosa*)**	6	Late Antiquity context	*Sekelj Ivančan 2013*, 50, n. 3	/
7	Virje - Sušine 2013.	S - 7	317	waste	Yes	**Alder (Lat. *Alnus glutinosa*)**	7	Beginning of the 5th century	*Sekelj Ivančan 2014b*, 100, n.2	/
8	Virje - Sušine 2013.	S - 7	321	channel/ elongated object	No	Common Hornbeam (Lat. *Carpinus betulus*)	1	Late Iron age	*Sekelj Ivančan 2014b*, 102	/
9	Virje - Sušine 2013.	S - 7	340	channel	No	Common Hornbeam (Lat. *Carpinus betulus*)	2	Modern perion, secondary context	*Sekelj Ivančan 2014b*, 102.	/
10	Virje - Sušine 2013.	S - 8	319	object/house	No	Wild cherry (Lat. *Prunus avium*)	2	8th century	*Sekelj Ivančan 2018b*, 37, 41-42, plate 5:34-44	*Sekelj Ivančan - Tkalčec 2018*, 37
11	Virje - Sušine 2013.	S - 8	330	fired doub	No	Common Hornbeam (Lat. *Carpinus betulus*)	4	Mid 11th - begining of 12th century	*Sekelj Ivančan 2018b*, 37, 41-43, plate 7:63-65	*Sekelj Ivančan - Tkalčec 2018*, 37
12	Virje - Sušine 2014.	S - 10	397	object	No	Alder (Lat. *Alnus glutinosa*)	2	end of 11th - early 13th century	*Sekelj Ivančan 2019a*, table 3,4	/
13	Virje - Sušine 2014.	S - 10	405	object/artifact	No	Common Hornbeam (Lat. *Carpinus betulus*)	6	end of 11th - early 13th century	*Sekelj Ivančan, T., 2019a*, table 5	/
14	Virje - Sušine 2014.	S - 10	436	object	No	Common Hornbeam (Lat. *Carpinus betulus*)	1	8th century	*Sekelj Ivančan, T., 2017a*, 117, Pl. 1-4	*Sekelj Ivančan 2017a*, 117

Tab. 1. Representation of samples of hornbeam, wild cherry, and alder within the analysed archaeological units at the sites of Virje-Volarski breg and Virje-Sušine (© Ivan Valent).

Institute 'Jovan Hadzija' of the SAZU Scientific Research Centre in Ljubljana, an exterior associate of the TransFER project, in the area of the iron-ore smelting workshops at Virje-Volarski breg and Virje-Sušine, the most comon type of wood was oak, but within the analysed units finds of hornbeam, alder, and wild cherry were also found (*Sekelj Ivančan 2017a*, 117; *Sekelj Ivančan – Tkalčec 2018*, 37; *Sekelj Ivančan et al. 2019*, 54-55, 60) (Tab. 1). It is visible from the table that wild cherry was represented by only one sample; hornbeam was represented within seven units, but only one with a smelting context; and alder was represented by six samples, four of which from within a structure with a smelting context. Comparing the results from Tab. 1, it can be noted that alder is the most common type of wood in terms of both quantity and frequency in the structures of these two sites, the context of which is related to smelting activity. If the above data are related to the fact that the experimental process confirmed that the negative of the leaf found inside the furnace wall in the waste area of the smelting workshop at Sušine most likely belonged to an alder, these data can serve to draw a conclusion about in which part of the calendar year the smelting activity could have taken place at our site.

Conclusion

If we look at the change of seasons in the Podravina area, which is dominated by a moderately warm and humid climate characterised by warm, sometimes hot summers and cold to harsh winters (*Feletar – Feletar 2009*, 183), it is evident that precipitation is greatest in late spring and early summer and also in late autumn, during October and November, while the least rain falls during winter, between December and March. In winter, the area is covered with snow, but given the climate, the average thickness of the snow cover is not high (*Feletar – Feletar 2009*, 184). There are two main factors that affect climatic conditions in the Podravina region: the European mountain systems, especially the Alps, on which rain-bearing clouds are formed, and the air carried by the western winds, which, upon arrival in the Pannonian Plain, causes weather disturbances and rain (*Feletar – Feletar 2009*, 183).

If we try to reconstruct which time of year was the most favourable for working in an iron-ore smelting workshop, it is necessary to consider the natural factors that influenced the selection of the locations where smelting was carried out with the noted climatic characteristics of the region. As it was concluded in the aforementioned research that the bog ore used for smelting processes was exploited in the Podravina area, the described climatic conditions can reveal to us what was the most favourable time for the exploitation and preparation of the raw materials needed for the functioning of the smelting workshop. There are several reasons that would cause us to exclude the winter for these activities: a) in that time of year the soil was frozen and the clay needed to build the furnace could not be collected, b) the upper surfaces of streams were also frozen and access to the water necessary for making the furnace walls was difficult, c) due to the low temperatures, the charcoal that could be produced was damp, making it difficult to store, and ultimately, what is perhaps most important, d) the discerning in the landscape of the small ore deposits, such as are believed to have existed in the Podravina region, and their exploitation would have been exceptionally difficult.

Observing the hydrographic characteristics of the region, it is evident that the most rain falls in late spring and early summer. Furthermore, the beginning of spring is marked by melting snow and large torrents of water that flow down the slopes of the Bilogora Hills and from the alpine area into the Drava River, spilling over into its tributaries and retention areas. In that time of the year, the level of water in creeks and also in marshy areas is extremely high. For this reason, it would certainly be difficult to both identify and exploit wetland iron ore, primarily due to the inaccessibility of the sides of the stream bed, for example, where it would ordinarily be easily accessible. On the other hand, it is precisely this situation with greater quantities of precipitation and the flooding of wetlands that enabled the recognition of potential ore deposits, deposits that could be exploited after the rainy season. Apart from the difficult access to ores, it is unlikely that the smelting process itself took place during the rainy season, due to the fact that heavy rain can interrupt and destroy the smelting process, which most probably, according to current knowledge, took place outdoors. During the investigations of the smelting workshops in Podravina, no traces were found at all of canopies or coverings that could be raised above the smelting furnaces and serve as some kind of protection against adverse weather conditions. This additionally supports the conclusion that the furnaces were built in an open area and activities took place during fine weather. For this reason, the period of the second annual precipitation maximum, which is recorded for the Podravina area during October and November, can also be ruled out as a time of year when the smelting workshops would have functioned.

Yet another part of the production process should be considered in terms of the preparation and exploitation of the raw materials required for the smelting process, specifically the procurement of wood and the production of charcoal. The optimal time for cutting wood is late winter and early spring when deciduous trees are still dormant, that is, they have not started to grow their leaf shoots and contain the least amount of natural sap. For this reason, it was assumed that the wood cutting took place at that time, as the wood needed to be dry, or at least partially dried, for charcoal production, and that took a certain amount of time. So, the charcoal production process itself was therefore also likely to have taken place under favourable weather conditions, during dry and sunny weather.

From everything stated above, it is evident that the production of charcoal, the exploitation of iron ore, and the very process of its smelting in the Podravina region required stable, dry, and sunny weather. The logical conclusion is that this activity could have taken place during the sunny spring period, during the summer months, or at the beginning of autumn. This is supported by the discovery of the negative impression of a leaf, most probably from an alder, on the wall of a smelting furnace from the site of Virje-Sušine, found in a context of waste from a smelting workshop dating to Late Antiquity. Although the leaf is not complete, it is possible to state that it was a young leaf that could have grown throughout the growing season, from spring to late summer, and consequently it could have fallen off the tree during this period. With this in mind, as well as the described climatic and hydrographic conditions and changes throughout the year, it can be concluded as very likely that the process of smelting iron ore at the Sušine site, and probably throughout the entire Podravina area, took place during the summer months.

References

Brenko, T. 2018:

Mineraloško-geokemijska poveznica između močvarnog tipa ležišta željezne rude [bog iron] i arheoloških predmeta u nizinskom slivu rijeke Drave [poster]. Dan doktoranata RGNF, University of Zagreb, 30. 06. 2017.

Brenko, T. – Borojević-Šoštarić, S. – Ružičić, S. – Sekelj Ivančan, T. in press:

Evidences for the formation of bog-iron ore in soils of the Podravina region, NE Croatia: geochemical and mineralogical study.

Feletar, D. – Feletar, P. 2008:
Prirodna osnova kao čimbenik naseljenosti gornje hrvatske Podravine, Podravina: Časopis za multidisciplinarna istraživanja VII:13, 167-212.
Gömöri, J. 2000
The archaeometallurgical sites in Pannonia from the Avar and early Arpád period. Register of industrial archaeological sites in Hungary, I. Ironworking, Sopron.
Pleiner, R. 2000:
Iron in archaeology, the European bloomery smelters, Archeologický ústav AVČR, Prag.
Sekelj Ivančan, T. 2007:
Novi površinski nalazi s lokaliteta Virje-Volarski breg, Obavijesti Hrvatskog arheološkog društva 39:3, 73-79.
Sekelj Ivančan, T. 2009:
Arheološka istraživanja ranosrednjovjekovne radionice za preradu željezne rudače na lokalitetu Virje-Volarski breg**,** Annales Instituti Archaeologici V, 65-70.
Sekelj Ivančan, T. 2010:
Talionička djelatnost u okolici Molva u ranom srednjem vijeku, in: Kolar, M. – Petrić, H. (eds.), Zbornik radova sa znanstvenog skupa Molve – ljudi, selo i okoliš u dugom trajanju (1658.-2008.) u povodu 350-te obljetnice osnivanja današnjeg sela Molve. Molve, 30-45.
Sekelj Ivančan, T. 2011a:
Rezultati istraživanja nalazišta Virje-Volarski breg u 2010. godini, Annales Instituti Archaeologici VII, 50-53.
Sekelj Ivančan, T. 2011b:
Virje-Volarski breg, rani srednji vijek, 8.-9. st. Naselje i talionička djelatnost, in: Čimin, R. (ed.), Zaštitna arheologija višeslojnih nalazišta: Virje-Volarski breg (2008., 2010.) i Delovi – Grede 1 (1982.). Koprivnica, 18-21.
Sekelj Ivančan, T. 2013:
Nastavak arheoloških istraživanja na položajima Volarski breg i Sušine kraj Virja u 2012. godini, Annales Instituti Archaeologici IX, 48-54.
Sekelj Ivančan, T. 2014a:
Pregled dosadašnjih arheoloških istraživanja na lokalitetu Virje-Volarski breg/Sušine, Podravski zbornik 40, 159-166.
Sekelj Ivančan, T. 2014b:
Četvrta sezona arheoloških istraživanja nalazišta Virje-Volarski breg-Sušine, Annales Instituti Archaeologici X, 99-103.
Sekelj Ivančan, T. 2015:
Arheološki ostaci triju naselja na Sušinama u Virju, Annales Instituti Archaeologici XI, 50-53.
Sekelj Ivančan, T. 2016:
Predindustrijska obrada željeza: pokazatelji talioničke djelatnosti na primjeru arheoloških nalazišta u Podravini, Podravina: Časopis za multidisciplinarna istraživanja XV:29, 118-125.
Sekelj Ivančan, T. 2017a:
Ranosrednjovjekovni objekt na Sušinama u Virju, Cris: Časopis povijesnog društva Križevci XIX, 115-128.
Sekelj Ivančan, T. 2017b:
Ranosrednjovjekovno naselje na Volarskom bregu u Virju, in: Sekelj Ivančan, T. – Tkalčec, T. – Krznar, S. – Belaj, J. (eds.), Srednjovjekovna naselja u svijetlu arheoloških izvora, Zbornik Instituta za arheologiju 6. Zagreb, 111-129.
Sekelj Ivančan, T. 2018:
Nastavak istraživanja talioničke radionice i naselja na lokalitetu Hlebine-Velike Hlebine, Annales Instituti Archaeologici XIV, 65-71.
Sekelj Ivančan, T. 2019a:
Arheološki tragovi naseljenosti Sušina u Virju tijekom razvijenoga srednjeg vijeka, Zbornik Zorka Markovića (in press).
Sekelj Ivančan 2019b:
Arheološka istraživanja lokaliteta Hlebine-Dedanovice, Annales Instituti Archaeologici XV, 129-135.
Sekelj Ivančan, T. – Karavidović, T. 2016:
Tkalački stan iz Virja, Prilozi Instituta za arheologiju 33, 171-235.
Sekelj Ivančan, T. – Marković, T. 2017:
The primary processing of iron in the Drava river basin during the Late Antiquity and Early Middle Ages – the source of raw materials, in: Vitezović, S. – Antonović, D. (eds.), Archeotechnology studies: raw material exploitation from prehistory to the Middle Ages. Belgrade, 143-160.
Sekelj Ivančan, T. – Mušić, B. 2014:
Geofizička i arheološka istraživanja na nalazištu Virje – talioničkoj radionici iz vremena kasne antike i ranog srednjeg vijeka, Starohrvatska prosvjeta III:41, 177-183.
Sekelj Ivančan, T. – Tkalčec, T. 2018:
Settlement continuity at Sušine site near Virje (North Croatia) throughout the Middle Ages, Konštantínove listy 11:2, 35-66.
Sekelj Ivančan, T. – Valent, I. 2017:
Ostaci talioničke radionice na lokalitetu Hlebine-Velike Hlebine, Annales Instituti Archaeologici XIV, 73-76.
Sekelj Ivančan, T. – Botić, K. – Culiberg, M. 2019:
Biljni pokrov Đurđevačkih pijeska i okolice – arheološka perspektiva: studija slučaja Virje-Volarski breg, in: Tomić, F. (ed.), Đurđevački pijesci: Geneza, stanje i perspektive. Zagreb-Križevci, 47-69**.**
Valent, I. – Zvijerac, I. – Sekelj Ivančan, T. 2017:
Topografija arheoloških lokaliteta s talioničkom djelatnošću na prostoru Podravine, Podravina: Časopis za multidisciplinarna istraživanja XVI:32, 5-25.

Valent, I. – Krznar, S. – Tkalčec, T. – Sekelj Ivančan, T. 2018:
Terenski pregled koprivničke i đurđevačke Podravine, Annales Instituti Archaeologici XVI, 142-147.
Valent, I. – Krznar, S. – Tkalčec, T. 2019:
Novi arheološki lokaliteti s metalurškom djelatnošću na prostoru Podravine, Podravina: Časopis za multidisciplinarna istraživanja 35, 5-25.
Weronska, A. 2009:
Influence of environmental conditions on holocene iron ores accumulation, Gospodarka Surowcami Mineralnymi 25:2, 23-36.
Zatykó, C. 2013:
Obrasci naselja. Korištenje krajolika u srednjovjekovnom Berzencu (Mađarska) [Settlement pattern. Landscape use in medieval Berzence (Hungary)], Podravski zbornik 39, 164-172.